HHS Public Access

Author manuscript

Br J Nutr. Author manuscript; available in PMC 2018 May 10.

Published in final edited form as:

Br J Nutr. 2013 February 14; 109(3): 503–510. doi:10.1017/S0007114512001183.

Variety in fruit and vegetable intake and cognitive function in middle-aged and older Puerto Rican adults

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Abstract

Higher variety in fruit and vegetable intake has been associated with a lower risk of several chronic diseases. It remains unclear whether such associations exist relating to cognition. The authors examined associations between total quantity and variety in fruit and vegetable intake and cognitive function in a cross-sectional sample of 1412 Puerto Rican adults, aged 45–75 years from the Boston Puerto Rican Health Study, 2004–9. Fruit and vegetable intake was assessed with a FFQ. Cognitive function was measured with a battery of seven tests; the Mini Mental State Examination (MMSE) was administrated to assess global cognitive function. Greater variety, but not total quantity, of fruit and vegetable intake was associated with a higher MMSE score after multivariate adjustment (*P* for trend=0·012). This association remained significant after further adjusting for total quantity of fruit and vegetable intake (*P* for trend=0·018). High variety of fruit and vegetable intake was also associated with individual cognitive domains, including executive function, memory and attention (all *P* for trend<0·05). Variety, more than total quantity, of fruit and vegetable intake may offer cognitive protection in middle-aged and older adults, but longitudinal studies are needed to clarify direction of causality.

Keywords

Fruit; Vegetables; Dietary variety; Cognition; Middle-aged adults; Puerto Ricans

Greater fruit and/or vegetable intake has been associated with a lower risk of several chronic diseases, including CHD[1,2], stroke[3,4] and several types of cancers[5–7]. A higher intake of vegetables has also been associated with less cognitive decline[8,9]; and a lower intake of fruit and vegetables has been related to poorer executive function and memory[10] and a higher risk of dementia and Alzheimer's disease[11].

Fruit and vegetables are generally rich in antioxidants (vitamin C, carotenoids, etc.) and other bioactive compounds. Dietary antioxidants have been associated with a lower risk of dementia and Alzheimer's disease in some studies[12,13], but not others[14,15]. However, several intervention studies with antioxidant vitamins have not shown beneficial effects on cognition in older adults[16–19]. The inconsistency among these studies could be due to

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differences in study design, or to limitations in the supplements provided – in that other nutrients or bioactive compounds in fruit and vegetables, rather than investigated specific antioxidant vitamins, may be protective against cognitive decline. Further, different fruits and vegetables have varied nutrients and bioactive compounds. The combination of different types of fruits and vegetables may provide additive and/or synergistic beneficial effects relative to individual fruits and vegetables[20].

To our knowledge, no studies have examined the association between variety in fruit and vegetable intake and cognitive function. We aimed to simultaneously study the associations between variety and total quantity of fruit and vegetable intake and cognitive function in a middle-aged and older population.

Materials and methods

Participants

Participants in the baseline interview of the Boston Puerto Rican Health Study, an ongoing study to explore sociological, environmental and genetic factors contributing to ageing-related chronic diseases and quality of life, were included in these analyses[21]. Details of this study design have been reported previously[21]. In brief, baseline data collection was completed between 2004 and 2009. Census tracts with twenty-five or more Puerto Rican adults, aged 45–75 years, were selected from the year 2000 census in the greater Boston, Massachusetts area, and all blocks with ten or more Hispanic adults, aged 45–75 years, were enumerated. If more than one household member qualified for the study, one was randomly selected. Approximately 77·4 % of our sample was identified with this method, with additional participants solicited randomly at major community events (9·8 %), from referral (7·2 %) or individual calls to the study (5·6 %). Of the 2170 individuals identified, seventy-seven were excluded because of serious health conditions that would preclude answering questions, a planned move away within 2 years or a lack of a permanent address. Of those remaining, 1811 agreed to participate and 1500 (83·2 %) completed the baseline survey: 302 participants did not finish the survey due to difficulty in scheduling or unsuccessful follow-up; and nine were excluded because of their low Mini Mental State Examination (MMSE) scores (≤10, indicating severe cognitive impairment)[22]. For the present analysis, we further excluded individuals with implausible energy intake (<2510 kJ/d (600 kcal/d) or >20 083 kJ/d (4800 kcal/d)) and those with incomplete cognitive tests or blood lipids, resulting in a sample of 1412. The present study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects were approved by the Institutional Review Board at Tufts Medical Center. Written informed consent was obtained from all subjects.

