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CONSIDERATIONS IN SELECTION OF DIET ASSESSMENT METHODS FOR EXAMINING THE EFFECT OF NUTRITION ON COGNITION

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Abstract

Older adults are the most rapidly growing age group in the United States, and it is estimated that 22.2 % of U.S. adults over 71 years of age have cognitive impairments without dementia and 13.9% have dementia. Cognitive impairment is associated with reduced quality of life, increased risk of hospitalization, inability to live independently, and increased health care costs; therefore, identification of modifiable risk factors for prevention and delay of cognitive decline is of increasing importance. There is a growing body of research and interest in the relationship between diet and cognitive function. Epidemiologic studies suggest that cognitive function may be improved and cognitive decline prevented as a function of a particular nutrient, food group or dietary pattern; however, results from these trials have failed to be replicated in randomized controlled trials. One possible reason for the equivocality of findings in the diet and cognitive function literature may be the methodological issues and limitations in the assessment of dietary patterns and nutritional intake. Self-reported dietary data can be biased by many factors such as age, gender, socioeconomic status, and education; yet, there is limited research on the impact of cognitive function on the integrity of self-reported dietary data. Cognitive function itself may bias diet assessment methods, subsequently obscuring the evaluation of the nutrition- cognition relationship. The present review summarizes methodological validation studies that provide insight into potential errors of diet assessment methods due to cognitive function, identifies research gaps and provides recommendations for improving diet assessment accuracy in studies of individuals with cognitive impairments.

Keywords

Diet assessment; nutrition/diet; cognition

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Introduction

Older adults (≥ 65 years) are the most rapidly growing age group in the United States, and this segment of the population is expected to double to 72 million by 2030 (1). It is estimated that 22.2 % of U.S. adults over 71 years of age have cognitive impairments without dementia (2) and 13.9% have dementia (3). Cognitive impairment is associated with reduced quality of life, increased risk of hospitalization, inability to live independently, and increased health care costs (2). The incidence of cognitive impairment is expected to increase as the population of older adults continues to grow and will subsequently increase demands on the health care system. Therefore, identification of modifiable risk factors for prevention and delay of cognitive decline is of increasing importance and can have a significant impact on public health.

There is a growing body of research and developing interest in the relationship between diet and cognitive function. Observational studies suggest that cognitive function may be improved and cognitive decline prevented as a function of a particular nutrient, food group or dietary pattern (4). Antioxidants, B vitamins, polyunsaturated fatty acids, and Vitamin D are a few of the nutritional factors that have been associated with reduced risk of age-related cognitive decline and dementia (4). It has been estimated that interventions that could delay the onset of Alzheimer's disease by one year would result in 11.8 million fewer cases worldwide by 2050 (5); thus, even modest delays in disease onset and progression could significantly decrease the future burden of dementia. However, identification of dietary factors for future prevention strategies is hindered because results from observational trials have failed to be replicated in randomized controlled trials (RCTs). For example, RCTs examining the effects of supplementation of omega-3 and/or omega-6 fatty acids have found little or no improvements in cognitive function in individuals with varying degrees of cognitive impairment (6). Similarly, RCTs examining the effects of B6, B12 and folate supplements report null results across a range of supplementation doses and follow- up periods (7). These costly RCTs, designed after abundant observational studies, have yet to provide sufficient support for previous observational findings.

One possible reason for the equivocality of findings in the diet and cognitive function literature may be the methodological issues and limitations in the assessment of dietary patterns and nutritional intake. The majority of observational studies examining the relationship between nutrition and risk of cognitive decline have been conducted in older adults, and changes in cognitive function are common in this population (8). Self-reported dietary data can be biased by many factors such as age, gender, socioeconomic status, and education (9), yet there is limited research on the impact of cognitive function on the integrity of self-reported dietary data. Critical analysis and interpretation of self-reported dietary data, especially in populations with high incidence of cognitive impairment are necessary for progress in the field of nutrition and cognition and successful translation of nutrition research for clinical benefit. Cognitive function itself may bias diet assessment methods, subsequently interfering with the evaluation of the nutrition-cognition relationship. In the present review, we first describe the most commonly used methods of dietary assessment and briefly overview examples from the literature linking diet to cognition using these methods. We then summarize methodological validation studies that provide insight

into potential errors of diet assessment methods due to cognitive dysfunction, identify research gaps and provide recommendations for improving diet assessment accuracy in studies of individuals with cognitive impairments.

