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Research Article

Adherence to Dietary Guidelines and Successful Aging Over 10 Years

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Abstract

Background. We aimed to prospectively examine the relationship between overall diet quality (reflecting adherence to dietary guidelines) and successful aging in a population-based cohort of older adults.

Methods. In this population-based cohort study, we analyzed 10-year follow-up data from 1,609 adults aged 49 years and older, who were free of cancer, coronary artery disease, and stroke at the baseline and who had complete dietary data. Dietary data were collected using a semiquantitative food frequency questionnaire. Total diet scores (TDS) were allocated for intake of selected food groups and nutrients for each participant as described in the national dietary guidelines. Higher scores indicated closer adherence to dietary guidelines. Successful aging was defined as the absence of disability, depressive symptoms, cognitive impairment, respiratory symptoms, and chronic diseases (cancer, coronary artery disease, and stroke).

Results. At 10-year follow-up, 610 (37.9%) participants had died and 249 (15.5%) participants aged successfully. After multivariable adjustment, each 1-unit increase in TDS at baseline was associated with a 8% increased odds of successful aging 10 years later, odds ratio 1.08 (95% confidence interval 1.00–1.15). Participants in the highest (high adherence to dietary guidelines) versus lowest quartile (poor adherence to guidelines) of TDS at baseline had 58% higher odds of successful aging after 10 years, odds ratio 1.58 (95% confidence interval 1.02–2.46).

Conclusions. Greater compliance with recommended national dietary guidelines (higher diet quality) was associated with an increased likelihood of successful aging, as determined through a multidomain approach.

Key Words: Epidemiology—Morbidity—Normative Aging—Nutrition—Public Health—Successful Aging

The ageing demographics of most developed countries is one of the most challenging public health and policy issues, and hence, it has become critical to identify prognostic markers of remaining free of disease and in good functional health for as long as possible (1). It has been suggested that a multidomain approach of successful aging, rather than research focused on risk factors for single health

outcomes, such as chronic diseases or functioning, could be more informative (1,2). Rowe and Kahn were one of the first to describe successful aging as absence of disease, good social engagement, lack of physical disability, and good mental health (3). However, there has been considerable research on disability outcomes at older ages (4–6), but less attention has been focused on successful aging combining favorable functioning outcomes with good mental health and the absence of chronic diseases and disability (1,7).

Although dietary patterns are thought to be associated with healthy aging (8), there is scarce epidemiological data on the association between eating patterns and successful aging in the longer term. Sabia and colleagues (1) showed that daily consumption of fruits and vegetables was associated with a 35% increased odds of aging successfully in U.K. adults who were followed over 16.3 years. In this study, successful aging was defined as having good mental health, having good cognitive, physical, and cardiorespiratory function, and being free of disability and chronic diseases (eg, stroke, diabetes, and cancer). However, this U.K. study did not explore the associations between total diet and successful aging. More recently, an Australian cohort study showed that fruit-based eating pattern was positively associated with successful aging outcome (ie, lack of chronic diseases, little limitation in physical function, and good mental health) over 12 years (9). In contrast, an eating pattern based on meat and other fatty foods was negatively associated with successful aging (9). This study used factor analysis to determine diet quality and subsequently its association with successful aging.

In the current study, we have taken the approach of grouping foods "a priori" that are representative of current nutrition knowledge in the form of dietary guidelines or other dietary recommendations that is, diet quality (10,11). This may be a more useful tool in public health practice to assess a population's adherence to current dietary guidelines based on empirical evidence (12). To our best knowledge, no population-based studies have assessed the effect of diet quality in terms of adhering to dietary guidelines, on successful aging. In this cohort of older adults aged 50 years and older, we used a tool modeled on both Australian and U.S. diet quality indices (13,14), to examine the independent relationship between overall diet quality (an assessment of adherence to national dietary guidelines) and a comprehensive definition of successful aging that included being free of disability and chronic diseases (coronary artery disease, stroke, diabetes, and cancer), having good mental health and functional independence, and having good physical, respiratory, and cognitive function, over a 10-year follow-up period.

