Education attenuates the association between dietary patterns and cognition

Tasnime N Akbaraly[1*], PhD; Archana Singh-Manoux,[1,2,3] PhD; Michael G. Marmot, [1] MD PhD; Eric J. Brunner, [1] PhD.

*Corresponding author and address
[1]Department of Epidemiology and Public Health
1-19 Torrington Place
University College London
London WC1E 6BT, UK
Email : t.akbaraly@ucl.ac.uk
Tel:+44(0)20 7679 1908, Fax: +44(0)20 74196732

[2]INSERM U687-IFR69, France
[3]Centre de Gérontologie, Hôpital Ste Périne, AP-HP

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ABSTRACT

Background/Aims: Various foods have been shown to be associated with cognitive outcomes. As individual food items are not consumed in isolation, we examined the association between dietary patterns and cognitive function, with special attention to the role of education on this association. **Methods:** Analyses were carried on 4693 stroke-free "white" European participants of the Whitehall II study. Two dietary patterns were determined using principal component analysis : a "Whole food" and a "Processed Food" pattern. Cognitive function was assessed using a battery of 5 tests. **Results**: After adjustment for demographic, behavioral and health measures, higher intake of "whole food" diet was associated with lower and high consumption of "processed food" with higher odds of cognitive deficit. However, adjustment for education significantly attenuated most of these associations. **Conclusions**: Education, through its role as a powerful confounder, shapes the relationship between dietary patterns and cognitive deficit in a healthy middle-aged UK cohort.

INTRODUCTION

Cognitive impairment and dementia are among the most prevalent of the aging related pathologies and the world faces an increase in both the number of elderly people and lifespan at the oldest ages [1]. The association between nutrition and cognition has increasingly been investigated in the last decade [2, 3]. Studies on single nutrients or foods associated with cognition constitute the large majority of the literature [3] while studies that examine the associations with dietary patterns are limited [3, 4].

A number of factors, socio-demographic, health behaviors and chronic diseases, are associated both with nutrition and cognition [5], making it important to consider them as potential confounders in the analysis of the association between nutrition and cognition. The role of education may be important as it has been shown to shape food choices [6, 7]. Further, there is extensive evidence to suggest that high education might delay or protect from cognitive impairment [8-11]. As the onset of dementia is insidious with the underlying pathologies believed to be active many years before clinical expression, it is important to examine risk factors for cognitive deficit and decline earlier than in elderly populations. The objective of this study was to examine the association between nutrition typologies, rather than “single nutrients”, and cognition in a middle aged population. A further objective was to investigate the influence of socio-demographic factors, health behaviors and health measures on this association, with special attention to the role of education.

SUBJECTS AND METHODS

Study Population

The target population for the Whitehall II study was all London-based office staff, aged 35–55 years, working in 20 civil service departments. The cohort consisted of 10,308 participants at the first phase in 1985 [12]. A total of 6,767 participants completed the phase 7 screening examination (2002–2004). Analyses in this study were restricted to the 4693 white European participants with data on cognitive function, dietary assessments and all covariates at phase 7. Black (N=93) and Asian (N=197) participants were excluded due to differences in eating behavior. We also excluded participants with self-reported stroke or transient ischemic attack (n=120).

After complete description of the study to the subjects, written informed consent was obtained; the University College London ethics committee approved the study.

Dietary Assessment

A machine-readable Food Frequency Questionnaire (FFQ) [13] based on one used in the US Nurses Health study [14] was sent to the participants. The food list (127 items) in the FFQ was anglicised, and foods commonly eaten in the UK were added [15]. A common unit or portion size for each food was specified, and participants were asked how often, on average, they had consumed that amount of the item during the previous year. Response to all items was on a 9-point scale, ranging from ‘never or less than once per month’ to ‘six or more times per day’. The selected frequency category for each food item was converted to a daily intake.

According to the nutrient profile and culinary use of food items, the 127 items of the FFQ were grouped in 37 predefined food groups (by adding food items within each group) (Appendix 1). Dietary patterns were identified using principal component analysis of these 37 groups. The factors were rotated by an orthogonal transformation (Varimax rotation function in SAS; SAS Institute, Cary, NC) to achieve a simple structure, allowing greater interpretability. Two dietary patterns were identified using multiple criteria: the diagram of eigenvalues, the Scree plot, the interpretability of the factors and the percentage of variance explained by the factors (Table 1). The factor score for each pattern was calculated by summing intakes of food groups weighted by their factor loadings. Factors loadings represent correlation coefficients between the food groups and particular patterns. The first pattern was heavily loaded by high intake of vegetables, fruits, dried legume and fish, labeled the "whole food" pattern. The second pattern, labeled "processed food", was heavily loaded by high consumption of sweetened desserts, chocolates, fried food, processed meat, pies, refined grains, high fat dairy products, margarine and condiments. Each participant received a factor score for each identified pattern. Factor analysis does not group individuals into clusters, instead all individuals contribute to both factors and it is the homogeneity between food items that defines the factors. To assess the validity of the dietary patterns resulting from this "a posteriori" 37 food grouping, we reanalysed the principal component analyses using the 127 individual food items and the results obtained were similar.

