The Journal of Nutrition
Nutritional Epidemiology

An Index of Diet and Eating Patterns Is a Valid Measure of Diet Quality in an Australian Population[1,2]

Sarah A. McNaughton,[3]* Kylie Ball,[3] David Crawford,[3] and Gita D. Mishra[4]

[3]Centre for Physical Activity and Nutrition Research, School of Exercise and Nutrition Sciences, Deakin University, Melbourne, Australia 3125; and [4]Department of Epidemiology and Public Health, University College and Royal Free Medical School, London, UK WC1E 6BT

Abstract

Diet indices represent an integrated approach to assessing eating patterns and behaviors. The aim of this study was to develop a comprehensive food-based dietary index to reflect adherence to healthy eating recommendations, evaluate the construct validity of the index using nutrient intakes, and evaluate this index in relation to sociodemographic factors, health behaviors, risk factors, and self-assessed health status. Data were analyzed from adult participants of the Australian National Nutrition Survey who completed a 108-item FFQ and a food habits questionnaire ($n = 8220$). The dietary guideline index (DGI) consisted of 15 items reflecting the dietary guidelines, including dietary indicators of vegetables and legumes, fruit, total cereals, meat and alternatives, total dairy, beverages, sodium, saturated fat, alcoholic beverages, and added sugars. Diet quality was incorporated using indicators relating to whole-grain cereals, lean meat, reduced/low fat dairy, and dietary variety. We investigated associations between the DGI score, sociodemographic factors, health behaviors, chronic disease risk factors, and nutrient intakes. We found associations between the DGI scores and sex, age, income, area-level socioeconomic disadvantage, smoking, physical activity, waist:hip ratio, systolic blood pressure (males only), and self-assessed health status (females only) (all $P < 0.05$). Higher DGI scores were associated with lower intakes of energy, total fat, and saturated fat and higher intakes of fiber, β-carotene, vitamin C, folate, calcium, and iron ($P < 0.05$). This food-based dietary index is able to discriminate across a variety of sociodemographic factors, health behaviors, and self-assessed health and reflects intakes of key nutrients. J. Nutr. 138: 86–93, 2008.

Introduction

Increasingly, whole foods (rather than nutrients), their combination in complex eating patterns, and their potential synergistic effects are being recognized as important in the prevention of chronic disease (1,2). This has led to the development of methods suitable for the characterization of total diet or dietary patterns. Two approaches to dietary pattern research exist: multivariate statistical techniques such as factor analysis and cluster analysis (also known as data-driven approaches) (3,4); and the development of dietary scores determined by a priori dietary guidelines and recommendations (5,6). Diet indices represent a measure of "healthy" eating patterns and are known by various names, including diet quality indices or healthy eating indices.

Dietary indices or scores have certain advantages over data-driven dietary pattern approaches. They are based on existing knowledge of optimal dietary patterns and provide a clear nutritional benchmark. Consequently, diet indices may be easy to interpret and may therefore be more easily understood by the public (4). Data-driven approaches often identify eating patterns that do not reflect guidelines or knowledge about optimal eating patterns and therefore, lack of associations with health and disease may not be surprising (7).

Measures of diet patterns have a number of uses or purposes. For example, they may be used in monitoring and surveillance to assess how well people comply with dietary guidelines and to monitor trends in the population over time. They may also be used as predictors of disease or as a summary of dietary behaviors to investigate interactions with other health behaviors or confounding of other exposure-disease relationships.

Currently, there are 2 commonly used diet scores: the Healthy Eating Index and the Revised Diet Quality Index (8,9). Both of these are based on the U.S. dietary guidelines and include both food and nutrient-based indicators. Although they have been adapted for use in other countries by altering the cut-offs (10), there has been little adaptation of the range of indicators to reflect the dietary guidelines in other countries or to focus solely on food-based indicators.

Food-based dietary indices have a number of advantages over those based on food and nutrient intakes. They retain the com-

[1] Supported by a National Health and Medical Research Council Public Health Postdoctoral Fellowship (to S.A.M.), by a National Health and Medical Research Council/National Heart Foundation of Australia Career Development Award (to K.B.), by a Victorian Health Promotion Foundation Senior Research Fellowship (to D.A.C.), and by the Medical Research Council (United Kingdom) (to G.D.M.).
[2] Author disclosures: S. A. McNaughton, K. Ball, G. D. Mishra, and D. Crawford, no conflicts of interest.
* To whom correspondence should be addressed. E-mail: sarah.mcnaughton@deakin.edu.au.

0022-3166/08 $8.00
Manuscript received 26 June 2007. Initial review completed 30 July 2007. Revision accepted 11 October 2007.

plexity of food intake and indirectly assess intakes of nutrient and nonnutrient components in food (11). In addition, developing a food-based score may lend itself to further adaptation to short methods of dietary assessment that may be particularly relevant for use in monitoring and surveillance activities (12,13).

The aims of this study were to develop a comprehensive food-based dietary index to reflect adherence to the Dietary Guidelines for Australian Adults (DGAA)[5] (14), to evaluate the construct validity of the index using nutrient intakes, and to evaluate this index in relation to sociodemographic factors, health behaviors, and chronic disease risk factors.

Materials and Methods

Subjects and procedure

This analysis is based on data from adult participants (≥19 y, n = 10,851) of the latest (1995) Australian National Nutrition Survey (NNS) (15–17). The NNS was conducted on a subset of participants of the National Health Survey (18) and was based on a multi-stage area sample of households in urban and rural areas in all states and territories in Australia. Ethics approval for the survey was provided by the Ethics Committee of the Australian Institute of Health and Welfare (17). Detailed descriptions of the sampling and methodology used are presented elsewhere (17). The NNS consisted of a single 24-h recall, a FFQ, and a food habits and attitudes questionnaire (FHQ). Physical measurements including anthropometric measures and blood pressure were taken and interviewer-administered questionnaires were used to collect information on sociodemographic details and a range of health behaviors, such as smoking and physical activity, and self-assessed health status.

Measures

Health behaviors and outcomes. Waist circumference, hip circumference, height, and weight were measured with standardized protocols and BMI was calculated (weight/height^2) (17). Blood pressure was measured twice, with the survey member seated after resting during the dietary recall using a Tycos Aneroid sphygmomanometer. If the systolic readings differed by >6 mm Hg and/or the diastolic readings differed by >4 mm Hg, a 3rd measurement was made. The mean of the 2 measurements (or the 2 closest measurements) was used for this analysis (17).

