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Research Report

The Association Between Dietary Pattern Adherence, Cognitive Stimulating Lifestyle, and Cognitive Function Among Older Adults From the Quebec Longitudinal Study on Nutrition and Successful Aging

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Abstract

Objectives: This study examined the effect of dietary patterns and engagement in cognitive stimulating lifestyle (CSL) behaviors on the trajectory of global cognition, executive function (EF), and verbal episodic memory (VEM).
Methods: Western and prudent dietary patterns were empirically derived using food frequency questionnaire responses from 350 community-dwelling older adults (mean age: 73.7 years) participating in the Quebec Longitudinal Study on Nutrition and Successful Aging. CSL was represented by a binary composite indicator based on education, occupational complexity, and social engagement. Global cognition, EF, and VEM were assessed prospectively.
Results: Primary effect models revealed an association between higher Western dietary pattern score and a greater rate of decline in global cognition and EF. Higher Western dietary pattern adherence was also associated with poorer baseline VEM. Primary effect models also revealed that CSL was independently associated with baseline global cognition and EF. Effect modification models suggested an interactive effect between Western dietary pattern and CLS on global cognition only. No associations were found for prudent dietary pattern score.

Discussion: Contributing to existing research supporting the negative impact of consuming an unhealthy diet on cognitive function, the current study suggests increased vulnerability among older adults who do not engage in a CSL. These findings can inform the development of lifestyle intervention programs that target brain health in later adulthood.

Keywords: Cognitive aging, Cognitive stimulation, Nutrition, Resilience

With population aging and a surge in research examining predictors of cognitive health in later adulthood, it is increasingly recognized that lifestyle behaviors may modulate late-life cognitive function (Lee et al., 2009; Sabia et al., 2009). The investigation of lifestyle behaviors and their potential synergistic effect is essential for the development of targeted strategies with maximum impact that may beneficially influence the trajectory of cognitive function with increasing age.

Over the last decade, a number of observational cohort studies, employing either theoretically based (e.g., Mediterranean diet) or empirically derived dietary patterns (e.g., Western diet, prudent diet), have reported a significant predictive value of dietary pattern adherence on age-related cognitive function (Parrott et al., 2013). However, as the influence of diet on cognitive function does not act in isolation (Fiocco et al., 2012), a more holistic approach entails understanding how diet may act in combination with other lifestyle behaviors to influence cognition. Engagement in mentally stimulating experiences is of particular interest because they contribute to the development of cognitive reserve, a theoretical concept that explains how older adults may maintain cognitive function despite possessing high levels of brain pathology or age-related neural changes (Stern, 2012; Stern et al., 2018).

The objectives of this study were twofold: (a) to determine whether dietary patterns are associated with the trajectory of cognitive function, independent of a cognitive stimulating lifestyle (CSL), and (b) to determine whether a CSL modifies the relationship between diet and cognitive trajectory. It was hypothesized that higher adherence to a Western dietary pattern and low adherence to a prudent dietary pattern would associate with lower baseline performance and greater declines on tests of cognition. It was further hypothesized that a CSL would moderate the diet–cognition relationship, such that a lower CSL would exacerbate the aforementioned relationship and a higher CSL would minimize the impact of an "unhealthy" diet on cognitive function.

Method

Participants

The Quebec Longitudinal Study on Nutrition and Successful Aging (NuAge) is a 4-year prospective cohort study (Gaudreau et al., 2007). The present study is based on an embedded subsample of 350 participants of the NuAge Database and Biobank who underwent additional cognitive evaluations as part of the Nutrition and Cognition substudy (for sample selection see the work of Presse et al., 2013). Participants had a Modified Mini-Mental State Examination (3MS, Teng & Chui, 1987) score greater than 85 at baseline, complete dietary data, and were considered free of self-reported health conditions that could impair cognition. The study protocol was approved by research ethics boards at Institut universitaire de gériatrie de Montréal and Institut universitaire de gériatrie de Sherbrooke.

