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Dietary Factors and Cognitive Function in Poor Urban Settings

Regina S. Wright, PhD[1], **Constance Gerassimakis, MD**[2], **Desirée Bygrave, PhD**[1], and **Shari R. Waldstein, PhD**[3,4]

[1]School of Nursing, University of Delaware, 25 N. College Ave., Newark, DE 19716, (302) 831-8364

[2]Department of Behavioral Health and Nutrition, University of Delaware

[3]Department of Psychology, University of Maryland Baltimore County

[4]Geriatric Research Education and Clinical Center, Baltimore Veterans Affairs Medical Center

Abstract

A significant body of evidence suggests that poor dietary intake is associated with reduced cognitive function. However, few studies have examined this relation in poor urban settings. Our brief review suggests that (a) higher overall diet quality may play a particularly important role in cognitive function among the poorest; and (b) greater vitamin E intake is related to better cognitive performance, at least in part, via fewer depressive symptoms. The broader recent literature strongly suggests the beneficial role of diet for learning and memory, and potentially synergistic influences on other cognitive domains. However, adherence to healthful diet among urban poor may be limited by factors such as cost and access. Here, we propose several potential moderators and mediators of diet-cognition relations among urban poor. Future studies should focus on the complex interplay among factors that influence the role of diet in cognitive function among poor, urban-dwelling persons.

Keywords

cognitive function; diet quality; dietary patterns; dietary factors; poor; socioeconomic status; urban setting

Introduction

Cognitive function is a vital component of quality of life across the lifespan [1]. Unhealthful eating is one of several poor health behaviors that have been associated with decrements in cognitive function [2–5]. Poor diet quality has been related to reduced cognitive performance and promotes the onset and progression of cognitive decline and dementia [6].

Corresponding Author: Regina S. Wright, Ph.D., School of Nursing, 25 N. College Ave., Newark, DE 19716, (302) 831-8364 (P), (302) 831-2382 (F), rsims@udel.edu.

Conflict of Interest

Regina S. Wright, Constance Gerassimakis, Desirée Bygrave, and Shari R. Waldstein declare that they have no conflict of interest.

Human and Animal Rights and Informed Consent

This article does not contain any studies with human or animal subjects performed by any of the authors.

Further heightening the significance of these associations is that the majority of Americans do not adhere to federal dietary guidelines for healthful eating and consume diets that include high consumption of saturated fatty acids, sodium, solid fats, and added sugars [7, 8].

In general, studies that have evaluated dietary factors and cognitive function have focused on specific micronutrients, fatty acids, and dietary patterns and their relations to overall cognitive ability and performance in specific cognitive domains (e.g., memory, attention). Examining dietary patterns as well as components of the diet has been vital for gaining an understanding of the role of diet in cognitive function. Moreover, understanding the context within which eating occurs and environmental factors that may promote unhealthful eating is key to a comprehensive understanding of these associations. Poor urban settings tend to promote poor dietary patterns and diet quality [9]. Within these environments, socioeconomic and neighborhood conditions may moderate relations of dietary factors to cognitive function. In addition, dietary factors may partially mediate associations between psychosocial factors and cognitive function.

In this review, we will provide an overview of recent studies that examine relations between dietary factors and cognitive function, summarize the few recent studies that have examined these associations in poor urban settings, explain the biologically plausible mechanistic pathways of influence, and suggest potential mediators and moderators of the dietary factor —cognitive function link in poor urban settings.