Self-assessed health status was measured using standardized items from the SF36 questionnaire in which respondents are asked to rate their own health from excellent to poor. Regarding smoking, respondents were asked whether they currently smoked or if they had ever smoked. Physical activity was also assessed by self-report using standardized questions (19). Respondents were asked whether during the previous 2 wk they engaged in any walking for sport, recreation or fitness, moderate exercise (apart from walking), or vigorous exercise; if yes, they were asked the number of times and the total amount of time spent for each exercise. These data were then used to derive an overall measure of physical activity.

Socioeconomic position. Two measures of socioeconomic position were investigated. The Index of Relative Socioeconomic Disadvantage (SEIFA) is an area-level indicator based on the economic resources, education, occupation, family structure, and ethnicity of households within a specific geographical area (census district) (15). The lowest quintile represents areas with a greater number of families of low income and a greater number of people with little training or in unskilled occupations (15). Equivalent household income is a derived index based on the individual dollar income of all members of the income unit, expressed as quintiles.

Dietary intake. The 108-item FFQ assessed usual frequency of intake of food and beverages during the last 12 mo. Each item had a choice of 9 frequency categories ranging from "Never or less than once a month" to "six or more times per day." Frequencies of consumption were converted to equivalent daily frequencies. Because this FFQ did not include portion size, each eating occasion was assumed to represent consumption of 1 serving of the food (20). The FFQ was a modified version of an existing validated questionnaire developed for use in Australian populations with additional foods included (21). The FHQ consisted of questions on a range of food habits, including breakfast consumption, salt use, type of milk consumed, fat trimming from meat, and daily fruit and vegetable consumption. Questions on the FHQ have been evaluated and shown to be valid measures of food intake behaviors (22,23).

During the 24-h recall, information was collected on all food items and beverages that were consumed on the previous day. Across the study population, all days of the week and seasons were represented. The multiple-pass method consisted of the completion of a quick list of food and beverage items consumed, followed by the collection of detailed information for each item listed in the quick recall, and finally a review phase to allow respondents to report any foods that may have been forgotten (17). The method was based on that developed by the USDA (24). Nutrient intake was calculated by the Australia Bureau of Statistics using a customized food composition database (25).

Dietary guideline index. A dietary guideline index (DGI) aimed at reflecting the DGAA was developed (**Table 1**). Indicators were identified for each dietary guideline with the development of cut-offs and food groupings guided by the Australian Guide to Healthy Eating (AGHE), which provides age- and sex-specific recommendations for the consumption of 5 core food groups (vegetables, fruits, cereals, meat and alternatives, and dairy) and "extra foods" (26). According to the AGHE, extra foods are defined as foods that are not essential to provide nutrient requirements and contain too much fat, sugar, and salt and include foods such as soft drinks, cordials, fruit juice drinks, mayonnaise and dressing, chips, jam and marmalade, confectionery, chocolate, hamburgers, hot chips, meat pies, pizza, cakes and muffins, pies and pastries, puddings, ice cream, cream, biscuits, and all alcoholic beverages (26). Diet quality was incorporated by inclusion of items relating to whole-grain cereals, lean meat, reduced or low fat dairy, and dietary variety. The AGHE was devised as a food guide aiming to provide recommended dietary intakes. Although the Australian recommended dietary intakes have recently been updated (27), there is currently no revised food selection guide, and therefore the AGHE provides the most current food-based recommendations. Existing national recommendations for food-based nutrition indicators for saturated fat, added sugars, and sodium (28,29) were utilized. We chose indicators based on available data items from the FFQ and FHQ, because these measures are designed to represent usual intake or behavior. A total of 15 indicators were included in the DGI.

Each component was scored from 0–10, 10 indicating that a participant was meeting the recommendation or had an optimal intake. The total score was the sum of 15 items so that the diet score had a possible range of 0–150, with a higher score reflecting increased compliance with the dietary guidelines. Cut-offs for maximum and minimum scores are detailed in Table 1, with those participants consuming intermediate amounts scored proportionately as recommended (5). For example, with respect to fruit intake, 2 servings per day (recommended amount) scored 10 points, 1 serving per day scored 5 points, and no fruit consumption scored 0 points.

A measure of dietary variety was developed based on consumption of food from the core food groups only (fruits, vegetables, meat/protein, dairy, and cereals). Variety within each core food group was defined as the proportion of core foods consumed at least once per week as a proportion of the total number of core foods listed of the FFQ. Each core food group was allocated a score out of 2 and total variety score was calculated as the sum of the score for each food group. This approach avoids the dominance of commonly used food variety scores by fruit and vegetables (30,31) and avoids using data-driven cutoffs, such as the 11 quantiles used by McCullough et al. (32,33), which are population dependent and therefore not comparable between studies. This scoring approach is also analogous to that used by Kant et al. (31) in the development of the Recommended Food Score.

Fruit and vegetable intakes were based on responses to short questions about total fruit and total vegetable intake from the FHQ, which have been shown to be reliable measures of fruit and vegetable

[5] Abbreviations used: AGHE, Australian Guide to Healthy Eating; DGAA, Dietary Guidelines for Australian Adults; DGI, dietary guideline index; FHQ, food habits questionnaire; NNS, National Nutrition Survey; P:S ratio, polyunsaturated fat:saturated fat ratio; SEIFA, Index of Relative Socioeconomic Disadvantage.