Cognitive function

The cognitive test battery [16] consisted of five standard tasks chosen to comprehensively evaluate cognitive functioning in middle-aged adults. High scores on all tests denote better performance. The first was a 20-word free-recall test of *short-term verbal memory*. Participants were presented with a list of 20 one- or two-syllable words at 2-sec intervals and were then asked to recall in writing as many of the words as they could, in any order; they had 2 min to do so. Next was the *AH4-I* [17], composed of a series of 65 verbal and mathematical reasoning items of increasing difficulty. This test of inductive reasoning measures the ability to identify patterns and infer principles and rules. Participants had 10 min to complete this section. This was followed by the *Mill Hill vocabulary test* [18] that assesses knowledge of verbal meaning and encompasses the ability to recognize and comprehend words. We used this test in its multiple format, which consists of a list of 33 stimulus words ordered by increasing difficulty and six response choices. Finally, we used two measures of verbal fluency: phonemic, and semantic [19]. *Phonemic fluency* was assessed via "s" words and *semantic fluency* via "animal" words. Subjects were asked to recall in writing as many words beginning with "s" and as many animal names as they could. One minute was allowed for each test of fluency.

Covariates

Socio-demographic variables consisted of age, gender, marital status (married or cohabited, single, divorced, widowed) and education, regrouped into five levels (no formal education, lower secondary education, higher secondary education, university degree, higher university degree). Health behaviours measured were smoking habits (non smoker, former, current smoker) and physical activity, converted into MET-scores [20] and categorized as "mildly energetic" (MET values below 3), "moderately energetic" (MET values ranging from 3 to 6) and "vigorous" (MET values of 6 or above) physical activity. Health status was ascertained by prevalence of Coronary Heart Disease (CHD), based on clinically verified events and included fatal and non fatal myocardial infarction and definite angina as described previously [21], diabetes (diagnosed according to WHO definition), hypertension (systolic / diastolic blood pressure ≥ 140 / 90 mm Hg respectively or use of hypertensive drugs), dyslipidemia (LDL cholesterol ≥ 4.1 mmol/L or use of lipid-lowering drugs), BMI (calculated from measured high and weight, kg/m^2) and mental health, using the 30-item General Health Questionnaire [22].

Statistical analysis

Cognitive deficit was defined as performances in the worst sex-specific quintile. Among men (women), this corresponded to scores ≤5 (5) for memory, ≤39 (31) for reasoning, ≤24 (21) for vocabulary, ≤13 (12) for phonemic and semantic fluency. Logistic regression was used to model the association between the tertiles on the two factors representing the two dietary patterns and cognitive deficit. In the first model (M1), the analyses were adjusted for sex, age and energy intake. In the fully adjusted model (M2), the analyses were further adjusted for marital status, health behaviors and health measures. All the analyses were carried out first without and then after adjustment for education. Interaction between dietary pattern and education were also tested, and analyses of the association between dietary patterns and cognition stratified by education (by grouping no formal education and lower secondary education together and levels above higher secondary education) were performed. All analyses were conducted with the use of SAS software, version 9 (SAS Institute).

RESULTS

Compared to the 6767 stroke free participants still alive at phase 7, participants included in the analyses (n=4693) were less likely to be women (26.2% vs. 39.2%) or to have no academic qualifications or lower secondary education (30.7 % vs. 45.0%).