Diet Assessment Methods

The nutritional epidemiology of cognitive function remains inconsistent in part due to the inherent errors and limitations of available diet assessment methods. Protocols, strengths and limitations of different assessment methods have been discussed and reviewed in greater detail elsewhere (see (9)). This section will briefly discuss traditional methods of dietary assessment and how they have been used in studies investigating the relationship between nutrition and cognitive function.

Dietary Records

Respondents complete dietary records by documenting all food and beverage intake over a given time period, typically three to seven days. Food records are completed electronically or through pen and paper methods at the time of the eating occasion to minimize reliance on memory, and are based upon either estimated or weighed food measurements. Estimated food records use standard household measures such as cups or tablespoons, food models, or pictures for quantification of dietary intake, and weighed food records require an individual to use a scale to weigh every item consumed. Food records can successfully capture a high level of detail relative to food intake when the respondent accurately records the amount consumed, preparation method, brand names, and recipes. Unfortunately, this method is subject to underreporting and incomplete records because of the requirements of respondent motivation, literacy, and the influence of recording intake on dietary behaviors (9). Despite these limitations, weighed food records are regarded as a “gold standard” and often serve as the reference instrument for validation of other diet assessment methods. Food records are rarely used in large-scale studies due to expensive analysis and the need for in-person instruction and review of records for the entire sample. However, a 3-day food record booklet, designed to remove the need for in-person instruction and review yield results comparable to records “corrected” by an in-person review with a nutritionist (10).

Several studies have used food records to identify associations between dietary intake and cognitive function. A prospective study of older adults in Madrid assessed dietary intake with 7-day estimated and 5-day weighed food records (11). Individuals with adequate mini-mental state examination (MMSE) scores (≥28) at baseline had higher intakes of total food, fish, alcoholic drinks, thiamin, folate and vitamin C and lower intakes of saturated fats, cholesterol and snack foods than those with MMSE scores <28. A cross-sectional and short-term prospective study of the elderly evaluated dietary intake with 3-day estimated food records (12). Although no dietary differences were identified at baseline between individuals with normal or low MMSE score, individuals that showed improvement in MMSE scores at follow-up (mean = 8.5 months) had significantly higher consumption of calcium and omega-3 fatty acids than subjects without improvement. A cross-sectional study in young and middle-aged adults investigated the relationship between dietary intake of saccharides and cognitive performance (13). Dietary intake was measured with a 3-day food record and

results indicated that saccharide intake was a significant predictor of verbal memory in middle-aged adults. In a prospective trial, community-dwelling older adults, completed a 7-day food record at baseline; five years later, cognitive function was assessed with a cognitive battery, and brain volume was measured by magnetic resonance imaging (MRI) (14). Lower consumption of meat and meat products was associated with better cognitive functioning and greater total brain volume at follow up, suggesting that lower meat intake may be protective of brain health. Overall, several studies using food records for diet assessments of large cohorts have identified associations between dietary intake and cognitive function.

24-hour Dietary Recall

In a 24-hour dietary recall, respondents are asked to report all foods, beverages and supplements consumed within the last 24 hours. Structured interviews are conducted in person, over the telephone or through an automated self-administered collection system. A well-trained interviewer and the use of specific probes and multiple pass methods can help respondents recall more foods and details such as portion sizes and preparation methods (15). Due to intra-individual variation in dietary intake, multiple recalls are required to assess an individual's usual intake. High levels of physical functioning and literacy of participants are not required, reducing the potential for nonresponse bias, and the recall period is short, reducing the reliance on long-term memory. Similar to food records, underreporting is a concern and can be affected by several factors such as obesity, gender, education, social desirability and literacy (9). Despite these limitations, the National Health and Nutrition Examination Survey (NHANES) collects 24-hour dietary recalls with the U.S. Department of Agriculture's (USDA) fully computerized Automated Multiple Pass Method (16).

