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Diet quality and its implications on the cardio-metabolic, physical and general health of older men: the Concord Health and Ageing in Men Project (CHAMP)

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Abstract

The revised Dietary Guideline Index (DGI-2013) scores individuals' diets according to their compliance with the Australian Dietary Guideline (ADG). This cross-sectional study assesses the diet quality of 794 community-dwelling men aged 74 years and older, living in Sydney, Australia participating in the Concord Health and Ageing in Men Project; it also examines sociodemographic and lifestyle factors associated with DGI-2013 scores; it studies associations between DGI-2103 scores and the following measures: homoeostasis model assessment – insulin resistance, LDL-cholesterol, HDL-cholesterol, TAG, blood pressure, waist:hip ratio, BMI, number of co-morbidities and medications and frailty status while also accounting for the effect of ethnicity in these relationships. Median DGI-2013 score was 93·7 (54·4, 121·2); most individuals failed to meet recommendations for vegetables, dairy products and alternatives, added sugar, unsaturated fat and SFA, fluid and discretionary foods. Lower education, income, physical activity levels and smoking were associated with low scores. After adjustments for confounders, high DGI-2013 scores were associated with lower HDL-cholesterol, lower waist:hip ratios and lower probability of being frail. Proxies of good health (fewer co-morbidities and medications) were not associated with better compliance to the ADG. However, in participants with a Mediterranean background, low DGI-2013 scores were not generally associated with poorer health. Older men demonstrated poor diet quality as assessed by the DGI-2013, and the association between dietary guidelines and health measures and indices may be influenced by ethnic background.

Key words: Ageing: Men: Australia: Diet quality

Old age is a major risk factor for disease and poor health and the number of older people is increasing, leading to a growing recognition of the need to develop strategies to reduce the health burden associated with aging[1]. Nutrition is one of the most important and modifiable factors affecting health in older age[2]. Using cross-sectional baseline data, the Melbourne Longitudinal Study on Healthy Aging identified nutrition at baseline as an independent predictor of independence in daily living, good self-rated health and psychological wellbeing (i.e. 'ageing well') in older community-dwelling individuals[3]. Ethnicity has also been identified as a predictor of successful ageing[4,5]. For example, people who consume diets associated with particular cultures, such as the Mediterranean and Okinawan diets, appear to have improved health outcomes and longevity[6,7]. On the negative side, older individuals tend to have suboptimal diets[8–11]. This particularly applies to older men who are at an even higher risk of nutritional inadequacies than

Abbreviations: ADG, Australian Dietary Guideline; CHAMP, Concord Health and Ageing in Men Project; COB, Country of birth; DGI, Dietary Guideline Index; DHQ, diet histories questionnaire; HOMA-IR, homoeostasis model assessment – insulin resistance.

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women secondary to limited involvement in the planning and preparation of meals[12] and nutritional knowledge[13]. Therefore, it is important that studies examining the relationship between diet and health take age, sex and ethnicity into consideration.

There are many approaches to investigating the relationship between dietary intake and health. Traditionally, ‘single nutrient’ or ‘one-variable-at-a-time’[14] approaches have been used to explore associations between individual nutrients and health outcomes and this has been very effective for identifying the effects of nutritional deficiencies[15,16]. However, with increasing rates of diet-related obesity and cardio-metabolic diseases[16], and a growing recognition of the complexity of diets and interactions between nutrients, there has been a shift towards exploring the relationship between health and broader classifications of dietary composition. Dietary patterns analysis has emerged as one such method to investigate the association between dietary intake and risk of chronic diseases[15]. This type of method focuses on foods and their intake rather than specific nutrients.

The ‘dietary index’ is a type of dietary pattern analysis in which individuals’ diets are scored according to how well they comply with established dietary guidelines[17]. The revised Australian Dietary Guideline Index (DGI-2013)[18] is a food-based dietary index developed to investigate the compliance of adults to the Australian Dietary Guidelines (ADG)[17] (Table 1). The ADG are based on evidence related to the prevention of diet-related conditions and chronic diseases and the Australian National Health and Medical Research Council nutrient reference values[17].

Using the dietary index approach we investigated the association between food intake and health measures and indices in older men using data from the Concord Health and Ageing in Men Project (CHAMP). This cohort study was established to investigate geriatric syndromes of older men and the relationship between nutrition and health[19]. One-quarter of the CHAMP participants have Italian or Greek (Mediterranean) backgrounds, which has provided an opportunity to investigate whether the relationship between the DGI-2013 and health is influenced by ethnicity. Therefore, the aims of this study were to evaluate diet quality of older men using the DGI-2013, to discover sociodemographic and lifestyle factors associated with it, to investigate the associations between diet quality and some health measures and indices common in older age while accounting for the effect of ethnicity on these relationships.

Methods

Participants

The original selection of CHAMP subjects has been described in detail elsewhere[19]. In brief, 1705 men aged 70 years and over

Table 1. Components and scoring methods of the revised Dietary Guideline Index (DGI-2013)

Dietary guidelines	Indicator and description	Criteria for maximum score*	Criteria for minimum score	Maximum score
Guidelines for adequate intake				
1. Enjoy a variety of nutritious foods†	Number of food items consumed per day	≥19	<19	10
2. Vegetables and legumes/beans	Total vegetable intake: servings per day	≥5	0	10
3. Fruit	Total fruit intake: servings per day	≥2	0	10
4. Grain (cereal) foods, mostly wholegrain and/or high cereal fibre varieties	a. Total grains intake: servings per day	≥4·5	0	5
	b. Chooses mostly wholegrain or high fibre cereals	≥50 %	0	5
5. Meats and poultry, fish, eggs, tofu, nuts and seeds and legumes/beans	Total meat and alternatives intake: servings per day	≥2·5	0	10
6. Milk, yogurt, cheese	Total dairy products and alternatives intake: servings per day	≥3·5	0	10
7. Drink plenty of water	a. Total beverage intake‡: litres per day	≥2·6	0	5
	b. Water: proportion of water to total beverage intake per day	≥50	0	5
Guidelines to limit or moderate intake				
8. Limit intake of foods containing SFA, added sugars and alcohol	Limit discretionary foods	≤3	>3	10
9. Small allowance of unsaturated oils, fats or spreads	Unsaturated spreads and oils: servings per day	≤2	>2	10
10. Limit intake of foods high in SFA	Limit SFA intake§	≤10 %E	>10 %E	10
11. Limit intake of foods and drinks containing added sugars	Limit extra sugar: servings per day‖	≤1·5	>1·5	10
12. Limit intake of foods and drinks containing added salt	Limit Na intake¶	460–2300 mg	<460 or >2300 mg	10
13. If you choose to drink alcohol, limit intake	Limit alcohol: servings per day	≤2	>2	10

%E, percentage contribution to total energy.
* Criteria for maximum score has been derived from Australian Dietary Guidelines (1) according to age (70+) and sex (male) unless otherwise noted and total possible score = 130.
† Food variety scores were calculated based on the number of different food items consumed in a day; food item was only considered if it belonged to a core food group (grains, fruit, vegetable, protein foods and dairy products); if participant was to consume a different food item to meet their requirements of each food group, he would consume a minimum of nineteen different food items (rounded as one cannot consume half of a new food item.
‡ Fluid intake included water and water present in milk, fruit juice, tea and coffee.
§ Amount of SFA as a percentage of total energy.
‖ Since added sugar intake is not recommended there are no cut-off values for the number of recommended servings, instead half of the maximum discretionary food cut-off were used consistent with the original DGI.
¶ Na intake derived from salt added before or after cooking, packaged food items and salt naturally present in food.

