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Prospective associations between diet quality and health-related quality of life in the Australian Diabetes, Obesity and Lifestyle (AusDiab) study

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Abstract

Changes between diet quality and health-related quality of life (HR-QoL) over 12 years were examined in men and women, in 2844 adults (46 % males; mean age 47·3 (SD 9·7) years) from the Australian Diabetes, Obesity and Lifestyle study with data at baseline, 5 and 12 years. Dietary intake was assessed with a seventy-four-item FFQ. Diet quality was estimated with the Dietary Guideline Index, Mediterranean-Dietary Approaches to Stop Hypertension Diet Intervention for Neurological Delay Index (MIND) and Dietary Inflammatory Index. HR-QoL in terms of global, physical component summary (PCS) and mental component summary (MCS) was assessed with the Short-Form Health Survey-36. Fixed effects regression models adjusted for confounders were performed. Mean MCS increased from baseline (49·0, SD 9·3) to year 12 (50·7, SD 9·1), whereas mean PCS decreased from baseline (51·7, SD 7·4) to year 12 (49·5, SD 8·6). For the total sample, an improvement in MIND was associated with an improvement in global QoL ($\beta = 0·28$, 95 % CI (0·007, 0·55)). In men, an improvement in MIND was associated with an improvement in global QoL ($\beta = 0·28$, 95 % CI (0·0004, 0·55)). In women, improvement in MIND was associated with improvements in global QoL ($\beta = 0·62$ 95 % CI (0·38, 0·85)), MCS ($\beta = 0·75$, 95 % CI (0·29, 1·22)) and PCS ($\beta = 0·75$, 95 % CI (0·29, 1·22)). Positive changes in diet quality were associated with broad improvements in HR-QoL, and most benefits were observed in women when compared to men. These findings support the need for strategies to assist the population in consuming healthy dietary patterns to lead to improvements in HR-QoL.

Keywords: Diet quality: Dietary patterns: Health-related quality of life: Longitudinal studies

Maintaining health across the lifespan continues to be a significant public health interest and encompasses striving for high levels of physical, social and psychological functioning, including wellbeing and quality of life (QoL)[1]. The WHO defines health-related quality of life (HR-QoL) in terms of 'individuals' perception of their position in life in the context of the culture and value systems in which they live and in relation to their goals, expectations, standards and concerns'[2].

Assessment of dietary exposures when examining the diet–disease relationship has traditionally focused on individual foods and nutrients; however, there is an increased focus on assessment of the whole diet or diet quality[3,4]. Diet quality can be determined by two approaches: *a posteriori* multivariate statistical techniques including factor or cluster analysis to derive dietary patterns[5], and *a priori* dietary indices of diet quality informed by dietary guidelines and recommendations, which are important for investigating the diet–disease relationship in populations and the promotion of health[6].

The relationship between diet quality, measured by dietary indices, and HR-QoL is a growing area of interest. Evidence from cross-sectional studies have reported positive associations with the Dietary Guideline Index (DGI), which assesses adherence to the Australian Dietary Guidelines[7], and QoL[8]. The Mediterranean-Dietary Approaches to Stop Hypertension (DASH) Diet Intervention for Neurological Delay (MIND) index, with neuroprotective dietary components[9], has been associated with lower rates of depression over time[10] and reduced odds of cognitive impairment[11]. However, any potential benefits of the

Abbreviations: AusDiab, Australian Diabetes, Obesity and Lifestyle study; DASH, Dietary Approaches to Stop Hypertension; DII, Dietary Inflammatory Index; DGI, Dietary Guideline Index; HR-QoL, health-related quality of life; MCS, mental component summary; MIND, Mediterranean-DASH diet Intervention for Neurological Delay; QoL, quality of life; SF-36, Short-Form Health Survey-36.

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MIND diet on HR-QoL are not known. The inflammatory potential of the diet, as measured using the Dietary Inflammatory Index (DII), may be inversely related to inflammatory processes in the brain and development of mental illness[12]. Currently, there is limited research investigating the relationship between the DII and QoL.

Most of the evidence investigating the association between diet quality and HR-QoL are from cross-sectional studies, which cannot provide insight into the temporal order of the relationship. Furthermore, the few longitudinal studies used a single baseline score for diet quality[13], assuming it remains stable over many years. However, one study reported an increase in a healthful plant-based diet was associated with improvements in QoL[14]. More longitudinal studies are required that model the full trajectory of diet quality and HR-QoL over multiple time points.

The aim of this study was thus to examine the association between change in three diet quality indices (DGI, MIND and DII) and change in HR-QoL over a 12-year period in community-dwelling Australian men and women.