Although the 24-hr recall method is not frequently administered in large cohort studies, due to the need for multiple recalls and well-trained staff, it has effectively been used to identify associations between dietary intake and cognitive function. In a sample of over 400 Korean adults, 24-hr recalls were used to examine the relationship between dietary intake and cognitive performance (MMSE for Koreans) (17). Total amount of foods and energy were significantly related to lower cognitive function scores, and individuals with lower cognitive scores had diets lower in most nutrients, suggesting that inadequate nutrient intake is associated with reduced cognitive status. The Supplementation with Antioxidant Vitamins and Minerals study (SU.VI. MAX ; n=12,741), a randomized trial evaluating the effect of an antioxidant supplement on the incidence of cancers and cardiovascular disease in French middle-aged adults (18), collected 24-hour dietary recalls every two months via computerized questionnaires during the two year intervention. Thirteen years later, participants were invited to participate in the SU.VI.MAX 2 which included a battery of neuropsychological tests. Secondary analyses from these trials has used dietary data collected during SU.VI.MAX to evaluate the association between midlife dietary habits and cognitive performance assessed 13 years later in SU.VI.MAX 2. Positive associations between cognitive performance and carotenoid-rich dietary pattern (19), total polyphenols (20) fruit and vegetables (21), and a healthy dietary pattern (22) have been reported in this cohort. Thus, analysis of dietary intake with 24-hr recalls is feasible in large cohorts and can be used to identify dietary patterns associated with cognitive function.

Food Frequency Questionnaires (FFQ)

FFQs collect information on the usual frequency of consumption of a list of foods over a specific time period, which typically ranges from 1 month to 1 year. Several FFQs such as the Block (23), Willett (24), and Diet History Questionnaires (25) have been utilized, validated, and adapted for an array of populations. FFQs are typically validated with food records, multiple 24-hr recalls, and/or nutrient biomarkers. FFQs are frequently administered in epidemiological studies because they are self-administered, retrospective (i.e., capturing usual intake over an extended period of time), low cost, circumvent recent diet changes and require relatively minimal respondent burden. However, this method has a considerable amount of both systematic and random measurement error because food lists are not comprehensive and accurate recall of usual diet is a complex task, highly reliant on memory and conceptual skills. Therefore, FFQ data should only be used to rank individuals in a population by food or nutrient intake and not for estimating absolute levels (i.e. mean and variance) of dietary intake (9). The majority of observational studies that have identified a correlation between dietary intake and dementia or cognitive impairment have utilized FFQs, and a recent review discussed numerous observational studies that have used FFQs to investigate this relationship (26). Epidemiologic studies that have used FFQs generally support a protective role of monounsaturated fatty acids, polyunsaturated fatty acids, fish consumption, fruit and vegetable consumption, dairy consumption, and higher adherence to a Mediterranean- type diet against cognitive decline and risk of progression to dementia (27). FFQs are by far the most commonly used method used in observational studies, but due to the large amount of error in FFQs, caution should be taken in interpretation of the data.

Nutrient Biomarkers

Nutrient biomarkers are analyzed from blood, urine, or tissue and function as biochemical indicators of an individual’s dietary intake and exposure to a particular nutrient and can be used to validate intake estimates from other dietary assessment methods. Dietary biomarkers can be divided into two categories: “recovery” and “concentration” (27). Recovery biomarkers provide an absolute, quantitative measure of intake (i.e. 24-h urinary nitrogen excretion as a measure of protein intake and doubly labeled water for assessment of daily total energy expenditure), yet few biomarkers fall into this category. The majority of biomarkers are “concentration” biomarkers and simply quantify the concentration of a given dietary constituent at a given point in time and are not an absolute measure of intake. Although some biomarkers are reflective of long-term intake (i.e. selenium in toenails), a single measurement is typically not reflective of long-term dietary intake and usual nutrient status of an individual. Thus, the majority of “concentration” biomarkers measures should only be used for grouping individuals by relative levels of intake. Collection of nutrient biomarkers requires 24-hr urinary collections, fasting, and/or blood draw which are burdensome. Not all nutrients or phytochemicals have identifiable biomarkers, and analysis of multiple nutrients can be expensive; therefore, researchers may be limited to single nutrient analysis which cannot capture the complexity and entirety of an individual’s diet. The efficacy of whole foods and combinations of foods within the diet are neglected when assessment is focused on individual compounds, and dietary sources of a nutrient and frequency of consumption cannot be determined without another diet assessment method. Another limitation with nutrient biomarkers is the potential for being confounded by intra-

and inter-individual differences in absorption and metabolism (27). Furthermore, reliability for many biomarkers has not been thoroughly evaluated in older adults. Recently, metabolomics, the global analysis of metabolites in biological fluids, has emerged as a new tool with potential application in dietary assessment and identification of novel dietary biomarkers of foods, dietary components, and dietary patterns. This technique has identified potential biomarkers for foods such as raspberries (28), broccoli (28), and citrus (29), and dietary patterns including high-meat diet (30), fruit and vegetable intake (30), and Western diet (31). Despite the potential utility of metabolomics, research on the application in dietary assessment is currently lacking. To our knowledge, nutritional metabolomics has not been utilized in the investigation between diet and cognition.