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living in the suburbs of Burwood, Canada Bay and Strathfield in Sydney, Australia who were on the electoral roll enrolled in CHAMP at baseline (2005–2007). Participants have been followed up since 2005[19], and in 2012 during the 5-year follow-up (third follow-up wave), the nutritional data were collected from 794 participants who completed a diet history questionnaire[20].

All participants gave written informed consent. The study was approved by the Sydney South West Area Health Service Human Research Ethics Committee, Concord Repatriation General Hospital, Sydney, Australia.

Dietary intake

The dietary assessment method used in CHAMP has been described elsewhere[20,21]. In brief, typical dietary intake was assessed using a diet histories questionnaire (DHQ) and covered usual intake over the past 3 months[22] A research dietitian conducted and recorded all diet histories in the participant's residence with the process averaging 45 min for completion. The validity of DHQ was established by comparison to a 4-d weighed food record collected in a subgroup of fifty-six CHAMP men and results published previously[21].

Data handling and database conversion

Participants' daily dietary intakes were initially analysed using FoodWorks 7 Professional for Windows (2012; Xyris Software (Australia) Pty Ltd), which uses the Australian food, supplement and nutrient database 2007 (AUSNUT 2007). The national database has recently been updated (AUSNUT2001-13) therefore we have used the matching file[23] to update all foods and recipes information from reported intake in the CHAMP study; this database also converts participants' number of serves of each food group. Branded products were matched to AUSNUT 2007 food name using AUSNUT 2007 Brand Match File[24], then AUSNUT 2007 food name was matched to AUSNUT 2011-13 using matching file[23]. Foods that were not completely matched via AUSNUT 2007 to 2011-13 matching file were manually matched by an experienced research dietitian (R. V. R.).

Revised Dietary Guideline Index

The original Australian DGI[25] is a food-based dietary index developed to investigate the compliance of adults to the Dietary Guidelines for Australian Adults[26]. Thorpe *et al.*[18] revised the original DGI after the release of the new ADG containing changes in terminology and recommendations according to age and sex as well as a new component related to unsaturated fats.

Details of DGI-2013 has been provided elsewhere[18], in brief, the DGI-2013 is comprised of thirteen components each scored out of 10 (overall possible maximum score = 130), with 0 indicating low compliance to ADG and 10 better compliance, and therefore, higher diet quality. DGI-2013 is divided into categories of adequate intake (intake encouraged) and moderate intake (restrict intake recommended). Cut-offs for maximum and minimum scores are presented in Table 1 which was adapted from Thorpe *et al.*[18] publication.

The DGI (original and revised) were developed using data obtained through a 111-item FFQ. However, in the present study we have used DHQ to assess food intake that means there are no limitations on the number and quantities of food and beverages reported as is the case with FFQ. Therefore because of the nature of the data obtained – more quantitative than qualitative information – the following adaptations of DGI criteria were made:

(1) Added salt intake was not assessed in this study; therefore overall dietary Na intake was used to measure compliance with ADG. Individuals who consumed between 460 and 2300 mg (lower cut point of adequate intake to upper level of intake)[27] of Na a day received the maximum score.
(2) For the guideline about limiting intake of foods high in SFA, the percentage of total energy derived from SFA was used as information on fat trimming and type of milk was not systematically collected in the present study.
(3) Variety of food intake was measured based on the number of different foods participants consumed a day. For this calculation, only core food groups were taken into consideration because they are the basis of a balanced diet containing essential macro and micronutrients[28]. A participant received the maximum score for food variety if they consumed at least nineteen different foods from core food groups.
(4) Total fluid intake was calculated by summing participant's intake of water (including water present in coffee and tea), milk and fruit juice[17].
(5) Solid fat equivalents was calculated by summing fats naturally occurring in meat, poultry, eggs, dairy products, fully or partially hydrogenated oils, shortening, palm oil and coconut oil.
(6) Number of serves of discretionary foods was determined by summing the number of serves of added sugar (1 teaspoon (4·2 g) = 1 serve), solid fat equivalents (1 teaspoon (4·8 g) = 1 serve) and alcoholic drinks (1 standard drink = 1 serve).

Sociodemographic and lifestyle factors

Data on sociodemographic and economic factors, smoking status and physical activity were obtained through a self-completed questionnaire. Country of birth (COB) was grouped into three categories: (1) Australia and New Zealand; (2) Italy and Greece; and (3) other (total of thirty-eight countries). Income source was used as a proxy for personal income, assuming that age pensioners had the lowest income (age pensioners are provided with a modest pension if they are unable to support themselves) compared with those with other incomes, that is, repatriation pension, veteran's pension, superannuation or other private income, own business/farm/partnership, wage or salary, other or any income source combination[4]. Information on who is responsible for grocery shopping and cooking was obtained during the diet history interview and the data were dichotomised as self or other/assisted. Self-rated health data were obtained and dichotomised into excellent/good *v.* fair/poor/very poor.

Health measures and indices of interest

Number of co-morbidities and medications. Data on medical conditions were obtained from a self-reported questionnaire in which participants reported to be professionally diagnosed with any of the following diseases: diabetes, thyroid problems, osteoporosis, Paget's disease of bone, stroke, Parkinsons disease, kidney stones, dementia, depression, epilepsy, hypertension, myocardial infarction, angina, heart failure, peripheral vascular disease, chronic obstructive pulmonary disease, liver disease, chronic kidney disease, arthritis and cancer (excluding non-melanotic skin cancer and benign tumours such as bowel polyps and meningioma). Multi-morbidity was defined as having two or more of these conditions[29]. Participants were asked to bring prescription and non-prescription medications used daily or almost daily to their 5-year follow-up clinic appointment. Polypharmacy was defined as the use of five or more regular prescription medicines[30].

Insulin sensitivity, lipidaemia and blood pressure. Fasting blood was collected from 663 (84 %) participants to measure circulating levels of glucose, insulin, TAG, LDL-cholesterol and HDL-cholesterol. Each of these measures was performed at the Diagnostic Pathology Unit of Concord RG Hospital, which is a National Australian Testing Authority accredited pathology service, using a MODULAR Analytics system (Roche Diagnostics). Levels of cholesterol and HDL-cholesterol were measured on a Roche Cobas 8000 analyser (Roche Diagnostics International Ltd) using a standard automated enzymatic methodology. Fasting blood samples for glucose measurement were put into fluoride-oxalate (anticoagulant) tubes. Plasma glucose was measured using the Hexokinase method. homoeostasis model assessment – insulin resistance (HOMA-IR) was calculated using HOMA calculator version 2.2.3 (©Diabetes Trials Unit, University of Oxford). The remaining 128 (16 %) participants were not fasted at the time of blood collection and so the results for these participants have not been included in the current analysis. Blood pressure was measured by trained staff according to a standardised protocol using a sphygmomanometer as previously described[31]. Participants with systolic blood pressure ≥140 mmHg and diastolic ≥90 mmHg were categorised as hypertensive, those with systolic blood pressure 120–139 mmHg and diastolic 80–89 mmHg were categorised as normal-high blood pressure and those with systolic blood pressure <120 mmHg and diastolic <80 mmHg were categorised as normal blood pressure[32].

Anthropometry. Height and weight were measured according to a standardised protocol[33] and BMI was calculated as kg/m^2. BMI was categorised as underweight (<22 kg/m^2), normal (22–30 kg/m^2) and overweight/obese (>30 kg/m^2) in accordance with recent studies in older individuals (65 years and over) showing an increased risk of mortality in the lowest and highest cut-offs[34–39]. Waist and hip circumferences were measured following a standardized protocol as recommended by the World Health Organization[40]. Values above 0·9 (for men) indicate an increased health risk because of the abdominal obesity[40]. Activity level was determined through the Physical Activity Scale for the Elderly (PASE). The PASE questionnaire includes twelve types of occupational, household and leisure related activities from previous 7-d period; scoring is calculated from weights (e.g. intensity and duration) and frequency values for each type of activity[41].