Methods

Study design and sample selection

Australian Diabetes, Obesity and Lifestyle study (AusDiab) is a prospective, population-based cohort study of 11 247 adults (5049 men and 6198 women) aged ≥25 years randomly selected from areas in Australia and recruited in 1999–2000. There was complete data available for analysis on 2844 participants (25·3 % of the baseline sample; Fig. 1). A detailed description of the study protocol including exclusion criteria has been reported previously[15]. Briefly, a stratified cluster sampling method was used, involving seven strata (the six states and the Northern Territory), and clusters (*n* 42) were based on census collector districts. Five-year follow-up was conducted in 2004–2005 and 12-year follow-up was conducted in 2011–2012. The current study used a subset of participants with complete data at baseline, year 5 and year 12. All participants provided written informed consent before commencing the study, which was approved by the International Diabetes Institute Ethics Committee and Alfred Health Ethics Committee. An ethical

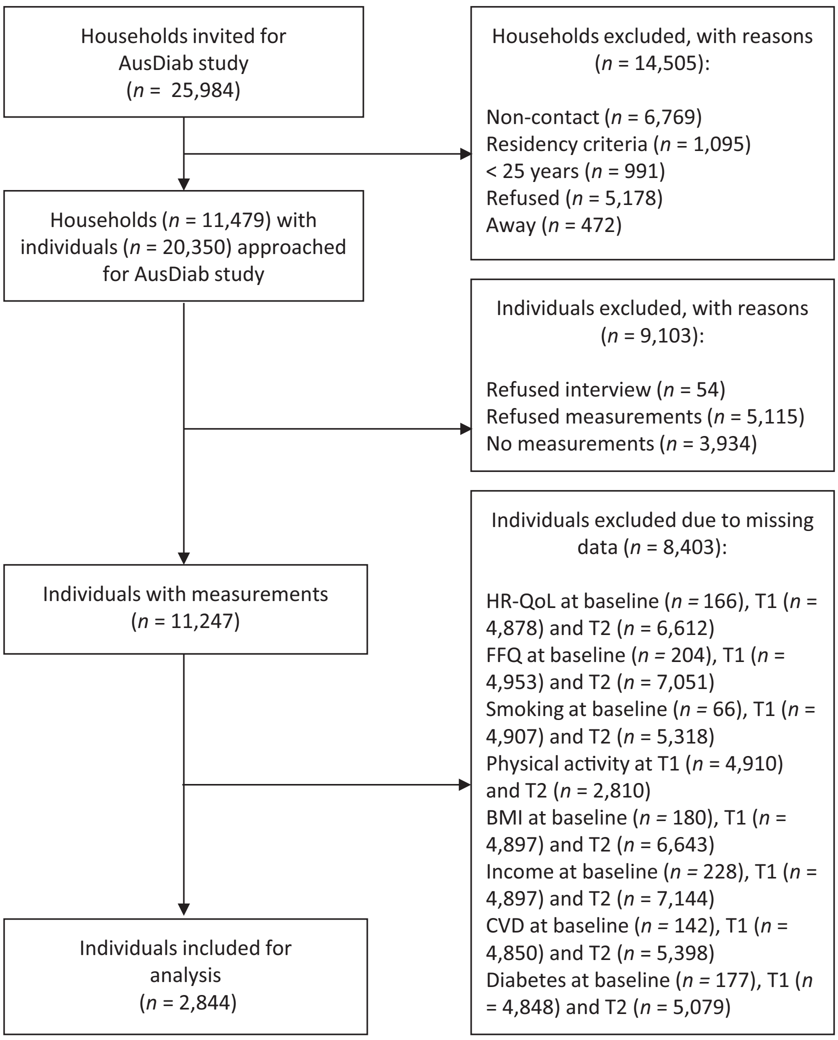

Fig. 1. Flow diagram of participants included in the longitudinal Australian Diabetes, Obesity and Lifestyle (AusDiab) study. HR-QoL, health-related quality of life.

British Journal of Nutrition

exemption was approved by the Deakin University Human Research Ethics Committee (Project number 2020-209).

Sample characteristics

Participants were classified as having diabetes if they reported having doctor diagnosed diabetes and were either taking hypoglycaemic medication or had fasting plasma glucose (FPG) ≥7·0 mmol/l or a 2-h plasma glucose (2 h PG) ≥11·1 mmol/l. Past history of presence or absence of CVD was self-reported. Height to the nearest 0·5 cm was measured without shoes using a stadiometer[16]. Weight to the nearest 0·1 kg was measured without shoes and excess clothing, with a mechanical beam balance at baseline and digital weighing scales at year 5 and 12[16]. BMI was calculated as weight (kg) divided by height (m^2).

Health-related quality of life

HR-QoL was assessed using the Short-Form Health Survey-36 (SF-36) questionnaire (version 1) at each time point[17]. This multi-item scale, which is designed for self-administration, contains thirty-six questions from which two summary scores are derived: the physical component summary (PCS) and the mental component summary (MCS). The PCS includes four domains: physical functioning (physical health), role physical (role limitation because of physical health), bodily pain and general health (general health perceptions); and the MCS includes four domains: vitality, social functioning, role emotional (role limitations because of emotional problems) and mental health (general mental health). An overall HR-QoL global score was calculated as the mean of all the eight health subdomains. Higher scores indicate better QoL. All scores are reported using Australian norm-based scores according to previously published guidelines[18,19]. The use of norm-based weights gives each domain score a mean of 50 and a SD of 10, allowing change in scores to be assessed on a comparable scale. The SF-36 has demonstrated good construct validity, internal consistency and test–retest reliability[20–22].