There has been limited use of biomarkers of dietary intake to investigate the association between diet and cognitive function. Higher concentrations of omega-3 polyunsaturated fatty acid in erythrocyte membranes and plasma have both been associated with reduced risk of cognitive decline (32, 33). Bowman et. al analyzed plasma biomarkers of diet in community-dwelling older adults and constructed nutrient biomarker profiles with principal component analysis to identify nutrient combinations that may be associated with brain health (34). The pattern of high plasma B vitamins, C, D and E was associated with better global cognitive function and total cerebral brain volume, and the pattern high in omega-3 fatty acids was associated with better executive function (34). Worse overall cognitive function and less total cerebral brain volume were associated with the high trans fat pattern (34). However, PCA of nutrient biomarkers must be conducted within each study sample due to variations between populations of interest. Thus, the nutrient biomarker patterns previously identified by Bowman et. al. may not be associated with the same cognitive outcomes and vice-versa. Although nutrient biomarkers are an objective assessment of dietary intake, the use in diet and cognition research has been limited, and validity and reliability of many biomarkers has not been thoroughly assessed in different populations.

Cognitive Processes in Dietary Recall

The cognitive processes engaged by the respondent during completion of diet assessment methods must be understood in order to identify how cognitive function may influence the utility of diet assessment methods. Four main stages of cognitive processing in dietary recall (FFQ and 24-hr recalls) have been proposed: 1) question comprehension, 2) information retrieval, 3) estimation/judgement, and 4) response formulation (35). In the first stage, respondents must be able to understand the question and how to answer it. Question comprehension may be influenced by demographic factors such as intelligence, education and age (35). In the second stage of information retrieval, the individual must retrieve the requested information from memory, and memory impairments can significantly impact recall at this stage. Given the FFQs reliance on respondent’s long term memory, recall accuracy declines as the time between the reference period and administration of the FFQ (i.e., retention interval) increases (36). The third stage of the cognitive process includes estimation and judgments about the recalled information (35). If the information recalled in the previous stage is considered inadequate, respondents tend to rely on general knowledge of their typical diet, such as what they routinely eat, rather than memory of what they actually eat (36, 37). This can result in errors of omission (i.e., failure to report items

consumed) and intrusions (i.e., reporting items that were not consumed) (36). Estimations about usual frequency and portion size must also be made in the third stage, and FFQs that include portion sizes (i.e., semi-quantitative) increase the complexity of the task. Portion sizes are not constant over time and mental averaging must be done to determine consumption of seasonal items or whether the portion size referred to in the questionnaire is different than what is typically consumed (35). Respondents generally lack long-term memory about the typical portion size of foods they eat (36), and defined portion sizes used in semi-quantitative FFQs do not significantly increase validity of the questionnaire (38). 24-hr recalls are less challenging conceptually than FFQs and have considerably less error than FFQs (25, 39). In the final stage of the cognitive process, response formulation, individuals formulate a response after gauging expectations of the interviewer. Thus, even if the individual was able to recall and estimate intake correctly, the final response may be subject to error from social desirability bias.

Error and bias are possible at each stage of the cognitive processes of dietary recall and may be exacerbated by impairments in cognition. Cognitive abilities affect comprehension of the method and the cognitive processes that contribute to self-reporting of diet. Different dietary assessment methods require multiple cognitive abilities including literacy, word comprehension, memory, estimation, abstract reasoning, and knowledge of food items and preparation. Researchers must recognize the potential consequences of fallibility of cognitive function including reduced validity and or reliability of diet assessment methods.