Measures

As part of the NuAge Study protocol, global cognition was assessed using the 3MS at baseline and reassessed annually three additional times after baseline assessment (mean follow-up of 3.0 ± 0.2 years). Participants recruited into the NutCog substudy underwent additional testing sessions for verbal episodic memory (VEM) and executive function (EF), which took place approximately 1.9–4.0 years (3.0 ± 0.6 years) after baseline assessment, with one follow-up assessment (mean follow-up = 1.7 ± 0.8 years). VEM was assessed using the RL/RI-16 Free and Cued Recall Task (Dion et al., 2015) and EF was evaluated using the Stroop test (Spreen & Strauss, 1998). Dietary intake was assessed at baseline using a validated semiquantitative Food Frequency Questionnaire estimating usual intake of 78 food items over the previous 12 months (Shatenstein et al., 2005). Two dietary patterns, accounting for 9.2% and 8.8% of the variance, were identified by a principle component analysis: a "prudent pattern" characterized by consumption of vegetables, salad dressing, fruits, legumes, nuts and seeds, whole-grain bread, fish and seafood, poultry, and lower-fat dairy; and a "Western pattern" characterized by consumption of red and processed meats, white bread, potatoes, sugary drinks, candy, butter, and baked goods. Finally, participants were sorted into upper and lower categories of a multidimensional CSL indicator that gave equal weighting to self-reported educational attainment, past occupational complexity, and current level of social engagement (Opdebeeck et al., 2016). See Supplementary Material for more detail on the aforementioned measures and measurement of study covariates.

Statistical Analysis

All analyses were conducted using SAS 9.4 (SAS Institute, Cary, NC). Association of dietary patterns with baseline characteristics was assessed using general linear models or the Mantel–Haenszel chi-square test for categorical variables. Multiple imputation by chained equations was used for missing values (11%) in the CSL composite score. Independent associations of dietary pattern scores (continuous *z*-scores) and CSL (binary indicator) with cognitive function (continuous raw scores), and their interaction, were assessed using linear mixed-effects models for repeated measures with a heterogeneous compound symmetry covariance structure. The trajectory (i.e., the course taken over time) of each cognitive variable was assessed by modeling baseline performance and the subsequent rate of decline. Independent effects models for dietary patterns were adjusted for CSL; models for CSL were adjusted for dietary patterns. All models were adjusted for total energy intake, age, sex, physical activity, smoking, body mass index, hypertension, and type 2 diabetes (Supplementary Material).

Results

Participant Characteristics

Baseline participant characteristics are presented by tertile of dietary pattern score in Table 1. Of the 350 participants (mean age 73.7 ± 3.8 years, range = 68–82), 188 (54%) were female. Although eight (2%) participants reported receiving employment income; all participants were collecting retirement benefits. Higher prudent pattern adherence was found in women, those with a high CSL indicator,

Table 1. Baseline Characteristics of the Study Population by Tertile of Dietary Pattern Score

Characteristic	Lower tertile	Middle tertile	Upper tertile	*p* Trend
Adherence to the Western dietary pattern				
Sample size (*n*)	116	118	116	—
CSL composite (% high)	47	43	41	.421
Sex (% female)	59	59	44	.025
Ever smoked (% yes)	46	43	50	.511
Hypertension (% yes)	61	64	64	.684
Type 2 diabetes (% yes)	16	13	9	.110
Age (years)	73.7 ± 3.8[a]	73.6 ± 4.1	73.2 ± 3.8	.382
BMI (kg/m^2)	27.3 ± 4.6	28.1 ± 4.4	28.1 ± 4.6	.187
PASE score	96.9 ± 45.9	94.5 ± 56.8	110.3 ± 46.6	.042
Vitamin C (mg/day)[b]	158.5 ± 6.2	156.8 ± 5.8	116.0 ± 6.3	<.001
Folate (μg/day)	355.0 ± 7.5	339.5 ± 6.9	300.9 ± 7.6	<.001
PUFA:SFA	0.750 ± 0.026	0.629 ± 0.024	0.538 ± 0.026	<.001
Sodium (g/day)	2.589 ± 0.053	2.678 ± 0.049	2.907 ± 0.054	<.001
Global cognition	95.6 ± 3.6	95.5 ± 3.3	95.2 ± 3.5	.309
Executive function	−22.5 ± 11.3	−21.6 ± 11.5	−22.2 ± 9.1	.887
Episodic memory	10.0 ± 2.5	9.6 ± 2.2	9.7 ± 2.4	.309
Adherence to the prudent dietary pattern				
Sample size	115	119	116	—
CSL composite (% high)	38	41	52	.035
Sex (% female)	46	53	63	.010
Ever smoked (% yes)	50	46	43	.325
Hypertension (% yes)	67	62	59	.241
Type 2 diabetes (% yes)	19	10	8	.009
Age (years)	74.2 ± 4.0	73.2 ± 3.6	73.2 ± 4.1	.044
BMI (kg/m^2)	28.4 ± 4.7	27.6 ± 4.4	27.6 ± 4.5	.191
PASE score	99.0 ± 49.0	98.6 ± 45.7	104.1 ± 56.3	.444
Vitamin C (mg/day)	108.2 ± 5.7	145.8 ± 5.5	177.1 ± 5.9	<.001
Folate (μg/day)	282.5 ± 6.6	331.8 ± 6.3	380.7 ± 6.7	<.001
PUFA:SFA	0.552 ± 0.025	0.641 ± 0.024	0.724 ± 0.026	<.001
Sodium (g/day)	2.763 ± 0.052	2.739 ± 0.050	2.672 ± 0.054	.488
Global cognition	95.0 ± 3.6	95.3 ± 3.3	96.0 ± 3.4	.016
Executive function	−23.2 ± 12.7	−22.4 ± 9.7	−20.7 ± 9.2	.085
Episodic memory	9.3 ± 2.4	9.9 ± 2.1	10.1 ± 2.6	.001