Dietary intake

Dietary intake was assessed using the Cancer Council of Victoria's validated self-administered seventy-four-item semi-quantitative FFQ (version 2)[23]. Participants were asked to indicate how often they had consumed each food or beverage item during the preceding 12 months, with ten options ranging from 'never', '1 to 3 times/month', '5 to 6 times/week' to '3 or more times/d'. There were ten questions on food habits including type of milk, cheese and bread consumed, daily consumption of fruit, vegetables, milk, bread, fat spreads and sugar, and weekly consumption of eggs. The survey included additional questions on portion size, enabling the determination of daily energy (kJ) food (g) and nutrient intake (μg, mg or g) using NUTTAB95 food composition data[23]. The FFQ has demonstrated high agreement levels with weighed food records with differences of less than 20 % observed in twenty-one out of twenty-seven nutrients[23].

Diet quality

Diet quality was assessed using three previously developed indices: DGI, MIND and the DII. The DGI is a food-based dietary index that assesses adherence to the Australian Dietary Guidelines[7] (online Supplementary Table 1). The DGI was updated to reflect the 2013 Australian Dietary Guidelines[24]. Indicators were identified for each dietary guideline with the development of age- and sex-specific cut-offs and food groupings guided by the Australian Dietary Guidelines[25]. The DGI included eleven items: diet variety; vegetables; fruit; grains and cereals; meat and alternatives; dairy products and alternatives; discretionary foods; saturated fat; unsaturated fats; sugar; and alcohol based on available data from the seventy-four-item FFQ. Two items usually included in the DGI (fluid intake and limiting foods high in salt) were not included, as the FFQ did not include questions for these items. Each item was scored from 0 to 10, with 10 indicating a person was fully meeting the recommendation. The total score ranged from 0 to 110, with higher scores indicating greater compliance with the Australian Dietary Guidelines and therefore better diet quality[26].

The MIND is a food-based dietary index and combines the Mediterranean and DASH diet with a particular focus on dietary components that are reported to be neuroprotective[9]. The MIND is comprised of fifteen components: ten brain healthy foods (green leafy vegetables, other vegetables, nuts, berries, wholegrains, fish, poultry, olive oil and wine) and five less healthy foods (red meat, butter/margarine, cheese, pastries and sweets, and fried/fast food) (online Supplementary Table 2). Each MIND component was scored a 0, 0·5 or 1 according to the methodologies employed in previous studies[9], and a total MIND index was calculated by adding the individual component scores. Two items usually included in the MIND index (olive oil and butter/margarine) were not recorded in the FFQ and were omitted from the final index calculation. The possible range of the MIND index in the current sample was 0–13, which aligns with an established approach[11]. Increasing scores reflect better adherence and a healthier diet.

The DII is a food- and nutrient-based dietary index designed to assess a respondent's diet on a scale from anti-inflammatory to pro-inflammatory[27]. A scoring algorithm was derived from approximately 6500 peer-reviewed research articles that assessed the effect of dietary components on inflammation. Forty-five food components were identified for inclusion in the algorithm. An overall inflammatory effect score for each of the forty-five food components was calculated as detailed by Shivappa *et al.*[27]. This was done by allocating a score to each constituent of +1 for pro-inflammatory (significantly increased IL-1β, IL-6, TNF-α or CRP, or decreased IL-4 or IL-10) or −1 for anti-inflammatory. Each score of +1 or −1 was then weighted depending on the strength of the evidence which was based on the number of studies assessing each food component and the study design. The intake for respondents is then converted to a *Z*-score by dividing the intake by the global daily mean intake and dividing it by its SD. Each respondent is then allocated a percentile of intake using the *Z*-score. The percentile was used to calculate a symmetrical distribution centred on zero by dividing

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the percentile by 100 multiplying it by 2 and subtracting 1. This results in a distribution ranging from −1 to +1 for each food component. This score was then multiplied by the overall inflammatory effect score described above. Potential DII scores range from −8·87 to 7·98 based on this methodology when all forty-five components are available. DII scores were calculated using data from the AusDiab using the methodology described above by Shivappa *et al.*[27]. AusDiab has data for twenty-six of the forty-five food components identified for the DII (online Supplementary Table 3).

Confounders

Data on age, sex, income, smoking and physical activity were collected by interview-administered questionnaire at all time points[15]. Income was coded into six categories: $0–199, $200–399, $400–599, $600–799, $800–1499 and $1500+ per week. Smoking status was categorised as current daily smokers or non-/ex-smokers (smoking less than daily for at least the last 3 months but used to smoke daily and non-smoker)[16].

Physical activity undertaken in the past 7 d was determined using the Active Australia Survey, a validated questionnaire[28]. Total physical activity was calculated as the sum of the time spent walking (if continuous and >10 min), the time spent doing moderate-intensity activities plus double the time spent participating in vigorous physical activity[28]. Total physical activity >840 min/week were truncated to 840 min to avoid over-reporting, in line with the Active Australia Survey Manual[28].