Influence of Cognitive Function on Dietary Assessment – Experimental Evidence

Several studies have evaluated the validity and reliability of diet assessment methods in older adults and do not suggest additional problems in dietary intake assessment compared to younger age groups (40–42). However, these studies have primarily been conducted in healthy, well-functioning older adults, and may not be applicable to older adults with cognitive impairments or those experiencing age-related cognitive decline. It estimated that in the U.S., 22% of adults over 71 years of age have cognitive impairments without dementia (2). Changes in cognitive performance including reductions in executive function, working memory and long-term memory are common in older adults (8). Potential methodological issues in the nutritional assessment of individuals with impaired cognitive function must be considered, and studies designed to assess the relationship between dietary factors and cognitive function must understand the effect of cognitive function itself on the utility of self-reported dietary intake. Although research in this area is limited, a few studies have investigated the impact of cognitive function on accuracy of dietary reporting (Table 1).

Reliability and validity of a modified, self-administered Harvard Youth/Adolescent FFQ (43) was assessed in a biracial sample of older adults from the Chicago Health and Aging Project (44). Global cognitive scores were calculated from performance on East Boston Tests of Immediate Memory (short-term memory), Delayed Memory, Mini-Mental State Examination (45) and Symbol Digit Modalities Test (processing speed). Although the reliability and validity for the average of 15 nutrients did not differ across the tertiles of global cognitive function, a few individual nutrients were significantly associated with cognitive function. Reliability for Vitamin E from foods and Vitamin D, and validity of

calcium intake were significantly lower in the lowest cognitive score tertile; however, variations by nutrient were not addressed by the authors. Furthermore, long-term memory, which was not assessed in this study, is more likely to affect one's ability to complete a FFQ than processing speed and short-term memory; therefore, the use of a global cognitive score may mask poor performance on specific domains of cognition that have a more direct impact on accurate dietary recall.

The validity of an interviewer-administered, Harvard semi-quantitative FFQ (24) for estimation of dietary intake of eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) was assessed in a sample of community-dwelling older adults (46). FFQ estimates of EPA and DHA intake were significantly associated with plasma phospholipid total very-long-chain omega-3 fatty acid concentrations, and correlation coefficients were similar between subjects with low or high cognitive function and across clinical diagnoses of normal, mild cognitive impairment and dementia. However, estimated intake of EPA and DHA were calculated from only four questions in the FFQ about fish and seafood consumption and use of dietary supplements. Thus, estimated intake of nutrients that are more ubiquitous in the diet may be more susceptible to errors than EPA and DHA which are less abundant in the diet.

Under and over reporting errors are common in dietary recall and have a considerable effect on the validity and reliability of diet assessment methods (47, 48). Cognitive ability of community-dwelling older adults from a longitudinal cohort study was assessed with the Modified Mini Mental State Exam (3MS) at baseline (49), and participants completed the Block FFQ (23). Individuals with reporting errors had significantly lower 3MS scores than those without errors, and the association between cognitive ability and reporting errors remained even after adjustments for age, race, gender, education, BMI and physical activity. The results from this bi-racial sample of older adults suggest that lower cognitive function is associated with more reporting errors and can subsequently bias FFQ data.

Reliability and validity of a 175-item Scottish Collaborative Group FFQ was evaluated in free-living older adults from Scotland (50). Reliability for the average of 25 nutrients was similar across low-, medium, and high- scores of short-term memory and executive function. The validity correlation coefficients for the average of 25 nutrients was lowest in the low-score tertile of short-term memory and executive function, suggesting that validity is adversely affected by cognitive function. Reliability and validity of individual nutrients was not reported; thus, it is unknown whether specific nutrients were more affected by cognitive ability than others.

Bowman et. al compared reliability and validity of a FFQ and plasma nutrient biomarkers in a small sample of older adults with and without mild cognitive impairment (MCI) (51). The National Cancer Institute-Diet History Questionnaire (25) was self-administered, and trained personnel were available to assist the participants with completion of the FFQ. Many of the nutrient biomarkers had good reliability in both groups but was lower in those with MCI. However, this study had a small sample size and may be underpowered to account for the inter- and intra-individual variability in nutrient biomarker analysis. Interestingly, FFQ reliability was lower in nonimpaired individuals compared to those with MCI, which the

authors believe to be a demonstration of memory deficit falsely inflating reliability. FFQ validity was also influenced by cognitive function. In individuals with MCI, more negative correlation coefficients were identified, and estimates of carotenoids and long chain fatty acids from the FFQ did not correlate with plasma estimates. This novel study demonstrated that reliability and validity of the FFQ and nutrient biomarkers varied by nutrient and that cognitive impairment can inflate reliability and decrease validity of the FFQ.

