Inflammatory potential of diet and mortality in Australian adults

Azam Majidi[1,2] , Maria Celia B Hughes[2] , Imogen K Webb[3], Kyoko Miura[2,4] and Jolieke C van der Pols[2,3,*]

[1]Gynaecological Cancers Group, Population Health Program, QIMR Berghofer Medical Research Institute, Brisbane, Australia: [2]Cancer and Population Studies Group, Population Health Program, QIMR Berghofer Medical Research Institute, Brisbane, Australia: [3]Queensland University of Technology (QUT), Faculty of Health, School of Exercise and Nutrition Sciences, Brisbane QLD 4059, Australia: [4]School of Biomedical Sciences, Faculty of Medicine, University of Queensland, Brisbane, Australia

Abstract

Objective: Inflammation is implicated in chronic diseases including cancer and CVD, which are major causes of mortality. Diet can influence inflammation status. We therefore examined whether the inflammatory potential of a person's diet is associated with mortality.

Design: The inflammatory potential of the usual diet was assessed by calculating Dietary Inflammatory Index (DII) scores from repeated FFQ data (collected in 1992, 1994 and 1996), placing each participant's diet on a continuum from anti- to pro-inflammatory. DII scores were analysed as a continuous variable and as categories by creating quartile groups. Death registry data were used to ascertain all-cause mortality and separately mortality from CVD, cancers and other causes between 1992 and 2022. Cox proportional hazard regression analysis was used to calculate adjusted hazard ratios (HR) with 95 % CI, comparing higher and lowest quartile groups, or HR change per one DII unit increase.

Setting: Nambour, Australia.

Participants: A community-based sample of 1440 adults aged 25–75 years.

Results: During follow-up, 488 participants died, including 188 from CVD, 151 from cancer and 170 from other causes. Participants in the most pro-inflammatory diet group were at increased risk of all-cause mortality ($HR_{Q4\ v.\ Q1}$ = 1·55; 95 % CI 1·19, 2·03; P < 0·001) and other-cause mortality ($HR_{Q4\ v.\ Q1}$ = 1·69; 95 % CI 1·12, 2·54; P 0·01). A one-unit increase in DII score was associated with a 36 % increased risk of CVD among those younger than 55 years of age (HR for a one-unit increase in DII score 1·36, 95 % CI 1·04, 1·78). The risk of cancer mortality was also increased for those with a more pro-inflammatory diet in age ≤ 55 years (HR for a one-unit increase in DII score 1·20, 95 % CI 1·02, 1·40) and age 56–65 years (HR for a one-unit increase in DII score 1·11, 95 % CI 1·00, 1·23).

Conclusions: A pro-inflammatory diet increases the risk of all-cause mortality. Our results support the promotion of anti-inflammatory diets to help promote longevity.

Chronic low-grade inflammation has been implicated in many chronic diseases, including cancer[1], CVD[2] and type 2 diabetes[3]. Diet has the potential to influence systemic inflammatory status[4]. For instance, *n*-3 fatty acids from fish can have anti-inflammatory and immune function effects[5]. Dietary fibre can also have anti-inflammatory effects, possibly mediated by the intestinal microbiome[6]. In contrast, SFA have pro-inflammatory effects[7]. Thus, a person's diet can contain a mix of pro- and anti-inflammatory foods and nutrients.

The overall inflammatory potential of a person's diet can be summarised by calculating a summary score, such as the Dietary Inflammatory Index (DII)[8]. The underlying basis for this index consists of evidence of associations between specific foods or nutrients and systemic inflammation. A growing number of studies have investigated associations between DII and mortality[9–14]. A recent umbrella review of previous systematic reviews, evaluating health outcomes associated with adherence to different diet indices, indicated that a pro-inflammatory diet, as measured by the DII, was

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associated with increased all-cause and CVD mortality[9]. Similarly, a meta-analysis of previous studies suggested that a more pro-inflammatory diet, measured by DII scores, was associated with higher cancer mortality[10–14].

Previous studies have predominantly included subjects from Europe and North America—evidence from Australia is still very limited. A cohort study of older women in Western Australia showed increased CVD mortality among those with a more pro-inflammatory diet[15]. Similar associations were seen in a study of older adults in Melbourne, particularly those of Northern European ancestry[16], but more evidence from general population samples in Australia is needed.