Statistical analysis

All analyses were performed using the Statistical Package for the Social Sciences software version 24.0 (SPSS. Inc.) and STATA/SE 15.0 software (Stata Corp., LP). A complete case analysis was used. Model residuals were assessed for normality and heteroscedascity using P-P plots and plots of residuals against fitted values, respectively. Descriptive statistics (mean values and standard deviations or numbers and percentages) were calculated to describe the participant characteristics. A one-way repeated measures ANOVA for continuous variables and the Friedman test for categorical variables compared scores across the three time points. Energy (kJ), food and nutrient intake at baseline across the diet quality tertiles were assessed using one-way between-groups ANOVA. Differences between men and women were assessed using independent-sample t tests for continuous variables and χ^2 tests for categorical variables. Differences between included and excluded participants were assessed using independent-sample t tests for continuous variables and χ^2 tests for categorical variables. Z-scores for the diet quality indices were calculated prior to analysis to make it easier to interpret results across different scales. Fixed effect regression models were conducted to estimate repeated measures associations between changes in diet quality (exposure variable) and changes in HR-QoL (outcome variable). Fixed effects analysis of repeated measures data minimises the impact of bias from confounding by time-invariant factors (measured and unmeasured) which is common in observational studies[29]. In the model, each individual acts as his/her own control, and only variables that vary across time are included. Confounders included in the model were determined by the use of a directed acyclic graph (DAG) developed using the online tool DAGitty[30] (Fig. 2). Variables that could confound both the exposure and outcome variable, that were not on the causal path and determined by background literature, were included in the model: age, energy intake, physical activity (continuous variables), smoking status and weekly gross income (categorical variables)[7]. Variables that were considered as potential confounders but were on the causal pathway and not included in the model were BMI, CVD and diabetes. Additionally, all models were adjusted for clustering including forty-two clusters and seven stratas. Statistical interactions for sex by diet quality were computed using fixed effects regressions to determine if the association between diet quality and HR-QoL differed by sex. Significance was set at $P < 0·05$.

Results

Participant characteristics

There was complete data available for analysis on 2844 participants (25·3 % of the baseline sample; Fig. 1). At baseline, all participants (n 2844) had a mean age of 47·3 (SD 9·7) years, and 46·2 % were male (Table 1). In all participants, mean DGI score increased from 66·1 (SD 12·7) at baseline to 69·5 (SD 12·6) at year 12. Mean MIND score increased from 6·5 (SD 1·5) at baseline to 6·9 (SD 1·4) at year 12, while the mean DII remained the same. At baseline, women compared with men had a higher mean DGI and MIND score, but a more inflammatory diet (Table 1). Women compared with men also had lower Global QoL, MCS, energy intake, BMI, physical activity, higher rates of non-smokers, higher rates of high-income earners, and lower rates of diabetes and CVD (Table 1). Overall, the final sample at baseline (included *v.* excluded with incomplete data) was younger, had a higher energy intake and lower BMI, had fewer smokers and higher income, and had a lower proportion with CVD and diabetes (online Supplementary Table 4). There was no difference between included and excluded participants in the proportion of men and women and level of physical activity reported at baseline.

Food, energy and nutrient intakes across diet index tertiles at baseline are shown in Table 2. Higher DGI and MIND scores were associated with greater intakes of fruits, vegetables and low-fat dairy products, but lower intakes of lean meats. The total energy intake was also lower with the percentage of total fat decreasing with increasing DGI and MIND scores. Food group consumption and energy intake decreased with increasing DII scores (more inflammatory diet), but there were no differences in fat, protein and carbohydrate as a percentage of total energy intake.

Diet quality x sex interaction was significant for DGI ($P < 0·05$), and there was a trend for significance for MIND ($P = 0·068$). Therefore, we presented the findings for the total sample and by sex, and this was supported by previous literature[13,31,32].