Variety and quantity of fruit and vegetable intake

Information about dietary intake was collected for the previous 12 months with a validated semi-quantitative FFQ with 223 items, interviewer-administered in the home[21]. Nutrient intake was calculated using the Nutrition Data System for Research software version 2007 (Nutrition Coordinating Center, University of Minnesota, Minneapolis, MN, USA, Food and Nutrient Database 2007). The number of servings of fruit and vegetables per d was

calculated using reference serving sizes from the Pyramid Servings Database for USDA Survey Food Codes version 2.0[23]. The FFQ includes questions for the intake of specific fruits, vegetables, 100 % fruit juice and 100 % vegetable juice[24]. Dried beans and starchy vegetables (potatoes and potato products, plantains, tannier and cassava) were not included for the calculation of total quantity and variety in fruit and vegetable intake. Each specific type of fruit, vegetable, 100 % fruit juice or 100 % vegetable juice that was consumed at least once per month was counted towards the variety score. The possible ranges for the summed variety scores were from 0 to 27 for fruit intake (including 100 % fruit juice) and from 0 to 26 for vegetable intake (including 100 % vegetable juice). The FFQ fruit and vegetable items are shown in Table S1 (available online).

Assessment of cognitive function

A trained research assistant administered a battery of seven neuropsychological tests with each participant, in his or her home, before the FFQ data were collected. The MMSE was used as a measure of global cognitive function (ranged from 12 to 30 in the present sample)[25]. Other cognitive tests included: a word-list learning test to assess verbal memory, with sub-scores for learning and immediate recall, recognition, and percentage retention[26]; digit span forward and backward tests to measure attention and working memory[26]; the Stroop test for cognitive flexibility, response inhibition and processing speed[21]; the verbal fluency test to measure the speed at which one can provide examples to a category (initial letter of a word)[26]; clock-drawing[27] and figure-copying[28] tests to measure visual–spatial organisation. Scores for figure copying were weighted for the complexity of the figure, by assigning 1 point for easy figures and to 4 points for the most difficult. Greater scores on each of these seven tests reflect better cognition.

The MMSE score was our primary outcome because the MMSE measures global cognitive function. Scores from each neuropsychological test were standardised with a mean of 0 and a standard deviation of 1. A factor analysis for data reduction was then conducted with standardised scores. After performing varimax rotation, three meaningful cognitive function factors were obtained: executive function; memory; attention (Table S2, available online). The standardised factor-scoring coefficients for converting individual test scores to factor scores are shown in Table S3 (available online).

Assessment of covariates

Educational attainment was categorised into four categories: none or primary school; secondary school; high school; college or higher. Participants were classified as never smoker (<100 cigarettes in entire life), former smoker or current smoker. Alcohol use was classified as not current, current moderate (≤1 drink/d for women or ≤2 drinks/d for men) or current heavy (>1 drink/d for women or >2 drinks/d for men). Physical activity was evaluated with a modified Paffenbarger questionnaire from the Harvard Alumni Activity Survey[21]. Poverty was defined ‘yes’ if a participant’s total annual household income was below the poverty threshold released each year by the US Department of Health and Human Services, relative to family size. For example, the poverty threshold for a family with two members was $13 690 for Massachusetts residents in 2007[29]. An acculturation score was calculated based on answers to seven questions regarding the extent of use of English and/or

Spanish for work and daily life[21], ranging from 0 (only using Spanish) to 100 (only using English). Physical disability was assessed with a modified Activities of Daily Living (ADL) scale with twelve items with total scores ranging from 0 to 36[30]. Greater ADL scores indicate lower physical function.

During the home interview, height and weight were measured with standard methods[21], and BMI was calculated. Blood pressure was measured at three time points during the home interview with the latter two measures averaged for data analysis. Hypertension was defined as systolic blood pressure ≥140 mmHg or diastolic blood pressure ≥90 mmHg, or use of antihypertensive medications. Fasting blood samples were collected and concentrations of glucose, total cholesterol, HDL-cholesterol and TAG were determined with standardised methods[21]. Diabetes was defined as 'yes' if a participant had fasting glucose ≥7·0 mmol/l or was taking medication for diabetes[31].