Dietary factors and cognitive function

Cognitive function encompasses the spectrum from normal inter-individual variability in cognitive performance to mild cognitive impairment and dementia. A substantial body of evidence confirms that poor diet quality and dietary patterns negatively impact this spectrum of cognitive function [6]. Recent, targeted studies have examined cognitive function in relation to single nutrients, specific foods, diet quality indices, and adherence to dietary patterns. Adequacy of specific nutrient intakes including choline [10], long-chain omega 3 fatty acids [11], plant polyphenols such as resveratrol [11, 12], monounsaturated fatty acids [13], vitamins A, B12, D, E, folic acid [14, 15] and the mineral selenium [16, 17] has been associated with cognitive benefits and optimal brain outcomes as assessed by magnetic resonance imaging (MRI). In that regard, higher concurrent intake of the nutrient choline, a precursor to the neurotransmitter acetylcholine, was associated with better verbal and visual memory performance among dementia-free adults in the Framingham Offspring Study, whereas higher remote choline intake was inversely related to pathologic brain white-matter hyperintensities [10]. Better verbal retention was also noted among healthy older adults who participated in a 26-week resveratrol supplementation trial; these improvements further correlated with increased functional connectivity of the hippocampus [12]. Lastly, multiple domains of cognitive function, including global cognition, episodic memory, working memory, semantic memory, visuospatial ability, and perceptual speed, has been associated with greater consumption of particular foods such as nuts, olive oil, green leafy vegetables and berries, although not all fruits [18]. In contrast, cross-sectional and longitudinal studies show a linkage between high consumption of saturated fatty acids (SFA) over the lifespan

and greater decline in global cognition and verbal memory [13], poor verbal learning, and increased risk of dementia [4, 19, 20]. Furthermore, greater habitual intake of total sugars was associated with decreased verbal learning, and sugar-sweetened beverages and added sugar were linked to lower Mini-Mental State Exam (MMSE) scores among middle-aged and older adults [21].

Recent studies of associations of diet quality indices with cognition are limited and inconsistent. Lower diet quality scores using the Healthy Eating Index (HEI)-2010 were associated with lower verbal memory and learning performance [22, 23], while no independent association was found between the Canadian Healthy Eating Index diet quality score and cognitive measures [24].

More recent research has focused on dietary pattern adherence, based on the concept of food synergy, which acknowledges that the interrelations of foods within the diet is more relevant and impactful to health than isolated nutrients or individual foods [25], and that there are interactions between individual nutrients, such as omega-3 fatty acids and B vitamins, in relation to cognitive function [26]. Adherence to dietary patterns such as the Mediterranean (MeDi) diet [27], the Dietary Approach to Systolic Hypertension (DASH) [28], and the MeDi-DASH Diet Intervention for Neurodegenerative Delay (MIND) diet score [18] have been linked to cognitive benefits. There are several variants of the MeDi diet, originally examined in relation to cardiovascular disease risk and overall mortality, with a common emphasis on high intakes of unprocessed fruit, nuts, vegetables, grains, legumes, olive oil and fish, moderate wine and small amounts of high fat dairy and red meat [29]. In prospective and randomized trials, the MeDi diet has been demonstrated to protect cognitive function, slow the rate of cognitive decline, and decrease progression to dementia [30–32].

The DASH diet shares some components with the MeDi diet, but includes higher dairy intake, and does not specify olive oil or moderate wine consumption. Evidence for benefit of the DASH diet on cognitive function is supportive, but limited. A DASH diet intervention demonstrated improved psychomotor speed among overweight or obese hypertensive adults compared to controls [33]. Among elderly adults in Cache County, UT, those with higher conformity to both the DASH and MeDi diets had better global cognitive performance on the Modified MMSE, and the MeDi diet score and the DASH diet score were positively correlated [34]. Similarly, among a cohort of elderly Chicago residents, both the DASH and MeDi diets were associated with slower rates of decline in global cognition, episodic memory and semantic memory [35].

An intriguing new modification of the MeDi and DASH diets is the MIND diet [18]. The MIND score specifies ten “brain healthy” and five “unhealthy” components which have been associated with compelling neurocognitive associations [18]. In a prospective study of the MIND, DASH and MeDi patterns, elderly Chicago residents with higher MIND scores showed slower annual cognitive decline rate, over multiple cognitive domains of memory, visuospatial ability, and perceptual speed, equivalent to being 7.5 years younger in the highest tertile compared to the lowest. The MIND diet score was a stronger predictor of cognitive decline than the MeDi and DASH diets [18] Recent evidence for the benefit of healthful nutrient and food consumption, and higher adherence to the MeDi, DASH and

MIND dietary patterns on cognitive outcomes is very encouraging. Interventional studies focused on the MeDi and MIND dietary patterns as potentially modifiable factors to decrease the growing burden of cognitive decline and dementia will be crucial over the next several decades.