Sample characteristics as a function of the tertiles of the two dietary patterns, “whole food” and “processed food” are shown in Table 2. Tables 3 and 4 shows the association between the tertiles of the “whole food” (Table 3) and “processed food” (Table 4) dietary patterns and cognitive deficit, defined as performance in the worst quintile for each cognitive test. In analyses unadjusted for education, being in the highest tertile of “whole food” dietary pattern was associated with lower odds of deficit on all cognitive tests. On the other hand, participants with high intake of “processed food” compared to those with a low intake had higher odds of cognitive deficit for reasoning (Odds ratio (OR)=1.55; 95% Confidence Interval (CI)=1.21-1.98), vocabulary (OR=2.36; 95% CI=1.84-3.04), phonemic (OR=1.70; 95% CI=1.33-2.19) and semantic fluency (OR=1.58; 95% CI=1.25-2.01) but not for memory (OR=1.26; 95% CI=0.95-1.67) in analyses adjusted for marital status, health behaviors and health status (M2, Table 4). However adjustment for education attenuated all associations. The lower odds of cognitive deficit associated with higher intake of “whole food” pattern only remained significant for vocabulary (OR=0.75; 95% 0.60-0.92) and semantic fluency (OR=0.72; 95% CI=0.59-0.88) (Table 3). Similarly the higher odds of cognitive deficit associated with greater intake of “processed food” pattern remained significant for vocabulary

(OR=1.63; 95% CI=1.25-2.13) and phonemic fluency (OR=1.34; 95% CI=1.04-1.74) (Table 4).

The interaction term between the dietary patterns and education (by grouping no formal education and lower secondary education together and levels above higher secondary education) did not provide any evidence for a moderating effect for education (all p between 0.12 and 0.89). In analyses stratified by education, there was no evidence of different associations between diet and cognition in the different education groups (results not showed).

DISCUSSION

We examined associations between two distinct dietary patterns, "whole food" (rich in fruit, vegetables, dried legume and fish) and "processed food" (rich in processed meat, chocolates, sweet desserts, fried food, refined cereals and high fat dairy products) and cognitive deficit in a middle aged population. In fully adjusted models, but without taking account the influence of education, our results suggested that "whole food" pattern was associated with lower and the "processed food" pattern with increased odds of cognitive deficit. However, adjustment for education considerably attenuates these associations, suggesting that education is an important confounder in the association between nutrition and cognition.

While dietary patterns have been investigated in relation to several chronic diseases such as cardiovascular diseases [23], or diabetes [24], studies on the relation between dietary patterns and cognitive functioning are less frequent. One exception is a recent study [4] that examined the association between dietary pattern, using dietary indices, and the risk of Alzheimer's disease and cognitive decline in an elderly population. They showed that high adherence to Mediterranean Diet [25] decreased the risk of cognitive decline and Alzheimer's disease in a non demented, multi-ethnic elderly cohort (N=2258, mean age 77.2 ±6.6 years). This association remained significant after adjustment for education. The use of an "a priori" definition like the Mediterranean score presents the inconvenience of weighting equally the underlying individual food component categories, which, in turn are composed of a number of food constituents. Using an "a posteriori" factor analyses, our results, unadjusted for education, support those reported using the Mediterranean Diet [4] by suggesting that a diet rich in fruits, vegetable and fish is associated with lower odds of cognitive deficit while a diet rich in processed meat, chocolates and sweeteners desserts, fried food, refined grains and high fat dairy products is associated with greater odds of cognitive deficit.

In our analysis, the diet and cognition relationship remained unchanged after adjustment for sex, age, energy intake, marital status, physical activity, smoking habits, chronic diseases (diabetes, dyslipidemia, CHD, hypertension), BMI and mental health. Our finding, before adjustment for education, of a relationship between the "whole food" dietary pattern and cognitive deficit is supported, partly, by results of two prospective studies that found high intake of vegetables to be associated with a slower rate of cognitive decline at older ages [26, 27]. The beneficial effect of fruits and vegetables on cognition could be a result of high amounts of antioxidants in these foods. However, the literature on the association between antioxidants levels in blood or estimated from food intake and cognitive performances or dementia is inconsistent and dependent on the specific nutrient examined [28]. Our "whole food" dietary pattern also included a high intake of fish and there is consistent evidence to support this finding. Many studies have shown high fish consumption to be associated with low incidence of dementia [29, 30] including Alzheimer diseases [29-31], slower cognitive decline in elderly [32, 33] and with lower cognitive impairment in a middle aged population [34]. The protective effects of fish consumption has been traditionally attributed to its high content in long chain omega 3 poly-unsaturated fatty acids (PUFA) which are a major components of neuron membranes and have vascular and anti-inflammatory properties [35]. Then, the association between the "whole food" diet on cognition observed in our study could be explained by the cumulative and synergic effect of nutrients from different source of foods rather than by the effect of one isolated nutrient.

The "processed food" factor described in our study was highly loaded by sweets desserts, fried food, processed food, refined grain products and high fat dairy products was very close to the "Western" pattern defined in the American population [36] which has been shown to be correlated with markers of systemic inflammation [37]. Several lines of investigation have suggested that inflammation is involved in the pathogenesis of dementia [38-42]. However, the association between inflammation and cognition is still under debate [43] and more studies are needed to better understand the association between the "processed food" intake, inflammation process and cognition.