Statistical analyses

Participants were placed in quintiles according to the total number of servings and variety score of fruit and vegetable intake, respectively. General linear models were used to compare continuous variables and logistic regression models were used to compare categorical outcome variables across quintiles of total intake quantity and variety scores. Means in the last four quintiles were compared with means in the first quintile, after Tukey's adjustment for multiple comparisons. Cognitive performance scores for each quintile were calculated after multivariate adjustment with general linear models. In the first model, we adjusted for age (years), sex, educational attainment (none or primary school, secondary school, high school, or college or higher), income below the poverty threshold (yes/no), acculturation score (continuous), BMI (kg/m^2) and total energy intake (kJ/d). In a second model, we further adjusted for potential confounders and mediators, including smoking status (never, past smoker or current smoker), alcohol use (never, moderate or high), physical activity score (continuous), supplement use (yes/no), use of five or more types of medications within the past 12 months (yes/no), ADL score (continuous), hypertension (yes/no) and diabetes (yes/no). In a final full model, we further adjusted for the variety score for the total serving variable, and vice versa. Original continuous total servings and variety score were used for trend tests. We also investigated whether lipids (total cholesterol, HDL-cholesterol and TAG) or the dietary intake of PUFA and MUFA would attenuate the associations between total servings and variety score and cognitive function. In a secondary analysis, we repeated all analyses to examine whether fruit intake (servings *v.* variety) or vegetable intake (servings *v.* variety) was individually associated with cognitive function. All statistical analyses were conducted with SAS version 9.2 (SAS Institute, Inc.). A value of $P<0·05$ (two-sided) was considered statistically significant.

Results

Participants in the highest quintile of fruit and vegetable intake had a 4·6-fold higher intake than those in the first quintile (median 6·5 *v.* 1·4 servings/d; Table 1), and those in the highest quintile of variety in fruit and vegetable intake consumed twice the variety of those in the lowest quintile. Those with higher fruit and vegetable intake, or with higher fruit and

vegetable variety, tended to have education at the college level or higher, to be not current smokers, to drink alcohol moderately, to have a higher physical activity score, a lower ADL score, and to have a higher intake of total energy and a higher use of supplements, relative to those with the lowest quantity or variety in fruit and vegetable intake, respectively. Participants with the highest variety scores also tended to be female, to be more acculturated, above the poverty line, to have higher total and HDL-cholesterol concentrations, and were less likely to have diabetes and to use medications, than those with the lowest variety scores. The total quantity of fruit and vegetable intake was moderately associated with the variety score (Spearman's correlation coefficient 0·34, $P<0·001$).

Higher variety in fruit and vegetable intake (P for trend<0·001), but not quantity (P for trend=0·13), was associated with a greater MMSE score after adjustment for age, sex, educational attainment, household income, acculturation score, BMI and total energy intake (model 1; Table 2). The association between variety in fruit and vegetable intake and the MMSE score remained significant after further adjustment for smoking, alcohol use, physical activity score, supplement use, medication use, ADL score, hypertension and diabetes (model 2, P for trend=0·012), and total quantity of fruit and vegetable intake (model 3, P for trend=0·018). Each of the seven points of the fruit and vegetable variety score (β = 0·17, SE = 0·07, P=0·012) was also inversely similar to 5 years of age on MMSE scores (β = −0·16, SE = 0·07, P=0·018), after multivariate adjustment in model 3. Higher variety score was also associated with better executive function, memory and attention (model 1–3, all P values for trend<0·05). Further adjustment for blood lipids (total cholesterol, HDL-cholesterol and TAG) and dietary intake of PUFA and MUFA did not change the observed associations mentioned above (data not shown).

We further examined the associations between total quantity and variety in fruit and vegetable intake and the scores of individual cognitive tests (Table 3). A higher fruit and vegetable variety score was significantly associated with better scores for word-list immediate recall, word-list percentage recognition and retention, letter fluency, digit span forward and backward, and clock drawing, after multivariate adjustment including total intake of fruits and vegetables (all P values for trend<0·05).