TABLE 1 Components of the DGI according to the DGAA (14)

Dietary guideline	Indicator and description	Criteria for maximum score (10)[1]	Criteria for minimum score (0)[1]
Enjoy a wide variety of nutritious foods	Dietary variety: proportion of foods for each core food group that are consumed at least once per week	100%	0%
Eat plenty of vegetables, legumes, and fruits	Fruit: servings of fruit per day	≥2	0
	Vegetables: servings of vegetables and legumes per day	≥5	0
Eat plenty of cereals (including breads, rice, pasta, and noodles), preferably whole-grain	Cereals: frequency of consumption of breads and cereals per day	19–60 y: M ≥ 6, F ≥ 4; >60 y: M ≥ 4, F ≥ 4	0
	Whole-grain cereals[2]: proportion of whole-meal/whole-grain bread consumed relative to total bread	100%	0%
Include lean meat, fish, poultry, and/or alternatives	Meat and meat alternatives: frequency of consumption of lean meats and alternatives per day	≥1	0
	Lean protein sources: proportion of lean meats and alternative relative to total meats and alternatives	100%	0%
Include milks, yoghurts, cheeses, and/or alternatives Reduced-fat varieties should be chosen, where possible	Dairy foods: frequency of consumption of dairy products per day	≥2	0
	Low-fat/reduced-fat dairy: type of milk usually consumed	Low-fat milk	Whole milk
Drink plenty of water	Fluids: frequency of consumption of beverages	≥8	0
	Fluids: proportion of water consumed relative to total beverages[2]	50%	0%
Limit saturated fat and moderate total fat intake	Saturated fat intake: type of milk usually consumed	Low-fat milk	Whole milk
	Saturated fat intake: trimming of fat from meat	Usually	Never or rarely
Choose foods low in salt	Salt use: salt used in cooking	Never or rarely	Usually
	Salt use: salt used at the table	Never or rarely	Usually
Limit your alcohol intake if you choose to drink	Alcohol: frequency of consumption of all alcoholic beverages per day	M ≥ 2, F ≥ 1	M ≥ 4, F ≥ 2
Consume only moderate amounts of sugars and foods containing added sugars	Added sugars[3]: frequency of consumption of soft drink, cordial, fruit juice drink, jam, chocolate, confectionary per day	19–60 y: M < 1.5, F < 1.25; >60 y: M < 1.25, F < 1	19–60 y: M > 1.5, F > 1.25; >60 y: M > 1.25, F > 1
Prevent weight gain: be physically active and eat according to your energy needs	Extra foods[3]: frequency of consumption of extra foods per day	19–60 y: M < 3, F < 2.5; >60 y: M < 2.5, F < 2	19–60 y: M > 3, F > 2.5; >60 y: M > 2.5, F > 2

[1] Servings unless otherwise indicated. Participants with intakes between the maximum and minimum amount were assigned scores proportionately.
[2] No quantitative Australian guidelines currently exist. Maximum score cut-offs are based on the Dietary Guidelines for Americans (61) and United States Beverage Guidance Panel (62).
[3] Guidelines for added sugars and extra foods are presented as an upper limit. Because there is no quantitative guideline for added sugars, one-half the extras foods guideline is used which is consistent with existing dietary indices (60).

intake (34). Short questions based on nutrition monitoring and surveillance methodology have been used in dietary indices previously (13). This approach avoids concerns about over-reporting of fruits and vegetables on FFQ measures (35). The FFQ data on fruits and vegetables were used in the food variety component of the score as described above. Whereas fruit and vegetables are covered in 1 dietary guideline statement, we chose to separate these items into 2 index components to reflect the AGHE and recent recommendations on dietary index methodology (5). Cereal consumption was assessed using items on the FFQ. Whole-grain cereal consumption was assessed based on the consumption of whole-grain and whole-meal bread only, because the other cereal items on the FFQ (pasta, rice, and breakfast cereals) did not distinguish whole-grain varieties.

The dietary guidelines are intended to be considered in combination with each other and the indicators and cut-offs used in the diet score were developed to take this into account. For example, considering recommendations concerning added sugars and weight gain, only low-energy soft drinks and cordials were counted as contributors to beverage or fluid intake and only lean items were counted as contributors to meat and alternatives intake. Similarly, guidelines for alcohol consumption provided in the DGAA are lower than the Australian Alcohol Guidelines (36), because they take into consideration the additional energy provided by alcohol and the implications for weight maintenance. Therefore, the DGAA guideline amounts and the Australia Alcohol Guidelines (36) were used to quantify the cut-offs. This also reflects recommendations for including alcohol in diet indices (5).

Analysis

The current analysis is based on data from 8220 adults aged >19 y with valid data from the FFQ (<20 items with missing responses; $n = 228$) (17) and complete responses to data items from the FHQ used in the

TABLE 2 Scores for each component of the DGI and percentage of men and women meeting recommendations or optimal intake

	Males		Females	
Dietary score component	DGI[1]	Meeting recommendations[2]	DGI[1]	Meeting recommendations[2]
Food variety[3]	4.5 ± 0.0	0	5.0 ± 0.0*	0
Vegetables	4.9 ± 0.1	15	5.4 ± 0.0*	22*
Fruit	7.1 ± 0.1	46	7.7 ± 0.0*	55*
Cereals	4.2 ± 0.0	3	5.6 ± 0.0*	7*
Whole-grain cereals	5.4 ± 0.1	45	6.4 ± 0.1*	57*
Meat and meat alternatives	9.8 ± 0.0	90	9.7 ± 0.0	87*
Lean protein sources[3]	7.6 ± 0.0	0	8.1 ± 0.0*	0
Dairy foods	6.9 ± 0.1	33	6.8 ± 0.1	30
Low-fat/reduced-fat dairy	3.8 ± 0.1	37	5.1 ± 0.1*	50*
Fluids	6.8 ± 0.0	10	7.4 ± 0.0*	14*
Saturated fat intake	5.9 ± 0.1	30	7.0 ± 0.1*	43*
Salt use	6.3 ± 0.1	32	6.9 ± 0.1*	39*
Alcoholic beverages	9.1 ± 0.0	86	9.3 ± 0.0*	86
Added sugars	5.6 ± 0.1	56	5.6 ± 0.1*	56
Extra foods	3.0 ± 0.1	30	3.7 ± 0.1*	37

[1] Data are means ± SEM weighted for the survey design (17,63). *Different from males, $P < 0.05$ (Student's t test).
[2] Data are percentages weighted for the survey design (17,63). A score of 10 was assigned when meeting recommendations. * Different from males, $P < 0.05$ (chi-square test).
[3] For the food variety and the lean protein sources component, no participants met the optimal intake.