Frailty status. Frailty scores were determined using the five frailty components used in the Cardiovascular Health Study (CHS)[42]. Weakness and slowness components were determined using the same criteria and the same cut-off points as in the CHS[42]. Weight loss, exhaustion, and low activity criteria were adapted in the CHAMP study, as the exact measurements used in the CHS were not available. Weight loss was defined as current weight lower by 15 % or more than self-reported heaviest weight (or than weight at 25 years old, if missing data on heaviest weight); participants were asked 'How much of the time during the past 4 weeks did you have a lot of energy?'[43], and classified as exhausted if their response was 'a little' or 'none of the time'; low activity was defined as being in the lowest quintile on the PASE (cutoff score <73)[41]. Participants were classified as follows: frail (score ≥3), pre-frail (score 1–2) and robust (score = 0)[42].

Statistical analysis

Data on number of serves of each food group, individual DGI component scores and total DGI scores were checked for normality using graphical and statistical methods (Shapiro–Wilk test) and were found to have skewed distribution, hence, medians and ranges (minimum to maximum) were calculated. Percentages of individuals meeting each component of DGI were also calculated.

To discover factors associated with diet quality (as per DGI-2013), we used a multi-model inference procedure based on information theory[44]. We first implemented a global linear model (LM) using the 'glm' function in the *base* package within the statistical programming environment R version 3.3.0 for windows[45], which contained DGI score as the response and all potential predictors of diet quality (age, marital status, level of education, income source, cooking responsibility, grocery shopping responsibility, smoking status, physical activity level, BMI and its quadratic effect) fitted additively. BMI was considered as both a predictor of DGI and an outcome of poor compliance to DGI. COB is a well-known factor associated with dietary patterns[46,47] and was explored in detail separately but not included in the model for the following reasons: (1) 'other' category contained forty-eight countries including England/UK, China, Croatia, Hungary and Malta, for example, making this a very heterogeneous group with not many similarity in terms of dietary patterns, and (2) excluding participants from 'other' COB was an option we avoided as that would significantly reduce our sample and the power of our analyses. The model was standardised to the *Z* scale using the 'standardise' function in the *arm* package[48]. A set of candidate models was created using the 'dredge' function in the *MuMIn* package[49]. Models were then ranked based on Akaike information criterion with correction for small sample size (AICc). Rather than restrict our inference to that based on a single 'best-fitting' model, which may be subject to model-selection uncertainty and model-selection bias, we used multi-model inference[50]. From the set of candidate models, a top model set comprising those models with an AICc within two of the top model (that with the lowest AICc) were obtained. Model-averaged coefficients were then obtained using the 'model.avg' function in *MuMIn*. For each coefficient we also report relative importance, adjusted SE, 95 % CI (1·96 × SE)[51], and the coefficient estimates with shrinkage. R^2 for global model was calculated using the equation 10 in Nakagawa & Schielzeth[52].

Chi-square and Mann–Whitney *U* test were used to compare DGI-2013 scores, food intake and health measures of Italian and Greek-born men v. Australian and New Zealand-born participants.

We examined whether DGI-2013 scores predicted health measures and indices by independently fitting each health measure as the response in a model with DGI score as the predictor. We explored models that were fitted both with and without socioeconomic factors that were associated with DGI-2013 (based on model averaging) and that differed between ethnic groups (Australia/New Zealand *v.* Italy/Greece). We used LM for continuous health measures and indices (HOMA-IR, LDL-cholesterol, HDL-cholesterol, TAG, waist:hip ratio and BMI) and quasi-poisson (log-link) generalised linear models (GLM) for all health measures and indices quantified as integers (number of co-morbidities and medications), implemented with the 'glm' function in the *base* package. For measures and indices expressed in categories (hypertension and frailty status), we used multinomial (logit-link) GLM implemented with the 'multinom' function in the *nnet* package[53]. For all multinomial measures and indices, the healthy status (normal blood pressure and robust) was fitted as the multinomial denominator. These analyses were performed in the whole sample. However, we also explored a subset of the data including only Australian/New Zealander and Italian/Greek-born participants. For this subset of the data we fitted models with interactions (i.e. effect-modifier) between COB and DGI score to explore whether DGI differentially predicted health as a function of ethnic background. Evidence against the null hypotheses was considered statistically significant if the resulting *P* values were <0·05.

Results

Participants' characteristics, food intake and Dietary Guideline Index scores

Participants' characteristics are presented in Table 2. The median age was 80 years (74–98) and median BMI was 27·5 (15·2–43 kg/m^2). The majority of participants were Australian or New Zealand-born (*n* 427), married and relied exclusively on the age pension as income source. Italian and Greek-born participants (*n* 188) were significantly less educated, more likely to live exclusively on the age pension and be married. Australian and New Zealand-born men were less likely to be smokers or former smokers, had a higher HDL-cholesterol and were more likely to rate their health as excellent/good. Overall, health measures and indices were similar in both groups (Table 2).

Participants' median food intake, DGI-2013 scores and proportion meeting guidelines are presented in Table 3. The average DGI-2013 score was 93·7 (54·4–121·2) with the majority of participants meeting the minimum guidelines for grains/cereals, meat and alternatives, water, alcohol and salt intake. Median dairy products and vegetable intakes were considerably below minimum guidelines. Only 1 % of the population consumed more than the recommended 2·6 litre of fluid per day. The majority of the population failed to consume enough fluid and over-consumed unsaturated fat and discretionary foods.

Factors associated with Dietary Guideline Index compliance

The top model set for predictors of DGI score, and associated AICc values is given in the online Supplementary Table S1. Model-averaged coefficients from these models are presented in the online Supplementary Table S2. Higher level of education, income and physical activity were associated with higher DGI scores, whereas being a smoker was associated with lower DGI scores.

Dietary Guideline Index-2013 and health measures and indices

Table 4 shows the results of analyses investigating the association between health measures and indices and DGI-2013 before and after adjustment for factors education and income. After adjustments, high DGI scores were associated with lower HDL-cholesterol, lower waist:hip ratios and lower probability of being frail. Proxies of good health such as fewer co-morbidities and medications were not associated with better compliance to the ADG.

The influence of ethnicity on Dietary Guideline Index and health measures and indices

The DGI-2013 scores of men born in Italy and Greece was significantly lower than those born in Australia and New Zealand (Table 3). Total energy intakes were similar between the two groups of men; however, Italian and Greek-born men consumed less total energy from protein and carbohydrate but more from fat. Italian and Greek-born men had higher intake of total and MUFA fat intake, red and orange vegetables, legumes (both as vegetables and as meat alternative), refined cereals, alcohol, oil equivalents, legume protein and fresh vegetables (tomatoes, dark green, red and orange vegetables) and lower intakes of SFA, starchy vegetables, wholegrain cereals, nuts, dairy products and discretionary foods including added sugar, SFA and salt (Table 3).

In the subset analysis (Australian/New Zealander and Italian/Greek-born participants only) investigating effect of COB on the relationship between DGI and health measures and indices, we found significant interaction between COB and DGI scores for probability of being classified as frail (P = 0·01), HOMA-IR (P = 0·005), number of co-morbidities (P = 0·039) and medications (P = 0·005) (Table 5). For those born in Australia and New Zealand, higher DGI-2013 scores were associated with lower HOMA-IR, number of co-morbidities, medications and lower probability of being classified as frail whereas for Italian and Greek-born men, increasing DGI scores had the opposite effect (Table 5, Fig. 1).