In this middle aged British population, we showed education to influence the relationship between dietary pattern and cognition. The test for interaction suggests that it does not moderate the association between dietary factors and cognition, in that the diet-cognition association is similar in high and low education groups. The attenuation of the diet-cognition association after adjustment for education is a statistical result and could suggest two things. One, that education mediates the association between dietary factors and cognition in that dietary factors influence education which then influences cognition. However, the first part of this causal chain is unlikely as education was assessed prior to the dietary measures and it appears unlikely that dietary factors influence education in this way. The second explanation for the substantially attenuated in the association between dietary patterns and cognition is that education acts as a confounder. Previous research shows that education is linked to dietary behavior [6, 7], the exposure being considered here and cognition [8-11], the outcome. Thus, we argue that education plays an important confounding role in the association between dietary patterns and cognition.

The confounder role of education could work in several ways. One, education is associated with dietary habits and nutrients intake. Low education is associated with poor health behaviors, smoking, less regular physical activity, etc. Thus, participants with lower education have less healthy eating patterns compared to those with higher education. Furthermore, there is some evidence to show that lower socio-economic position, of which education is a measure, is associated with purchase of foods that are cheaper per unit of energy rather than foods rich in protective nutrients [44-47]. Finally, low education is also related to poorer health-related nutrition knowledge [6, 7] that are determinants of food choice. Second, education as a risk factor of cognitive impairment could confound the diet-cognition relationship. Low education has been shown to be associated with increased risk of dementia [8-11]. These observations are supported by the cognitive reserve hypothesis [48, 49] which stipulates that cognitive reserve delays the onset of clinical manifestations of dementia.

Our study has several potential limitations. First, the use of semi-quantitative food questionnaire, only on specific foods, is recognized to be less precise than dietary assessment using diary questionnaire. However, in this study population, at a previous wave of data collection, we have shown that nutrient intakes estimated by the FFQ method were well correlated with biomarker levels and with intake estimates from the generally more accurate 7 day-diary [13]. Second, the cross-sectional framework of the analyses makes it impossible to draw causal inferences on the association between nutrition and cognition. Third, Whitehall II study participants are office-based civil servants, and who are not fully representative of the British population [12, 50]. Finally, the factors analyses approach used to identify these patterns involves several arbitrary decisions such as the consolidation of food items into food groups, the number of factors extracted, the methods of rotation or labeling of the factors [51].

Despite these limitations, by considering an overall diet approach rather than a "single" nutrient or food approach, our study is the first to show, in middle aged general population, that education, through its role as a powerful confounder, shapes the relationship between the 2 dietary patterns -"whole food" and "processed food" pattern- and cognitive function.

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The Author report no conflict of interest.

TNA had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

REFERENCES

1. World Health Organization, *Active Ageing : A Policy Framework*. 2002, World Health Organization, : Madrid, Spain.
2. Luchsinger, J.A. and R. Mayeux, *Dietary factors and Alzheimer's disease*. Lancet Neurol, 2004. **3**(10): p. 579-87.
3. Van Dyk, K. and M. Sano, *The impact of nutrition on cognition in the elderly*. Neurochem Res, 2007. **32**(4-5): p. 893-904.
4. Scarmeas, N., et al., *Mediterranean diet and risk for Alzheimer's disease*. Ann Neurol, 2006. **59**(6): p. 912-21.
5. Berr, C., et al., *[Epidemiology of dementia.]*. Presse Med, 2007. **36**(10P2): p. 1431-1441.
6. Parmenter, K., J. Waller, and J. Wardle, *Demographic variation in nutrition knowledge in England*. Health Educ Res, 2000. **15**(2): p. 163-74.
7. Wardle, J., K. Parmenter, and J. Waller, *Nutrition knowledge and food intake*. Appetite, 2000. **34**(3): p. 269-75.
8. Ngandu, T., et al., *Education and dementia: what lies behind the association?* Neurology, 2007. **69**(14): p. 1442-50.
9. Roe, C.M., et al., *Education and Alzheimer disease without dementia: support for the cognitive reserve hypothesis*. Neurology, 2007. **68**(3): p. 223-8.
10. Scarmeas, N., et al., *Education and rates of cognitive decline in incident Alzheimer's disease*. J Neurol Neurosurg Psychiatry, 2006. **77**(3): p. 308-16.
11. Stern, Y., et al., *Influence of education and occupation on the incidence of Alzheimer's disease*. Jama, 1994. **271**(13): p. 1004-10.
12. Marmot, M.G., et al., *Health inequalities among British civil servants: the Whitehall II study*. Lancet, 1991. **337**(8754): p. 1387-93.
13. Brunner, E., et al., *Dietary assessment in Whitehall II: comparison of 7 d diet diary and food-frequency questionnaire and validity against biomarkers*. Br J Nutr, 2001. **86**(3): p. 405-14.
14. Willett, W.C., et al., *Reproducibility and validity of a semiquantitative food frequency questionnaire*. Am J Epidemiol, 1985. **122**(1): p. 51-65.
15. Bingham, S.A., et al., *Validation of dietary assessment methods in the UK arm of EPIC using weighed records, and 24-hour urinary nitrogen and potassium and serum vitamin C and carotenoids as biomarkers*. Int J Epidemiol, 1997. **26 Suppl 1**: p. S137-51.
16. Singh-Manoux, A. and M. Marmot, *High blood pressure was associated with cognitive function in middle-age in the Whitehall II study*. J Clin Epidemiol, 2005. **58**(12): p. 1308-15.
17. Heim, A.W., *AH 4 group test of general intelligence ASE*. Windsor ed. 1970, Windsor : UK: NFER-Nelson Publishing Co. LTD.
18. Raven, J., *Guide to using the Mill Hill vocabulary scale with progressive matrices*. 1965, London: HK Lewis.
19. Borkowski, J., A. Benton, and O. Spreen, *Word fluency and brain damage*. Neuropsychologica, 1967. **5**: p. 135-140.