DGI. Data for males and females were analyzed separately. Mean diet score and scores for each component, along with the percentage of participants meeting each guideline, were calculated and compared between males and females using *t* tests and chi-square for proportions. Associations between the DGI score and sociodemographic variables, self-assessed health status, health behaviors, and risk factors (BMI, waist circumference, waist:hip ratio, and blood pressure) were investigated using regression analyses. Quintiles of DGI were calculated, with Q1 indicating a diet least consistent with the dietary guidelines and Q5 indicating a diet most consistent with the dietary guidelines. To evaluate the construct validity of the DGI, mean nutrient intakes from the 24-h recalls and linear trends across DGI quintiles were assessed. Statistical analysis was conducted with SPSS Version 14.0 and Stata Version 8.0 and differences of $P < 0.05$ were considered to be significant. Values in the text are means ± SEM.

Results

DGI scores differed for males and females, with females having a higher score (91.0 ± 0.4 vs. 99.6 ± 0.3, respectively; $P < 0.05$). Females also performed better on many of the individual components of the DGI score (**Table 2**). Overall, there were few dietary guidelines that were well met by the study population.

We identified significant associations between the DGI score and age, income, area-level SEIFA (females only), smoking status, and self-reported physical activity (**Table 3**). Older participants, participants with higher income, participants living in the least socioeconomically disadvantaged areas, nonsmokers, and those with moderate or vigorous physical activity levels had higher DGI scores.

Among men, the DGI score was inversely associated with the waist:hip ratio and systolic blood pressure (**Table 4**). Among women, the DGI score was inversely associated with the waist: hip ratio but was also directly associated with BMI, with higher DGI scores associated with higher BMI. The DGI was also directly associated with self-reported health status; participants reporting higher DGI scores also reported significantly better health.

Among males, higher DGI scores were associated with lower energy intake; lower intakes of total fat, saturated fat, and monounsaturated fat; higher intakes of fiber, vitamin A, β-carotene equivalents, folate, vitamin C, calcium, iron, and potassium; and a higher polyunsaturated fat:saturated fat ratio (P:S ratio) (**Table 5**). Similarly, among females, higher DGI scores were associated with lower energy intakes; lower intakes of total, saturated, monounsaturated, and polyunsaturated fat; and higher intakes of protein, fiber, vitamin A, β-carotene equivalents, folate, vitamin C, calcium, iron, and potassium. Energy-adjusted nutrient intakes showed similar results. In addition, higher DGI scores were associated with higher energy-adjusted intakes of protein, polyunsaturated fat, total sugars, and total carbohydrates among men, and higher energy-adjusted intakes of total sugars and total carbohydrates among women.

Discussion

This article describes the development and evaluation of a food-based dietary index aimed at reflecting healthy eating pattern recommendations in Australia. The DGI showed variations across sex, age, measures of socioeconomic status, health behaviors, and some chronic disease risk factors, and reflected intakes of key nutrients such as total fat and saturated fat, fiber, β-carotene equivalents, vitamin C, folate, calcium, and iron.

This work shows that compliance with the dietary guidelines as measured by this index is generally poor in this study population, a finding that is consistent with previous work in Australian women (20). The current findings extend these observations to men and highlight that on average, women have more favorable diets. In addition, older participants, participants with higher income, participants living in the least socioeconomically disadvantaged areas, nonsmokers, and those with moderate/vigorous physical activity levels had the highest DGI scores. These findings have important implications for nutrition promotion in identifying target groups for intervention. It is important to note that for some indicators, no participants met the "optimal" intake (e.g. food variety, lean meat). This may be partly due to the methodology used. There are no quantitative targets for these guidelines and alternative approaches would have required the use of arbitrary or data-driven cut-offs such as those used by McCullough et al. (37).

Diet quality as measured by the DGI was associated with age, measures of socioeconomic position, and other health behaviors. Younger adults had poorer diets than older adults, with higher DGI scores at younger ages in females compared with males. This is consistent with reports of diet quality among adults in the United States and elsewhere, although not all studies have stratified by sex (13,38–41). However, longitudinal studies are required to investigate whether dietary quality improves across the life-course. These results are also consistent with previous studies suggesting that lower socioeconomic position is associated with poorer diet quality and that health-related behaviors cluster together (42–49).

TABLE 3 Regression coefficients and 95% CI from regression analyses of the DGI score for sociodemographic variables adjusted for all other variables in men and women[1,2]

	Males	*P*-value	Females	*P*-value
Age group, *y*		<0.0001		<0.0001
18–29	−7.03 (−9.16, −4.91)		−3.14 (−5.07, −1.20)	
30–39	−6.40 (−8.43, −4.37)		−0.30 (−2.23, 1.63)	
40–49	−4.69 (−6.78, −2.60)		0.85 (−1.16, 2.87)	
50–64	0.08 (−1.86, 2.02)		3.77 (1.91, 5.64)	
>65	Reference		Reference	
Equivalent income		<0.0001		<0.0001
1st Quintile	−3.76 (−5.73, −1.79)		−4.00 (−5.87, −2.13)	
2nd Quintile	−5.24 (−7.22, −3.26)		−4.55 (−6.39, −2.72)	
3rd Quintile	−2.57 (−4.42, −0.71)		−4.19 (−6.03, −2.36)	
4th Quintile	−3.15 (−4.91, −1.39)		−3.32 (−5.12, −1.51)	
5th Quintile	Reference		Reference	
SEIFA[3]		0.09		0.04
1st Quintile	−2.63 (−4.58, −0.68)		−2.69 (−4.55, −0.82)	
2nd Quintile	−0.46 (−2.36, 1.44)		−1.63 (−3.47, 0.20)	
3rd Quintile	−1.18 (−3.05, 0.69)		−1.11 (−2.93, 0.70)	
4th Quintile	−0.85 (−2.67, 0.96)		−0.33 (−2.09, 1.43)	
5th Quintile	Reference		Reference	
Smoking status		<0.0001		<0.0001
Smoker	−10.32 (−11.92, −8.71)		−8.76 (−10.30, −7.22)	
Ex-smoker	−2.17 (−3.59, −0.74)		0.01 (−1.38, 1.41)	
Never smoked	Reference		Reference	
Physical activity		<0.0001		<0.0001
Moderate/vigorous	6.95 (5.48, 8.42)		7.20 (5.70, 8.70)	
Low	5.30 (3.75, 6.86)		5.85 (4.46, 7.23)	
Sedentary	Reference		Reference	

[1] Data are regression coefficients (95% CI) adjusted for all other variables.
[2] A higher DGI score indicates a diet more consistent with the dietary guidelines.
[3] Quintile 1 represents areas with a greater number of families of low income and a greater number of people with little training or in unskilled occupations.