Note: BMI = body mass index; CSL = cognitive stimulating lifestyle; PUFA = polyunsaturated fatty acids; SFA = saturated fatty acids.
[a]Values are mean ± standard deviation or standard error for nutritional variables.
[b]Nutritional variables adjusted for total energy intake.

Table 2. Results From Primary Effect Models Investigating Associations With Rate of Cognitive Decline and Baseline Cognitive Function (n = 350)

	Global cognition		Executive function		Episodic memory	
	β ± *SE*	*p* Value	β ± *SE*	*p* Value	β ± *SE*	*p* Value
Western pattern						
Time	−0.36 ± 0.06	<.001	−0.14 ± 0.26	.604	−0.19 ± 0.05	<.001
Diet	−0.23 ± 0.19	.226	0.23 ± 0.71	.739	−0.28 ± 0.14	.046
Diet × Time	−0.16 ± 0.06	.009	−0.60 ± 0.27	.027	−0.02 ± 0.05	.705
Prudent pattern						
Time	−0.35 ± 0.06	<.001	−0.12 ± 0.26	.640	−0.19 ± 0.05	<.001
Diet	0.10 ± 0.19	.593	0.40 ± 0.70	.560	0.08 ± 0.14	.547
Diet × Time	−0.06 ± 0.06	.339	−0.01 ± 0.27	.984	0.01 ± 0.05	.819
CSL indicator						
Time	−0.29 ± 0.08	.001	−0.09 ± 0.57	.718	−0.17 ± 0.07	.011
CSL	1.96 ± 0.35	<.001	3.96 ± 1.31	.002	0.36 ± 0.26	.126
CSL × Time	−0.15 ± 0.13	.217	−0.09 ± 0.36	.661	−0.04 ± 0.11	.638

Notes: β = regression coefficient; CSL = cognitively stimulating lifestyle; SE = standard error. All models adjusted for total energy intake, age, sex, physical activity, smoking, body mass index, hypertension, type 2 diabetes. Models for dietary patterns are also adjusted for CSL. Models for the CSL indicator are also adjusted for the Western and prudent dietary patterns.

and younger participants. Higher Western pattern adherence was found in men, but was not associated with CSL or age.

Independent Effects of Diet and CSL on Cognition

As shown in Table 2, primary effects models revealed an association between Western dietary pattern intake and the trajectory of global cognition and EF, such that faster decline associated with higher adherence to the Western dietary pattern (global cognition: β = −0.16 ± 0.06, p = .009; EF: β = −0.60 ± 0.27, p = .027). Specifically, for every one-point increase in Western dietary pattern score, participants lost an additional 0.16 points per year on the 3MS and displayed 0.60 s of additional cognitive interference per year on the Stroop test. Although not statistically associated with the trajectory of VEM, higher adherence to the Western dietary pattern was associated with poorer baseline VEM (β = −0.28 ± 0.14, p = .046). Specifically, for every one-point increase in Western dietary pattern score, there was a 0.28 decrease in the average number of recalled words. Prudent dietary pattern intake was not found to associate with baseline or trajectory in cognitive function (p = .339–.984).