In secondary analyses, higher variety, but not quantity, of fruit intake was significantly associated with a higher MMSE score, and with the executive function, memory and attention factors, after multivariate adjustment (model 1–3, all P values for trend<0·05; Table S4, available online). Higher quantity and variety in vegetable intake were both significantly associated with a greater MMSE score after adjustment for age, sex, education, household income below the threshold, acculturation score, BMI and total energy intake (P for trend<0·05; Table S5, available online). Variety, but not quantity, of vegetable intake remained significantly associated with the MMSE score after further adjustment for lifestyle factors, supplement and medication uses, ADL score, diabetes and hypertension (P for trend=0·024). Higher variety in vegetable intake was marginally significantly associated with the MMSE score (P for trend=0·065) and memory (P for trend=0·067), and significantly associated with executive function and attention (both P for trend<0·05) after further adjustment for total quantity of vegetable intake.

Discussion

To our knowledge, this is the first study to show that greater variety in fruit and vegetable intake was significantly associated with better cognitive function in middle-aged and older adults. Further, this association was maintained after adjustment for total quantity of fruit and vegetable intake.

Available studies about the association between fruit and vegetable intake and cognitive function are limited. In the Nurses' Health Study, intake of some types of vegetables, but neither of fruit, nor total fruit and vegetable intake, was associated with less cognitive decline after a 2-year follow-up[8]. In the Chicago Health and Aging Project, with adults aged ≥65 years, vegetable intake, but not citrus fruit intake, was associated with a slower rate of cognitive decline after a 6-year follow-up[9]. We did not observe significant associations between the total intake of fruit, the combination of fruit and vegetables and the MMSE score or individual cognitive domains (executive function, memory and attention). The total quantity of vegetable intake was significantly associated with the MMSE score only before adjustment for lifestyle factors, supplement and medication use, ADL score, diabetes and hypertension.

In contrast, higher variety in fruit and vegetable intake was associated with a better MMSE score, executive function, attention, memory function and several individual tests. These associations remained significant or continued to approach significance, even after adjustment for total quantity. The present results support the Dietary Guidelines for Americans, 2010[32] recommendation to increase variety in fruit and vegetable intake.

Fruit and vegetables are rich sources of antioxidant vitamins, B vitamins, minerals and other bio-compounds such as polyphenols. Our previous analysis has shown that higher variety in fruit and vegetable intake was significantly correlated with greater blood concentrations of carotenoids and ascorbic acid[24]. Oxidative stress has been indicated in the pathophysiological process of cognitive impairment and dementia[33,34]. Antioxidants in fruit and vegetables may protect against neurodegeneration by scavenging free radicals. Nonetheless, previous studies have yielded inconsistent results about the associations between the intake of conventional antioxidant vitamins and cognitive decline and dementia[16–19]. Limited data suggest that non-vitamin antioxidants may have higher neuroprotective capacity than antioxidant vitamins[35]. Further, different fruits and vegetables have varied bioactive components. Therefore, the combination of multiple types of fruits and vegetables may have additive and/or synergistic effects on physiology above that of isolated nutrients or individual foods. Wang *et al.*[36] recently demonstrated that there were additive or synergistic effects on the total antioxidant capacity of the combination of specific foods within food categories (fruit or vegetable). More importantly, the combination of specific foods across categories was more likely to have synergistic effects on the total antioxidant capacity than the combinations within categories[36]. Their data support our present findings that higher variety in fruit and vegetable intake, relative to total quantity, was more strongly associated with better cognitive function.

The observed associations between higher variety in fruit and vegetable intake and cognitive function could also be due to other nutrients and/or bio-compounds. For example, low folate concentrations have been observed among those with neurodegenerative disorders[37]. A higher dietary folate intake has been linked with a slower decline of cognitive function[38]. In addition, inflammatory factors have been associated with poor cognitive function, cognitive impairment and dementia[39]. Higher variety in fruit and vegetable intake was also associated with lower C-reactive protein (a chronic low-grade inflammatory biomarker) in our previous analysis[24].

Strengths of the present study include a large sample size and our ability to adjust for a variety of covariates. We were able to examine the independent associations between variety in fruit and vegetable intake and cognitive function because the correlation between total quantity and variety in fruit and vegetable intake was moderate. We administrated a series of cognitive tests to examine several domains of cognition. However, due to the cross-sectional nature of the present analysis, we cannot infer a casual direction to our observed association. It is possible that those with lower cognitive function may change their dietary intake, or may recall their dietary intake in a less accurate way than others. However, we have previously shown that interviewer-administrated FFQ reporting may be valid in those with cognitive impairment, due to the superior retention of generic memory, relative to episodic memory for specific events, in most individuals[40]. Additionally, residual confounding remains a possibility. While our sample is restricted to the Puerto Rican population, there is no reason to suspect that the present results cannot be generalised to other populations or minority groups.