The DGI was shown to be significantly associated with intakes of key nutrients in the expected direction, based on data from an independent measure of dietary intake. Total sugars was not associated with DGI score in either men or women. However, the DGI included indicators of the intake of added sugars, but food composition data for added sugars in Australia are not currently available and total sugars includes those present in fruit and milk (foods associated with healthy eating as defined by the AGHE). It should also be noted that the DGI represents a range of eating behaviors and some components of the DGI will not contribute variation to all the nutrients examined.

The significant association between higher DGI scores and higher BMI among women is difficult to explain but may be related to the cross-sectional study design and reverse causality (i.e. overweight women adopt a healthier diet to lose or manage their weight) or dietary under-reporting among those with a higher BMI (50,51). Some previous cross-sectional studies of

TABLE 4 Regression coefficients and 95% CI from regression analyses of the DGI score for each risk factor adjusted for age, income, SEIFA, smoking status, and physical activity in men and women[1]

	Males	*P*-value	Females	*P*-value
BMI, kg/m^2	0.17 (−0.59, 0.93)	0.657	1.20 (0.31, 2.08)	0.008
Waist circumference, *cm*	−1.96 (−4.10, 0.18)	0.072	1.08 (−1.01, 3.16)	0.312
Waist:hip ratio	−0.02 (−0.04, −0.01)	<0.001	−0.02 (−0.03, −0.01)	0.003
Systolic blood pressure,[2] *mm Hg*	−3.80 (−6.85, −0.75)	0.015	−0.55 (−3.15, 2.05)	0.677
Diastolic blood pressure,[2] *mm Hg*	−1.88 (−3.96, 0.20)	0.076	−1.03 (−2.81, 0.75)	0.257
Self-assessed health status[3]	0.08 (−0.15, 0.32)	0.489	0.27 (0.06, 0.47)	0.012

[1] Data are regression coefficients and 95% CI multiplied by 100 and adjusted for age, income, SEIFA, smoking status and physical activity.
[2] Systolic and diastolic blood pressure also adjusted for BMI. Participants reporting using blood pressure medication were excluded from the analysis.
[3] A randomly selected subset of the NNS study population completed the question regarding self-assessed health (males, $n = 1849$; females, $n = 2268$).

TABLE 5 Daily dietary intakes by quintile of DGI in men and women[1]

	Males, $n = 3760$				Females, $n = 4460$			
	Q1	Q3	Q5	*P*-value[2,5]	Q1	Q3	Q5	*P*-value[2,5]
Energy,[3] *kJ*	10,514 (10,216, 10,821)	10,169 (9906, 10439)	9722 (9474, 9977)	<0.05	7070 (6869, 7276)	7027 (6841, 7218)	6668 (6493, 6847)	<0.05
Protein, *g*	96.4 (93.2, 99.7)	97.9 (95.0, 100.9)	99.0 (96.2, 102.0)	NS	62.8 (60.6, 65.2)	68.4 (66.3, 70.5)	71.2 (69.3, 73.2)	<0.05
Total fat, *g*	91.4 (88.1, 94.8)	87.8 (84.7, 91.1)	76.6 (73.9, 79.4)	<0.05	63.2 (60.6, 65.9)	60.4 (58.2, 62.6)	50.8 (48.8, 52.9)	<0.05
Saturated fat, *g*	36.0 (34.5, 37.6)	33.8 (32.4, 35.3)	26.9 (25.7, 28.1)	<0.05	25.1 (24.0, 26.2)	23.3 (22.3, 24.3)	18.0 (17.2, 18.9)	<0.05
MUS fat,[4] *g*	33.0 (31.7, 34.4)	31.6 (30.4, 32.8)	28.0 (27.0, 29.1)	<0.05	22.3 (21.4, 23.3)	21.1 (20.3, 21.9)	18.0 (17.2, 18.8)	<0.05
PUS fat,[4] *g*	12.2 (11.6, 12.8)	12.3 (11.8, 12.9)	12.0 (11.6, 12.6)	NS	8.6 (8.2, 9.0)	8.6 (8.2, 9.0)	7.8 (7.4, 8.1)	<0.05
P:S ratio[4]	0.40 (0.38, 0.41)	0.42 (0.41, 0.44)	0.50 (0.49, 0.52)	<0.05	0.40 (0.38, 0.41)	0.43 (0.41, 0.44)	0.49 (0.47, 0.50)	<0.05
Total sugars, *g*	109.6 (103.8, 115.8)	108.4 (103.6, 113.3)	111.4 (107.3, 115.7)	NS	83.3 (79.5, 87.2)	82.6 (79.3, 86.0)	85.0 (82.0, 88.1)	NS
Total carbohydrates, *g*	266.0 (257.0, 275.2)	268.5 (260.9, 276.2)	275.6 (267.9, 283.4)	NS	190.7 (184.7, 196.8)	193.7 (188.3, 199.3)	193.9 (188.6, 199.3)	NS
Dietary fiber, *g*	18.9 (18.2, 19.6)	23.3 (22.5, 24.1)	29.4 (28.4, 30.5)	<0.05	14.6 (14.0, 15.2)	19.1 (18.4, 19.7)	22.9 (22.2, 23.6)	<0.05
Vitamin A, *μg*	862 (812, 916)	922 (874, 973)	971 (918, 1026)	<0.05	671.6 (633.5, 712.0)	756.9 (718.9, 797.0)	763.5 (724.5, 804.5)	<0.05
β-Carotene equivalents, *μg*	1671 (1519, 1839)	1972 (1813, 2145)	2687 (2483, 2907)	<0.05	1398 (1284, 1522)	1867 (1726, 2019)	2379 (2203, 2570)	<0.05
Folate, *μg*	258 (250, 267)	275 (267, 284)	320 (311, 330)	<0.05	180 (173, 186)	214 (207, 220)	239 (233, 246)	<0.05
Vitamin C, *mg*	78.1 (72.4, 84.2)	89.6 (83.5, 96.2)	119.1 (112.0, 126.8)	<0.05	57.3 (53.1, 61.8)	80.3 (75.2, 85.8)	97.4 (91.8, 103.4)	<0.05
Iron, *mg*	13.4 (13.0, 13.9)	14.8 (14.3, 15.2)	16.6 (16.1, 17.1)	<0.05	9.6 (9.3, 9.9)	11.2 (10.8, 11.5)	11.9 (11.6, 12.3)	<0.05
Calcium, *mg*	690 (660, 720)	798 (765, 833)	937 (903, 972)	<0.05	548 (525, 571)	670 (646, 696)	768 (742, 795)	<0.05
Potassium, *mg*	3208 (3103, 3316)	3364 (3268, 3462)	3799 (3695, 3906)	<0.05	2289 (2212, 2367)	2646 (2570, 2724)	2950 (2873, 3029)	<0.05

