Dietary intake and cognitive performance in Canadian community-dwelling older adults.

Mariam R Ismail[1]*, Alan W Salmoni[2]

[1]School of Health and Rehabilitation Sciences, Faculty of Health Sciences, Western University, London, Ontario, Canada
[2]School of Kinesiology, Faculty of Health Sciences, Western University, London, Ontario, Canada

Abstract

Diet-related health problems are on the rise as a result of poor dietary intake. The primary purpose of the study was to examine cognitive function differences between older adults who did and did not consume the recommended servings of specific food groups. The secondary purpose of the study was to examine the potential role the nutrients provided by food groups can have on cognitive function. A cross-sectional study was conducted with 35 community-dwelling older adults, aged 60 years and over at baseline. The Montreal Cognitive Assessment (MoCA), Rey Complex Figure Test and Recognition (RCFT), Trail-Making Test (TMT), Victoria Stroop Test (VST), and the Digit Span Test (DST) were used to record performance on cognitive tasks. Dietary intake was collected using a five-day food intake record (FIR). An independent t-test was used to determine the differences between the frequency/incidence of food group consumption and cognitive function. Multiple regression was used to analyze the relationship between food nutrients and cognitive function. A total of 32 participants, 8 males and 24 females, completed the study. The average age and BMI were 70.59 (7.07) years old and 27.59 (4.45) kg/m2, respectively. No differences were found in cognitive task performance between the group who consumed and did not consume the recommended amount of servings per day in any of the food groups. However, a number of associations were found between the nutrients found in foods and cognitive function. A positive correlation was found between the level of vitamin D and the RCFT [r=0.348, p=0.051], and the MoCA [r=0.372, p=0.036]. A negative correlation was found between the level of calcium, poly fat, and protein and performance on VST with [r=-0.457, p=0.009]; [r=-0.412, p=0.019], and [r=-0.345, p=0.053], respectively. In addition, regression analyses revealed that calcium level may predict performance on VST [F (1,30)=7.908, p=0.009, R2=0.209]. Consumption of foods was associated with better performance on cognitive tasks but underlying mechanisms are still to be determined in a longitudinal and well-powered population-based intervention studies.

Keywords: Nutrition, Food groups, Nutrients, Cognition, Cognitive function, Older adults

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Introduction

Globally, older adults aged 65 years or older are the fastest growing population with an expected trajectory to double their current 8% of the world's total population by 2050 [1]. For Canada, this means an expected 10.4 million older adults by 2036 [2]. Canada incurred an expenditure of an estimated 33 billion dollars per year, including combined medical costs and lost earnings associated with cognitive decline in 2012, and it's projected to increase to $293 billion a year by 2040, putting a significant financial strain on the health care system [3]. Therefore, devising responses and prevention strategies to address the modifiable personal and financial losses associated with cognitive decline is a priority.

Diet is one important non-pharmacological modifiable lifestyle approach that can play a role in cognitive ageing. Some research has demonstrated associations between dietary patterns, such as Mediterranean diet, Western diet or specific food groups and cognitive performance [4,5]. For example, a known relationship exists between consumption of fruits and vegetables (FVs), and dairy foods and improved cognitive function [6-13]. Links have also been established between improved dementia symptoms in older adults and intake of nutrients including vitamins C and E, omega 3 polyunsaturated fatty acids, and vitamin B complex (vitamins B6 and B12, and folate) [14-17].

In order to add to this literature the aim of the present study was to examine the impact of food intake on the performance of specific cognitive tests in community-dwelling older adults. While cognitive function was the main focus of the present study, other measures of physical health and cardio metabolic health were also included to gain a comprehensive picture of overall health and well-being in the sample.

Methods

Participants

A total of 35 older adults (9 males, 26 females) were voluntarily recruited from London, Ontario, Canada. Recruitment flyers were posted at various locations (e.g., Retired Academic Associations, churches, community libraries) where older adults usually gather. For interested participants the study protocol was explained fully by the researcher and all participants provided a written informed consent. Participants were reassured that their privacy would be protected as outlined in the study letter of information (LOI). Participants were excluded if they were less than 60 years old, unable to read or write in English, lived in long-term care or assisted living facilities, required assistance with activities of daily living, or had visual impairment such as colour blindness and/or auditory impairment uncorrected by aids. This study was approved by the Western University Research Ethics Board (#105710).

Measures

Demographic and overall health measures: Demographic measures, including age, gender, BMI [body weight (kg)/height (m^2)], marital and employment status and education were reported through a self-administered demographic questionnaire. Information on lifestyle factors including smoking, alcohol and soft-drink consumption, history of diseases and use of medication and supplements were also recorded. Reported answers were classified in a binary fashion.