20. Ainsworth, B.E., et al., *Compendium of physical activities: classification of energy costs of human physical activities.* Med Sci Sports Exerc, 1993. **25**(1): p. 71-80.
21. Singh-Manoux, A., et al., *Socioeconomic status moderates the association between carotid intima-media thickness and cognition in midlife: Evidence from the Whitehall II study.* Atherosclerosis, 2007.
22. Goldberg, D., *The Detection of Psychiatric Illness by Questionnaire*. 1972, London, England: Oxford University Press Inc.
23. Hu, F.B., et al., *Prospective study of major dietary patterns and risk of coronary heart disease in men.* Am J Clin Nutr, 2000. **72**(4): p. 912-21.
24. van Dam, R.M., et al., *Dietary patterns and risk for type 2 diabetes mellitus in U.S. men.* Ann Intern Med, 2002. **136**(3): p. 201-9.
25. Trichopoulou, A., et al., *Adherence to a Mediterranean diet and survival in a Greek population.* N Engl J Med, 2003. **348**(26): p. 2599-608.
26. Kang, J.H., A. Ascherio, and F. Grodstein, *Fruit and vegetable consumption and cognitive decline in aging women.* Ann Neurol, 2005. **57**(5): p. 713-20.
27. Morris, M.C., et al., *Associations of vegetable and fruit consumption with age-related cognitive change*. Neurology, 2006. **67**(8): p. 1370-6.
28. Akbaraly, T., *Etude des facteurs biologiques nutritionnels dans le vieillissement cerebral*. 2006, Faculte de Medecine du Kremlin Bicetre Paris-Kremlin-Bicetre.
29. Barberger-Gateau, P., et al., *Fish, meat, and risk of dementia: cohort study.* Bmj, 2002. **325**(7370): p. 932-3.
30. Kalmijn, S., et al., *Dietary fat intake and the risk of incident dementia in the Rotterdam Study.* Ann Neurol, 1997. **42**(5): p. 776-82.
31. Morris, M.C., et al., *Consumption of fish and n-3 fatty acids and risk of incident Alzheimer disease.* Arch Neurol, 2003. **60**(7): p. 940-6.
32. Morris, M.C., et al., *Fish consumption and cognitive decline with age in a large community study.* Arch Neurol, 2005. **62**(12): p. 1849-53.
33. van Gelder, B.M., et al., *Fish consumption, n-3 fatty acids, and subsequent 5-y cognitive decline in elderly men: the Zutphen Elderly Study.* Am J Clin Nutr, 2007. **85**(4): p. 1142-7.
34. Kalmijn, S., et al., *Dietary intake of fatty acids and fish in relation to cognitive performance at middle age.* Neurology, 2004. **62**(2): p. 275-80.
35. Yehuda, S., et al., *The role of polyunsaturated fatty acids in restoring the aging neuronal membrane.* Neurobiol Aging, 2002. **23**(5): p. 843-53.
36. Hu, F.B., *Dietary pattern analysis: a new direction in nutritional epidemiology.* Curr Opin Lipidol, 2002. **13**(1): p. 3-9.
37. Lopez-Garcia, E., et al., *Major dietary patterns are related to plasma concentrations of markers of inflammation and endothelial dysfunction.* Am J Clin Nutr, 2004. **80**(4): p. 1029-35.
38. Campbell, I.L., et al., *Transgenic models to assess the pathogenic actions of cytokines in the central nervous system.* Mol Psychiatry, 1997. **2**(2): p. 125-9.
39. Ho, G.J., et al., *Mechanisms of cell signaling and inflammation in Alzheimer's disease.* Curr Drug Targets Inflamm Allergy, 2005. **4**(2): p. 247-56.
40. Eikelenboom, P. and R. Veerhuis, *The importance of inflammatory mechanisms for the development of Alzheimer's disease.* Exp Gerontol, 1999. **34**(3): p. 453-61.