[1] Values are means ± SEM. Quintiles of dietary pattern score are indicated by Q1–Q5.
[2] *P* for linear trend.
[3] Energy-adjusted mean intakes are not shown. Significant linear trends were identified as for unadjusted data. In addition, significant linear trends were shown for energy-adjusted intakes of protein, polyunsaturated fat, total sugars, and total carbohydrates among men and energy-adjusted intakes of total sugars and total carbohydrates among women with higher diet scores associated with higher intakes.
[4] MUS, monounsaturated; PUS, polyunsaturated.
[5] NS, $P \geq 0.05$.

diet quality have also found similar results (5,13,40) and studies investigating dietary patterns derived from factor and cluster analysis have also shown mixed results in relation to their associations with overweight and obesity (52).

Few published studies have investigated the relationship between dietary patterns and self-reported health status. Osler et al. (53) identified a prudent pattern using factor analysis methods that was directly associated with self-reported health status and mortality. The current study showed a direct association between the DGI and self-reported health status and some, but not all, chronic disease risk factors. It is possible that the risk factors assessed relate to longer-term dietary patterns that are not reflected in the cross-sectional NNS data, whereas perceptions of health status and health behaviors such as diet are more closely related temporally. An alternative explanation is that dietary intake and self-reported health are susceptible to similar reporting bias and that the association reflects a tendency to report both diet and health as more favorable than they really are. It is possible that this bias is greater in women, resulting in the different findings for men and women. Further investigation of the DGI in longitudinal studies is required to answer these questions.

The lack of associations with some risk factors is consistent with previous studies of diet indices (5,54). It may result from the cross-sectional nature of the study or may reflect a lack of variation in the population and the fact that too few subjects are consuming an "optimal" diet. It must also be recognized that not all of the dietary guidelines relate to each of the health outcomes investigated (e.g. obesity and measures of salt consumption). Although this study has shown that the DGI has construct validity with respect to nutrient intakes, it highlights that further work is required to determine whether this index has predictive validity with respect to health in longitudinal studies (55).

As described previously, a limitation of this study is its cross-sectional design. There are also other limitations with respect to the available data for use as indicators. For example, there is limited information on whole-grain intakes in the Australian population and the best way to measure them at a population level. A limitation with the short questions on fruit and vegetable intake in the NNS is that the response categories do not fully reflect the quantitative guidelines for fruits and vegetables. In addition, measures of salt intake were limited to intake used in cooking and at the table and although these are currently used in monitoring surveillance in Australia (28,29), development of additional indicators to adequately reflect salt in processed foods is required. The lack of portion size data on the FFQ is also a limitation of this study. However, the index could be modified as the methods for measurement of dietary guideline indicators are improved and applied to other data sources.

Strengths of this study include the large, nationally representative study population, the use of measures of usual dietary intake, the objective health measures, and the ability to investigate construct validity by comparison with nutrient intakes. The focus on food-based indicators is also a strength of this study. A recent review of diet index methodology has recommended that diet indices should be food based (5). A focus on food intakes acknowledges the complexity of dietary patterns and the nutrient and nonnutrient components of the diet (11). A further strength of this index is the incorporation of additional measures of diet quality. The concept of diet quality extends beyond quantitative assessment of macro and micronutrients (56) to whole foods and types of foods and dietary variety. These aspects of diet quality have been incorporated in the DGI. Development of a food-based score may lend itself to further adaptation to short methods of dietary assessment that focus on food intakes rather than detailed measures of intake (12) and therefore may be particularly relevant for use in monitoring and surveillance activities (13). This dietary index is an improvement on previous food-based scores, because it includes measures of over-consumption (57). In addition, we used age- and sex-specific cut-offs where they are available to incorporate variations in requirements (26). This is important because consuming more food overall likely results in higher intakes of many nutrients (5). Food-based diet indices also reflect the move toward food-based dietary guidelines (58) and are most similar to other methods of assessing dietary patterns (3).

Diet indices or scores, such as the DGI presented here, are integrated measures of healthy eating patterns and have a number of potential uses or purposes. When based on dietary guidelines, they represent the best available evidence and consensus of what constitutes a healthy diet. They can be used in epidemiological studies either to investigate associations of overall healthy eating patterns and health outcomes or investigate interactions with other health behaviors or as a confounder in other disease (33,59,60). Diet scores can be used in monitoring and surveillance to assess how well people comply with dietary guidelines, to monitor trends in the population over time, and to target diet and nutrition messages for the public (13). They may also have important uses in studying the behavioral determinants of healthy eating patterns where an integrated measure of diet can be used as the outcome of interest.

This dietary index, based on the recommendations for healthy eating in Australia, is able to discriminate across a variety of socioeconomic factors and reflects intakes of key nutrients. Further work is required to investigate the ability of this index to predict health outcomes in longitudinal studies.