Physical activity measure: The Yale Physical Activity Survey (YPAS) was used to assess physical activity level; YPAS was included in the battery because it is sensitive enough to detect the lower ranges of physical activities engaged in by older adults [18]. The YPAS contains a wide range of physical activities including those involved in household chores, recreation, and structural exercises. Participants were required to report the frequency, intensity and duration of physical activity from five categories (e.g., work, yard work, caretaking, exercise and recreation). This survey contains two sections. In the first section, the time for each YPAS activity is multiplied by an intensity code and then summed for all activities during a typical 7-day period to create an energy expenditure summary index (kcal/wk). In the second section, activities performed in the last month are calculated by multiplying a frequency score by a duration score for each of the five specific activities (vigorous, leisurely walking, moving, standing and sitting) and multiplying again by a weighting factor. Weights are based on the relative intensity of the activity dimension. An index score for each of these categories was computed as a product of frequency, duration, and a weighting factor for each of the physical activities. A summary score, known as the Yale index, was computed as the sum of the index scores across the above-mentioned five categories.

Cognitive function measures: Five neuropsychological tests were selected based on their sound psychometric properties and their wide use in the literature, ensuring a thorough assessment of a wide range of cognitive abilities. General cognitive status was assessed using MoCA [19]. Visuospatial functioning and visual memory were assessed using RCFT [20]. Selective attention and cognitive flexibility were assessed using VST [21-24]. Attention and concentration were assessed using DST; both forward and backward [25-27]. Visual search, psychomotor speed and cognitive flexibility were assessed using TMT [26,28,29].

Dietary measure: Dietary intake was assessed using a five-day food intake record (FIR) including 2-weekend days and 3-weekdays. The diary was structured with headings relating to the time of consumption, actual food and drink consumed, the method of preparation, and portion size consumed. Instructions on how to fill in the diary along with information on portion size using a catalogue of pictures of individual food portions were also provided.

Procedures

Participants completed the demographic questionnaire, YPAS, and 5-day FIR prior to cognitive testing. All questionnaires were checked for completion and for any corrections or changes the participant wished to make. There were five separate cognitive tasks: two computerized using the PEBL battery tests (TMT and DST) and three paper-based formats (MoCA, RCFT and VST). For the computer format, the tasks were administered using a personal, computer running Microsoft Windows. Each participant underwent the same order of cognitive tests. Participants were offered breaks in between tasks and given time to ask questions. On completing the protocol, the participants were thanked for their participation and asked if they would like to receive a final research report/summary of the study main findings.

Data analysis

Data were analysed using the Statistical Package for the Social Sciences software version 25.0 (Spss, Inc., Chicago, IL, USA). Independent t-tests were used to investigate group differences in the number of servings of food groups consumed and performance on neuropsychological tests. The independent variable was the frequency/incidence numbering of servings of food group and the dependent variables were cognitive test scores.

Exploratory analyses were conducted using Pearson's product-moment correlation coefficients to investigate if cognitive performance on the neuropsychological tests was associated with the nutrient intake from dietary foods. Since a large number of analyses were performed, there is an elevated probability of type I errors. However, because of the exploratory nature of this study, the traditional $p \leq 0.05$ significance level was retained. The interpretation of the association's strength was determined according to Cohen's guidelines [30].

Multiple regression was also conducted to determine whether performance on cognitive tests could be predicted by nutrient intake. Because nutrient intake is influenced by total energy intake, analyses were adjusted for energy intake using the nutrient density method, to reflect intakes per 1000 kilocalories (kcal) [31]. Also, analyses were adjusted for age because cognitive performance is usually influenced by the age of an individual [32]. Preliminary analyses were performed to ensure no violation of the assumptions (e.g., linearity, homoscedasticity, normality, and multicollinearity).

Food intake obtained from the FIR was analysed using Elizabeth Stewart Hands and Associates nutritional analysis software (ESHA Research Inc., 2014, Salem, Oregon). Individual participant intakes of food group servings were compared with current Canada Food Guide Healthy Eating

Recommendations for food groups [33]. Nutrients from Food group were compared with the 2007 Canadian Nutrient File (CNS) using the Recommended Dietary Allowances (RDA) to describe population prevalence of inadequate nutrient intakes [33-35].

Results

Sample characteristics

Of the original 35 study participants, three were unable to complete the entire study protocol because of family obligations and fear of being diagnosed with dementia. Of the 32 (91%) participants who completed the study, 8 males and 24 females had an average age of 70.59 years (7.07) and BMI of 27.59 (4.45) kg/m^2. Almost two thirds (62.5%) of the participants had a university education and the majority of participants (84%) were regular users of dietary supplements (Table 1).