41. Schmidt, R., et al., *Early inflammation and dementia: a 25-year follow-up of the Honolulu-Asia Aging Study.* Ann Neurol, 2002. **52**(2): p. 168-74.
42. Engelhart, M.J., et al., *Inflammatory proteins in plasma and the risk of dementia: the rotterdam study.* Arch Neurol, 2004. **61**(5): p. 668-72.
43. Schram, M.T., et al., *Systemic markers of inflammation and cognitive decline in old age.* J Am Geriatr Soc, 2007. **55**(5): p. 708-16.
44. Davey Smith, G. and E. Brunner, *Socioeconomic differentials in health: the role of nutrition.* Proc Nutr Soc, 1997. **56**: p. 75-90.
45. Dowler, E., *Budgeting for food on a low income in the UK: the case of lone-parent families.* . Food Policy, 1997. **22**: p. 405-417.
46. James, W.P., et al., *Socioeconomic determinants of health. The contribution of nutrition to inequalities in health.* Bmj, 1997. **314**(7093): p. 1545-9.
47. Stallone, D.D., et al., *Dietary assessment in Whitehall II: the influence of reporting bias on apparent socioeconomic variation in nutrient intakes.* Eur J Clin Nutr, 1997. **51**(12): p. 815-25.
48. Katzman, R., *Education and the prevalence of dementia and Alzheimer's disease.* Neurology, 1993. **43**(1): p. 13-20.
49. Stern, Y., *What is cognitive reserve? Theory and research application of the reserve concept.* J Int Neuropsychol Soc, 2002. **8**(3): p. 448-60.
50. Marmot, M. and E. Brunner, *Cohort Profile: the Whitehall II study.* Int J Epidemiol, 2005. **34**(2): p. 251-6.
51. Martinez, M.E., J.R. Marshall, and L. Sechrest, *Invited commentary: Factor analysis and the search for objectivity.* Am J Epidemiol, 1998. **148**(1): p. 17-9.

TABLES

Table 1: Factor loading* for high loading items (≥0.40)** on the two dietary patterns

	1st Pattern : "Whole food" pattern	2nd Pattern : "Processed food" pattern
Leafy vegetables	0.68	-
Other vegetables	0.67	-
Cruciferous vegetables	0.57	-
Tomatoes	0.55	-
Fruits	0.53	-
Fish	0.46	-
Salad dressing	0.43	-
Peas and dried Legume	0.42	-
Desserts/biscuits	-	0.55
Chocolate and sweets	-	0.50
Fried food	-	0.49
Processed meats	-	0.46
Quiche/Pie	-	0.45
Margarine	-	0.44
Refined grain	-	0.41
High fat dairy products	-	0.41
Condiments	-	0.41

*The 2 dietary patterns were identified using principal component analysis. Factor loadings issued from orthogonal rotation, represent the correlation between the factors and individual items from food group.
** Values < 0.40 were not listed in order to simplify interpretation of the factors (see Appendix 1)

Table 2: Characteristics of the sample as a function of the dietary patterns at phase 7 (2002-04).