Studies examining whether cognitive factors can predict dietary intake are limited. One prospective study observed that higher baseline Wechsler Adult Intelligence Scale (WAIS) scores were positively related to consumption of vegetables, nuts, legumes, fish and meats, and inversely related to intake of carbonated sugary beverages and total grains, suggesting that there may be a bidirectional association [37].

In sum, poor diet quality and poor adherence to healthful dietary patterns are consistently related to poorer brain and cognitive outcomes. Findings suggest that verbal learning and memory is the most commonly affected cognitive domain. Global cognition has also been associated with dietary factors in a number of studies. Given the practical need for intact memory and global cognition for making healthful dietary choices, it is necessary to examine the directionality of these associations in future studies as well as conduct studies that examine discrete components of the diet and specific cognitive domains to further elucidate associations and target cognitive function in dietary interventions. Furthermore, as discussed below, achieving healthful (or even adequate) dietary quality may be particularly challenging in poor urban environments where access is limited and costs are prohibitive.

Evidence from poor urban settings

There is a paucity of research that has examined the association between diet quality and cognitive abilities in poor urban settings. The lack of research in this area may be reflective of the few studies of cognitive function, in general, being conducted in such settings. A recent study by our group examined relations of diet quality to cognitive function among socioeconomically diverse middle age and older adults in Baltimore city using data from the Healthy Aging in Neighborhoods of Diversity across the Life Span (HANDLS) Study [23]. HANDLS is a 20-year epidemiological study of health disparities among African Americans and Whites in Baltimore City. A baseline analysis of 2,090 African American and White adults, age 30 to 64 years examined relations of diet quality to cognitive function and whether associations varied as a function of poverty status. Poverty status was a dichotomous variable defined as a family income above or below 125% of the 2004 U.S. Department of Health and Human Services federal poverty guideline, based on the size of the family unit. Findings showed that overall diet quality for the sample was poor, with a mean Healthy Eating Index-2010 (HEI-2010) score of 42.62 out of a possible score of 100. Furthermore, poorer overall diet quality was associated with lower levels of verbal learning and memory performance in the entire sample. Interesting moderating influences of poverty status also emerged. Significant interactions of HEI-2010 and poverty status indicated that higher diet quality was associated with better performance on tests of attention and cognitive flexibility, visuospatial ability and perceptual speed among those living below 125% of the federal poverty guideline; in contrast, there was an absence of associations for those living above 125% of the federal poverty guideline. These findings suggested that, particularly among the poor, higher diet quality may play an important role in cognitive function [23].

Another recent HANDLS study analysis examined associations between dietary antioxidants (vitamins A, C, E, and five carotenoids) and cognitive function in various cognitive domains, while examining socio-demographic differences in those associations and the mediating role of depressive symptoms [15]. Results showed that higher Vitamin E intake was associated with better verbal memory, immediate recall, and verbal fluency performance, especially among younger participants (age < 48 years). In addition, women with higher vitamin E intake showed better psychomotor speed performance. Importantly, the association between vitamin E and verbal memory performance was partially mediated by depressive symptoms. Notably, the study sample showed evidence of consumption of only 50% of the Estimated Average Requirement (EAR) of vitamin E, which was the only antioxidant related to cognitive performance within the study [15]. This intake level was lower than prior studies that examined vitamin E–cognition relations.

Overall, the two recent studies focused in poor urban environments suggest that both socioeconomic status and affect are important factors to consider for understanding how diet influences cognitive function in this context. However, these data are limited to the metropolitan Baltimore area. Future studies should test these associations in varied urban environments and include ample dietary, demographic, psychosocial, and cognitive measures.