Literature Cited

1. Gerber M. The comprehensive approach to diet. A critical review. J Nutr. 2001;131:S3051–5.
2. Schulze MB, Hoffmann K. Methodological approaches to study dietary patterns in relation to risk of coronary heart disease and stroke. Br J Nutr. 2006;95:1–10.
3. Newby PK, Tucker KL. Empirically derived eating patterns using factor or cluster analysis: a review. Nutr Rev. 2004;62:177–203.
4. Michels KB, Schulze MB. Can dietary patterns help us detect diet-disease associations? Nutr Res Rev. 2005;18:241–8.
5. Waijers PM, Feskens EJ, Ocke MC. A critical review of predefined diet quality scores. Br J Nutr. 2007;97:219–31.
6. Bach A, Serra-Majem L, Carrasco JL, Roman B, Ngo J, Bertomeu I, Obrador B. The use of indexes evaluating the adherence to the Mediterranean diet in epidemiological studies: a review. Public Health Nutr. 2006;9:132–46.
7. Jacques PF, Tucker KL. Are dietary patterns useful for understanding the role of diet in chronic disease? Am J Clin Nutr. 2001;73:1–2.
8. Haines PS, Siega-Riz AM, Popkin BM. The Diet Quality Index revised: a measurement instrument for populations. J Am Diet Assoc. 1999;99:697–704.
9. Kennedy ET, Ohls J, Carlson S, Fleming K. The healthy eating index: design and applications. J Am Diet Assoc. 1995;95:1103–8.
10. Shatenstein B, Nadon S, Godin C, Ferland G. Diet quality of Montreal-area adults needs improvement: estimates from a self-administered food frequency questionnaire furnishing a dietary indicator score. J Am Diet Assoc. 2005;105:1251–60.
11. Kant AK. Indexes of overall diet quality: a review. J Am Diet Assoc. 1996;96:785–91.
12. Massari M, Freeman KM, Seccareccia F, Menotti A, Farchi G. An index to measure the association between dietary patterns and coronary heart disease risk factors: findings from two Italian studies. Prev Med. 2004;39:841–7.
13. Rafferty AP, Anderson JV, McGee HB, Miller CE. A healthy diet indicator: quantifying compliance with the dietary guidelines using the BRFSS. Prev Med. 2002;35:9–15.
14. National Health and Medical Research Council. Dietary guidelines for Australian adults. 2003 [cited 2006 March 8]. Available from: http://www.nhmrc.gov.au/publications/synopses/_files/n33.pdf
15. Australian Bureau of Statistics. Technical Paper. National Nutrition Survey Confidentialised Unit Record File 1995. Canberra: AGPS; 2001.
16. Australian Bureau of Statistics. 1995 National Nutrition Survey Confidentialised Unit Record File. Canberra: Commonwealth of Australia; 2001.
17. McLennan W, Podger A. National Nutrition Survey Users' Guide Australian Bureau of Statistics Catalogue No. 4801.0. 1998 [cited 2007 Sept 13]; Available from: http://144.53.252.30/AUSSTATS/abs@.nsf/DetailsPage/4801.01995?OpenDocument
18. Australian Bureau of Statistics. 1995 National Health Survey: Users' Guide. Canberra: AGPS; 1996.
19. Armstrong T, Bauman A, Davies J. Physical activity patterns of Australian adults. Canberra: Australian Institute of Health and Welfare; 2000. Available from: http://www.aihw.gov.au/publications/health/papaa/
20. Ball K, Mishra GD, Thane CW, Hodge A. How well do Australian women comply with dietary guidelines? Public Health Nutr. 2004;7:443–52.
21. Ireland P, Jolley D, Giles G, O'Dea K, Powles J, Rutishauser I, Wahlqvist ML, Williams J. Development of the Melbourne FFQ: a food frequency questionnaire for use in an Australian prospective study involving and ethnically diverse cohort. Asia Pac J Clin Nutr. 1994;3:19–31.
22. Rutishauser IHE, Webb K, Abraham B, Allsopp R. Evaluation of short dietary questions from the 1995 National Nutrition Survey. National Food and Nutrition Monitoring and Surveillance Project. Canberra: Commonwealth Department of Health and Aged Care. 2001 [cited 2007 March 27]. Available from: http://www.health.gov.au/internet/wcms/publishing.nsf/Content/B1EB027FB11FEFD0CA256F190004C81F/$File/evaluation.pdf
23. Riley M, Rutishauser I, Webb K. Comparison of short questions with weighed dietary records. National Food and Nutrition Monitoring and Surveillance Project. Canberra: Commonwealth Department of Health and Aged Care. 2001 [cited 2007 March 27]. Available from: http://www.health.gov.au/internet/wcms/publishing.nsf/Content/953C018FE1A757DECA256F190004C6C7/$File/comparison.pdf
24. Conway JM, Ingwersen LA, Vinyard BT, Moshfegh AJ. Effectiveness of the US Department of Agriculture 5-step multiple-pass method in assessing food intake in obese and nonobese women. Am J Clin Nutr. 2003;77:1171–8.
25. Australia New Zealand Food Authority. AUSNUT: Australian Food and Nutrient Database. Canberra: Commonwealth of Australia; 1999.
26. Kellett E, Smith AS, Schmerlaib Y. Australian guide to healthy eating. Canberra: Commonwealth Department of Health and Family Services; 1998.
27. Commonwealth Department of Health and Ageing Australia, New Zealand Ministry of Health, National Health and Medical Research Council. Nutrient Reference Values for Australia and New Zealand including Recommended Dietary Intakes. Canberra: Commonwealth of Australia; 2006.
28. CATI Technical Reference Group. Nutritional food behaviour in Australia. Population health monitoring and surveillance: question development background paper. 2003 [cited 2007 April 12]. Available from: http://www.dhs.vic.gov.au/nphp/catitrg/nutritionbgpaper.pdf
29. Australian Institute of Health and Welfare. Towards national indicators for food and nutrition: an AIHW view. 2005 [cited 2007 April 12]. Available from: http://www.aihw.gov.au/publications/index.cfm/title/10198
30. Drewnowski A, Henderson SA, Driscoll A, Rolls BJ. The Dietary Variety Score: assessing diet quality in healthy young and older adults. J Am Diet Assoc. 1997;97:266–71.
31. Kant AK, Schatzkin A, Graubard BI, Schairer C. A prospective study of diet quality and mortality in women. JAMA. 2000;283:2109–15.
32. McCullough ML, Feskanich D, Stampfer MJ, Rosner BA, Hu FB, Hunter DJ, Variyam JN, Colditz GA, Willett WC. Adherence to the Dietary Guidelines for Americans and risk of major chronic disease in women. Am J Clin Nutr. 2000;72:1214–22.
33. McCullough ML, Feskanich D, Rimm EB, Giovannucci EL, Ascherio A, Variyam JN, Spiegelman D, Stampfer MJ, Willett WC. Adherence to the dietary guidelines for Americans and risk of major chronic disease in men. Am J Clin Nutr. 2000;72:1223–31.