Cognitive performance on the neuropsychological tests

All participants had a normal global cognitive function score, all having a score of at least 26 out of 30 on the MoCA. The participants had normal scores on DST forward and backward as 6 ± 1. The participants fell within the average range for the copy (33.42-29.63), immediate recall (17.65-9.00), delayed recall (17.29-8.60) and recognition (20.23-19.33) tests for the RCFT. The participants had scores above the average range (95.9-204s) for the TMT. This is due to the fact that the test was measured using the computer timer. However, when the timer was manually started, the average test score of 202 seconds was obtained, which is within the range scores associated with this age group. As for the VST, the sample participants performed better than the average efficiency scores of 2.55-2.95 for adults aged 60-80 years (Table 2).

Physical activity

All participants were considered physically active with an average of 3.73 (± 2.23) hours per day during a typical week. Participants scored on average 60.16, categorized as vigorous, leisurely walking, moving, standing and sitting, which is considered within the average range (0-120).

Dietary intake

Adequacy of individual total dietary intake: Dietary data showed that 100% of the participants met the Acceptable Macronutrient Distribution Range (AMDR) recommendation for protein, 60% of participants met the AMDR for fat and 54% of the participants met the AMDR for carbohydrates. In addition, the dietary data indicated that 100% of the participants consumed more than the recommended intake of saturated fat (<7%), whereas 100% were within the recommended amount of dietary intake for polyunsaturated fat (<10%). Also 56.25% of the participants had a cholesterol level within the recommended amount of <300mg. In general, the micronutrients of vitamin and mineral intakes, particularly, vitamin D and calcium were well below the Dietary Reference Allowances (RDA) guidelines, with 100% and 84.4% of participants falling below the recommended amounts for vitamin D and calcium, respectively (Table 3).

In addition, dietary data showed that only 18% and 15% of the participants met the Canada Food Guide (CFG) recommendations for fruit and vegetables (FVs), and grain foods, respectively. Only 10 participants (31%) reported consumption of the recommended amount of dairy foods per day, whereas the majority of the participants (71%) met the CFG recommendations for meat foods (Table 4).

Dairy intake of food group consumption and cognitive performance: Results showed that there were no significant differences for participants who consumed the recommended number of servings of dairy foods (3 servings per day) compared

Table 1. *Demographic and health characteristics of the sample.*

Characteristics	N (%)
Age Group	32
60-65	4 (12.5%)
65-74	19 (59.3%)
75+	9 (28.13%)
Gender	
Male	8 (25%)
Female	24 (75%)
Marital Status	
Single	3 (9.4%)
Widowed	3 (9.4%)
Separated	0 (0%)
Divorced	3 (9.4%)
Common-law	3 (9.4%)
Married	20 (62.5%)
Education	
Elementary	0 (0%)
High School	4 (12.5%)
Vocational/Technical School	2 (6.25%)
College	4 (12.5%)
University: Bachelor Degree	10 (31.25%)
University: Post-Graduate Degree	10 (31.25%)
Professional Degree	2 (6.25%)
Most Frequent Self-Reported Health Problems	
High Blood Pressure (Hypertension)	14 (43.75%)
High Blood Sugar (Diabetes)	3 (9.4%)
High Blood Cholesterol (Dyslipidemia)	8 (25%)
Obesity (High Waist Circumference)	2 (6.25%)
Depression	4 (12.5%)
Anxiety	2 (6.25%)
Stress	3 (9.4%)
Taking Prescription Medications	
Yes	20 (62.5%)
No	10 (31.25%)
Taking Dietary Supplements	
Yes	27 (84.4%)
No	5 (15.63%)
Consume Soft Drinks	
Yes	12 (37.5%)
No	20 (62.5%)
Consume Alcohol	
Yes	26 (81.25%)
No	6 (18.75%)
Smoking	
Yes	1 (3.13%)
No	31 (96.88%)
Physical Activity	
Part I (Energy Expenditure Summary Index)	4023.1Kcal/week
Part II (Yale Physical Activity Index)	60.16