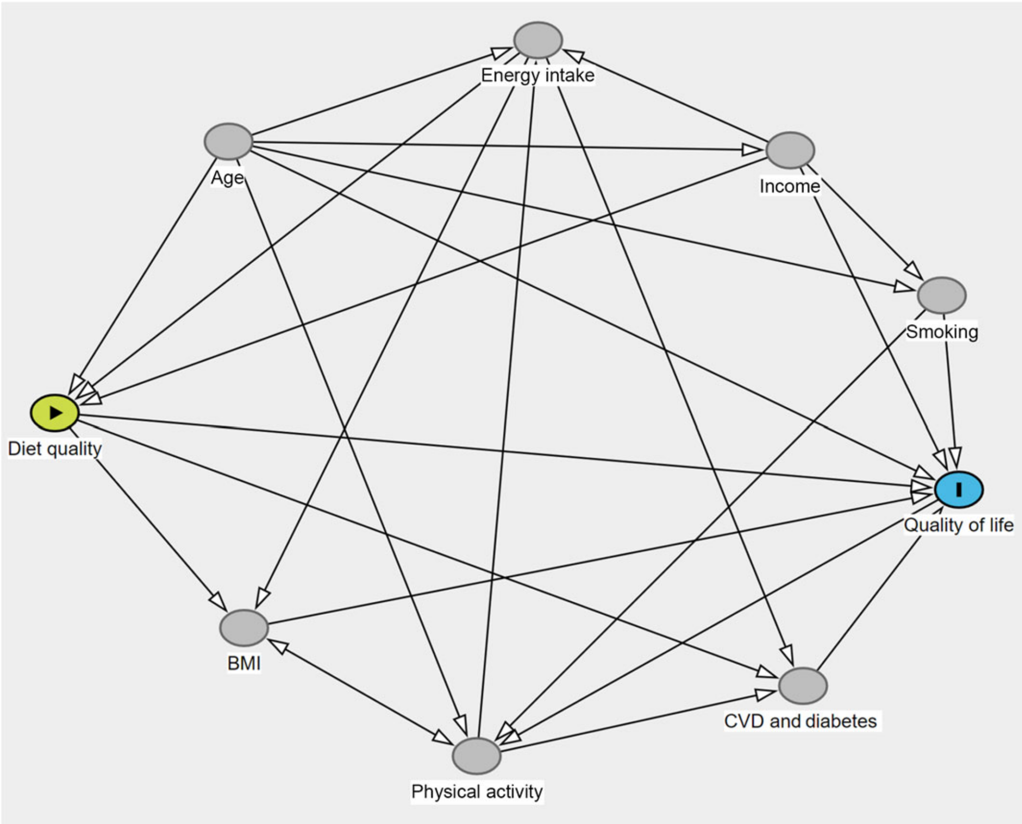

Fig. 2. Directed acyclic graph examining confounders and collider bias for association between diet and health-related quality of life.

Associations between change in diet quality and change in quality of life

Table 3 presents the results from the adjusted fixed effects models. For the total study sample, there were no associations between the change in DGI and change in QoL. In men, a one-unit increase (improvement) in DGI was associated with a 0·24 increase in (improvement) in global QoL ($\beta = 0{\cdot}24$, 95 % CI (0·006, 0·48)). In women, a one-unit increase (improvement) in DGI was associated with a 0·43 (95 % CI (0·23, 0·62)) increase (improvement) in global QoL and 0·79 (95 % CI (0·47, 1·10)) increase in MCS.

For the total study sample, every one-unit increase (improvement) in the MIND score was associated with a 0·28 increase (improvement) in global QoL ($\beta = 0{\cdot}28$, 95 % CI (0·007, 0·55)). In men, a one-unit increase (improvement) in the MIND score was associated with an increase (improvement) of 0·28 (95 % CI (0·0004, 0·55)). In women, a one-unit increase (improvement) in the MIND score was associated with an increase (improvement) in global QoL of 0·62 (95 % CI (0·38, 0·85)), and increase in MCS of 0·75 (95 % CI (0·29, 1·22)) and increase in PCS of 0·42 (95 % CI (0·10, 0·73)).

For the total sample, a one-unit decrease (improvement) in the inflammatory diet was associated with an increase in MCS of 0·59 ($\beta = -0{\cdot}59$, 95 % CI (−1·01, −0·17)). In men, a one-unit decrease (improvement) in the inflammatory diet was associated with an increase (improvement) in the MCS of 0·5 (95 % CI (−0·97, −0·02)). In women, a one-unit decrease (improvement) in the inflammatory diet was associated with an increase (improvement) in the global QoL of 0·61 (95 % CI (−0·96, −0·25)) and increase in MCS of 1·08 (95 % CI (−1·70, −0·50)).

Discussion

In this analysis, we examined the association between concurrent changes in three diet quality indices (MIND, DGI and DII) and HR-QoL over a 12-year period in community-dwelling Australian men and women. We have reported for the first time that improvements in diet quality, as indicated by positive changes in the MIND score, were associated with broad improvements in Global QoL. Improvements in the DII were associated with improvement in the mental component score. The positive findings overall were being driven more by women compared with men. These findings support the need for strategies to assist the population of adult men and women in consuming healthy dietary patterns to lead to improvements in HR-QoL.

In this longitudinal study, we have reported for the first time that the MIND, a combination of the Mediterranean and DASH diet, was associated with broad improvements in Global HR-QoL in the total sample and MCS and PCS in the women. In accord with our findings, there is evidence from cross-sectional studies that greater adherence to a Mediterranean diet is associated with better physical QoL[33–35] and mental

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Table 1. Descriptive characteristics of participants from the Australian Diabetes, Obesity and Lifestyle (AusDiab) cohort