Methods

Study Population

The Blue Mountains Eye Study (BMES) is a population-based cohort study of common eye diseases and other health outcomes in a suburban Australian population located west of Sydney. Study methods and procedures have been described elsewhere (15). Baseline examinations of 3,654 residents aged 49 years and older were conducted during 1992–1994 (BMES-1, 82.4% participation rate). Surviving baseline participants were invited to attend examinations after 5 (1997–1999, BMES-2), 10 (2002–2004, BMES-3), and 15 years (2007–2009, BMES-4) at which 2,334 (75.1% of survivors), 1,952 participants (75.6% of survivors), and 1,149 (55.4% of survivors) participants were re-examined, respectively, with complete data. For the current study, we used data from BMES 1–3 (1992–1994 to 2002–2004), that is, 10 years. The University of Sydney and the Western Sydney Area Human Ethics Committees approved the study, and written, informed consent was obtained from all participants at each examination.

Nutritional Assessment

Dietary data were collected using a semiquantitative, 145-item self-administered food frequency questionnaire (FFQ) (16). At all BMES examinations, participants used a nine-category frequency scale to indicate the usual frequency of consuming individual food items during the past year. For the current study, FFQ data collected at BMES-1 were used in the analyses. Most nutrient correlations were between 0.50 and 0.60 for energy-adjusted intakes (17). A dietitian coded data from the FFQ into a customized database that incorporated the Australian Tables of Food Composition 1990 (baseline FFQ data) and follow-up FFQ data used NUTTAB95 (18,19).

A modified version of the Australian diet quality index (14), based on the Dietary Guidelines for Australian Adults (20) and the Australian Guide to Healthy Eating (21), was used to establish the total diet score (TDS), assessing adherence to the Australian dietary guidelines, which was the study factor. The methodology used to develop TDS has been previously reported (12), please see Supplementary Material 1 and Supplementary Table 1.

Assessment of Study Outcomes (Aging Status and Mortality)

The normal aging group in the context of this study included all participants who were alive at the end of the 10-year follow-up, but who were not classified as aging successfully (see definition below) (1). Among surviving participants aged 60 years and older, we used a definition similar to that used by Sabia and colleagues (1), who defined successful aging as satisfying each of the following criteria: no history of cancer, coronary artery disease, stroke, angina, acute myocardial infarction, or diabetes; good cognitive, physical, respiratory, and cardiovascular functioning; absence of disability; good mental health; and functional independence (Supplementary Material 1).

To identify and confirm persons who died after BMES-1, demographic information including surname, first and second names, gender, and date of birth of the participants were cross-matched with Australian National Death Index data, as previously described (22). Validity of National Death Index data has been reported to have high sensitivity and specificity for cardiovascular mortality (92.5% and 89.6%, respectively) (23). The census cutoff point for deaths was end of December 2004 (ie, a 10-year period from BMES-1 or the baseline examination).

Statistical Analysis

SAS 9.2 software (SAS Institute, Cary, NC) was used for statistical analyses. Study factor was TDS and three categories of study outcomes were defined: successful aging (key study outcome), death during follow-up, and normal aging (reference group). Baseline characteristics of study participants who were followed over 10 years were compared using χ^2 tests and general linear model. Multivariable logistic regression analyses for the outcomes of aging status (successful aging, died, and our reference group which was normal aging) used the generalized logit link and were adjusted for age, sex, marital status, living status, and smoking. Participants self-reported history of smoking as never, past, or current smoking. Current smokers included those who had stopped smoking within the past year. Participants also reported who they lived with (alone

or with eg, partner, child, or friend) and current marital status (married, widowed, divorced, or never married). We did not adjust for alcohol consumption or physical activity as these were included as components of the TDS. TDS was analyzed as a continuous variable (per 1-unit) and a categorical variable (quartiles). When examining the association between baseline TDS (diet quality) and the three categories of outcomes (normal aging, successful aging, and death) 10 years later, we used polytomous logistic regression with a generalized logit link. Polytomous logistic regression analysis was also used to determine the associations between above or below the median TDS (median score of ≥10.9) at all three BMES examinations (from baseline to the 10-year follow-up) and aging status at 10 years.