In conclusion, greater variety in fruit and vegetable intake was associated with better cognitive function in middle-aged and older adults. An emphasis on increasing variety, rather than only quantity of fruits and vegetables, may be advisable for this and other populations, to delay or prevent the onset of cognitive impairment and related chronic diseases.

Acknowledgments

This study was supported by the National Institute on Aging of the National Institutes of Health (NIH) (P01AG023394, R01AG02708), the National Heart Lung and Blood Institute of NIH (P50HL105185), and the US Department of Agriculture Agricultural Research Service (contract no. 58–1950–7–707). X. Y. contributed to the data analysis, the interpretation of the data and the writing of the manuscript. S. N. B. and K. L. T. contributed to the interpretation of the data and the critical revision of the manuscript. K. L. T. obtained the funding, conceived the study and supervised the data collection. All authors read and approved the final manuscript. None of the authors had any conflicts of interest.

Abbreviations

ADL	Activities of Daily Living
MMSE	Mini Mental State Examination

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Table 1

Characteristics of the participants by quintiles of total quantity and variety in fruit and vegetable intake from the Boston Puerto Rican Health Study, 2004–9 (Mean values with their standard errors; number of participants; percentages; medians and ranges)

	Fruit and vegetable intake (servings/d)							Fruit and vegetable variety						
	Quintile 1		Quintile 3		Quintile 5			Quintile 1		Quintile 3		Quintile 5		
Characteristics	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	***P*†**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	***P*†**
n	282		282		282			276		283		286		
Median	1·4		3·2		6·5			19		32		44		
Range	0·2–1·9		2·8–3·7		5·2–16·8			2–23		30–34		40–52		
Intake, variety	1·3	0·4	3·2	0·3	7·0	1·8		18·0	4·4	32·1	1·4	44·2	3·3	
Age (years)	57·2	8·0	57·0	7·7	58·0	7·4	0·31	56·1	7·6	57·3	7·8	56·9	7·0	0·11
Female (%)	66·0		70·2		75·5		0·12	62·0		72·8		73·8		0·003
Educational attainment (%)							0·003							<0·001
None or primary school	23·8		18·8		21·3			21·7		25·1		15·4		
Secondary school	25·5		24·5		22·7			30·4		28·3		20·6		
High school	39·7		44·0		32·3			38·8		36·8		33·6		
College or higher	11·0		12·8		23·8			9·1		9·9		30·4		
Household income below the threshold (%)	63·0		57·1		57·2		0·57	65·0		59·8		48·9		<0·001
Acculturation score	22·9	22·3	24·5	23·4	26·1	22·3	0·53	21·0	22·8	22·4	22·0	32·8***	23·3	<0·001
Smoking status (%)							0·024							0·004
Never	39·7		41·8		48·9			43·5		44·5		49·0		
Past smoker	29·8		31·9		33·0			23·9		33·9		32·9		
Current smoker	30·5		26·2		18·1			32·6		21·6		18·2		
Alcohol use (%)							0·002							<0·001
Never	71·8		55·6		57·9			68·6		63·4		46·7		
Moderate	21·7		38·4		35·6			24·7		29·8		46·7		
High	6·5		6·1		6·5			6·6		6·8		6·7		
Physical activity score	30·6	4·9	31·3**	3·8	32·1**	4·9	0·002	31·3	4·9	31·0	4·4	32·5*	5·0	<0·001
ADL score	4·9	6·2	4·1	5·1	4·0	4·7	0·039	4·6	5·9	4·8	5·4	3·0*	4·1	<0·001
Energy intake (kJ/d)	6607	2874	8791***	3305	11 473***	916	<0·001	8272	3502	9021	3774	9435**	3736	0·004