The limited research on the relationship between cognitive function and validity and reliability of dietary assessment methods has several limitations. First, it is important to recognize that in many cases, assessment of cognitive function has used the MMSE. This measure is a global “snapshot” of overall cognitive status that is better used as an initial screening measure than being representative of elements of cognitive function better captured by neuropsychological batteries. Measuring validity and reliability of dietary recall across global cognitive scores or MMSE scores cannot identify differences by specific cognitive domains and are not sensitive enough to detect subtle differences in cognitive abilities. The potential influence of specific cognitive domains that are more relevant to recall accuracy should be assessed such as executive function, long-term memory and short-term memory. Future validation studies should aim to further delineate the impact of specific domains of cognitive function on systematic errors in diet recall methods. Furthermore, the variation in reliability and validity of individual nutrients should be assessed. In two studies, reliability and validity of measurement for several individual nutrients varied by global cognitive score (44, 51). Although these findings were not thoroughly addressed in the discussion by the authors, this should be considered by investigators using FFQs to estimate intake of a particular nutrient of interest.

Considerations for Selection and Administration of Diet Assessments

There are inherent errors in all diet assessment methods, but further errors due to cognitive impairment requires additional consideration and possible modifications of existing assessment methods. Individuals with suspected cognitive impairments may benefit from new approaches and modification of existing methods for cognitive ease. If possible, FFQs should be administered by trained interviewers that can assist in clarification of questions, motivate respondents, utilize cognitive interviewing techniques to aid in recall, and ensure that all questions are answered completely (52). Interview administered questionnaires report higher reliability in recall data than self-administered questionnaires (35). Cues such as reminders of situations in which foods may be consumed, prepared, or purchased may be incorporated in a FFQ and can improve comprehension and information retrieval and reduce difficulties in formulating responses (53). Splitting longer FFQs into smaller parts reduces participate burden and the degree of attentional focus required at one time. Shortening the time frame recalled in a FFQ should be considered because recall of usual intake of the past few months is easier than the past year (36). Alternatively, short-period assessment methods such as repeated 24-hr recalls or food records do not rely on respondent’s long-term memory, and evidence suggests these methods are more accurate in assessing usual intake than FFQs (54, 55). Despite the higher respondent burden than a FFQ or 24-hr recall, dietary records should be used for those with suspected memory impairments because they are completed at the time of the eating occasion, minimizing the reliance on memory. Dietary

biomarkers and nutritional metabolomics, objective markers of diet assessment, are not subject to the potential errors due to cognitive function and can complement self-reported measurements by providing additional or substitute estimates of dietary intake. However, as reviewed earlier, dietary components are influenced by multiple metabolic and genetic factors, and these techniques still require further research for application, interpretation, and comparisons across different populations. Combining different methods with independent errors, such as a FFQ with nutrient biomarkers or food records, may circumvent some of the concerns with utilizing a single method. Additionally, combining methods can provide more accurate estimates of intake than one method (54), and novel statistical modelling can be applied to partly correct for errors of self-reported dietary intake (56–58).

Although this review has focused on traditional diet assessment methods, there is a significant area of research in the development and validation of innovative assessment tools utilizing internet and telecommunication technologies. As reviewed by Illner et. al (59), these innovative technologies can be utilized for short-term and or long-term dietary assessment and can be classified into six groups: (1) Personal digital assistant-technologies, (2) mobile-phone-based technologies, (3) interactive computer-based technologies, (4) web-based technologies, (5) camera-and tape-recorder-based technologies and (6) scan and sensor-based technologies. Similarly, traditional methods are being further refined and improved, including the development of computer-administered FFQ and 24-h recalls (60). Further description and evaluation of these innovative technologies have been reviewed elsewhere (59, 61). The innovative alternatives may be advantageous logistically and financially; however, many of these methods are still reliant on self-report, and thus, have similar methodological problems as traditional assessment tools (59). The new assessment technologies have the potential to enhance dietary assessment in future studies, but further research is needed on the applicability and usability of these new tools in an older population with impaired cognitive function and/or limited familiarity with technology.