Results

Of the 3,654 participants, who were aged 49 years and older, examined at the baseline examination (BMES-1), 1,116 were excluded as they had cancer, coronary artery disease, and/ or stroke at the baseline examination (Supplementary Figure 2). A further 929 were excluded as they did not have diet quality data or information on TDS at baseline and had insufficient information to characterize their aging status 10 years later (BMES-3), leaving 1,609 participants for longitudinal analyses. Of these 1,609 participants, 610 (37.9%) had died, 750 (46.6%) aged normally (reference group), and 249 (15.5%) were successful agers, 10 years later. The majority of participants who aged normally were not functionally independent, had chronic illnesses (eg, stroke, acute myocardial infarction, and diabetes), and had self-reported heart and respiratory problems (eg, continual shortness of breath) (Supplementary Table 2). At baseline, those who aged successfully compared with nonparticipants or those who aged normally or had died were more likely to be younger and married and less likely to live alone and smoke (Table 1). Persons who aged normally were less likely to be men compared with nonparticipants and those who died or aged successfully. Persons who died had significantly lower mean TDS compared with participants and nonparticipants (Table 1).

After adjusting for age, sex, marital status, living status, and smoking, each 1-unit increase in the TDS was associated with a 8% increased likelihood of aging successfully (p = .04), odds ratio 1.08 (95% confidence interval 1.00–1.15). Table 2 shows that those in the highest (greater adherence to recommended dietary guidelines) compared with the lowest quartile (poorer adherence to dietary guidelines) of TDS had a 58% increased likelihood of aging successfully rather than aging normally 10 years later, multivariable-adjusted 1.58 (95% confidence interval 1.02–2.46). The temporal association between each component of the TDS (analyzed as quartiles, with the 2nd and 3rd quartiles combined to form a "middle" group) and aging status over 10 years was analyzed (Table 3). Participants in the middle group of fruit consumption compared with the lowest group of consumption had 57% increased odds of aging successfully than aging normally. Participants in the highest group versus lowest group of breads/cereal consumption and total metabolic equivalents had 39% and 34% reduced odds of dying rather than aging normally, respectively (Table 3).

Of the 203 study participants who consistently remained above the median TDS (ie, a score of ≥10.9) at all three BMES examinations (from baseline to 10-year follow-up), 17 (8.4%) had died, 118 (58.1%) aged normally, and 68 (33.5%) aged successfully. Of the 607 participants below the median TDS at any time point over the 10 years, 58 (9.6%) had died, 394 (64.9%) aged normally, and 155 (25.5%) aged successfully. Table 4 shows that participants who maintained a TDS above the median compared with those who had a TDS below the median were more likely to age successfully rather than age normally after 10 years, multivariable-adjusted odds ratio 1.47 (95% confidence interval 1.02–2.12).

Discussion

Understanding the aging process as regulated by a modifiable factor such as nutrition should facilitate the development of targeted strategies for promoting successful aging (24). This cohort study shows that older adults who more closely followed recommended national dietary guidelines at baseline had a greater likelihood of aging successfully at the 10-year follow-up. Further, those who maintained optimal diet quality, that is, remained above the median TDS during the 10 years had 47% increased odds of aging successfully at follow-up. These epidemiological data are novel in that diet quality was assessed by the level of adherence to national dietary guidelines and that successful aging was determined through a multidimensional approach.

The proportion of successful agers in our cohort was 15.5% and is slightly lower than the 18.7% observed in the U.K. study by Sabia and colleagues (1), which used a similar comprehensive definition of successful aging to ours. An Australian study, which used a slightly

Table 1. Comparison of Baseline Characteristics of Blue Mountains Eye Study Participants and Nonparticipants