Table 2. *Neuropsychological outcomes of the sample.*

Cognitive Function	Neuropsychological test	Mean (+-SD)
Visual memory	RCFT-3 minute delay (Immediate recall) (raw score)	13.27 (6.87)
	RCFT-30 minute delay (Delay recall) (raw score)	12.86 (6.86)
	RCFT- recognition trial (raw score)	19.38 (1.99)
	RCFT- Composite score (Immediate recall+ Delayed recall+ Recognition)	-0.069 (0.85)
Executive function/selective attention	Stroop Test Efficiency Score (C/D) (seconds)	1.56 (0.37)
Attention/working memory/processing speed/visual attention/cognitive flexibility	Digit Span Test Forward (raw score)	6.25 (1.50)
	Digit Span Test Backward (raw score)	4.84 (1.27)
	Trail Making Test (TMT) (seconds)	250.59 (87.09)
Visuospatial functioning	RCFT-copy (raw score)	32.11 (4.82)
Global cognitive functioning	MoCA (raw score)	26.1 (2.32)
Note: In cognitive tests used, the higher result means better performance, except for Victoria Stroop Test and the Trail Making Test where the best performance is the least amount of time used		

Table 3. *Adequacy of dietary intake of macronutrients and micronutrients.*

Nutrients	Recommendations	Within	Below	Over
Macronutrients*				
Carbohydrates	45-65%	53.10%	46.90%	-
Protein	10-35%	100%	-	-
Fat	20-35%	59.40%	-	40.60%
Saturated Fat**	<7%	-	-	100%
Monounsaturated Fat**	10-15%	3.10%	96.90%	-
Polyunsaturated Fat**	<10%	100%	-	-
Cholesterol**	<300mg	-	53.10%	46.90%
Poly Fatty Acids**				
Omega-3 Fatty Acids	M= 1.6g/day	3.10%	62.50%	34.40%
	F=1.1g/day	-	-	-
Omega-6 Fatty Acids	M=14g/day	-	90.60%	9.40%
	F=11g/day	-	-	-
Ratio 6/3 2:1		-	6.25%	93.80%
Vitamins**				
Vitamin B12	2.4 mcg/day	-	53.10%	46.90%
Vitamin D	51-70 years	-	100%	-
	15mcg/day	-	-	-
	>70 years 20mcg/day	-	-	-
Vitamin A	M=900mcg/day	-	71.90%	28.10%
	F=700mcg/day	-	-	-
Folate	400 mcg/day	-	87.50%	12.50%
Vitamin B2 (Riboflavin)	M=1.3 mg/day	3.10%	37.50%	59.40%
	F=1.1mg/day	-	-	-
Minerals**				
Calcium	M=51-70 years	-	84.40%	15.60%
	1000mg/day	-	-	-
	F=51-70 years	-	-	-
	1200mg/day	-	-	-
	>70 years (M and W)	-	-	-
	1200mg/day	-	-	-
Sodium	51-70 years (M and F)= 1300mg/day	-	3.10%	96.90%
	>70 years= 1200mg/day	-	-	-
Iron	8mg/day	-	15.60%	84.40%
Magnesium	M=420mg/day	-	96.90%	3.10%
	F=320mg/day	-	-	-
Phosphorus	700mg/day	-	56.30%	43.80%
Potassium	4700mg/day	-	96.90%	3.10%
Zinc	M=11mg/day	-	93.80%	6.25%
	F=8mg/day	-	-	-
Note: *Recommendation is based on AMDR [Acceptable Macronutrient Distribution Range]. **Recommendation is based on RDA [Recommended Dietary Allowance].				

with participants who consumed less than the recommended number of serving per day in visual memory as measured by the RCFT-composite score; visuospatial functioning as measured by the RCFT-copy score; executive functioning and selective attention as measured by the VST; working memory as measured by the DST; visual attention, processing speed and cognitive flexibility as measured by the TMT and global cognitive functioning as measured by the MoCA (Table 5).

Fruit and vegetable intake of food group consumption and cognitive performance: Results showed that there were no significant differences for participants who consumed the recommended number of servings of FVs (7 servings per day) compared with participants who consumed less than the recommend number of servings per day in visual memory as measured by the RCFT-composite score; visuospatial functioning as measured by the RCFT-copy score; executive functioning and selective attention as measured by the VST; working memory as measured by the DST; visual attention, processing speed and cognitive flexibility as measured by the TMT and the global cognitive functioning as measured by the MoCA (Table 6).

Grain intake of food group consumption and cognitive performance: Results showed that there were no significant differences for participants who consumed the recommended number of servings of grain foods (6 servings per day) compared with participants who consumed less than the recommended number of servings per day in visual memory as measured by the RCFT-composite score; visuospatial functioning as measured by the RCFT-copy score; executive functioning and selective attention as measured by the VST; working memory as measured by the DST; visual attention, processing speed and cognitive flexibility as measured by the TMT and the global cognitive functioning as measured by the MoCA (Table 7).