Biologically Plausible Mechanistic Pathways

Poor diet quality, characterized by a vitamin-deficient diet high in fats, sugar, red meat and processed foods, can exert a negative impact on cognitive function through inflammatory processes [4, 37–40]. Proinflammatory biomarkers such as C-reactive protein (CRP) and interleukin-6 (IL-6), are directly associated with neurotoxicity, brain and cognitive impairment [38, 41], and are reported mechanisms through which diet quality and cognitive function are linked [39, 40, 42, 43]. Recent reports from longitudinal studies with middle-aged adults noted that, over time, adherence to a poor quality diet was associated with decreased verbal fluency via elevated CRP levels [40], and reduced reasoning and general cognitive functioning via elevated IL-6 levels [39]. Despite these findings, further investigation to identify biomarkers of inflammatory diet patterns on cognitive domains is needed.

Poor diet quality is also known to promote cardiovascular disease-related inflammatory pathogenesis [42] through multiple indirect pathways such as obesity, a known proinflammatory state [44, 45]. These pathways act through a number of biological mechanisms associated with oxidative stress [46, 47], insulin resistance [46], endothelial dysfunction [48], and metabolic and brain-derived neurotrophic factors that further advance inflammation and promote subsequent cognitive decline [4, 19, 44, 45, 49–51]). Conversely, adherence to a healthier, vitamin-rich diet, characterized by high intake of fiber, fruits and vegetables, protects against cardiovascular disease pathogenesis [52], and may benefit cognitive outcomes through a number of biological mechanisms including reducing risk of cardiovascular conditions associated with cognitive impairment and dementia [18, 30, 53], facilitating metabolic control related to insulin sensitivity and glucose metabolism [54], and

reducing oxidative stress [55, 56]. Given these findings, studies to fully understand the role that these pathways play in diet-associated cognitive functioning remain critical.

Opportunities for future research on dietary factors and cognitive function in poor urban settings: examining potential moderators and mediators

The dearth of existing research focused on quality of the diet and cognitive abilities in poor urban settings represents a tremendous opportunity to enhance both dietary and cognitive aging research. Future research must consider the unique contexts and conditions that characterize the urban environment and how these factors shape dietary patterns. The dietary literature has focused on several factors related to the urban environment that are vital to consider as potential moderators and/or mediators of interest in future studies. These include socioeconomic status, food insecurity, neighborhood access to healthy foods, and psychological factors such as stress and depressive symptoms.

Socioeconomic status

Socioeconomic status (SES) plays a significant role in diet quality and may serve as an important moderator of the relation of dietary factors to cognitive function. SES indicators such as low levels of income and education affect the quality of the diet [57]. Individuals living in poverty tend to consume poorer diets due to socioeconomic, environmental, and cultural barriers to healthy food consumption. Findings from the National Health and Nutrition Examination Survey (NHANES), 1999 to 2002, where participants were grouped into one of the three household income categories: low income (<131% poverty), medium income (131%–350% of poverty), and high income (>350% of poverty), showed that low-income adults had lesser than adequate intakes of many micro-nutrients than their medium-income and high-income counterparts [9]. They also ate less fruit, vegetables, milk, meat, poultry, and fish than high-income adults [9]. With respect to educational attainment, food and nutrient-based diet quality tends to vary with education level [58] and literacy [59]. Data from several nationally representative samples of American adults examined the relation of education to total diet quality, showing higher overall diet quality among individuals who attended college as compared to individuals with less than a high school degree [60].

A recent analysis of the NuAge study, a study of nutrition and aging in Quebec, examined how the socioeconomic context of the diet influences cognitive function [61]. Similar to the HANDLS Study, NuAge findings showed that adherence to a prudent eating pattern (vegetables, fruits, fish, poultry, and lower-fat dairy products) was associated with less cognitive decline over three years among participants with a low socioeconomic position (SEP). However, adherence to a prudent dietary pattern was associated with higher baseline cognitive scores at higher income levels. Adherence to a Western dietary pattern was associated with cognitive decline only among those with low educational attainment. These findings suggest that the pattern of associations between diet quality and cognition may be dependent upon socioeconomic circumstances and that improving diet quality would be of most benefit to the poor [61].