Characteristics	Normal Aging	Successful Aging	Died	Excluded*	Missing Data†	p Value
	(n = 750)	(n = 249)	(n = 610)	(n = 1,116)	(n = 929)	
Age (y)	61.9 (0.3)	59.9 (0.5)	71.2 (9.4)	68.9 (9.4)	64.8 (10.2)	<.0001
Male sex	280 (37.3)	105 (42.2)	312 (51.2)	530 (47.5)	355 (38.2)	<.0001
Marital status						<.0001
Married	500 (66.7)	191 (76.7)	363 (59.8)	685 (61.4)	550 (59.6)	
Widowed/divorced/never married	250 (33.3)	58 (23.3)	244 (40.2)	430 (38.6)	373 (40.4)	
Living status						<.0001
Lives alone	161 (21.6)	46 (18.6)	196 (32.6)	306 (27.8)	283 (31.0)	
Does not live alone	585 (78.4)	202 (81.5)	406 (67.4)	793 (72.2)	629 (69.0)	
Current smoking	98 (13.2)	19 (7.8)	106 (18.0)	147 (14.0)	148 (17.2)	.002
Mean total diet score	11.0 (0.1)	11.3 (0.1)	10.5 (2.3)	11.2 (2.3)	11.0 (2.4)	<.0001

Notes: Data are presented as mean (*SE*) or *n* (%).

*Participants who were excluded from further longitudinal analyses because they had cancer, coronary artery disease, and stroke at baseline.

†Participants who were excluded from analyses as they had incomplete dietary data or did not have sufficient information to characterize aging status 15 years later.

Table 2. Association Between Quartiles of Total Diet Scores (or diet quality) and Aging Status in the Blue Mountains Eye Study From 1992–1994 to 2002–2004 (n = 1,609)

Aging Status	Total Diet Score, Multivariable-adjusted OR (95% CI)*			
	1st Quartile (≤9.28)	2nd Quartile (9.30–10.90)	3rd Quartile (10.93–12.60)	4th Quartile (≥12.62)
	n = 413	n = 421	n = 399	n = 376
Normal aging (n = 750)	1.0 (ref)	1.0 (ref)	1.0 (ref)	1.0 (ref)
Successful aging (n = 249)	1.0 (ref)	1.21 (0.78–1.88)	1.24 (0.79–1.94)	1.58 (1.02–2.46)
Died (n = 610)	1.0 (ref)	1.03 (0.73–1.46)	0.88 (0.61–1.27)	0.80 (0.55–1.17)

Notes: CI = confidence interval; OR = odds ratio.
*Adjusted for age, sex, marital status, living status, and smoking status.

Table 3. Association Between Quartiles of Individual Components of the TDS and Aging Status* Over 10 Years in the Blue Mountains Eye Study (n = 1,609)

Components of the TDS	Successful Aging (%)	Normal Aging (%)	Died (%)	Successful Aging vs Normal Aging	Died vs Normal Aging
Vegetables					
Lowest	12.9	46.7	40.4	1.0 (ref)	1.0 (ref)
Middle	16.5	46.0	37.5	1.35 (0.92, 1.97)	0.92 (0.67, 1.25)
Highest	16.0	47.9	36.1	1.26 (0.82, 1.95)	0.83 (0.58, 1.19)
Fruits					
Lowest	11.0	47.8	41.2	1.0 (ref)	1.0 (ref)
Middle	16.7	44.4	38.9	1.57 (1.06, 2.34)	0.90 (0.66, 1.22)
Highest	17.6	49.9	32.5	1.49 (0.96, 2.32)	0.77 (0.54, 1.05)
Fish					
Lowest	12.2	45.5	42.3	1.0 (ref)	1.0 (ref)
Middle	17.3	48.0	34.8	1.29 (0.88, 1.89)	0.83 (0.61, 1.13)
Highest	15.4	45.1	39.6	1.21 (0.78, 1.88)	0.97 (0.68, 1.38)
Meat					
Lowest	14.4	49.1	36.5	1.0 (ref)	1.0 (ref)
Middle	17.4	45.7	36.9	1.27 (0.88, 1.84)	0.92 (0.67, 1.27)
Highest	12.6	45.9	41.5	0.84 (0.53, 1.33)	1.03 (0.71, 1.49)
Bread and cereals					
Lowest	10.3	44.2	45.4	1.0 (ref)	1.0 (ref)
Middle	17.0	47.4	35.6	1.42 (0.95, 2.11)	0.78 (0.58, 1.07)
Highest	18.0	47.7	34.3	1.53 (0.98, 2.38)	0.61 (0.42, 0.87)
Dairy					
Lowest	12.8	47.6	39.6	1.0 (ref)	1.0 (ref)
Middle	17.1	43.8	39.1	1.38 (0.96, 2.00)	1.02 (0.75, 1.38)
Highest	15.0	51.1	33.8	1.07 (0.70, 1.64)	0.82 (0.57, 1.16)
Biscuits and cakes					
Lowest	16.8	47.4	35.8	1.0 (ref)	1.0 (ref)
Middle	16.1	47.6	36.2	0.89 (0.62, 1.27)	0.88 (0.64, 1.21)
Highest	13.0	44.0	43.0	0.73 (0.47, 1.13)	1.07 (0.75, 1.53)
Sugar and confectionery					
Lowest	17.0	50.8	32.2	1.0 (ref)	1.0 (ref)
Middle	15.9	46.1	38.0	1.02 (0.71, 1.47)	0.99 (0.72, 1.36)
Highest	13.2	43.9	42.9	0.92 (0.60, 1.43)	0.88 (0.61, 1.28)
Nonalcoholic beverages					
Lowest	15.1	41.3	43.6	1.0 (ref)	1.0 (ref)
Middle	15.4	47.8	36.8	0.89 (0.62, 1.29)	0.68 (0.50, 0.94)
Highest	16.0	49.5	34.5	0.81 (0.53, 1.25)	0.95 (0.66, 1.37)
Kilojoules					
Lowest	15.9	47.4	36.7	1.0 (ref)	1.0 (ref)
Middle	14.9	47.4	37.6	0.85 (0.59, 1.23)	0.92 (0.67, 1.27)
Highest	16.1	44.4	39.5	0.89 (0.58, 1.38)	0.93 (0.64, 1.34)
Total METs					
Lowest	12.2	41.8	46.1	1.0 (ref)	1.0 (ref)
Middle	15.0	47.9	37.1	1.09 (0.73, 1.65)	0.79 (0.58, 1.09)
Highest	20.4	48.5	31.2	1.47 (0.95, 2.27)	0.66 (0.46, 0.95)