With respect to CSL, primary effects models revealed an association between high CSL and better performance on tests of global cognition and EF at baseline (global cognition: β = 1.95 ± 0.35, p < .001; EF: β = 3.95 ± 1.31, p = .002, Table 2). Specifically, high CSL (relative to low) was associated with 1.95-point better performance on the 3MS and lower cognitive interference by 3.95 s on the Stroop test at baseline. CLS, however, was not found to be associated with baseline VEM or cognitive trajectory across tasks (p range = .217–.661).

Effect Modification of the Diet–Cognition Relationship by CSL

As shown in Table 3, a marginally significant Diet × CSL × Time (β = 0.23 ± 0.13, p = .084) and Diet × CSL interactions (β = −0.61 ± 0.33, p = .060) were found for the Western pattern in relation to global cognition. Subgroup analysis revealed that the Western pattern was associated with accelerated global cognitive decline in those with low CSL (β = −0.26 ± 0.08, p = .001), but not high CSL (p = .624). Furthermore, the Western pattern was associated with worse baseline global cognition in individuals with high CSL (β = −0.58 ± 0.27, p = .033), but not low CSL (p = .873). As shown in Table 3, effect modification was not found for VEM or EF, or for analyses with prudent dietary pattern (p range = .489 –.730).

Discussion

In the current study, a multidimensional CSL composite indicator reflecting a mentally stimulating lifestyle diminished the adverse relationship between poor diet quality and the trajectory of age-related global cognition. Although a higher CSL diminished the adverse effects of an unhealthy diet on global cognitive decline, there was a persistent relative cost of poorer diet quality on baseline cognition, even in those who reported higher CSL behaviors. This may be due to the relatively robust association between a Western-type “unhealthy” dietary pattern and inflammatory mechanisms, which weakens microstructural white matter integrity and total brain volume in older adults (Gu et al., 2016).

Although the interactive effects of the Western dietary pattern and CSL indicator on EF and VEM were not statistically supported, important independent associations were

Table 3. Results From Effect Modification Models Investigating Whether Associations With Cognition Were Dependent on Level of Cognitive Stimulating Lifestyle (*n* = 350)

	Global cognition		Executive function		Episodic memory	
	β ± *SE*	*p* Value	β ± *SE*	*p* Value	β ± *SE*	*p* Value
Western pattern						
Diet	0.04 ± 0.24	.835	−0.22 ± 0.90	.788	−0.30 ± 0.18	.082
CSL	1.95 ± 0.34	<.001	4.13 ± 1.30	.001	0.37 ± 0.26	.119
Diet × CSL	−0.61 ± 0.33	.060	1.06 ± 1.25	.376	0.06 ± 0.24	.737
Time	−0.28 ± 0.08	.001	−0.05 ± 0.36	.742	−0.17 ± 0.07	.012
Diet × Time	−0.26 ± 0.08	.002	−0.75 ± 0.36	.035	−0.04 ± 0.07	.593
CSL × Time	−0.17 ± 0.13	.176	−0.16 ± 0.58	.593	−0.04 ± 0.11	.635
Diet × CSL × Time	0.22 ± 0.13	.084	0.36 ± 0.56	.489	0.03 ± 0.11	.689
Prudent pattern						
Diet	0.05 ± 0.26	.785	−0.36 ± 0.93	.686	0.02 ± 0.19	.776
CSL	2.00 ± 0.35	<.001	3.96 ± 1.31	.002	0.40 ± 0.26	.094
Diet × CSL	0.09 ± 0.35	.694	1.51 ± 1.24	.212	0.12 ± 0.26	.533
Time	−0.29 ± 0.08	.001	−0.09 ± 0.37	.714	−0.17 ± 0.07	.013
Diet × Time	−0.02 ± 0.09	.793	−0.03 ± 0.40	.783	0.02 ± 0.08	.717
CSL × Time	−0.14 ± 0.13	.280	−0.09 ± 0.58	.664	−0.04 ± 0.11	.638
Diet × CSL × Time	−0.06 ± 0.13	.589	0.08 ± 0.58	.696	−0.01 ± 0.11	.730

Notes: β = regression coefficient; CSL = cognitively stimulating lifestyle; SE = standard error. All models adjusted for total energy intake, age, sex, physical activity, smoking, body mass index, hypertension, and type 2 diabetes.