Meat intake of food group consumption and cognitive performance: Results showed that there were no significant differences for participants who consumed the recommended number of servings of meat foods (2 servings per day) compared with participants who consumed less than the recommended number of servings per day in visual memory as measured by the RCFT-composite score; visuospatial functioning as measured by the RCFT-copy score; executive functioning and selective attention as measured by the VST; working memory as measured by the DST; visual attention, processing speed and cognitive flexibility as measured by the TMT and the global cognitive functioning as measured by the MoCA (Table 8).

Relationship between total dietary nutrient intake and cognitive performance: Bivariate Pearson–Product Moment correlations were computed between nutrients from participants' dietary intake and their performance on cognitive tests. There was a positive correlation between vitamin D level and the RCFT composite score [r=0.348, n=32, p=0.051] and the MoCA score [r=0.372, n=32, p=0.036], with a higher level of vitamin D associated with better performance on the RCFT and MoCA. Another important finding was that higher calcium, poly fat and protein intake were associated negatively with performance on the VST. Higher intakes were associated with less time taken to complete the task [r=-0.457, n=32, p=0.009]; [r=-0.412, n=32, p=0.19] and [r=-0.345, n=32, p=0.053]. To control for the potential confounding effects of age and total calorie intake, multiple regression analyses were also employed to best-predict performance on the cognitive tests. Analyses revealed calcium level to be a significant predictor of VST test performance [F (1,30) =7.908, p=0.009, R^2 =.209]. This indicates that calcium levels might have an impact on executive functioning and selective attention as measured by the VST test (Table 9).

Table 4. *Adequacy of food group consumption.*

Food Groups	CFG Recommendations	Met the recommendations
Fruit and Vegetables	M: 7 servings/day	18% of the participants
	F:7 servings/day	
Grain products	M: 7 servings/day	15% of the participants
	F: 6 servings/day*	
Milk and milk alternatives	M: 3 servings/day	31% of the participants
	F: 3 servings/day	
Meat and meat alternatives	M: 3 servings/day	71% of the participants
	F: 2 servings/day**	
Note: CFG: Canada Food Guide; M: Males; F: Females; Recommendations are based on adults aged 51+ years old (Canada Food Guide, 2007) *Cut-off score was set on 6 servings of grain products per day as the majority of participants were female **Cut-off score was set on 2 servings of meat products per day as the majority of participants were female		

Table 5. *Comparison of mean scores on neuropsychological tests between (<3) and (≥ 3) servings of dairy foods.*

Cognitive test outcome measures	(<3 servings of dairy products) group N=22	(>=3 servings of dairy products) group N=10	T-test (p-value)
RCFT-Copy Score	32.614 (3.65)	31.00 (6.85)	-0.874 (0.389)
RCFT Composite Score	0.00 (1.02)	-0.143(0.77)	-0.331 (0.743)
Trial-Making Test (TMT)	4.04 (1.23)	4.54 (1.95)	0.876 (0.388)
Digit Span Test			
Forward (F)	6.00 (1.38)	6.80 (1.69)	1.419 (0.166)
Backward (B)	4.59 (1.01)	5.40 (1.65)	1.719 (0.096)
MoCA	26.14 (1.98)	26.00 (3.06)	-0.152 (0.880)
Victoria Stroop Test (Efficiency Score)	1.59 (0.43)	1.50 (0.22)	-0.631 (0.533)
Note: RCFT=Rey Complex Figure Test and Recognition Trail, TMT=Trail Making Test			

Table 6. *Comparison of mean scores on neuropsychological tests between (<7) and (≥ 7) servings of fruit and vegetables (FVs) foods.*

Cognitive test outcome measures	(<7 servings of fruit and vegetables) group N=26	(>=7 servings of fruit and vegetables) group N=6	T-test (p-value)
RCFT-Copy Score	32.519 (4.64)	30.333 (5.61)	-1.00 (0.325)
RCFT Composite Score	0.0400 (0.852)	-0.540 (0.727)	-1.539 (0.134)
Trial-Making Test (TMT)	4.096 (1.55)	4.650 (1.07)	0.825 (0.416)
Digit Span Test			
Forward (F)	6.42 (1.579)	5.50 (0.837)	-1.376 (0.179)
Backward (B)	5.00 (1.265)	4.17 (1.169)	-1.473 (0.151)
MoCA	25.96 (2.306)	26.67 (2.503)	0.665 (0.511)
Victoria Stroop Test (Efficiency Score)	1.569 (0.3782)	1.533 (0.3882)	-0.209 (0.836)
Note: RCFT=Rey Complex Figure Test and Recognition Trail, TMT=Trail Making Test			

Table 7. *Comparison of mean scores on neuropsychological tests between (<6) and (≥ 6) servings of grain foods.*