Table 2. Concord Health and Ageing in Men Project participants' characteristics
(Percentages and numbers; medians and ranges)

	Overall (*n* 794)*		Born in Australia/New Zealand (*n* 427)		Born in Italy/Greece (*n* 188)		
Characteristic	%	*n*	%	*n*	%	*n*	*P*
Sociodemographic							
Age (years) (*n* 794)							0·14
Median	80		81		80		
Range	74–98		74–98		75–93		
Post-school qualifications (*n* 791)							<0·001
Bachelor degree or higher	15	120	20	84	5	1	
Trade/apprenticeship	24	187	25	108	16	30	
Certificate/diploma	20	56	25	105	9	16	
High school and below	41	328	30	130	75	139	
Income source (*n* 791)†							<0·001
Other‡	40	315	25	105	63	118	
Age pension only	60	479	75	322	37	69	
Marital status (*n* 794)							<0·001
Married/*de facto*	75	597	70	299	86	161	
Divorced/separated/widowed/never married	25	194	30	128	14	26	
Country of birth (*n* 794)							
Australia/New Zealand	54	427	–		–		
Italy/Greece	24	188	–		–		
Other§	22	179	–		–		
Lifestyle							
Smoking status (*n* 776)							<0·001
Never smoked	40	313	48	202	24	44	
Former smokers	56	434	50	209	69	122	
Current smokers	4	29	2	10	7	13	
PASE (*n* 794)							
Median	120·8		121·5		127·0		
Range	0–507·4		0–507·4		58·6–264·2		
Body composition							
BMI (kg/m^2) (*n* 745)							0·59
Normal weight (22–30)	41	304	43	202	46	85	
Underweight (<22)	7	46	48	182	48	89	
Overweight/obese (>30)	60	444	9	37	6	12	
Median	27·5		27·1		29·2		
Range	15·2–43·0		15·2–41·1		21·3–43·0		
Waist:hip ratio (*n* 747)							0·002
>0·9	96	716	90	378	98	180	
Cardio-metabolic							
HOMA-IR (*n* 655)							0·12
Median	0·84		0·85		0·93		
Range	0·15–13·3		0·15–7·75		0·27–9·17		
Hypertension (*n* 774)‖							0·95
Yes	71	550	70	293	69	129	
HDL-cholesterol (*n* 663)							<0·001
Median	1·36		1·4		1·25		
Range	0·49–3·35		0·49–2·9		0·57–2·5		
LDL-cholesterol (*n* 653)							0·49
Median	2·4		2·3		2·4		
Range	1·0–6·0		1–5·5		1·1–5·4		
TAG (*n* 663)							0·21
Median	1·1		1·1		1·2		
Range	0·3–5·9		0·3–4·1		0·4–4·9		
General health							
Multi-morbidity (*n* 792)¶							0·45
Yes	71	564	71	303	74	139	
Polypharmacy (*n* 788)**							0·63
Yes	45	352	45	192	43	79	
Self-rated health (*n* 794)							0·004
Excellent/good	74	588	78	332	66	125	
Fair/poor/very poor	26	204	22	95	34	63	
Frailty status (score) (*n* 785)							0·59
Robust (0)	45	350	43	182	46	85	
Pre-frail (1–2)	47	370	48	202	48	89	
Frail (≥3)	8	65	9	37	6	12	

PASE, Physical Activity Scale for the Elderly; HOMA-IR, homoeostasis model assessment – insulin resistance.
* Overall sample included all countries of birth (Australia, New Zealand, Italy, Greece and other).
† Income source was used as a proxy of income assuming that 'others' have higher income than 'pensioners only'.
‡ Other sources of income includes repatriation pension, veteran's pension, superannuation or other private income, own business/farm/partnership, wage or salary, other or any income source combination.
§ There was a total of forty-eight countries of birth such as England/UK, China, Croatia, Hungary and Malta.
‖ Hypertension was defined as systolic blood pressure ≥140 mmHg and diastolic blood pressure ≥90 mmHg[32].
¶ Multi-morbidity was defined as having two or more of these conditions (seventeen).
** Polypharmacy was defined as the use of five or more regular prescription medicines.

Table 3. Median daily intake of food groups evaluated by Dietary Guideline Index (DGI-2013), participants' median scores, proportion of participants meeting guidelines, median intake of food groups and variety according to country of birth
(Percentages and numbers; medians and ranges)

		Overall				Subgroup				
		% Meeting guideline		DGI food groups intake		Australia/New Zealand		Italy/Greece		
No. of serves	Guideline (serves)	%	*n*	Median	Range	Median	Range	Median	Range	*P**
Variety†	≥19	49	390	18	4–45	18	4–45	18	5–42	0·980
Vegetables	≥5	24	188	3·5	0–23·7	3·5	0–23·7	3·6	1·2–21	0·093
Dark green	–	–		0·2	0–5·6	0·2	0–2·9	0·2	0–2·3	0·001
Red/orange	–	–		0·9	0–7·8	0·8	0–7·8	1	0·1–7·6	0·001
Tomatoes	–	–		0·2	0–5·8	0·2	0–2·4	0·5	0–5·8	<0·001
Other red/orange	–	–		0·9	0–7·8	0·5	0–7·8	0·4	0–5·8	0·001
Starchy	–	–		0·6	0–4·2	0·7	0–3·7	0·4	0–4·1	<0·001
Potatoes	–	–		0·5	0–4·2	0·6	0–3·5	0·3	0–3·8	<0·001
Other starchy	–	–		0	0–3·3	0	0–1·7	0	0–3·3	0·044
Legumes	–	–		0·7	0–6·6	0	0–2·1	0·2	0–6·6	<0·001
Other	–	–		1·3	0–12·8	1·3	0–12·8	1·3	0–9·7	0·715
Fruit	≥2	44	349	1·8	0–11·7	1·8	0–9·1	1·8	0–11·7	0·885
Fruit juice	–	–		0	0–8	0	0–2·9	0	0–8	0·031
Grains/cereals	–	–		5	0·1–17	4·8	0·1–13·7	4·8	1·4–17·1	0·853
Refined grains	–	–		2·7	0–17·1	2·2	0–12·4	3·4	0–17·1	<0·001
% Wholegrains	–	39	313	40·4	0–100	41·3	0–100	42·4	0–100	<0·001
Meat and alternatives	≥2·5	62	494	2·9	0–9·7	2·9	0·2–9·7	2·9	0–7·3	0·286
Red meats	–	–		1·1	0–6	1·2	0–4·8	1·1	0–4·1	0·136
Poultry	–	–		0·3	0–3·7	0·3	0–2·9	0·4	0–3·7	0·094
Eggs	–	–		0·2	0–1·5	0·1	0–1·4	0·1	0–1·2	0·397
Processed meats	–	–		0·1	0–1·5	0·1	0–1·3	0·1	0–1·5	<0·001
Organ meats	–	–		0	0–0·8	0	0–0·8	0	0–0	0·035
Seafood	–	–		0·3	0–3·3	0·3	0 –2·3	0	0–0	0·058
Nuts seeds	–	–		0·2	0–6·9	0·2	0–6·9	0	0–4·7	0·009
Legumes protein	–	–		0·05	0–4·2	0	0–1·3	0·2	0–4·2	<0·001
Soya products	–	–		0	0–2·6	0	0–0·5	0	0–0·2	0·144
Dairy products and alternatives	≥3·5	9·6	76	1·7	0–9·7	1·9	0–9·7	1·4	0–6·3	<0·001
Milk	–	–		1·1	0–6·7	1·3	0–6·5	0·7	0–5·4	<0·001
Cheese	–	–		0·3	0–5·5	0·3	0–3·6	0·4	0–5·5	0·002
Yogurt	–	–		0	0–3·4	0	0–1·8	0	0–1·2	<0·001
Milk alternatives	–	–		0	0–8·3	0	0–8·3	0	0–1·1	0·248
Plant protein‡	–	–		0·4	0–8·5	0·34	0–8·5	0·43	0–4·8	0·05
Fluid intake§	≥2·6	1	8	901·1	1–4295·7	993·6	117·7–4295·7	697·6	1–2613·4	<0·001
Water (%)	≥50	80·5	639	68·8	0–100	67·6	0–100	72·9	0–100	<0·001
Discretionary‖	≤3	0·5	3	17·2	1·3–66	18·7	2·7–58·4	13·5	3·3–66	<0·001
Added sugar	≤1·5	8·8	70	7·3	0–41·9	0·8	0–41·5	5	0–41·9	<0·001
Alcohol	≤2	73·6	584	0·8	0–12·5	0·8	0–12·5	1·3	0–6·9	0·028
SFA¶	≤10	31	246	11·5	3·4–33·2	8·2	2·3–27	6·8	0·9–21·5	<0·001
Unsaturated fat**	≤2	1·5	1·2	8·0	0·9–40	9·3	1·2–30·8	12·4	1·7–40·7	<0·001
Salt††	460–2300	70·3	558	1887·0	263·2–18 628·7	1971·0	535·4–7574·7	1702	632·8–4182	<0·001
Total DGI-2013‡‡	–	–			–					<0·001