	"Whole food" dietary pattern				"Processed food" dietary pattern			
	Tertile 1* n=1564	Tertile 2* n=1565	Tertile 3* n=1564	*P* for trend	Tertile 1* n=1564	Tertile 2* n=1565	Tertile 3* n=1564	*P* for trend
% women	24.2	24.3	30.1	<10-4	38.5	25.2	14.9	<10-4
Age** (year)	60.7 (5.9)	61.1 (6.0)	61.3 (5.9)	0.02	60.9 (5.8)	61.0 (5.9)	61.2 (6.2)	0.45
% Single or divorced	24.1	17.3	16.3	<10-4	20.9	17.6	19.2	<10-4
% no academic qualification	13.0	8.6	6.9	<10-4	8.2	8.8	8.2	0.05
% Current Smoker	14.7	9.3	8.6	<10-4	9.4	10.9	12.3	0.02
% Low level of physical activity	19.7	12.7	11.5	<10-4	15.5	14.1	14.4	0.59
% Diabetic	5.9	5.9	5.9	0.98	4.8	6.8	5.9	0.06
% with hypertension	34.6	35.8	36.8	0.45	36.1	36.9	34.3	0.32
% dyslipidemic	39.2	38.9	37.4	0.54	39.8	40.0	35.7	0.02
% with coronary heart diseases	6.3	7.1	6.6	0.64	6.1	6.3	7.5	0.22
BMI **(kg/m2)	26.6 (4.3)	26.5 (4.0)	26.5 (4.2)	0.48	26.3 (4.4)	26.6 (4.1)	26.6 (4.0)	0.17
GHQ ** (score)	77.1 (15.8)	77.6 (15.3)	78.3	0.09	77.5	78.5	77.0	0.02

			(15.0)		(16.2)	(14.5)	(15.4)	
Total energy* (kcal/day)	1927 (568)	2186 (551)	2489 (666)	<10-4	1723 (405)	2115 (393)	2765 (596)	<10-4

BMI Body Mass Index; GHQ General Health Questionnaire

*Tertile 1, 2 and 3 represent individuals in the lowest, intermediate and highest thirds of the dietary factor score

** for continuous variable, m with its standard deviation were given.

Table 3: Association between tertiles of the “whole food” pattern and cognitive deficit

		Without adjustment for education						After adjustment for education					
		T1†	T2†		T3†			T1†	T2†		T3†		
		OR	OR	OR	OR	95% CI	p*	OR	OR	95% CI	OR	95% CI	p*
Memory	M1	1	0.79	0.65-0.97	0.67	0.54-0.84	0.002	1	0.87	0.71-1.07	0.78	0.62-0.98	0.09
	M2	1	0.85	0.69-1.05	0.74	0.59-0.93	0.03	1	0.93	0.75-1.15	0.85	0.68-1.08	0.42
Reasoning	M1	1	0.68	0.57-0.82	0.64	0.53-0.77	<10-4	1	0.81	0.67-0.98	0.85	0.70-1.05	0.08
	M2	1	0.73	0.61-0.88	0.69	0.57-0.84	0.0002	1	0.86	0.71-1.04	0.92	0.75-1.13	0.31
Vocabulary	M1	1	0.68	0.57-0.81	0.55	0.45-0.67	<10-4	1	0.84	0.70-1.02	0.78	0.63-0.96	0.04
	M2	1	0.68	0.56-0.81	0.54	0.44-0.66	<10-4	1	0.82	0.68-1.00	0.75	0.60-0.92	0.02
Phonemic	M1	1	0.77	0.64-0.92	0.72	0.59-0.88	0.002	1	0.87	0.72-1.05	0.89	0.73-1.10	0.32
fluency	M2	1	0.83	0.69-1.00	0.80	0.66-0.98	0.06	1	0.94	0.77-1.13	0.98	0.80-1.21	0.77
Semantic	M1	1	0.66	0.56-0.79	0.57	0.47-0.68	<10-4	1	0.75	0.63-0.90	0.70	0.57-0.85	0.0004
fluency	M2	1	0.69	0.58-0.82	0.59	0.50-0.72	<10-4	1	0.78	0.65-0.93	0.72	0.59-0.88	0.002

M1: adjusted for age, sex and energy intake

M2: Model1+ adjusted for marital status, health behaviour (smoking habits, physical activity) and health status (diabetes, hypertension, CHD, dyslipidemia, BMI and mental health)

T: tertile

*p for trend

[†] Tertile 1, 2 and 3 represent individuals in the lowest, intermediate and highest thirds of the dietary factor score

Table 4: Association between tertiles of the "processed food" pattern and cognitive deficit