Cognitive test outcome measures	(<6 servings of grain products) group N=27	(>=6 servings of grain products) group N=5	T-test (p-value)
RCFT-Copy Score	32.130 (4.844)	32.000 (5.255)	-0.054 (0.957)
RCFT Composite Score	0.0077 (0.859)	-0.4816 (0.742)	-1.189 (0.244)
Trial-Making Test (TMT)	4.163 (1.55)	4.400 (1.06)	0.325 (0.747)
Digit Span Test			
Forward (F)	6.15 (1.53)	6.80 (1.30)	0.888 (0.382)
Backward (B)	4.81 (1.36)	5.00 (0.707)	0.294 (0.770)
MoCA	26.11 (1.92)	26.00 (4.18)	-0.097 (0.924)
Victoria Stroop Test (Efficiency Score)	1.593 (0.39)	1.400 (0.10)	-1.060 (0.298)
Note: RCFT=Rey Complex Figure Test and Recognition Trail, TMT=Trail Making Test			

Table 8. *Comparison of mean scores on neuropsychological tests between (<2) and (≥ 2) servings of meat foods.*

Cognitive test outcome measures	(<2 servings of meat products) group N=6	(>=2 servings of meat products) group N=26	T-test (p-value)
RCFT-Copy Score	34.583 (2.15)	31.538 (5.10)	-1.417 (0.167)
RCFT Composite Score	0.402 (0.892)	-0.1773 (0.8200)	-1.537 (0.135)
Trial-Making Test (TMT)	3.667 (0.659)	4.323 (1.58)	0.982 (0.334)
Digit Span Test			
Forward (F)	7.00 (1.26)	6.08 (1.52)	-1.376 (0.179)
Backward (B)	5.50 (1.37)	4.69 (1.22)	-1.424 (0.165)
MoCA	27.33 (2.733)	25.81 (2.173)	-1.480 (0.149)
Victoria Stroop Test (Efficiency Score)	1.300 (0.178)	1.623 (0.382)	1.997 (0.055)
Note: RCFT=Rey Complex Figure Test and Recognition Trail, TMT=Trail Making Test			

Table 9. *Pearson product moment correlations (Dietary Intake).*

RCFT-Composite Score		MoCA	Stroop
Poly fat	-	-	-0.412 (0.019)*
Vitamin D	0.348(0.051)	0.372 (0.036)*	-
Calcium	-	-	-0.457 (0.009)**
Protein	-	-	-0.345 (0.053)
Note: Data are presented as Pearson-Product Moment correlation coefficient r (p-value) ** Correlation is significant at the 0.01 level (2-tailed) * Correlation is significant at the 0.05 level (2-tailed)			

Discussion

The findings of the present study indicated that dietary intakes from food for the study participants were less than the recommended level for a number of nutrients including vitamin D and Calcium. They were within the recommended levels for poly fat and protein, whereas they were well above the recommendations for saturated fatty acids (SFA). Findings also indicated that 18% of the participants met the recommended number of servings of FVs, 15% for grain, 31% for dairy and 71% for meat food group consumption. This suggests that a significant proportion of the non-institutionalized elderly did not meet daily food group requirements as supported by results from Health Canada [33,34]. This is concerning as inadequate dietary intake contributes to an inadequate nutritional status which in turn may prevent optimal health and successful aging. Therefore, future health promotion interventions are needed to improve older adult's consumption of food groups, particularly in terms of FVs. Although a large body of research has demonstrated associations between diet high in FVs, legumes, and fish with decreased incidence of dementias and Alzheimer's Disease, and better cognitive performance, these studies rarely specify how much is "high" or "low" [4,15,36]. As a result, following the recommended amounts set by the Canada Food Guide (CFG) for healthy eating is important because these amounts are based on evidence-based guidelines established to ensure older adults have optimal overall health.

Our study also indicates that almost 84% of the participants consumed dietary supplements, although this study was not able to take into account levels of nutrient intake from supplements. Our findings confirm with Health Canada statistics that seven in ten Canadians have tried natural health products (NHPs) such as vitamins [35]. Furthermore, majority of the participants had some form of health problems. Most frequently cited problems were high blood pressure (43.75%) and elevated blood cholesterol (25%). Literature has shown that metabolic syndrome, a clustering of several commonly occurring disorders that include (1) abdominal obesity, (2) hypertriglyceridemia, (3) low high-density lipoprotein (HDL) level, (4) hypertension, and (5) hyperglycemia play a significant role in the pathogenesis of Alzheimer Disease (AD) as well as in the development of Vascular Dementia (VD) [37,38]. This indicates that enhancing awareness about the link of unhealthy eating habits has significant health implications on the overall health and well-being of older adults, and therefore, older adults should follow the recommended dietary guidelines.