* *P* value for difference of intake between subgroups (Australia and New Zealand-born *v.* Italy and Greece-born participants) derived from Wilcoxon's signed-rank test. Median may not differ between groups, however, values will be ranked differently (as per Wilcoxon's signed-rank test method) hence significant *P* values for difference.
† Food variety scores were calculated based on the number of different food items consumed in a day; food item was only considered if it belonged to a core food group (grains, fruit, vegetable, protein foods and dairy products); if participant was to consume a different food item to meet their requirements of each food group, he would consume a minimum of nineteen different food items (rounded as one cannot consume half of a new food item.
‡ Includes milk alternatives, legumes, soya products, nuts and seeds.
§ Fluid intake included water and water present in milk, fruit juice, tea and coffee.
‖ Number of serves of discretionary foods was determined by summing the number of serves of added sugar, solid fat equivalents and alcoholic drinks.
¶ Amount of SFA as a percentage of total energy.
** Fats naturally occurring in nuts, seeds, avocado, seafood and un-hydrogenated vegetable oils.
†† Salt intake derived from salt added before or after cooking, packaged food items and salt naturally present in food.
‡‡ Total possible score = 130.

Discussion

Our study is the first to assess diet quality in men aged 74 years and older. Overall compliance to the ADG was suboptimal with at least one-third of participants not meeting the recommendation for fruit, grains and meat. Even more concerning, more than half of individuals were not meeting recommendations (under-consuming) for vegetables, dairy products and alternatives and fluid but over-consuming added sugar, unsaturated fat and SFA fat, and discretionary foods. The main factors associated with DGI-2013 were education, income, smoking status and physical activity level.

Several studies have found an association between lower income and poorer dietary quality[25,54–57]. Nutritious and

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Table 4. Statistical analyses investigating the association between health measures/outcomes and Dietary Guideline Index (DGI-2013) scores in Concord Health and Ageing in Men Project (*n* 794)
(Estimates and 95 % confidence intervals)

Outcomes	Coefficient	Estimate	95 % CI	*P*
HOMA-IR	Model 1			
	Intercept	0·641	−0·008, 1·290	0·05
	Total score	0·004	−0·004, −0·012	0·22
	Model 2			
	Intercept	0·834	0·112, 1·557	0·024
	Total score	0·004	−0·004, 0·012	0·258
	$Education_{trade/apprenticeship/certificate/diploma}$	−0·210	−0·432, 0·012	0·063
	$Education_{high\ school\ and\ below}$	−0·115	−0·344, 0·115	0·328
	$Income_{other}$	−0·062	−0·214, 0·09	0·424
LDL-cholesterol	Model 1			
	Intercept	2·616	2·007, 3·226	<0·001
	Total score	−0·001	−0·007, 0·006	0·82
	Model 2			
	Intercept	2·410	1·731, 3·091	<0·001
	Total score	0·001	−0·007, 0·008	0·884
	$Education_{trade/apprenticeship/certificate/diploma}$	0·139	−0·071, 0·349	0·194
	$Education_{high\ school\ and\ below}$	0·109	−0·108, 0·325	0·325
	$Income_{other}$	−0·034	−0·177, 0·11	0·646
HDL-cholesterol	Model 1			
	Intercept	1·702	1·428, 1·976	<0·001
	Total score	−0·003	$-6{\cdot}25\times10^{-0{\cdot}3}$, $-4{\cdot}50\times10^{-04}$	0·02
	Model 2			
	Intercept	1·950	1·65, 2·252	<0·001
	Total score	−0·005	−0·009, −0·003	0·001
	$Education_{trade/apprenticeship/certificate/diploma}$	−0·089	−0·182, 0·004	0·059
	$Education_{high\ school\ and\ below}$	−0·161	−0·257, −0·066	0·001
	$Income_{other}$	0·072	0·009, 0·136	0·026
TAG	Model 1			
	Intercept	1·574	1·134, 2·014	<0·001
	Total score	−0·003	−0·008, 0·001	0·002
	Model 2			
	Intercept	1·328	0·839, 1·817	<0·001
	Total score	−0·002	−0·007, 0·004	0·500
	$Education_{trade/apprenticeship/certificate/diploma}$	0·108	−0·043, 0·259	0·159
	$Education_{high\ school\ and\ below}$	0·162	0·007, 0·317	0·041
	$Income_{other}$	−0·065	−0·168, 0·038	0·213
Waist:hip ratio	Model 1			
	Intercept	1·056	$1{\cdot}02\times10^{+00}$, $1{\cdot}09\times10^{+00}$	<0·001
	Total score	−0·001	$-1{\cdot}16\times10^{-3}$, $3{\cdot}80\times10^{-04}$	<0·001
	Model 2			
	Intercept	1·037	0·997, 1·077	<0·001
	Total score	−0·001	−0·002, −0·001	0·002
	$Education_{trade/apprenticeship/certificate/diploma}$	0·016	0·004, 0·029	0·012
	$Education_{high\ school\ and\ below}$	0·013	0·001, 0·027	0·044
	$Income_{other}$	−0·009	−0·018, 0·001	0·050
BMI	Model 1			
	Intercept	30·05	27·57, 32·52	<0·001
	Total score	−0·025	−0·005, 0·001	0·06
	Model 2			
	Intercept	27·981	25·288, 30·676	<0·001
	Total score	−0·011	−0·039, 0·016	0·412
	$Education_{trade/apprenticeship/certificate/diploma}$	1·002	0·178, 1·828	0·017
	$Education_{high\ school\ and\ below}$	1·539	0·682, 2·398	0·000
	$Income_{other}$	−0·532	−1·116, 0·052	0·074
Number of co-morbidities	Model 1			
	Intercept	0·92	0·540, 1·312	<0·001
	Total score	$1{\cdot}00\times10^{-04}$	−0·004, 0·004	0·96
	Model 2			
	Intercept	0·940	0·515, 1·367	<0·001
	Total score	$2{\cdot}40\times10^{-04}$	−0·005, 0·005	0·912
	$Education_{trade/apprenticeship/certificate/diploma}$	−0·049	−0·18, 0·083	0·465
	$Education_{high\ school\ and\ below}$	−0·006	−0·141, 0·129	0·925
	$Income_{other}$	−0·008	−0·101, 0·085	0·864
Number of medications	Model 1			
	Intercept	1·58	1·15, 2·02	<0·001
	Total score	−0·001	−0·006, 0·004	0·69