We therefore investigated associations between the inflammatory potential of the diet and mortality in a community-based sample of Australian adults, including consideration of the timing of deaths in relation to age. Based on prior evidence, we hypothesised that a pro-inflammatory diet, as measured by the DII, would be positively associated with mortality, including CVD and cancer mortality.

Methods

Study sample

We used data from the Nambour Skin Cancer Prevention Study, a prospective cohort study in Queensland, Australia. Participants aged 20–69 years were randomly selected from the electoral roll (voting is compulsory in Australia) for a survey of skin cancer prevalence in 1986. In 1992, 1621 of the original survey participants were enrolled in a skin cancer prevention trial (1992–1996). In a two-by-two factorial design, participants were randomly allocated to either daily or discretionary sunscreen use and daily β-carotene supplement or placebo group[17,18].

Dietary assessment

We used dietary intake data collected using a self-administered, semi-quantitative FFQ completed by Nambour Study participants in 1992, 1994 and 1996. The FFQ was initially created for the Nurses' Health Study in the USA and was adapted for the Nambour Study to ensure the list of foods appropriately represented the Australian diet[19]. The FFQ was validated in this study population which indicated exact agreement with weighed food records between 30 % and 50 % for almost all nutrients and for black tea (63 %)[20,21]. Participants were asked to record their usual intake of 129 foods or food groups during the previous 6 months. A common serving size was specified, and participants were asked to estimate the frequency at which they ate the given amount of food. The nine response options for frequency ranged from 'never' to '4+ times per day'. Seasonal variation was accounted for by asking participants to state their consumption frequency of seasonal foods to which a

weighting factor was applied based on typical duration of availability. Food intake in grams was calculated by multiplying the standard serving size of each food by the consumption frequency, expressed as a proportion of daily use. Nutrient intakes were calculated using the Australian food composition tables, NUTTAB95[22]. Participants with energy intakes outside the normal ranges (500–3500 kcal/d for women and 800–4000 kcal/d for men)[23] were excluded. Nutrient intake from supplements was analysed using a specially designed supplement database[24]. Nutrient intakes from both foods and supplements were included in the present analysis.

To assess the inflammatory potential of the dietary intakes of our study participants, we calculated DII scores using the DII and methods developed by Shivappa and colleagues[8]. The DII was created by applying a weighted scoring algorithm based on published literature on the relationship between forty-five food parameters and six inflammatory biomarkers. The DII comprises forty-five weighted scores, each summarising the inflammatory effect of one food parameter. To calculate a DII score for an individual's diet, we first calculated the energy-adjusted mean intake for each food parameter (except for tea intake) from each of the three FFQ, which was then averaged for each individual. This was converted to a z-score using standardised values from eleven nutritional databases. The z-score was then converted to a percentile using the PROBNORM function in SAS (SAS Institute Inc.), centred and multiplied by the relevant literature-derived inflammatory effect score. The results for individual food parameters were summed to provide a DII score for the participant[8]. The resulting DII scores for all participants represent a continuum from anti- to pro-inflammatory diets, with lower DII scores indicating a less inflammatory diet and higher scores indicating a more inflammatory diet.

For our analysis, thirty-one of the possible forty-five food parameters that comprise the DII were available and were used to calculate DII scores (including ethanol, β-carotene, carbohydrate, cholesterol, energy, fat, fibre, iron, magnesium, monounsaturated fat, niacin, *n*-3 fatty acid, *n*-6 fatty acid, protein, polyunsaturated fat, riboflavin, saturated fat, selenium, thiamine, retinol equivalents, vitamin C, vitamin D, vitamin E, flavan-3-ols, flavones, flavonols, flavanones, anthocyanidins, isoflavones, black tea and zinc). The literature supports the calculation of DII scores based on between twenty-two and thirty-six food parameters[25,26].

Outcome assessment

The outcomes of interest were mortality due to all causes and mortality due to CVD, cancer or other causes (referred to as other-cause mortality hereafter, which included unclassified death events). Mortality and cause of death data were obtained for all participants from 1992 to 31 March 2022 from the National Death Index of Australia and

the Queensland Registry of Births, Deaths and Marriages. The cause of death was classified per the WHO International Classification of Diseases and Related Health Problems 10th Revision (ICD-10). Mortality due to CVD was defined by the presence in the death certificate of an ICD-10 code in the range I25–I29 (CHD) and I60–I69 (stroke) and cancer mortality by a code in the range C00–C97. Causes of death not otherwise classified as CVD or cancer were analysed collectively as other causes. Additionally, a subject could be classified as having died from multiple causes, including CVD and cancer.