Notes: MET = metabolic equivalent; TDS = total diet score.
*Adjusted for age, sex, living status, marital status, and smoking status.

Table 4. Association Between TDS and Aging Status in the Blue Mountains Eye Study Over 10 Years (n = 810), Presented as Adjusted Odds Ratios and 95% Confidence Intervals*

	Normal Aging	Successful Aging	Died
TDS	n = 512	n = 223	n = 75
Above the median (n = 203)	1.0 (ref)	1.47 (1.02–2.12)	1.27 (0.68–2.35)
Below the median (n = 607)	1.0 (ref)	1.0 (ref)	1.0 (ref)

Notes: TDS = total diet score.
*Adjusted for age, sex, living status, marital status, and smoking status.

different definition of healthy aging, also showed that 18.6% of their cohort were successful agers (9). Our observed proportion is, however, within the range of 0.4% to 95% of successful agers indicated by recent reviews (25). The large variability in the range of healthy agers is likely to be due to the lack of a common definition, different sample and measurement procedures, and existing biases (2,25).

It is well known that dietary habits are strongly associated with health (2,26). There are, however, few reports on the association between diet and healthy aging, despite the numerous studies of eating pattern measures, such as the Mediterranean Diet Score and various health outcomes (9). An Australia cohort study (9) also showed that dietary patterns based on frequent consumption of fruits and vegetables were positively associated with a comprehensive definition of successful aging. We have previously shown that higher TDS scores were associated with reduced all-cause mortality risk (27) and better functional ability and quality of life in this cohort of older adults (28). Observed findings from the present study are in accordance with this published literature, as it underscores the importance of a healthy dietary pattern (ie, closely following national dietary guidelines) in the process of successful aging. Specifically, we show that older adults in the highest (greater adherence to dietary guidelines) versus lowest quartile (poor adherence to dietary guidelines) of the TDS had a 58% increased likelihood of aging successfully over the 10 years. Moreover, participants who consistently demonstrated close adherence to the national dietary guidelines during the 10-year follow-up also had significantly increased odds of healthy survival.