		Without adjustment for education						After adjustment for education					
		T1[†]	T2[†]		T3[†]			T1[†]	T2[†]		T3[†]		
		OR	OR	OR	OR	95% CI	p*	OR	OR	95% CI	OR	95% CI	p*
Memory	M1	1	1.17	0.94-1.46	1.40	1.06-1.85	0.06	1	1.06	0.85-1.32	1.15	0.87-1.55	0.61
	M2	1	1.13	0.91-1.41	1.26	0.95-1.67	0.26	1	1.03	0.83-1.29	1.06	0.79-1.41	0.92
Reasoning	M1	1	1.37	1.13-1.66	1.68	1.31-2.14	<10-4	1	1.14	0.93-1.39	1.15	0.89-1.49	0.43
	M2	1	1.34	1.10-1.62	1.55	1.21-1.98	0.001	1	1.12	0.91-1.37	1.09	0.84-1.42	0.55
Vocabulary	M1	1	1.62	1.33-1.96	2.45	1.92-3.14	<10-4	1	1.33	1.08-1.63	1.63	1.25-2.13	0.001
	M2	1	1.58	1.30-1.92	2.36	1.84-3.04	<10-4	1	1.31	1.07-1.62	1.63	1.25-2.13	0.001
Phonemic	M1	1	1.26	1.04-1.53	1.83	1.43-2.35	<10-4	1	1.10	0.90-1.34	1.42	1.10-1.83	0.02
fluency	M2	1	1.23	1.01-1.49	1.70	1.33-2.19	10-4	1	1.07	0.88-1.32	1.34	1.04-1.74	0.06
Semantic	M1	1	1.21	1.00-1.45	1.68	1.33-2.12	<10-4	1	1.04	0.86-1.26	1.28	1.00-1.63	0.10
fluency	M2	1	1.17	0.97-1.42	1.58	1.25-2.01	0.0005	1	1.02	0.84-1.24	1.23	0.96-1.57	0.17

M1: adjusted for age, sex and energy intake

M2: Model1+ adjusted for marital status, health behaviour (smoking habits, physical activity) and health status (diabetes, hypertension, CHD, dyslipidemia, BMI and mental health)

T: tertile

*p for trend

† Tertile 1, 2 and 3 represent individuals in the lowest, intermediate and highest thirds of the dietary factor score

Appendix 1: Food Groups Used for Factor Analyses

Foods or Food groups	Food items
Red Meat	Beef, beef burgers, pork, lamb
Poultry	Chicken or other poultry
Processed meats	Bacon, Ham, corned beef, Spam, luncheon meats, sausages
Organ meat	Liver
Fish	White fish, oily fish and shellfish
Refined grain	White bread and rolls, cream cracker, cheese biscuits, crisp bread, Refined grain ready-to-eat cereals, white pasta, white rice
Whole grain	Brown bread and rolls, wholemeal bread and rolls, wholemeal pasta, brown rice, whole grain ready-to-eat cereals
Eggs	Eggs
Butter	Butter
Margarine	Margarines, spread
High fat dairy	Full cream milk, Channel Island milk, Coffee whitener, Single or clotted cream, cheese, ice cream
Low fat dairy	Skimmed milk, sterilized milk, dried milk, yoghurt, cottage cheese
Soya product	Soya milk, tofu, Soya bean curd, Soya meat, TVP, vege-burger
Liqueurs/Spirits	Port, sherry, Liqueurs, spirits
Wine	Wine
Beer	Beers, ciders
Hot drinks	Tea, Regular coffee, Decaffeinated coffee, Cocoa, hot chocolate, Chicory

Fruits	Apples, pears, oranges, mandarins, grapefruit, bananas, grapes, melon, peaches, plums, apricots, strawberries, raspberries, tinned fruit, dried fruits
Fruit juice	100 % Real fruit juice
Leafy vegetables	Spinach, salads
Cruciferous vegetables	Broccoli, kales, Brussels spouts, cabbage, cauliflower, coleslaw
Other vegetables	Carrots, marrow, courgettes, parsnip, leeks, mushroom, peppers onion, garlic
Tomatoes	Tomatoes
Peas and dried Legume	Beans, peas, baked beans, dried lentils
Soup	Vegetable soup, meat soup
Nuts	Peanuts, other nuts, peanut butter
Potatoes	Boiled, mashed potatoes, jacket potatoes, potato salad
Quiche/Pie	Quiche, meat pie
Pizza/Lasagne	Pizza, Lasagne
Fried food	Chips or French fries, Roast potatoes, Fish fingers, fried fish in batter
Snacks	Crisps
Desserts/biscuits	Sweet biscuits, cakes, buns, pastries, fruits pies, tarts, crumbles, milk pudding, sponge puddings
Chocolate and sweets	Chocolate bars, sweets, toffees, sugar added to tea, coffee, jam, marmalade, honey.
Sugar beverages	Fizzy soft drinks, fruit squash
Low calorie beverages	Low calorie or diet fizzy soft drinks
Condiments	Sauce, tomato ketchup, pickles, marmites
Salad dressing	French vinaigrette, salad cream