This study was approved by the Human Research Ethics Committee of the QIMR Berghofer Medical Research Institute, and all participants gave written informed consent.

Statistical analysis

Cox proportional hazard regression was performed to calculate hazard ratios (HR) and 95 % CI. Continuous DII scores were ranked from lowest to highest and divided into four sex-specific groups; the least inflammatory DII scores were in quartile 1, and the most inflammatory DII scores were in quartile 4. HR were estimated for higher compared with the lowest quartile group. To test for linear trends, we assigned an ordinal number ranging from 1 (lowest quartile) to 4 (highest quartile) and modelled this value as a continuous variable. We also examined DII scores as a continuous variable, wherein the estimated HR indicated the increased risk per one-unit increase in DII score.

In models for cause-specific mortality, each death is attributed exclusively to only one cause, creating a 'competing risk' situation where the assumption that subjects will experience an event of interest if followed up for long enough, no longer holds due to the occurrence of another event[27]. To correct for bias from competing risks in our analysis, we fit standard proportional sub-distribution hazard models using the %PSHREG macro in SAS[28].

All analyses were adjusted for age using age as the time scale and for the randomised intervention groups (daily sunscreen and/or β-carotene groups). Additionally, all models were adjusted for smoking status and medical conditions (self-reported diabetes, hyperlipidaemia, hypertension, angina, heart attack, stroke, cancer and medication use for cardiac disorders or diabetes). We also adjusted models for sex by including this covariate in the modelling of continuous DII scores. For quartile analyses, sex-specific quartiles were calculated when DII scores were categorised. Additional adjustments for other potential confounding variables, including education, BMI, physical activity and dietary supplement use, did not alter results markedly. The proportional hazard assumption for models on all-cause mortality was assessed using the ASSESS option of PHREG in SAS. Weighted Schoenfeld-type residuals were used to evaluate possible violation of the proportional sub-distribution hazard assumption by the cause-specific mortality models using the %PSHREG macro

in SAS version 9.4[28]. In models that considered DII scores as a continuous variable, the proportionality of hazards was not met; thus, we further assessed models in attained age groups ≤ 55, 56–65, 66–75, 76–85 and 86–96 years old.

Restricted cubic spline regression using the %RCS_reg macro was used to check for possible non-linearity of the association between DII analysed as a continuous variable and mortality in the Cox proportional hazard model, with three knots located at the 5th, 50th and 95th percentiles[29]. Results of the restricted cubic spline analysis showed no evidence of a non-linear association between continuous DII scores and all-cause mortality ($P = 0.36$), CVD mortality ($P = 0.99$), cancer mortality ($P = 0.70$) and other-cause mortality ($P = 0.61$).

The cause of death for thirty-three recent deaths was unspecified in the National Death data. In the main analyses, we classified these cases as other causes. However, in a sensitivity analysis, we excluded these deaths from the analysis of other causes of death.

$P < 0.05$ was considered statistically significant (two-sided). All analyses were carried out using SAS software version 9.4.

Results

Of the 1621 Nambour Study participants, 1529 completed at least one FFQ. Overall, 1032 (68 %) participants completed three valid FFQ, 284 (19 %) completed two FFQ and 213 (14 %) participants completed one FFQ. Participants with missing information on whether they suffered from a medical condition were excluded (eighty-nine), resulting in a sample of 1440 study participants for the present analysis. A comparison of baseline characteristics of included and excluded participants indicated that those who were included were somewhat older (49.6 ± 13.1 years v. 46.7 ± 13.5 years, respectively; $P = 0.006$) and more often used dietary supplements (54 % v. 35 %, respectively, $P < 0.001$), but they were otherwise the same as those excluded.