found. Western dietary pattern adherence was associated with poorer baseline VEM and accelerated decline in EF and global cognition, independent of CSL. Furthermore, CSL was found to associate with baseline global cognition and EF, with high CSL associated with better cognitive performance. Taken together, these results are in line with previous studies that highlight the importance of considering multiple lifestyle behaviors, which may jointly influence cognitive function (Fiocco et al., 2012; Lee et al., 2009), and further support inclusion of lifelong mental stimulation as an important lifestyle behavior. The CSL indicator used in the present study is similar to that used by Valenzuela et al. (2007), who reported that a higher cognitive stimulating composite score was associated with greater neuronal density in frontal regions of the brain, but did not associate with hippocampal neural density. This selective association may explain the domain-specific effects of CSL in the current study as tasks of EF are more dependent on frontal lobe integrity, while VEM is largely a hippocampal-dependent task (Farias et al., 2013).

It is unclear why the Western pattern and CSL were associated with specific dimensions of cognition (decline vs. baseline performance). It is plausible that the timing of assessment and duration of follow-up influenced the study findings. Older adults without dementia display greater age-related changes in frontal lobe integrity relative to non-frontal regions (Hedden & Gabrieli, 2004; West, 2000). This may explain the current findings such that performance on tests that encompass EF were more sensitive to accelerated decline by poor diet quality, relative to VEM performance (Hedden & Gabrieli, 2004). It is also notable that education, which contributed to the CSL indicator, has been found to associate with baseline cognitive function, but not with rate of decline (Karlamangla et al., 2009), whereas Western dietary patterns have been found to associate with both cross-sectional performance and rate of decline (Parrott et al., 2013; Shakersain et al., 2016). Collectively, these findings are consistent with the current study, where CSL was associated only with baseline performance whereas the Western dietary pattern was associated with both baseline performance and rate of decline depending on the tested domain.

While a greater rate of decline in global cognitive function among participants with low CSL was expected, the suggested interaction effect of Western dietary pattern intake and CSL on baseline cognitive function was unexpected. With little point of comparison, as such stratification has not been undertaken in previous studies, it may be speculated that the null association between Western dietary pattern intake and global cognition in low CSL participants was a function of floor effects in a high-functioning sample of older adults. However, it should be emphasized that, despite the overall improvement to the trajectory of global cognition afforded by a higher CSL through its association with baseline performance, there was always a relative cost of poorer diet quality in those with low or high CSL, whether it be accelerated decline or lower baseline performance.

Although the current study findings contribute to the growing body of literature investigating the effect of modifiable behaviors on cognitive function in later adulthood, methodological limitations must be considered. First, the relatively small sample size may have underestimated true associations in the interplay between diet, CSL, and cognition. Second, the analytical sample was composed of cognitively healthy older adults, with a mean age of 73 years. This limits the generalizability of study findings and limits the ability to model age-related cognitive decline and clinically meaningful impairment over a short period of time; Third, although the measurement of CSL was derived from past cognitive engagement and current social engagement, retirement status may affect cognitive function depending on the job from which the individual has retired (Meng et al., 2017). Furthermore, length of retirement and reasons for retirement (e.g., forced retirement) were not assessed, which may have influenced study findings; and fourth, the observational study design precludes any statements regarding cause and effect. Patterns of reverse causation have been proposed, with higher cognitive aptitude in childhood predicting adherence to a "healthy" diet and better cognitive performance in late life (Corley et al., 2013). Such findings stand in contrast to evidence from randomized trials that report beneficial effects of diet quality improvement in later life on cognitive function (Martinez-Lapiscina et al., 2013; Smith et al., 2010). Accordingly, comprehensive studies in large cohorts that assess and follow participants across the life span are needed to address the issues of confounding and temporality.

Despite these limitations, the current findings are important as they support the value of engaging in mentally stimulating activities for cognitive health in later adulthood, and further suggest that the deleterious effects of consuming an unhealthy diet may be minimized in persons who engage in CSL behaviors. These results may help inform intervention programs that target cognitive function, highlighting the importance of considering the additive and synergistic interplay of multiple behavioral components in cultivating lifelong cognitive health.

Supplementary Material

Supplementary data are available at *The Journals of Gerontology, Series B: Psychological Sciences and Social Sciences* online.

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Conflict of Interest

None declared.

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