In addition, the findings of the present study indicate that there were no significant differences on mean cognitive test scores between the groups that consumed the recommended servings of food groups (e.g., FVs, grain, dairy, and meat) versus the group that consumed less than the recommended servings of food groups per day. The present finding is incongruent with a study conducted by Crichton who reported that participants who consumed at least one food serving of dairy per day had significantly higher scores on multiple domains of cognitive function compared with those who never or rarely consumed dairy foods [9]. In another study, Crichton reported that participants who consumed four servings of dairy foods per day over six months had better performance on spatial working memory compared to individuals who consumed 1 serving per day [13]. This considerable variant in findings may be due to different cut-off values used to define impact on cognitive function. For example, the present study used 3 servings of dairy foods compared to those of Crichton's 1 serving of dairy foods. It is important to note that these cut-off values of our study were not arbitrary but based on evidence-based guidelines (Canada Food Guide Healthy Eating Recommendations), which aim to promote healthy eating and overall nutritional well-being. Another reason may be the fact that, in the present study, the findings were based on 32 participants, compared to other studies which included at least 1000 participants. This indicates that longitudinal, well-powered intervention-based studies are needed to confirm these findings.

Several associations were found between the levels of nutrients in these food groups and older adults' performance on the cognitive tests. The level of vitamin D in the dietary intake was positively associated with performance on MoCA and RCFT. This is congruent with Rondanelli who reported that lower dietary intake of vitamin D was associated with lower scores on the MoCA [39]. The possible mechanism by which vitamin D can exert its effect is by reducing the pathogenesis related to cardiovascular diseases (CVD), themselves, such as dementia and AD. Literature have long shown that vitamin D regulates neurotrophin expression, such as nerve growth factor, neurotrophin 3, and glial-derived neurotrophic factor, and the survival, development, and function of neural cells, which all have shown to support the hypothesis that vitamin D may be neuroprotective to the development of cognitive decline and impairment [40]. This indicates that adequate dietary intake is necessary to prevent age-related cognitive functions, however, the optimal level of vitamin D for positive health remains controversial. For example, one study hypothesized that the risk of cognitive decline markedly increases below a threshold of <25 mmol/L whereas another study showed that "sufficiency" in the context of dementia risk may be in the region of 50 mmol/L [40,41]. This considerable discrepancy, therefore, adds to the on-going debate regarding the optimal level of vitamin D that is necessary and/or required to reduce the risk and/or incidence of cognitive decline.

Although Health Canada defined recommended intake of vitamin D of 400 IU/day (i.e., 5 mcg/day or 35 mcg/week) is an essential level of good nutrition for different health outcomes, almost all participants (100%) were noted as not meeting the recommended intake of dietary vitamin D, and almost 84.4% of them were taking dietary supplements [33,42]. This confirms the value of a focus on the consumption of foods and food groups rather than a focus on single component of foods such as nutrients as more efficient health outcomes occur by altering dietary patterns [43]. Because people eat combinations of foods instead of a single nutrient, these complex combinations of nutrients are likely to interact and synergize the functions of each nutrient in the body, and therefore, it is valuable to examine the relationship between dietary pattern and risk of cognitive decline([44].

The study also showed an association between the dietary intake of calcium and performance on the VST, with a higher calcium intake associated with better performance. This is congruent with a previous study which found that a diet high in calcium was associated with improved cognitive function as measured by the Mini-Mental Status Examination (MMSE) [45]. Another study showed that a low intake of calcium was associated with lower scores on global cognitive function as measured by the MMSE [8]. Another found that a higher self-reported dietary intake of potassium, calcium and magnesium was associated with a lower incidence of all-cause dementia, especially AD and vascular dementia [46]. This is also supported by another prospective, a longitudinal study, which shows that increased blood pressure, a risk factor for cardiovascular and cognitive decline later in life, specifically vascular dementia (VaD) was associated with lower milk intake in midlife [47]. Little is known about the exact mechanisms by which dietary calcium has an impact on cognitive function. However, it has been suggested that the primary mechanisms by which dietary calcium imparts its effects on cognitive function is indirectly via mediating effects on cardio metabolic health through the antihypertensive properties of this mineral [48-51].