34. Coyne T, Ibiebele TI, McNaughton SA, O'Dea K, Hodge AM, Lee A, Findlay MG, McClintock C, Rutishauser IHE. Evaluation of brief dietary questions to estimate vegetable and fruit consumption: using serum carotenoids and red cell folate. Public Health Nutr. 2005;8:298–308.
35. Cade J, Thompson R, Burley V, Warm D. Development, validation and utilisation of food-frequency questionnaires: a review. Public Health Nutr. 2002;5:567–87.
36. National Health and Medical Research Council. Australian alcohol guidelines: health risks and benefits. 2001 [cited 12 April 2007]; Available from: http://www.nhmrc.gov.au/publications/synopses/ds9syn.htm
37. McCullough ML, Willett WC. Evaluating adherence to recommended diets in adults: the Alternate Healthy Eating Index. Public Health Nutr. 2006;9:152–7.
38. Patterson RE, Haines PS, Popkin BM. Diet quality index: capturing a multidimensional behavior. J Am Diet Assoc. 1994;94:57–64.
39. Forshee RA, Storey ML. Demographics, not beverage consumption, is associated with diet quality. Int J Food Sci Nutr. 2006;57:494–511.
40. Toft U, Kristofffersen LH, Lau C, Borch-Johnsen K, Jorgensen T. The Dietary Quality Score: validation and association with cardiovascular risk factors: the Inter99 study. Eur J Clin Nutr. 2007;61:270–8.
41. Fogli-Cawley JJ, Dwyer JT, Saltzman E, McCullough ML, Troy LM, Jacques PF. The 2005 Dietary Guidelines for Americans Adherence Index: development and application. J Nutr. 2006;136:2908–15.
42. Ball K, Crawford D, Mishra G. Socio-economic inequalities in women's fruit and vegetable intakes: a multilevel study of individual, social and environmental mediators. Public Health Nutr. 2006;9:623–30.
43. Martikainen P, Brunner E, Marmot M. Socioeconomic differences in dietary patterns among middle-aged men and women. Soc Sci Med. 2003;56:1397–410.
44. Mishra G, Ball K, Patterson A, Brown W, Hodge A, Dobson A. Socio-demographic inequalities in the diets of mid-aged Australian women. Eur J Clin Nutr. 2005;59:185–95.
45. Mishra GD, Prynne CJ, Paul AA, Greenberg DC, Bolton-Smith C. The impact of inter-generational social and regional circumstances on dietary intake patterns of British adults: results from the 1946 British birth cohort. Public Health Nutr. 2004;7:737–44.
46. Milligan RA, Burke V, Beilin LJ, Dunbar DL, Spencer MJ, Balde E, Gracey MP. Influence of gender and socio-economic status on dietary patterns and nutrient intakes in 18-year-old Australians. Aust N Z J Public Health. 1998;22:485–93.
47. Whichelow MJ, Prevost AT. Dietary patterns and their associations with demographic, lifestyle and health variables in a random sample of British adults. Br J Nutr. 1996;76:17–30.
48. McNaughton SA, Mishra GD, Paul AA, Prynne CJ, Wadsworth MEJ. Supplement use is associated with health status and health-related behaviors in the 1946 British Birth Cohort. J Nutr. 2005;135:1782–9.
49. Schuit AJ, Van Loon AJ, Tijhuis M, Ocke M. Clustering of lifestyle risk factors in a general adult population. Prev Med. 2002;35:219–24.
50. Rodriguez G, Moreno LA. Is dietary intake able to explain differences in body fatness in children and adolescents? Nutr Metab Cardiovasc Dis. 2006;16:294–301.
51. Rennie KL, Johnson L, Jebb SA. Behavioural determinants of obesity. Best Pract Res Clin Endocrinol Metab. 2005;19:343–58.
52. Togo P, Osler M, Sorensen TI, Heitmann BL. Food intake patterns and body mass index in observational studies. Int J Obes Relat Metab Disord. 2001;25:1741–51.
53. Osler M, Heitmann BL, Hoidrup S, Jorgensen LM, Schroll M. Food intake patterns, self rated health and mortality in Danish men and women. A prospective observational study. J Epidemiol Community Health. 2001;55:399–403.
54. Seymour JD, Calle EE, Flagg Ew, Coates RJ, Ford ES, Thun MJ. Diet quality index as a predictor of short-term mortality in the American Cancer Society Cancer Prevention Study II Nutrition Cohort. Am J Epidemiol. 2003;157:980–8.
55. Abramson JH, Abramson ZH. Survey methods in community medicine. 5th ed. London: Churchill Livingstone; 1999.
56. Newby PK. Examining energy density: comments on diet quality, dietary advice and the cost of healthful eating. J Am Diet Assoc. 2006; 106:1166–9.
57. Lowik MR, Hulshof KF, Brussaard JH. Food-based dietary guidelines: some assumptions tested for The Netherlands. Br J Nutr. 1999;81 Suppl 2:S143–9.
58. FAO/WHO. Preparation and use of food-based dietary guidelines. Report of a joint FAO/WHO consultation. Geneva: WHO; 1996.
59. Wayne SJ, Baumgartner K, Baumgartner RN, Bernstein L, Bowen DJ, Ballard-Barbash R. Diet quality is directly associated with quality of life in breast cancer survivors. Breast Cancer Res Treat. 2006;96:227–32.
60. Harnack L, Nicodemus K, Jacobs DR Jr, Folsom AR. An evaluation of the dietary guidelines for Americans in relation to cancer occurrence. Am J Clin Nutr. 2002;76:889–96.
61. United States Department of Health and Human Services and USDA. Dietary guidelines for Americans, 2005. 6th ed. Washington: (DC): U.S. Government Printing Office, 2005.
62. Popkin BM, Armstrong L, Bray GM, Caballero B, Frei B, Willett WC. A new proposed guidance system for beverage consumption in the United States. Am J Clin Nutr. 2006;83:529–42.
63. Rutishauser IHE. Getting it right: how to use the data from the 1995 National Nutrition Survey. 2000 [cited 2007 Sept 13]. Available from: http://www.healthconnect.gov.au/internet/wcms/publishing.nsf/Content/health-pubhlth-publicat-document-gettingitright-cnt.htm