Table 4. *Continued*

Outcomes	Coefficient	Estimate	95 % CI	*P*
	Model 2			
	Intercept	1·692	1·211, 2·173	<0·001
	Total score	−0·001	−0·006, 0·004	0·675
	$Education_{trade/apprenticeship/certificate/diploma}$	−0·080	−0·228, 0·068	0·288
	$Education_{high\ school\ and\ below}$	−0·069	−0·221, 0·084	0·376
	$Income_{other}$	−0·056	−0·16, 0·049	0·296
$Blood\ pressure_{high-normal}$	Model 1			
	Intercept	−0·119	−2·519, 2·281	0·92
	Total score	−0·008	−0·033, 0·018	0·56
	Model 2			
	Intercept	−0·544	−3·201, 2·113	0·69
	Total score	−0·008	−0·035, 0·018	0·54
	$Education_{trade/apprenticeship/certificate/diploma}$	0·517	−0·319, 1·352	0·23
	$Education_{high\ school\ and\ below}$	0·277	−0·582, 1·136	0·53
	$Income_{other}$	0·213	−0·382, 0·808	0·48
$Blood\ pressure_{hypertensive}$	Model 1			
	Intercept	1·280	−0·257, 2·816	0·10
	Total score	−0·001	−0·018, 0·015	0·88
	Model 2			
	Intercept	0·969	−0·716, 2·654	0·26
	Total score	<0·001	−0·016, 0·017	0·96
	$Education_{trade/apprenticeship/certificate/diploma}$	0·415	−0·088, 0·918	0·11
	$Education_{high\ school\ and\ below}$	0·140	−0·372, 0·652	0·59
	$Income_{other}$	−0·139	−0·509, 0·230	0·46
$Frailty\ status_{pre-frail}$	Model 1			
	Intercept	0·895	−0·433, 2·222	0·18
	Total score	−0·009	−0·023, 0·005	0·21
	Model 2			
	Intercept	1·229	−0·242, 2·701	0·10
	Total score	−0·011	−0·025, 0·004	0·16
	$Education_{trade/apprenticeship/certificate/diploma}$	−0·321	−0·769, 0·127	0·16
	$Education_{high\ school\ and\ below}$	−0·211	−0·677, 0·256	0·36
	$Income_{other}$	0·059	−0·252, 0·371	0·71
$Frailty\ status_{frail}$	Model 1			
	Intercept	2·404	0·178, 4·630	0·03
	Total score	−0·045	−0·069, −0·020	<0·001
	Model 2			
	Intercept	3·042	0·596, 5·489	0·01
	Total score	−0·048	−0·073, −0·023	<0·001
	$Education_{trade/apprenticeship/certificate/diploma}$	−0·916	−1·707, −0·124	0·02
	$Education_{high\ school\ and\ below}$	−0·369	−1·138, 0·400	0·35
	$Income_{other}$	0·316	−0·264, 0·897	0·29

Model 1, unadjusted; model 2, adjusted for education and income; HOMA-IR, homoeostasis model assessment – insulin resistance (high HOMA-IR values indicate low insulin sensitivity (insulin resistance)).

healthy foods tend to be more expensive[58,59] whereas energy dense and nutrition poor diets tend to be cheaper[60], therefore cost may be a large barrier for older adults – particularly those living on the Age Pension – when choosing and purchasing foods. Furthermore, processed foods are cheaper and more palatable making them more attractive to older individuals who tend to have poor gustatory function[61] and, among older men, limited cooking facilities and/or ability[62]. Education and nutritional knowledge tend to correlate[63], therefore it is not surprising that less educated individuals are more likely to have poor compliance to the ADG. Similarly, poor health behaviours' such as low physical activity and smoking are often associated with poor nutritional habits[18,64–66]. Morabia & Wynder[64] investigated the association between dietary intake and smoking status of 7860 subjects aged 25–74 years and found that smokers consumed less fruit and vegetables, more alcohol and coffee than never smokers; male smokers consumed more meat and less cereals than those who were never smokers.

Compared with the general population of similar age and sex, that is, the latest nationally representative Australian Health Survey (AHS)[67], CHAMP participants' intakes of vegetable, meat and alternatives, dairy products and alternatives and fluid intakes were higher, however this difference may be because of the difference in dietary assessment method used in the two studies (AHS used 24-h recall *v.* DHQ in current study). Regarding higher vegetable intake in CHAMP participants, one explanation for the difference between AHS and the present study results may be related to the large proportion of CHAMP participants with a Mediterranean background – known to consume more vegetables[7]. Income may also play a role in explaining some of the differences in intake between the two studies; foods high in protein (e.g. dairy products and meat) tend to be more expensive than carbohydrate rich foods[68], and given that at least 40 % of CHAMP participants are likely to be on higher income (as per income source), one can assume that they have access to high protein foods.

Table 5. Analyses investigating the association between health measures and indices and Dietary Guideline Index (DGI-2013) scores in Concord Health and Ageing in Men Project according to country of birth (Australia/New Zealand *v.* Italy/Greece) (*n* 615) (Estimates and 95 % confidence intervals)