	Total (*n* 2844)							Men (*n* 1313)							Women (*n* 1531)						
	Baseline		Year 5		Year 12			Baseline		Year 5		Year 12			Baseline		Year 5		Year 12		
	Mean	SD	Mean	SD	Mean	SD	*P**	Mean	SD	Mean	SD	Mean	SD	*P**	Mean	SD	Mean	SD	Mean	SD	*P**
DGI score	66·1	12·7	64·1	11·9	69·5	12·6	<0·001	63·1	12·2	61·4	11·2	66·4	12·2	<0·001	68·6	12·6†	66·5	12·0	72·0	12·4	<0·001
MIND score	6·5	1·5	6·8	1·5	6·9	1·4	<0·001	6·2	1·5	6·4	1·5	6·6	1·4	<0·001	6·7	1·5†	7·1	1·5	7·2	1·8	<0·001
DII score	–0·12	1·92	–0·13	1·90	–0·13	1·92	0·96	–0·67	1·84	–0·64	1·86	–0·62	1·92	0·56	0·36	1·81†	0·32	1·80	0·30	1·82	0·43
Health-related quality of life																					
Global QoL	50·4	6·1	50·6	6·2	50·1	6·6	<0·001	50·8	5·9	51·1	6·1	50·6	6·4	<0·01	50·1	6·1†	50·1	6·3	49·8	6·8	0·03
MCS	49·0	9·3	49·9	9·3	50·7	9·1	<0·001	49·5	9·2	50·4	9·0	51·0	8·9	<0·001	48·6	9·4‡	49·5	9·5	50·3	9·3	<0·001
PCS	51·7	7·4	51·1	8·0	49·5	8·6	<0·001	52·0	7·3	51·6	7·7	50·0	8·1	<0·001	51·5	7·5	50·7	8·3	49·1	9·1	<0·001
Age	47·3	9·7	52·3	9·7	59·2	9·7	<0·001	47·8	9·7	52·8	9·7	59·7	9·7	<0·001	46·8	9·6†	51·8	9·6	58·7	9·6	<0·001
Energy (kJ/d)	8316·0	3181·9	7741·6	3068·7	7166·9	2739·8	<0·001	9567·3	3326·6	8881·5	3066·7	8214·1	2894·9	<0·001	7243·0	2612·9†	6764·1	2713·2	6268·8	2239·1	<0·001
BMI (kg/m^2)	26·5	4·7	27·4	5·0	27·8	5·2	<0·001	26·9	3·9	27·7	4·2	28·0	4·5	<0·001	26·2	5·2†	27·2	5·6	27·7	5·8	<0·001
Physical activity (min/week)	290·2	333·5	309·7	338·0	366·9	370·8	<0·001	338·7	370·5	332·9	358·1	408·8	400·5	<0·001	248·6	291·8†	289·8	318·7	331·0	339·3	<0·001
	n	%	*n*	%	*n*	%		*n*	%	*n*	%	*n*	%		*n*	%	*n*	%	*n*	%	
Smoking							<0·001							<0·001							<0·001
Current smoker	268	9·4	226	8·0	154	5·4		148	11·3	127	9·7	81	6·2		120	7·8†	99	6·5	73	4·8	
Non-smoker	2576	90·6	2618	92·0	2690	94·6		1165	88·7	1186	90·3	1232	93·8		1411	92·2	1432	93·5	1458	95·2	
Income/week)							<0·001							<0·001							<0·001
\$0–199	705	24·8	319	11·2	1291	45·4		354	27·0	121	9·2	661	50·3		351	22·9†	198	12·9	630	41·2	
\$200–399	1020	35·9	1052	36·9	812	28·6		527	40·1	530	40·4	365	27·8		493	32·2	520	34·0	447	29·2	
\$400–599	402	14·1	1226	43·1	248	8·7		178	13·6	580	44·2	110	8·4		224	14·6	646	42·2	138	9·0	
\$600–799	360	12·7	127	4·5	258	9·1		150	11·4	24	1·8	101	8·4		210	13·7	103	6·7	157	10·3	
\$800–1499	260	9·1	103	3·6	203	7·1		75	5·7	53	4·0	67	5·1		185	12·1	50	3·3	136	8·9	
\$1500 or more	97	3·4	19	0·7	32	1·1		29	2·2	5	0·4	9	0·7		68	4·4	14	0·9	23	1·5	
Diabetes							<0·001							<0·001							<0·001
Yes	130	4·6	63	2·2	98	3·5		73	5·6	34	2·6	51	3·9		57	3·7‡	29	1·9	47	3·1	
No	2714	95·4	2781	97·8	2746	96·6		1240	94·4	1279	97·4	1262	96·1		1474	96·3	1502	98·1	1484	96·9	
CVD							0·05							0·29							0·07
Yes	82	2·9	103	3·6	106	3·7		57	4·3	70	5·0	66	5·0		25	1·6†	33	2·2	40	2·6	
No	2762	97·1	2741	96·4	2738	96·3		1256	95·7	1243	94·7	1247	95·0		1506	98·4	1498	97·8	1491	97·4	

DGI, Dietary Guideline Index (range 0–119); MIND, Mediterranean-Dietary Approaches to Stop Hypertension Diet Index (range 0–13); DII, Dietary Inflammatory Index; QoL, quality of life; MCS, mental component score; PCS, physical component score.

* One-way repeated measures ANOVA for continuous variables and Friedman test for categorical variables

† Baseline differences between men and women, $P < 0·01$.

‡ Baseline differences between men and women, $P < 0·05$.

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Table 2. Food, energy and nutrient intakes across diet indices tertiles at baseline