Participant characteristics at baseline, by DII quartile, are presented in Table 1. The mean ($\pm$SD) DII score was -0.08 ± 2.15, and scores ranged from -6.04 to $+6.65$. A one-unit increment of DII scores corresponded with approximately 8 % of the total range of DII scores in this population. Participants in the lowest quartile, thus with the least inflammatory diet, were older, had a slightly higher BMI, were more likely to have a medical condition, were more likely to be physically active, were less likely to be smoker and were more likely to use a dietary supplement (Table 1). There were no associations between DII categories and education level, BMI or the randomised trial treatment groups (β-carotene supplement or daily sunscreen use).

In total, 488 participants died between 1992 and 2022, including 188 deaths from CVD, 151 from cancer and 170 from other causes. DII categories showed a significant,

Table 1 Participant characteristics by Dietary Inflammatory Index (DII) quartile group at baseline, Nambour study, 1992 (*n* 1440)

	Dietary Inflammatory Index								Total population		
	Q1 (*n* 359)		Q2 (*n* 360)		Q3 (*n* 361)		Q4 (*n* 360)				
Variables	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	*P*
DII score	−2·6	0·8	−1·5	0·6	−0·5	0·7	1·2	1·2	−0·8	1·6	–
Age	54·5	12·0	51·1	12·9	47·7	12·9	45·0	12·7	49·6	13·1	< 0·001 *
	Median	IQR	Median	IQR	Median	IQR	Median	IQR	Median	IQR	
BMI, kg/m2	26·1	5·1	25·8	4·6	25·5	5·6	25·4	5·9	25·7	5·3	0·033‡
Sex											1·00†
Female	201	56	202	56	202	56	202	56	807	56	
Male	158	44	158	44	159	44	158	44	633	44	
Medical condition§											< 0·001†
No	186	52	211	59	220	61	251	70	868	60	
Yes	173	48	149	41	141	39	109	30	572	40	
Physical activity											0·005†
None	93	28	126	38	122	37	130	40	471	36	
≤ 1 h/week for females and ≤ 1·5 h/week for males	66	20	81	24	74	22	76	23	297	22	
≤ 3 h/week for females and ≤ 4 h/week for males	77	23	63	19	71	21	69	21	280	21	
> 3 h/week for females and > 4 h/week for males	93	28	62	19	65	20	53	16	273	21	
Smoking status											< 0·001†
Lifelong non-smoker	180	50	219	61	211	58	188	52	798	55	
Ex-smoker	149	42	105	29	94	26	96	27	444	31	
Current smoker	30	8	36	10	56	16	76	21	198	14	
Education											0·18†
High school	159	48	183	55	179	54	185	56	706	53	
Trade or other	66	20	56	17	66	20	73	22	261	20	
Certificate or diploma	84	25	72	22	69	21	52	16	277	21	
Bachelor degree or higher	21	6	22	7	18	5	20	6	81	6	
	n	%	*n*	%	*n*	%	*n*	%	*n*	%	
Dietary supplement use											< 0·001†
No	90	25	146	41	183	51	245	68	664	46	
Yes	269	75	214	59	178	49	115	32	776	54	
Sunscreen treatment group											0·70†
No	189	53	182	51	174	48	183	51	728	51	
Yes	170	47	178	49	187	52	177	49	712	49	
β-Carotene treatment group											0·63†
No	183	51	167	46	181	50	179	50	710	49	
Yes	176	49	193	54	180	50	181	50	730	51	

BMI, Basal Metabolic Index; Q1–4, quartile groups 1–4; IQR: interquartile range.
*P from ANOVA.
†*P* from Pearson χ^2.
‡*P* from Mann–Whitney *U* test.
§Participants responded yes to the presence of a medical condition if they had been told by a doctor or nurse that they had at least one of the following, diabetes, high cholesterol, high triglycerides, high blood pressure, angina, heart attack, stroke or cancer, or were taking medication for a cardiac disorder or diabetes.

positive association with all-cause mortality. Participants in DII quartile groups 2, 3 and 4 were more likely to die compared with participants in quartile 1, independent of confounders (HR$_{Q2\ v.\ Q1}$ = 1·38; 95 % CI 1·09, 1·75; HR$_{Q3\ v.\ Q1}$ = 1·42; 95 % CI 1·10, 1·83; HR$_{Q4\ v.\ Q1}$ = 1·55; 95 % CI 1·19, 2·03; *P* < 0·001) (Table 2). The association with continuous DII scores showed a similar relationship (Table 3), with a one-unit increase in DII corresponding with a 12 % increased risk of all-cause mortality (adjusted HR per one-unit increment of DII score = 1·12; 95 % CI 1·05, 1·19). This association was stronger among middle-aged participants (aged ≤ 55 years, 1·25; 95 % CI 1·11, 1·41; and aged

56–65 years, 1·18; 95 % CI 1·10, 1·19) and gradually attenuated among older-aged participants (Table 3).