When considering the role of socioeconomic status in diet quality and dietary patterns, it may also be important to consider whether individual, neighborhood, or more macro level socioeconomic factors are most influential. Unfortunately, the literature examining this important question is nearly non-existent. There is at least one study, however, that lends some insight into level distinctions and diet [62]. In a study of Canadian adolescents, researchers examined, among other aims, the influence of individual- and area-level measures of SES on unhealthy eating. Individual-level SES was defined both as material wealth and perceived family wealth using self-report scales. Area-level SES was defined by delineating the geographic area surrounding the adolescents' schools and using Census data to determine unemployment rate, percentage of adult residents with less than a high school education, and average employment income from head of household as proxies of SES. Findings showed that, in general, the individual-level SES variables were stronger predictors of unhealthy eating than area-level SES determinants; however, the authors acknowledged that the area-level variables may have underestimated true effects due to the broad nature of Census categories [62]. Future studies should examine this question using more sensitive measures of SES levels and a population with a wider age range.

Food insecurity

Food security is achieved when all individuals in a household have access to enough food at all times for a healthy, active lifestyle, and the household is able to acquire foods that are healthy, socially acceptable, and safe to consume [63]. In 2014, 14% of households in the U.S. were food insecure, and 5% of households reported very low food security [64]. Factors that drive food insecurity include the unemployment rate, annual inflation, and the relative price of food [64]. All of these factors are a source of challenge and unpredictability in poor urban environments. In general, children are protected from food insecurity due to food offerings in schools and other settings; however, among some adults, and more often older adults, food insecurity is a stark reality. Importantly, there are well-documented associations between food insecurity and a number of negative mental and physical health outcomes, suggesting that food insecurity is a significant public health problem. Adults in food-insecure households are significantly more likely to rate their health as poor or fair, and report lower health-related quality of life as compared to adults in food-secure households [65]. In addition, results from the National Health and Nutrition Examination Survey showed that low food security is a significant predictor of 10-year CVD risk [66]. Future studies of dietary factors and cognitive function should consider the role of food insecurity as a potential moderator variable.

Neighborhood environment and access to healthy foods

Poor diet and resulting health disparities have been reliably linked to neighborhood socioeconomic deprivation and minority composition [67, 68]. In the early 1990s, the term *food desert* was coined to describe a local food environment in a public housing sector [69]. More recently, food deserts have been defined as "poor urban areas, where residents cannot buy affordable, healthy food" [69]. Food deserts have also been characterized by increased exposure to tobacco and alcohol advertisements and greater numbers of fast food restaurants, convenience stores, and liquor stores [70]. These food deserts are

disproportionately housed in low-income and minority neighborhoods, and due to transportation and economic barriers, the poor tend to make food choices based on food outlets in their immediate neighborhoods [71–73]. A major consequence of food deserts is increased exposure to energy-dense and processed foods that promote poor diet quality, present a barrier to healthful eating and increase the risk of obesity and chronic cardiovascular and metabolic disease [74–76]. Food deserts may help to explain some of the health disparities that persist among minority populations and represent a significant risk to cognitive outcomes among urban-dwelling adults. Effective policy actions are needed to promote equitable access to healthy foods in urban environments [70, 77].

Stress and depression

In addition to these environmental influences on dietary patterns, there are other potential moderators that may exacerbate the negative association between quality of the diet and cognitive abilities in poor urban-dwelling individuals. Psychological factors such as stress and depression may contribute to both poor eating behaviors and related cardiovascular and metabolic conditions that promote cognitive decrements and cognitive decline [78, 79]. These independent associations beg the question of whether an unhealthful diet confers a greater risk for cognitive difficulties when the urban environment is stressful or negatively impacts affect. To our knowledge, these questions have not been empirically addressed in a poor urban setting; however, the research literature suggests potential moderation.