	Dietary Guideline Index							Mediterranean-Dietary Approaches to Stop Hypertension Diet							Dietary Inflammatory Index						
	Tertile 1		Tertile 2		Tertile 3		Trend*	Tertile 1		Tertile 2		Tertile 3		Trend*	Tertile 1		Tertile 2		Tertile 3		Trend*
	Mean	SD	Mean	SD	Mean	SD	*P*	Mean	SD	Mean	SD	Mean	SD	*P*	Mean	SD	Mean	SD	Mean	SD	*P*
Diet quality	52·4	5·8	65·7	3·3	80·3	7·1	<0·001	4·8	0·7	6·5	0·4	8·2	0·8	<0·001	−2·2	0·8	−0·1	0·5	2·0	0·9	<0·001
Food group intake																					
Fruit (g/d)	156·6	124·9	220·9	145·7	275·0	158·1	<0·001	167·4	129·5	218·1	151·3	269·6	155·6	<0·001	306·0	175·4	197·9	121·4	148·6	101·9	<0·001
Vegetables (g/d)	174·4	85·8	201·7	106·3	240·5	144·7	<0·001	188·4	100·6	199·0	110·0	231·8	138·8	<0·001	274·9	132·4	199·7	97·3	142·0	77·1	<0·001
Lean meat (g/d)	139·5	116·2	132·5	94·7	122·5	116·2	0·003	142·1	118·1	134·9	114·9	116·0	90·5	<0·001	180·9	153·7	124·3	73·1	89·3	53·7	<0·001
Low-fat dairy products (g/d)	114·4	157·4	219·4	206·6	304·4	218·6	<0·001	169·6	204·0	222·6	214·1	245·7	206·3	<0·001	239·0	229·1	216·0	211·2	183·2	186·3	<0·001
Total energy (kJ/d)	8873	3054	8755	3338	7501	2981	<0·001	8983	3357	8389	3276	7519	2657	<0·001	10 906	3495	7997	1919	6046	1587	<0·001
Nutrient intake (% energy)																					
Total fat	38·1	4·3	35·6	4·9	32·6	5·7	<0·001	37·4	4·5	35·4	5·2	33·3	6·0	<0·001	35·4	5·0	35·5	5·4	35·4	5·9	0·84
Saturated	15·7	3·0	14·5	3·0	12·3	3·0	<0·001	15·7	2·8	14·3	3·0	12·4	3·3	<0·001	13·5	3·0	14·1	3·3	14·7	3·5	<0·001
Polyunsaturated	5·8	1·9	5·5	1·8	5·6	2·1	<0·001	5·4	1·8	5·6	1·9	6·0	2·1	<0·001	6·0	1·8	5·6	1·9	5·3	2·0	<0·001
Monounsaturated	13·4	1·9	12·4	2·0	11·5	2·4	<0·001	13·0	1·9	12·4	2·1	11·8	2·6	<0·001	12·6	2·2	12·5	2·2	12·2	2·3	<0·001
Protein	18·4	2·9	19·3	2·7	20·8	3·0	<0·001	18·9	3·0	19·7	3·0	20·0	3·0	<0·001	19·5	3·0	19·5	2·9	19·5	3·2	0·90
Carbohydrate	43·5	5·7	45·1	5·6	46·6	6·3	<0·001	43·8	5·5	44·9	6·0	46·7	6·2	<0·001	45·2	0·6	45·0	5·9	45·1	6·3	0·75

* Differences between tertiles were tested with one-way between-groups ANOVA.

QoL[34,35]. Further, in a 15-year study of generally healthy American women from the Nurses' Health Study, greater adherence to the Alternate Mediterranean diet (A-MeDi) at baseline were associated with a higher likelihood of no mental health and physical function limitations as assessed by the SF-36[36]. Overall, these comparable findings might be expected as there are similarities between the MIND and Mediterranean diet. The MIND includes vegetables, fruit, fish, poultry, olive oil and wine which are also recommended when following the Mediterranean diet. Our current findings are also supported by an intervention study which found an 8-week DASH diet resulted in improvements of the SF-36 physical and mental subdomains[37].

The current study observed that the associations between diet quality and HR-QoL were driven more in women compared with men. These findings reflect previously reported differences in men and women between diet quality and QoL[13] and diet quality and mental health[38]. It is unclear why the present study reported an association between diet quality and HR-QoL predominantly in women but not men. It is possible that response biases in dietary reporting and with the SF-36 could account for the differences between men and women. Women in general have healthier lifestyles and are more likely to consume a healthy diet[39]. This was supported by our findings that women compared with men had a higher mean DGI and MIND scores at baseline reflecting a healthier diet. Furthermore, more women than men experience mental and behavioural conditions[40]. Consistent with this in our study, women compared with men at baseline had lower global QoL and MCS scores. It is recommended that future observational investigations of diet quality and HR-QoL are stratified by sex.

Another key finding from this study is that there were beneficial effects on mental QoL. Our findings are in line with previous research where an increase in a plant-based diet was associated with improvements in mental HR-QoL[14]. The associations in the present study were observed across the three dietary indices: DGI, MIND and DII. The beneficial effects of these dietary indices may be explained by several biological factors. The DGI, MIND and DII are associated with anti-inflammatory effects of fruits and vegetables, and this has been linked with lower depression risk[41,42]. The microbiota–gut–brain axis is an increasing focus of interest influencing the brain and behaviour. Consumption of plant-based diets, including the Mediterranean diet, modulate the intestinal microbiota reducing inflammation which is associated with mood disorders[43].