The only component of the TDS which was independently associated with successful aging was fruit consumption, and this is in agreement with a previous Australian study (9). These findings suggest that individual components of dietary recommendations, for example, single foods groups, specific nutrients, and physical activity levels are not strongly associated with successful aging, however, their combined or cumulative impact is likely to be substantial. These concur with previous research which suggests that nutrients reported to be associated with better outcomes in observational studies could be serving as biomarkers for the whole diet, and the benefits observed are likely to be associated with the whole dietary pattern which may promote successful aging and less illness and disablement (9).

BMES participants with higher levels of diet quality or TDS were shown to be consuming greater quantities of a range of recommended optimal food choices in their diets, including fruits and vegetables, fish, and whole-grain breads and cereals (12). This is in agreement with observations in populations with higher than average proportions of centenarians, whose diets are typically rich in fruits, vegetables, legumes and whole grain, and reduced saturated fat (29). It is likely that such a healthy dietary pattern is associated with significantly lower levels of lipid peroxidation and free-radical-induced damage (29), which in turn could facilitate successful aging transitions. Specifically, a higher diet quality is typified by lower concentrations of inflammatory markers such as C-reactive protein (30). Moreover, fruits and vegetables are high in antioxidants such as vitamin C and carotenoids, which may also reduce oxidative damage (31,32).

These study findings are of importance for public health, because demographic aging is one of the most challenging policy issues of the 21st century for developed countries, and targeted health policies are required (2). Moreover, understanding health benefits of following dietary guidelines is essential for setting up effective behavioral interventions (33). Indeed, a 1-point difference in the TDS in the context of the TDS 20 scoring scale is likely to be clinically relevant. For example, if a person was meeting their fruit serves versus not meeting required number of fruit serves, that would be 1 unit, or if someone is having ≥2 serves of fish per week versus less than 1 serve/week that would be 1 unit. Hence, our study moves the research forward by providing novel empirical evidence, which suggests that maintaining good functional status combined with the absence of chronic diseases in older ages could be improved by geriatricians and dieticians targeting the overall diet of older adults. For example, dietary counseling to maintain close adherence to recommended dietary guidelines could lead to appreciable improvements in the multidimensionally successful aging parameters.

Strengths of this study include its representative population-based sample with relatively high participation minimizing selection bias, prospective study design, use of a validated food questionnaire to collect dietary data, and a comprehensive definition of successful aging. Hence, our findings are applicable to general older Australians and could also be applicable to older adults in Western countries. Limitations include using FFQs for self-reported dietary intake, which can underestimate energy intake or overestimate fruit, vegetable, and dairy intakes (34). However, a comprehensive assessment of the whole diet is less subject to measurement error than is the assessment of energy intake alone (35,36). That is because even when people under- or overestimate the total amount they consume, the ratios of the foods that they self-report are still likely to be reflective of actual consumption (35). Nevertheless, several components of the total dietary score were designed to account for misreporting, for example, we increased the cutpoint for fruit and vegetable intake per day to 3 serves and 7 serves, respectively (27). An additional limitation is the assumption that the dietary guidelines used to define diet quality indexes are based on the best available scientific knowledge, which may not necessarily be correct as it is difficult to keep dietary guidelines up to date (37). Also, because of the collinearity among foods and nutrients, we are not able to accurately determine which specific components of the total dietary score are driving the observed associations (27). Further, some of the aging outcomes were self-reported and were not objectively measured (eg, respiratory function), hence, it could be subject to potential measurement errors. Also, participants compared with nonparticipants differed in several of the baseline characteristics (eg, age, sex, and smoking status). Hence, we cannot disregard the possibility of selection bias influencing observed associations. Finally, the variables used to construct the multidimensional successful aging outcome were available at different times, for example, chronic diseases throughout the 10 years while cognitive measures were available only at the end of follow-up. Hence, we were not able to assess the link

between duration of exposure and successful aging. Such analyses may have been biased by reverse causation (1).

In summary, we show that close adherence to recommended dietary guidelines significantly increases the likelihood of reaching old age disease free and fully functional. These findings could stimulate targeted intervention strategies that modify dietary practices of the aging population, thereby potentially preserving good functional and mental health status and an absence of chronic diseases and disability.

Supplementary Material

Supplementary material can be found at: http://biomedgerontology.oxfordjournals.org/

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Conflict of Interest

No authors declare a conflict of interest.

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