There was no significant association between DII categories and CVD mortality (HR$_{Q4\ v.\ Q1}$ = 0·75; 95 % CI 0·46, 1·17; *P* = 0·36) or when DII scores were considered as a continuous variable (adjusted HR per one-unit increment of the DII score = 0·96; 95 % CI 0·87, 1·06). However, a one-unit increase in continuous DII was associated with a 36 % (HR, 1·36; 95 % CI 1·04, 1·78) increased risk of CVD mortality among those younger than 55 years of age; this association was attenuated among older-aged participants (e.g. aged 56–65 years, 1·14; 95 % CI 0·97, 1·35) (Table 3).

Table 2 Associations between Dietary Inflammatory Index and mortality, Nambour study, 1992–2022

	Dietary Inflammatory Index							
	Q1		Q2		Q3		Q4	
	(n 359)		(n 360)		(n 361)		(n 360)	
Person-years of follow-up	9202		9121		9533		9549	P for trend
	HR (95 % CI)	HR	95 % CI	HR	95 % CI	HR	95 % CI	
All-cause mortality								
No. of deaths	(n 143)		(n 135)		(n 114)		(n 96)	–
Age-adjusted HR (95 % CI)*	1·00	1·34	1·06, 1·69	1·36	1·06, 1·74	1·59	1·23, 2·07	< 0·001
Fully adjusted HR (95 % CI)†	1·00	1·38	1·09, 1·75	1·42	1·10, 1·83	1·55	1·19, 2·03	< 0·001
CVD mortality								
No. of deaths	(n 71)		(n 48)		(n 3)		(n 26)	–
Age-adjusted HR (95 % CI)	1·00	0·82	0·57, 1·18	0·91	0·62, 1·32	0·68	0·43, 1·05	0·14
Fully adjusted HR (95 % CI)*	1·00	0·90	0·62, 1·30	1·04	0·70, 1·52	0·75	0·46, 1·17	0·36
Cancer mortality								
No. of deaths	(n 36)		(n 50)		(n 33)		(n 32)	–
Age-adjusted HR (95 % CI)	1·00	1·71	1·12, 2·63	1·29	0·80, 2·07	1·52	0·94, 2·44	0·19
Fully adjusted HR (95 % CI)*	1·00	1·73	1·13, 2·68	1·29	0·80, 2·08	1·45	0·89, 2·36	0·27
Other-cause mortality								
No. of deaths	(n 48)		(n 43)		(n 40)		(n 39)	–
Age-adjusted HR (95 % CI)	1·00	1·13	0·76, 1·69	1·29	0·86, 1·93	1·68	1·12, 2·53	0·01
Fully adjusted HR (95 % CI)*	1·00	1·14	0·76, 1·70	1·29	0·86, 1·93	1·69	1·12, 2·54	0·01

Q1–4, quartile groups 1–4; HR, hazard ratio.
*Adjusted for age only.
†Adjusted for age, medical conditions, smoking status and randomised trial treatment groups (β-carotene and/or daily sunscreen use). Other covariates such as dietary supplement use, BMI and physical activity did not confound these estimates.

There was no association between a pro-inflammatory diet and risk of death from cancer (HR$_{Q4\ v.\ Q1}$ = 1·45; 95 % CI 0·89, 2·36; P = 0·27), and there was no trend of associations across the quartile groups (Table 2). When DII was treated as a continuous variable (Table 3), the data suggested an increased risk of cancer deaths for persons with higher DII scores (adjusted HR per one-unit increment of the DII score = 1·08; 95 % CI 0·98, 1·19). Similar to CVD mortality, the risk of cancer mortality was particularly increased among middle-aged participants (aged ≤ 55 years, 1·20; 95 % CI 1·02, 1·40; and aged 56–65 years, 1·11; 95 % CI 1·00, 1·23) and not among older-aged participants.