A positive association was found between protein intake and cognitive performance on the VST. Almost 71% of the participants met the recommended intake of servings of meat food group consumption and 100% of the participants met the recommended amount of AMDR for protein (10-35g/day) [35]. It is important to note that in this study we included all types of meat (e.g., red and white). There is emerging evidence that dietary protein and its constituent amino acids are associated with cognitive function in older adults [52-54]. In a population based, prospective study of 937 elderly aged 70-89 years who were cognitively normal at baseline, a higher dietary protein intake was associated with a 21% reduced risk of mild cognitive impairment or dementia, independent of potential confounders [55]. Protein is a necessary and important part of the diet, and a number of studies have demonstrated its potential benefits on memory function via several pathways, including the regulation of various growth and neurotrophic factors [insulin-like growth factor-1 (IGF-1)]; brain-derived growth factor (BDNF)] and/or the modulation of systemic inflammation [56].

Although no association were found between the level of SFA and cognitive performance, the present study did find that all participants were over the recommended intake of SFA. One possible explanation for this finding is that the meat or dairy foods could have been rich in fat. The failure of the present study to account for the fat from these food groups merits further research (the methods used to assess the intake) since literature has shown that moderate to high levels of SFA from dairy foods and spreads were associated with poorer global cognitive function and prospective memory, and cognitive decline [57-59]. Other studies have also shown that high intake of SFA from dietary intake was associated with poorer global function and worse scores on multiple cognitive tests [7,12,60-64]. Potential mechanism by which SFA exerts its effects on cognitive function is via increasing the low-density lipoprotein (LDL), which is considered a risk factor for dyslipidemia, a component of metabolic syndrome and a risk factor of cardiovascular diseases, cognitive decline, VaD and AD [59,65]. This suggests that individuals should practice caution when consuming SFA as it may have a negative impact on cognitive function. While no association was found with SFA in the present study, a positive association between level of poly fat (w-3 and 6) and cognitive performance on the VST was found.

Literature has shown a dose-dependent effect of fish intake on neurocognitive functioning in a cross- sectional Norwegian study in healthy elderly people (n=2031) [66]. Results showed ten g or more per day of fish protected against poor performance on cognitive tasks with optimal performance reached at 75 g of fish per day, corresponding to two fish meals per week [54]. Poly Unsaturated Fatty Acids (PUFA) is important for the development, maintenance, and function of the nervous system. They make membranes more fluid and act as signal substances, directly or indirectly via metabolites. While omega-3 fatty acids are mainly anti-inflammatory, omega-6 fatty acids are pro-inflammatory. While the precise physiologic mechanisms underlying these dietary influences are not completely understood, modulation of brain insulin activity and neuro inflammation likely contribute [67]. Therefore, a diet that maximizes consumption of plant foods and includes fish, while limiting total and SFA intakes, presents the greatest potential for successful brain aging.

Conclusion

The findings from this study revealed that dietary intake was uniquely associated with specific performance on cognitive tests in men and women aged 65 years and older. However, the authors feel that the investigation of nutrient intakes by this particular sample is far from complete. Future work should consider intakes of foods, and food groups and the patterns of consumption. These findings form a preliminary basis for more targeted nutritional guidelines for the management and prevention of age-related neural health and cognitive function in elderly.

Limitations

There are several limitations in the present study. First, the inability to detect a statistical significance in the independent sample t-tests could be attributed to the relatively small sample size. Therefore, caution must be taken when interpreting the results. Second, the current sample was predominately conducted with highly educated, white females. Therefore, conclusions drawn from the current study prohibits generalization to other groups. Third, participants who are interested or concerned about their health may be more likely to participate in health research, and response bias may therefore exist. Also, residual confounding variables by unknown risk factors, such as gender, education, supplement use, polypharmacy, and BMI may have played an important role in altering the outcomes, and thereby future studies should control for a wide range of confounding variables. Furthermore, the cross-sectional nature of this study cannot address cause-and-effect relationships, namely cognitive performance affecting dietary intake or dietary intake affecting cognitive performance. Thus, longitudinal intervention studies would be beneficial to provide a clearer profile of causality. In addition, the dietary measurement method used self-reported data, which increases the risk of reporting bias. Measurement at only one point in time may not reflect long-term consumption patterns and therefore, administering a variety of dietary assessment methods as well as at different time points would be a valid method. Also, dietary intake alone is not an accurate representation of nutrient status. As a result, a combination of dietary, biochemical, clinical, and anthropometric methods can be regarded as the "gold standard" in estimating individual nutritional status. Finally, interviews and/or group interviews were not conducted to explore participant's perception, opinion and beliefs of the influences their nutritional status might have on cognitive tests performance. Their insights might have provided a fuller understanding of the findings.

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***Correspondence to:**

Dr. Mariam Ismail
School of Health and Rehabilitation Sciences
Faculty of Health Sciences, Western University
London, Ontario
Canada
Tel: +5194942102
E-mail: mismail8@uwo.ca