Outcomes	Coefficient	Estimate	95 % CI	*P*
HOMA-IR	Intercept	1·448	0·541–2·355	0·002
	COB$_{\text{Italy/Greece}}$	−2·061	−3·609–−0·513	0·009
	Total score	−0·003	−0·013–0·007	0·523
	Education$_{\text{trade/apprenticeship/certificate/diploma}}$	−0·164	−0·399–0·071	0·170
	Education$_{\text{high school and below}}$	−0·136	−0·391–0·119	0·299
	Income$_{\text{other}}$	−0·069	−0·234–0·096	0·412
	COB$_{\text{Italy/Greece}}$: Total score	0·024	0·008–0·04	0·005
LDL-cholesterol	Intercept	1·483	0·558–2·408	0·002
	COB$_{\text{Italy/Greece}}$	1·12	−0·464–2·704	0·166
	Total score	0·008	−0·002–0·018	0·078
	Education$_{\text{trade/apprenticeship/certificate/diploma}}$	0·264	0·021–0·507	0·034
	Education$_{\text{high school and below}}$	0·249	−0·016–0·514	0·065
	Income$_{\text{other}}$	−0·001	−0·17–0·168	0·988
	COB$_{\text{Italy/Greece}}$: total score	−0·012	−0·03–0·006	0·18
HDL-cholesterol	Intercept	1·854	1·446–2·262	<0·001
	COB$_{\text{Italy/Greece}}$	−0·316	−1·018–0·386	0·377
	Total score	−0·005	−0·009–−0·001	0·023
	Education$_{\text{trade/apprenticeship/certificate/diploma}}$	−0·028	−0·134–0·078	0·606
	Education$_{\text{high school and below}}$	−0·053	−0·169–0·063	0·368
	Income$_{\text{other}}$	0·072	−0·002–0·146	0·057
	COB$_{\text{Italy/Greece}}$: total score	0·002	−0·006–0·01	0·611
TAG	Intercept	1·578	0·904–2·252	<0·001
	COB$_{\text{Italy/Greece}}$	−0·161	−1·321–0·999	0·786
	Total score	−0·004	−0·01–0·002	0·221
	Education$_{\text{trade/apprenticeship/certificate/diploma}}$	0·094	−0·082–0·27	0·298
	Education$_{\text{high school and below}}$	0·159	−0·033–0·351	0·105
	Income$_{\text{other}}$	−0·062	−0·185–0·061	0·322
	COB$_{\text{Italy/Greece}}$: total score	0·002	−0·01–0·014	0·778
Waist:hip ratio	Intercept	1·035	0·986–1·084	<0·001
	COB$_{\text{Italy/Greece}}$	−0·015	−0·105–0·075	0·746
	Total score	−0·001	−0·001–−0·001	0·02
	Education$_{\text{trade/apprenticeship/certificate/diploma}}$	0·006	−0·008–0·02	0·4
	Education$_{\text{high school and below}}$	0·002	−0·012–0·016	0·786
	Income$_{\text{other}}$	−0·005	−0·015–0·005	0·308
	COB$_{\text{Italy/Greece}}$: total score	0·000	0·000–0·000	0·506
BMI	Intercept	29·377	25·827–32·927	<0·001
	COB$_{\text{Italy/Greece}}$	−0·404	−6·692–5·884	0·9
	Total score	−0·022	−0·057–0·013	0·216
	Education$_{\text{trade/apprenticeship/certificate/diploma}}$	0·318	−0·627–1·263	0·51
	Education$_{\text{high school and below}}$	0·445	−0·584–1·474	0·397
	Income$_{\text{other}}$	−0·409	−1·093–0·275	0·242
	COB$_{\text{Italy/Greece}}$: total score	0·024	−0·045–0·093	0·495
Number of co-morbidities	Intercept	1·347	0·784–1·91	<0·001
	COB$_{\text{Italy/Greece}}$	−1·029	−2·031–−0·027	0·045
	Total score	−0·003	−0·009–0·003	0·339
	Education$_{\text{trade/apprenticeship/certificate/diploma}}$	−0·157	−0·306–−0·008	0·04
	Education$_{\text{high school and below}}$	−0·114	−0·275–0·047	0·163
	Income$_{\text{other}}$	−0·062	−0·172–0·048	0·268
	COB$_{\text{Italy/Greece}}$: total score	0·011	−0·001–0·023	0·039
Number of medications	Intercept	2·062	1·433–2·691	<0·001
	COB$_{\text{Italy/Greece}}$	−1·583	−2·722–−0·444	0·007
	Total score	−0·005	−0·011–0·001	0·154
	Education$_{\text{trade/apprenticeship/certificate/diploma}}$	−0·137	−0·306–0·032	0·111
	Education$_{\text{high school and below}}$	−0·120	−0·306–0·060	0·196
	Income$_{\text{other}}$	−0·070	−0·192–0·052	0·265
	COB$_{\text{Italy/Greece}}$: total score	0·017	0·005–0·029	0·005
Blood pressure$_{\text{high-normal}}$	Intercept	−1·11	−4·793–2·566	0·55
	COB$_{\text{Italy/Greece}}$	−0·666	−7·004–5·678	0·84
	Total score	0·001	−0·035–0·037	0·96
	Education$_{\text{trade/apprenticeship/certificate/diploma}}$	0·215	−0·760–1·190	0·66
	Education$_{\text{high school and below}}$	−0·270	−1·331–0·790	0·62
	Income$_{\text{other}}$	0·228	−0·496–0·951	0·54
	COB$_{\text{Italy/Greece}}$: total score	0·011	−0·058–0·080	0·75
Blood pressure$_{\text{hypertensive}}$	Intercept	1·583	−0·734–3·900	0·18
	COB$_{\text{Italy/Greece}}$	−3·368	−7·499–0·763	0·11
	Total score	−0·002	−0·025–0·021	0·87
	Education$_{\text{trade/apprenticeship/certificate/diploma}}$	0·015	−0·613–0·643	0·96

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Table 5. *Continued*

Outcomes	Coefficient	Estimate	95 % CI	*P*
	Education$_{\text{high school and below}}$	−0·332	−0·997–0·333	0·33
	Income$_{\text{other}}$	−0·240	−0·695–0·215	0·30
	COB$_{\text{Italy/Greece}}$: total score	0·038	−0·007–0·083	0·10
Frailty status$_{\text{pre-frail}}$	Intercept	2·386	0·292–4·478	0·03
	COB$_{\text{Italy/Greece}}$	−3·355	−6·89–0·179	0·06
	Total score	−0·022	−0·043–−0·001	0·04
	Education$_{\text{trade/apprenticeship/certificate/diploma}}$	−0·280	−0·812–0·251	0·30
	Education$_{\text{high school and below}}$	−0·098	−0·678–0·482	0·74
	Income$_{\text{other}}$	−0·026	−0·406–0·354	0·89
	COB$_{\text{Italy/Greece}}$: total score	0·034	−0·004–0·073	0·08
Frailty status$_{\text{frail}}$	Intercept	5·993	2·644–9·343	<0·001
	COB$_{\text{Italy/Greece}}$	−9·592	−16·296–−2·889	0·01
	Total score	−0·080	−0·115–−0·045	<0·001
	Education$_{\text{trade/apprenticeship/certificate/diploma}}$	−0·896	−1·888–0·096	0·08
	Education$_{\text{high school and below}}$	−0·100	−1·089–0·888	0·84
	Income$_{\text{other}}$	0·264	−0·458–0·986	0·47
	COB$_{\text{Italy/Greece}}$: total score	0·100	0·027–0·172	0·01

COB, country of birth; HOMA-IR, homoeostasis model assessment – insulin resistance (high HOMA-IR values indicate low insulin sensitivity (insulin resistance)).