Participants with the most pro-inflammatory DII scores were more likely to die from other causes (HR$_{Q4\ v.\ Q1}$ = 1·69; 95 % CI 1·12, 2·54), but there was no association with lower DII categories (Table 2). A one-unit increase in continuous DII score was associated with an increase in mortality risk of 12 % from other causes (adjusted HR per one-unit increment of DII score = 1·12; 95 % CI 1·02, 1·22), and this association was also particularly apparent among middle-aged participants (Table 3). Exclusion of deaths with unknown cause from the analyses did not change these results (data not shown). Exclusion of the variable medical condition, which may be a mediator of associations between DII and mortality, did not substantially change results. For example, the estimate for overall mortality per unit increase in DII was HR 1·10, 95 % CI 1·04, 1·17, when medical condition was removed from the model, compared with HR 1·12, 95 % CI 1·05, 1·19, for the fully adjusted model (Table 3).

Discussion

Our results indicated that a more pro-inflammatory diet was associated with increased all-cause mortality. This association was strongest for deaths among younger (middle)-aged participants compared with older-aged participants. The cause-specific mortality analyses showed similar patterns of associations, with a more pro-inflammatory diet being associated with increased mortality due to other causes and with increased deaths due to CVD and cancer among middle-aged participants (≤ 55 years and ≤ 65 years, respectively).

These findings are broadly consistent with previous evidence[9], including two other Australian studies[15,16], thus supporting the notion that a more pro-inflammatory diet likely increases overall mortality, independent of other risk factors. No previous studies have assessed the timing of this association in terms of age at death, but our data suggest that this association is strongest for deaths that occur in middle age compared with old age. We cannot determine the exact reasons as to why these associations differed by age at death; however, it is possible that a pro-inflammatory diet may cause an acceleration of underlying disease mechanisms such as systemic inflammation, atherosclerosis and other common pathophysiology associated with chronic diseases and death, making this effect more easily detectable in middle age. Moreover, in old age, a multitude of different factors impact the probability of dying, including a person's history of smoking, physical activity and obesity[30–32], making it more difficult to tease out the influence of dietary factors. It is also possible that

Table 3 Risk of all-cause and cause-specific mortality in relation to Dietary Inflammatory Index (as a continuous variable), overall and at different age-at-death categories, Nambour study, 1992–2022

				Age time points†								
	Overall		≤ 55 years (n 29)		56–65 years (n 285)		66–75 years (n 388)		76–85 years (n 451)		86–96 years (n 287)	
	HR	95 % CI	HR	95 % CI	HR	95 % CI	HR	95 % CI	HR	95 % CI	HR	95 % CI
All-cause mortality												
Number of deaths		(n 488)		(n 18)		(n 43)		(n 83)		(n 172)		(n 172)
Adjusted HR*	1·12	1·05, 1·19	1·25	1·11, 1·41	1·18	1·10, 1·27	1·13	1·07, 1·19	1·09	1·02, 1·15	1·04	0·95, 1·13
CVD mortality												
Number of deaths		(n 188)		(n 5)		(n 7)		(n 26)		(n 73)		(n 77)
Adjusted SHR*	0·96	0·87, 1·06	1·36	1·04, 1·78	1·14	0·97, 1·35	1·00	0·90, 1·11	0·89	0·80, 0·99	0·79	0·67, 0·92
Cancer mortality												
Number of deaths		(n 151)		(n 10)		(n 25)		(n 38)		(n 47)		(n 31)
Adjusted SHR*	1·08	0·98, 1·19	1·20	1·02, 1·40	1·11	1·00, 1·23	1·04	0·94, 1·16	0·99	0·87, 1·13	0·94	0·79, 1·12
Other-cause mortality												
Number of deaths		(n 170)		(n 3)		(n 11)		(n 22)		(n 58)		(n 76)
Adjusted SHR*	1·12	1·02, 1·22	1·52	1·25, 1·84	1·31	1·15, 1·48	1·17	1·07, 1·27	1·06	0·96, 1·16	0·95	0·83, 1·08

HR, hazard ratio; SHR, sub-distribution hazard ratio.
*Adjusted for age (by using age as the time scale) and sex, medical conditions, smoking status and randomised trial treatment groups (β-carotene and/or daily sunscreen use).
†The number of deaths indicated in each age category is the number of deaths up to that age, for example, all deaths in participants up to age 55 years for the ≤ 55 year group, all deaths that occurred in participants aged 56–65 years for the 56–65 year category, etc.

dietary exposures earlier in life are more influential and critical in terms of longer-term risk of disease and death. These findings are in line with and corroborate global food-based dietary guidelines including those in Australia that promote consumption of fruits and vegetables with their anti-inflammatory health benefits throughout the life course[33].