Stress confers a negative impact on health behaviors. It is well documented that greater levels of perceived stress are associated with disinhibited eating and a preference for energy-dense, high fat, and high sugar foods [78–81]. Stress-driven eating increases the risk of developing obesity, a significant risk factor for cardiovascular and metabolic conditions [80,81]. In the poor, urban environment, unique stressors may exacerbate these relations. For example, poor perceived neighborhood safety, a plague in many urban environments, is a stressor that is associated with poor self-rated health [82]. Among racial minorities in poor, urban settings, perceived discrimination is another unique stressor that has been associated with increased risk for poor cardiovascular outcomes [83, 84]. In addition to predicting poorer diet directly, the impact of poor diet on cardiovascular and metabolic health may be exacerbated by a stressful environment. For example, a large body of literature in non-human primates has shown that social stress is associated prospectively with the development of coronary atherosclerosis in the presence of a high-fat diet but not a more healthful diet [85, 86].

The association between diet quality and depression is not as clear-cut. A 2013 review of 25 diet quality and depression studies showed inconsistent patterns of association between diet quality and depression, citing heterogeneous samples and varied measures of diet quality and depression as probable explanations for non-significant findings [87]. A separate systematic review of 21 studies that examined the association between dietary patterns and depression found that a healthful diet pattern was associated with significantly reduced odds of depression, whereas a Western diet pattern showed no association [88]. It is important to note that, in the aforementioned HANDLS analysis, depressive symptoms emerged as a mediator of diet quality and cognitive function [15]. Thus, future research should further

consider its potential role as a moderator or mediator of diet-cognition relations. Given the documented associations between diet quality and depression, and the significant and growing prevalence of depression among the adult population, it is imperative to fully understand the role that depression plays in the diet quality–cognitive ability link.

Psychosocial factors such as inadequate social contact or loneliness may further promote poor diet. For example, single and widowed marital status, solitary living arrangement, and social isolation have been association with consumption of lower fruit and vegetable variety and poorer overall nutritional status [89,90]. Conversely, greater social support and larger social networks have been associated with better diet quality and greater dietary resilience [91]. Dietary resilience is the development and use of adaptive strategies that promote maintenance of an adequate diet despite facing dietary challenges [92]. To the extent that individuals in poor, urban environments also lack adequate social contact, the potential for poor dietary consumption and related cognitive consequences is increased.

Conclusions

Poor diet quality and poor adherence to healthy dietary patterns have been associated with diminished performance across a number of cognitive domains and implicated in cognitive decline and dementia. Learning and memory processes may be disproportionately affected. These relations have been explained, in part, by a number of cardiometabolic and inflammatory pathways. Recent studies conducted in poor urban environments showed that a healthful diet may be most beneficial to cognitive function among those with lower SES, and that depressive symptoms may partly explain the influence of diet on cognitive function. Our review revealed a severe shortage of studies that focused on diet and cognitive function in poor, urban environments and therefore focused on the important task of highlighting potential areas for future study. These included identification of several potential socioeconomic, environmental, and psychological moderators and mediators of this association. Based on our review, there are several apparent opportunities for intervention, policy change, and future research.

Poor diet quality and poor adherence to dietary patterns represent an important opportunity for interventions that promote the healthfulness of dietary intake to maintain cognitive function or prevent cognitive decline. Dietary guidelines that explicitly address healthy cognitive outcomes as a potential benefit of healthful eating, as well as dietary interventions marketed specifically to enhance cognitive function, may help to improve dietary intake and cognitive health in our society. Public policy enhancements that focus on poor urban environments, in particular, are needed to (a) increase financial access to food for poor and food insecure adults, (b) target healthful diet messages in a way that individuals with low education can comprehend, (c) subsidize healthful food costs, and (d) incentivize healthful food entrepreneurship in poor urban neighborhoods.

Future research must consider the unique conditions that characterize the poor, urban environment and how these factors shape dietary intake. Specifically, studies should examine how diet impacts cognitive function within the context of multiple interrelated cardiometabolic, socioeconomic, environmental, and psychological influences with an

additional focus on how these influences may interact to further exacerbate poor cognitive function. Future studies that incorporate multi-level influences may provide much-needed evidence to promote the adoption of interventions and policy change to improve dietary patterns and promote optimal cognitive health. Given the growing prevalence and increasing financial burden of cognitive decline and dementia, this area of research has the potential to yield great public health significance.

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