	Fruit and vegetable intake (servings/d)							Fruit and vegetable variety						
	Quintile 1		Quintile 3		Quintile 5			Quintile 1		Quintile 3		Quintile 5		
Characteristics	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	***P*†**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	***P*†**
Hypertension (%)	67·9		67·6		68·8		0·93	65·7		69·3		67·0		0·58
Diabetes (%)	39·2		37·8		43·8		0·36	38·1		45·9		31·3		0·003
BMI (kg/m^2)	31·7	7·0	31·6	6·6	32·6	6·6	0·21	31·0	6·7	32·4	6·4	31·7	6·5	0·039
Total cholesterol (mmol/l)	4·67	1·11	4·80	1·03	4·74	1·10	0·69	4·62	1·11	4·69	1·09	4·82	1·03	0·049
HDL-cholesterol (mmol/l)	1·17	0·36	1·15	0·31	1·17	0·34	0·61	1·11	0·30	1·17	0·35	1·18	0·29	0·038
TAG (mmol/l)	1·74	0·97	1·90	1·31	1·80	1·30	0·50	1·81	1·45	1·80	0·96	1·80	1·15	0·54
Supplement use (%)	51·1		56·0		63·5		0·044	51·1		58·3		68·9		<0·001
Medication use (%)‡	47·8		45·2		47·9		0·29	44·5		57·7		40·0		<0·001

ADL, Activities of Daily Living.

Mean values were significantly different compared with the lowest quintile after Tukey's adjustment for multiple comparisons:

* *P*<0·05,

** *P*<0·01,

*** *P*<0·001.

† *P* values for ANOVA for continuous variables across quintiles of total quantity and variety in fruit and vegetable intake were calculated by PROC GLM with SAS 9.2, respectively, and χ^2 test for categorical variables across quintiles was performed by PROC FREQ.

‡ Medication use was defined as yes if a participant had taken more than five types of medications within the past 12 months.

Table 2

Cognitive performance by quintile of total quantity and variety in fruit and vegetable intake from the Boston Puerto Rican Health Study, 2004–9[†] (Mean values with their standard errors)

	Fruit and vegetable intake							Fruit and vegetable variety						
	Quintile 1		Quintile 3		Quintile 5			Quintile 1		Quintile 3		Quintile 5		
	Mean	SE	Mean	SE	Mean	SE	*P* for trend[‡]	Mean	SE	Mean	SE	Mean	SE	*P* for trend[‡]
MMSE score														
Model 1[§]	23·3	0·2	23·4	0·2	23·8	0·2	0·13	23·1	0·2	23·4	0·2	24·0*	0·2	<0·001
Model 2[‖]	23·4	0·2	23·3	0·2	23·7	0·2	0·41	23·2	0·2	23·4	0·2	23·8	0·2	0·012
Model 3[¶]	23·5	0·2	23·3	0·2	23·7	0·2	0·84	23·2	0·2	23·4	0·2	23·8	0·2	0·018
Executive function														
Model 1[§]	20·03	0·06	20·12	0·06	0·10	0·06	0·009	20·16	0·06	20·13	0·06	0·17***	0·06	<0·001
Model 2[‖]	20·04	0·07	20·19	0·07	0·03	0·07	0·076	20·19	0·07	20·13	0·07	0·07*	0·07	<0·001
Model 3[¶]	0·02	0·07	20·19	0·07	20·01	0·07	0·42	20·17	0·07	20·13	0·07	0·07*	0·07	<0·001
Memory														
Model 1[§]	20·16	0·07	20·05	0·07	20·001	0·07	0·99	20·24	0·07	20·06	0·07	0·07**	0·07	<0·001
Model 2[‖]	20·10	0·08	20·09	0·08	20·05	0·08	0·53	20·24	0·08	20·09	0·07	0·01	0·08	0·015
Model 3[¶]	20·06	0·08	20·10	0·08	20·08	0·08	0·18	20·25	0·08	20·10	0·08	0·02*	0·08	0·007
Attention														
Model 1[§]	0·06	0·07	0·18	0·06	0·06	0·07	0·87	20·04	0·07	0·10	0·06	0·17*	0·06	0·007
Model 2[‖]	0·08	0·08	0·17	0·07	0·04	0·08	0·60	20·04	0·08	0·10	0·07	0·16	0·07	0·022
Model 3[¶]	0·11	0·08	0·17	0·07	0·01	0·08	0·23	20·05	0·08	0·10	0·07	0·16	0·07	0·012

MMSE, Mini Metal State Examination.

Mean values were significantly different compared with the lowest quintile after Tukey's adjustment for multiple comparisons:

* *P*<0·05,

** *P*<0·01,

*** *P*<0·001.

† Results of the omitted quintiles generally follow the pattern of those of the shown quintiles, but are not presented for simplicity; adjusted means (with their standard errors) of cognitive performance scores according to quintiles of total quantity and variety in fruit and vegetable intake were calculated using general linear models (PROC GLM in SAS 9.2) after adjustment for covariates, respectively.