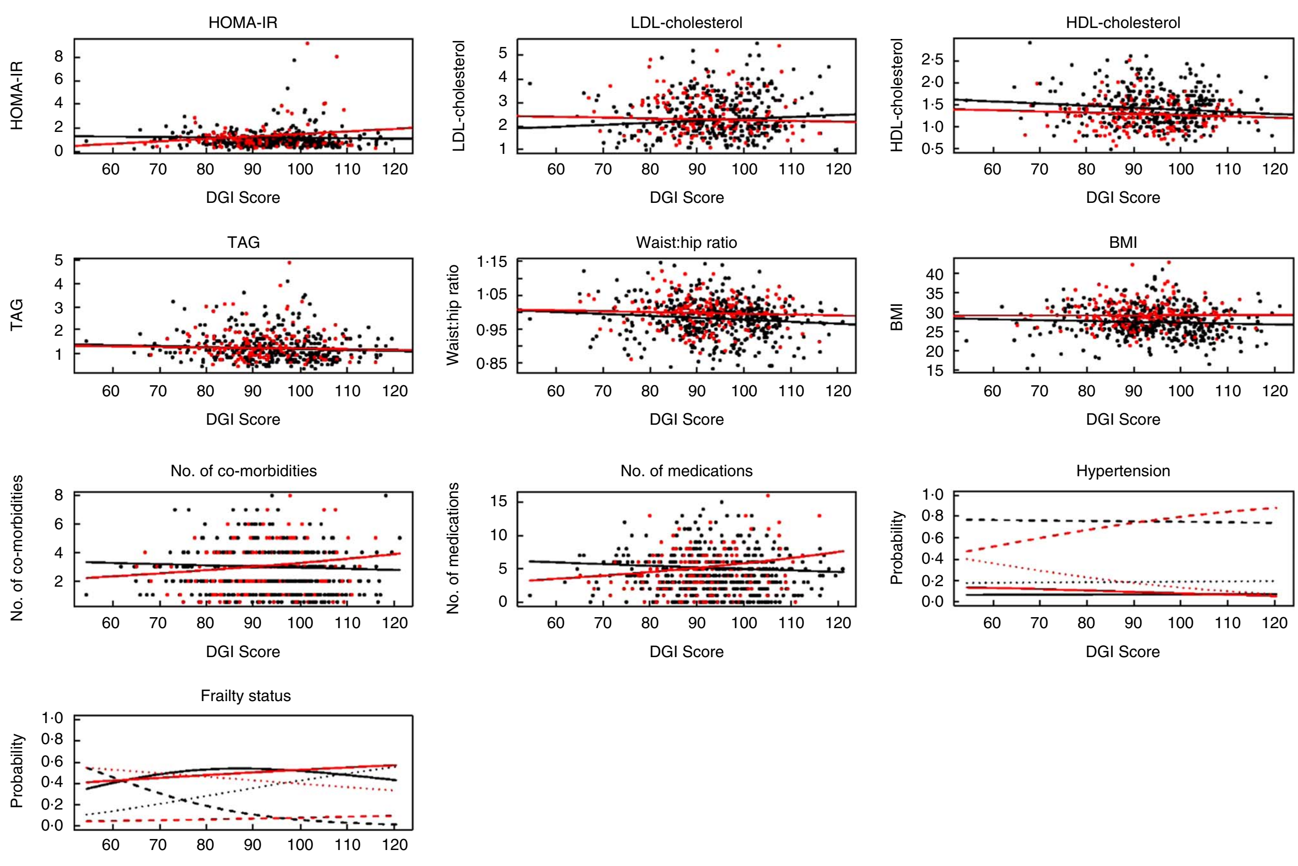

Fig. 1. Graphical representation of the association between health outcomes and Dietary Guideline Index (DGI)-2013 scores according to country of birth. HOMA-IR, homoeostasis model assessment – insulin resistance; ———, Australia/New Zealand; ———, Italy/Greece; ———, high normal/pre-frail; – – –, hypertensive/frail; ……, normal/robust. Linear regression used to investigate the association between continuous variables (HOMA-IR, LDL-cholesterol, HDL-cholesterol, TAG, waist: hip ratio and BMI) and DGI-2013 scores, general linear model was used to investigate the association between interval variables (number of co-morbidities and number of medications) and DGI-2013 scores, and multinomial analysis was used to investigate the association between nominal variables (hypertension and frailty status) and DGI-2013 scores. Models were adjusted for education, income as those were significantly different between Australian/ New Zealander born and Italian/ Greek born participants (Table 2) and were also associated with DGI-2013 scores (Tables 4 and 5).

Two of the ADG are known to have a direct effect on HDL-cholesterol levels: limiting consumption of SFA and consuming a small allowance of unsaturated fat[17]. In the present study, we found that high DGI scores (i.e. better compliance with ADG) were associated with lower HDL-cholesterol levels. One potential reason for this may be the limitation in unsaturated fat.

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Although one would expect that better compliance with dietary guidelines would result in healthier HDL-cholesterol levels (i.e. higher levels), other non-dietary factors such as obesity and smoking status, presence of the metabolic syndrome, hypertriacylglycerolaemia and even socioeconomic status may also influence HDL-cholesterol levels[69].

In this study, we found that high DGI scores were not associated with some indicators of better overall health such as fewer co-morbidities or number of medications. There are a number of potential explanations for this: first, ageing in itself is an important factor in the development of some of the health issues common in older age; second, some factors such as genetics, for example, have an impact on the relationship between nutrition and health measures and indices but cannot be accounted for. Similarly, although we have adjusted for a number of factors known to have an impact in those associations, there may still be some factors not yet identified that may confound these associations.

A recent systematic review involving both longitudinal and cross-sectional data, showed that better diet – as measured by a variety of dietary assessments and dietary indices – was associated with successful ageing as defined by better quality of life as well as good mental and physical health[5]. DGI is based on ADG, which provides evidence based guidelines on food types and quantities that are associated with a reduction in morbidity and mortality[17]. It follows that compliance with the dietary guidelines therefore, should result in better health measures and indices[70–72]. In our study we found that overall, although not always statistically significant, good compliance to the DGI was associated with better health measures and indices.

Evidence suggests that dietary preferences established in younger ages can influence food choices in later life[73]; therefore, it is likely that older individuals will follow the same dietary patterns as those established in their earlier age and COB. This may explain the observed higher intake of alcohol and unsaturated fats as well as significantly higher intake of legumes and non-starchy vegetables (Mediterranean dietary pattern) amongst Italian/Greek-born men. Surprisingly, Italian/Greek-born participants with better compliance to the ADG had a tendency to poorer health measures and indices, in particular number of co-morbidities. Mediterranean dietary patterns have been shown to have beneficial effects on several age-related health outcomes[7] and this may explain, at least in part, why Italian and Greek-born men have similar health to Australian and New Zealand-born men despite lower DGI scores. This also suggests that a dietary index developed for the general population may not be suitable for or accepted by those from diverse ethnic backgrounds. The poorer health in Italian and Greek migrants with greater compliance to the ADG could reflect the loss of the protective Mediterranean dietary pattern in this group but could equally be the result of reverse causality where men have changed their diets to conform more closely to the ADG in response to ill health.

Strengths and limitations

One of the main strengths of this study was the use of a validated dietitian-administered diet history questionnaire to assess dietary intake of its participants. DHQ is a retrospective method is particularly indicated for older people because their diets tend to be consistent over long periods of time, it does not rely on short-term memory and it uses a much more interactive approach than other methods[12,74–76]. Furthermore, diet histories have low respondent burden, which may improve response rates among older people and they require no literacy or numeracy skills from participants[77–79], making them suitable for participants from culturally and linguistically diverse backgrounds. Another advantage of using data derived from diet history questionnaires is that no pre-established serves and frequency are used, that gives a good notion of variety of food consumed and also permits us to proportionally score guidelines related to moderate and limited intake. The present study also had some limitations. First, we used data from a cross-sectional observational study, which precludes the investigation of causal mechanisms. Furthermore, when assessing these findings, it is important to take into account important 'survival effects' – that is, individuals with poor nutrition tend to be less likely to live to the advanced ages examined in this study[3]. Second, as in most studies on nutritional epidemiology, diet was self-reported and measurement bias may be present; however, measurement bias is likely to have been non-differential with regards to measures and indices and so will have led to underestimation of associations, rather than causing spurious associations. Similarly, self-reported food intake may have been influenced by participants' desire to gain approval from interviewer/researcher[80] based on what is believed to be 'healthy'. Finally, adaptation of DGI-2013 was necessary regarding salt and animal fat trimming; this resulted in a DGI composed of a mix of food and nutrient-based DGI score which may not be as practical in a clinical setting as a food-based dietary index.

Conclusion

In conclusion, this cross-sectional study has demonstrated that the diet of Australian men aged ≥74 years is suboptimal according to ADG. However, for participants with a Mediterranean background, having poor compliance to ADG was not associated with poorer health. These findings highlight the need for development of dietary guidelines that are more acknowledge and encourage dietary patterns from culturally diverse groups. Further investigation is required to confirm these findings, particularly in longitudinal studies.

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conducted all the data analyses and wrote the first draft of the manuscript. A. M. S. oversaw statistical analyses. V. H., A. M. S., A. K. G., R. G. C., F. M. B., V. N., L. M. W., D. J. H., M. J. S., S. J. S., F. S., M. A.-F. and D. G. L. C. collaborated in writing. All authors reviewed and approved the final version of the manuscript. All authors had primary responsibility for final content.

None of the authors has any conflicts of interest to declare.

Supplementary material

For supplementary material/s referred to in this article, please visit https://doi.org/10.1017/S0007114517001738

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