It is becoming common to investigate more than one *a priori* diet quality index simultaneously against a range of health outcomes[11,13,14]. In the present study, *Z*-scores for the three diet quality indices, which were measured on different scales, were calculated to compare the effect sizes, to make it easier to interpret the results. According to the fixed effects model in women, a 1 SD decrease in the DII (more anti-inflammatory diet) was associated with a 1·1 unit increase (improvement) in MCS. This is compared with a smaller 0·75 unit increase in MCS for women on the MIND diet. There are numerous nutrients in the DII that are beneficial to mental health and include antioxidants (vitamins A, C and E), *n*-3 PUFA and B-vitamins[12]. Antioxidants, primarily found in fruits and vegetables, aid in the prevention,

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Table 3. Fixed effect models of associations between change in diet quality and change in health-related quality of life over 12 years in the Australian Diabetes, Obesity and Lifestyle (AusDiab) cohort*†

	Dietary Guideline Index			Mediterranean-Dietary Approaches to Stop Hypertension Diet Intervention for Neurological Delay Index			Dietary Inflammatory Index		
	β	95 % CI	P	β	95 % CI	P	β	95 % CI	P
Total (*n* 2844)									
Global QoL	0·23	–0·004, 0·47	0·053	0·28	0·007, 0·55	0·045	–0·06	–0·30, 0·17	0·60
MCS	0·27	–0·09, 0·63	0·14	0·32	–0·13, 0·77	0·15	–0·59	–1·01, –0·17	<0·01
PCS	0·17	–0·13, 0·47	0·25	0·20	–0·17, 0·56	0·23	–0·04	–0·44, 0·35	0·82
Men (*n* 1313)									
Global QoL	0·24	0·006, 0·48	0·045	0·28	0·0004, 0·55	0·05	–0·25	–0·52, 0·02	0·06
MCS	0·27	–0·10, 0·64	0·14	0·30	–0·15, 0·75	0·19	–0·50	–0·97, –0·02	<0·05
PCS	0·19	–0·15, 0·53	0·23	0·22	–0·14, 0·57	0·23	–0·03	–0·42, 0·48	0·89
Women (*n* 1531)									
Global QoL	0·43	0·23, 0·62	<0·001	0·62	0·38, 0·85	<0·001	–0·61	–0·96, –0·25	<0·001
MCS	0·79	0·47, 1·10	<0·001	0·75	0·29, 1·22	<0·001	–1·08	–1·70, –0·50	<0·01
PCS	0·02	–0·23, 0·27	0·90	0·42	0·10, 0·73	<0·05	–0·06	–0·62, 0·28	0·82

* *Z*-scores for the diet quality indices were calculated prior to analysis.
† Model adjusted for time-varying confounders age, energy intake, BMI, smoking status, income, physical activity and clustering.

inhibition and repair of the damage caused by oxidative stress[12]. *n*-3 PUFA, found in fatty fish sources, also reduce oxidative stress and prevent defects in the transmission of serotoninergic and dopaminergic processes associated with emotional dysregulation and mood disorders[12]. B-vitamins, including folate, B_6 and B_{12} vitamins, found in a wide range of unprocessed foods, aid in the prevention of neurological deterioration and functional impairments in the brain[12]. The MIND diet, which is comprised of the Mediterranean and DASH diets, also contains neuroprotective nutrients due to its emphasis on green leafy vegetables, nuts, berries, wholegrains, fish, olive oil and wine[9].

Strengths and limitations

The strengths of this study include its prospective design and 12-year follow-up period allowing examination of long-term associations. The study used validated tools to measure diet quality (FFQ: exposure) and HR-QoL (outcome). We used a fixed effects analysis of repeated measures data which provided the most robust, consistent and biological approach to examine our understanding of the long-term effect of diet quality on HR-QoL compared with analyses based on prevalent or lagged-change in diet[29]. Several study limitations must be considered when interpreting the findings. Although the AusDiab participants were sampled across all states and regions of Australia, the sample included more younger and healthier participants and may not be generalisable to the general Australian population. Although this study included a range of confounders, it is possible residual confounding remained because of unmeasured confounders. We must consider the small risk of collider bias due to the exclusion of participants without complete data available, when an exposure and outcome independently cause a third variable, a collider variable[44]. However, a collider variable was not identified in the DAG or other unknown variables (Fig. 2). The omission of items in the scoring of DII, DGI and MIND could also limit the representation of these dietary scores. Most data were collected from self-reported questionnaires, which can be prone to biases and should be interpreted with caution. The FFQ which collected dietary data may result in recall bias leading to overreporting of healthy foods and underreporting of unhealthy foods. However, FFQ are commonly used in large population surveys[45], and the FFQ used in the current study is a validated tool.

Conclusion

This 12-year study in community-dwelling Australian adults has shown that positive changes in the MIND, DGI and DII diet quality indices diet were associated with broad improvements in HR-QoL, and the most changes were observed in women when compared with men. These findings support future population policies for Australian adults to adhere to healthy diets to promote improvements in HR-QoL.

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S. J. T., C. M. and K. M. L. conceived the study design; D. J. M. and J. E. S. acquired the data; L.-H. N. and S. J. T. conducted the analysis and wrote the manuscript; M. H. developed the DII, S. E. D. developed the MIND and S. J. T. developed the DGI; all authors critically reviewed the manuscript and read and approved the final version of the manuscript.

The authors declare no conflict of interest.

Supplementary material

For supplementary material/s referred to in this article, please visit https://doi.org/10.1017/S000711452200304X

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