Among cause-specific deaths, the inflammatory potential of diet was not associated with CVD deaths overall; it was only associated with deaths that occurred among those younger than 56 years of age when the DII score was treated as a continuous variable. A prior meta-analysis of CVD mortality outcomes indicated significant positive associations between DII scores and CVD mortality[34]; however, the sample size in our study was relatively small compared with previous studies, which may have restricted our ability to detect statistically significant relationships (e.g. there were 2399 CVD deaths out of 33 747 participants in a previous Swedish study[35]). Also, different dietary assessment methods were used in previous studies, and DII scores were calculated using a varying number of food parameters out of the possible forty-five, which may explain some of these differences.

Our results suggested that a more pro-inflammatory diet may be associated with cancer deaths, but this was also not statistically significant in the overall analyses. When we considered DII scores as continuous variable, these were associated with cancer deaths in those younger than 65 years (similar to our observation for CVD deaths). Inflammation is a consistent feature of the cancer microenvironment[36], and several complex, inflammation-induced, cancer-promoting pathways have been identified[37,38]. While we could not analyse associations with different cancer types, the literature indicates that the strongest associations with a pro-inflammatory diet are generally for digestive tract cancer mortality[11,12,39], and specific analyses of obesity-related cancers would also be of interest in future studies.

A more pro-inflammatory diet was associated with increased other-cause mortality in our study, both when DII scores were considered in quartile groups and as continuous variable. Again, this association was particularly seen in relatively younger-aged participants (before 75 years of age) compared with older age. While the causes of death included in this category are varied, there are a number of death causes within this group that are particularly associated with inflammation, including respiratory diseases such as pneumonitis, pneumonia, chronic obstructive pulmonary disorder and chronic bronchitis[40]. Inflammation is also thought to contribute to Alzheimer's disease development[41,42]. Thus, there are different possible disease mechanisms and death causes that could explain this association with other-cause mortality. The distribution of causes of death in this other-cause mortality group in our study was comparable with those reported in national data[43].

This study has strengths and limitations. The data were collected from a randomly selected community-based sample of Australian adults, thereby increasing the generalisability of the results. The use of repeated FFQ and the long follow-up are also the strengths of this study. We used a prospective study design, which reduced bias and possible reverse causation associated with some other study designs. Unlike many other studies, we adjusted for competing risks, which could otherwise influence results. Our study included a long follow-up period (1992–2022), and repeated measures of usual dietary intake were used to estimate DII scores where possible, thus ensuring that a more reliable estimate of long-term nutritional habits could be obtained; however, change in dietary habits over time may have occurred. The DII is an evidence-based index validated against multiple biomarkers in previous studies[8], and while we did not use a more recently developed energy-adjusted version of DII[44], our nutrient intake estimates were adjusted for energy within our study population before calculating z-scores, thereby removing potential confounding by energy intake. Due to the relatively small study population, we used relatively broad cause of death groupings to optimise statistical power by maximising the number of deaths that could be considered in each group (the main determinant of statistical power in these analyses), which may have hidden associations with individual disease outcomes. However, associations were apparent in some of the sub-groups with a relatively small number of deaths.

In conclusion, our findings generally support the notion that a pro-inflammatory diet is associated with increased mortality, in particular among middle-aged adults. Our results support the promotion of anti-inflammatory diets to help promote longevity.

Conflict of interest

The authors declare no conflict of interest.

Public Health Nutrition

Authorship

J.C.v.d.P., M.C.B.H., K.M., A.M., I.K.W.: conceptualised these analyses and were responsible for the methodology and statistical analysis. A.M., J.C.v.d.P., I.K.W.: wrote the first manuscript drafts. All authors provided critical revisions of the manuscript and approved the final manuscript.

Ethics of human subject participation

The Nambour Study was conducted according to the guidelines laid down in the Declaration of Helsinki, and all procedures involving research study participants were approved by the QIMR Berghofer Medical Research Institute Human Research Ethics Committee (HREC). Written informed consent was obtained from all subjects/patients.

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