‡ *P* values for trend were calculated using total quantity and variety in fruit and vegetable intake with PROC GLM in SAS 9.2, respectively.

§ Model 1, adjusted for age (years), sex, educational attainment (none or primary school, secondary school, high school, or college or higher), household income below the threshold (yes/no), acculturation score (continuous), BMI (kg/m^2) and total energy intake (kJ/d).

‖ Model 2, further adjusted for smoking status (never, past smoker or current smoker), alcohol use (never, moderate or high), physical activity score (continuous), supplement use (yes/no), taking more than five types of medications within the past 12 months (yes/no), activities of daily living scores (continuous), hypertension (yes/no) and diabetes (yes/no).

¶ Model 3, further adjusted for fruit and vegetable variety for fruit and vegetable intake and vice versa.

Table 3

Individual cognitive test performance by quintile of total quantity and variety in fruit and vegetable intake from the Boston Puerto Rican Health Study, 2004–9[†] (Mean values with their standard errors)

			Fruit and vegetable intake							Fruit and vegetable variety						
			Quintile 1		Quintile 3		Quintile 5			Quintile 1		Quintile 3		Quintile 5		
	Mean[‡]	SD[‡]	Mean	SE	Mean	SE	Mean	SE	*P* for trend[§]	Mean	SE	Mean	SE	Mean	SE	*P* for trend[§]
Word-list immediate recall	37·4	10·6	−0·08	0·07	−0·09	0·07	−0·05	0·07	0·81	−0·17	0·07	−0·11	0·07	0·08*	0·07	0·006
Word-list percentage recognition	29·4	6·14	0·01	0·08	−0·12	0·07	−0·1	0·08	0·074	−0·24	0·08	−0·01	0·07	0·14***	0·07	<0·001
Word-list percentage retention	82·6	37·5	−0·05	0·08	−0·03	0·07	−0·02	0·08	0·42	−0·18	0·08	−0·04	0·07	0·01	0·08	0·049
Stroop percentage	34·0	18·0	−0·15	0·08	−0·06	0·08	−0·1	0·08	0·79	−0·06	0·08	−0·13	0·07	−0·07	0·08	0·55
Letter fluency	23·7	10·3	0·06	0·07	−0·08	0·07	−0·05	0·07	0·23	−0·22	0·07	−0·09	0·07	0·18***	0·07	<0·001
Digit span forward	7·26	1·98	0·06	0·08	0·16	0·07	−0·01	0·08	0·61	−0·11	0·07	0·08	0·07	0·10	0·07	0·007
Digit span backward	3·35	1·57	−0·09	0·07	0·01	0·07	0·03	0·08	0·36	−0·12	0·07	−0·03	0·07	0·09	0·07	0·039
Clock drawing	2·07	1·02	−0·07	0·07	−0·13	0·07	0·1	0·08	0·041	−0·1	0·07	−0·18	0·07	0·14	0·07	0·009
Figure-copying weighted	10·1	7·6	0·03	0·07	0·04	0·07	0·15	0·07	0·28	0·05	0·07	−0·01	0·07	0·16	0·07	0·073

Mean values were significantly different compared with the lowest quintile after Tukey's adjustment for multiple comparisons:

*P<0·05,

***P<0·001.

[†]Results of the omitted quintiles generally follow the pattern of those of the shown quintiles, but are not presented for simplicity; adjusted means (with their standard errors) of cognitive performance scores (standardised with a mean of 0 and a standard deviation of 1) according to quintiles of total quantity and variety in fruit and vegetable intake were calculated using general linear models (PROC GLM in SAS 9.2), respectively, after adjustment for each other (original continuous values) and age (years), sex, educational attainment (none or primary school, secondary school, high school, or college or higher), household income below the threshold (yes/no), acculturation score (continuous), BMI (kg/m^2), total energy intake (kJ/d), smoking status (never, past smoker or current smoker), alcohol use (never, moderate or high), physical activity score (continuous), supplement use (yes/no), taking more than five types of medications within the past 12 months (yes/no), activities of daily living scores (continuous), hypertension (yes/no), diabetes (yes/no) and fruit and vegetable variety for fruit and vegetable intake and vice versa.

[‡]Sample mean and standard deviation of the corresponding original cognitive test score.

[§]*P* values for trend were calculated using total quantity and variety in fruit and vegetable intake with PROC GLM in SAS 9.2, respectively.