Summary

Assessing individuals' dietary intake has long been recognized as a challenge in nutrition research (62). The current review highlighted the potential influence of cognitive ability on errors in dietary data which has implications for epidemiological methodology and research on cognitive processes in diet assessment methods. Preventing or delaying the onset or progression of dementia through dietary interventions could have a significant impact on public health, and observational studies have identified several nutrients associated with reduced risk of cognitive impairment and decline (4). However, researchers must be more critical in the analysis and interpretation of self-reported dietary data, especially in populations with high incidence of cognitive impairments. In summary, we must better understand the role of cognitive function on assessment of dietary intake to improve current diet assessment methods, guide the development of new methods to increase reporting accuracy, and develop and effectively evaluate future nutrition interventions.

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References

1. Federal Interagency Forum on Aging-Related Statistics. Federal Interagency Forum on Aging-Related Statistics. Washington, DC: U.S. Government Printing Office; 2012. Older Americans 2012: Key Indicators of Well-Being.
2. Plassman BL, Langa KM, Fisher GG, Heeringa SG, Weir DR, Ofstedal MB, et al. Prevalence of Cognitive Impairment without Dementia in the United States. Ann Intern Med. 2008; 148:427–434. [PubMed: 18347351]
3. Plassman BL, Langa KM, Fisher GG, Heeringa SG, Weir DR, Ofstedal MB, et al. Prevalence of dementia in the United States: The aging, demographics, and memory study. Neuroepidemiology. 2007; 29:125–132. [PubMed: 17975326]
4. Gillette Guyonnet S, Abellan Van Kan G, Andrieu S, Barberger Gateau P, Berr C, Bonnefoy M, et al. Iana task force on nutrition and cognitive decline with aging. J Nutr Health Aging. 2007; 11:132–152. [PubMed: 17435956]
5. Brookmeyer R, Johnson E, Ziegler-Graham K, Arrighi HM. Forecasting the global burden of Alzheimer's disease. Alzheimer's and Dementia. 2007; 3:186–191.
6. Sydenham E, Dangour AD, Lim WS. Omega 3 fatty acid for the prevention of cognitive decline and dementia. Cochrane Database Syst Rev. 2012; 6:CD005379.doi: 10.1002/14651858.CD005379.pub3
7. Balk E, Raman G, Tatsioni A, Chung M, Lau J, Rosenberg IH. Vitamin B6, B12, and Folic Acid Supplementation and Cognitive Function. A Systematic Review of Randomized Trials. Arch Intern Med. 2007; 167:21–30. [PubMed: 17210874]
8. Reuter-Lorenz PA, Park DC. Human neuroscience and the aging mind: A new look at old problems. J Gerontol B Psychol Sci Soc Sci. 2010; 65:405–415. [PubMed: 20478901]
9. Thompson, FE., Subar, AF. Chapter 1 - dietary assessment methodology. In: Coulston, Ann M.Boushey, Carol J., Ferruzzi, Mario G., editors. Nutrition in the prevention and treatment of disease. third. Academic Press; 2013. p. 5-46.
10. Kolar AP, Kolar AS, Patterson RE, White E, Neuhouser ML, et al. A practical method for collecting 3- day food records in a large cohort. Epidemiology. 2005; 16:579–583. [PubMed: 15951680]
11. Requejo AM, Ortega RM, Robles F, Navia B, Faci M, Aparicio A. Influence of nutrition on cognitive function in a group of elderly, independently living people. Eur J Clin Nutr. 2003; 57:S54–S57. [PubMed: 12947454]
12. Velho S, Marques-Vidal P, Baptista F, Camilo ME. Dietary intake adequacy and cognitive function in free-living active elderly: A cross-sectional and short-term prospective study. Clin Nutr. 2008; 27:77–86. [PubMed: 18082291]
13. Best T, Kemps E, Bryan J. A role for dietary saccharide intake in cognitive performance. Nutr Neurosci. 2007; 10:113–120. [PubMed: 18019392]
14. Titova OE, Ax E, Brooks SJ, Sjögren P, Cederholm T, Kilander L, et al. Mediterranean diet habits in older individuals: Associations with cognitive functioning and brain volumes. Exp Gerontol. 2013; 48:1443–1448. [PubMed: 24126083]
15. Moshfegh AJ, Rhodes DG, Baer DJ, Murayi T, Clemens JC, Rumpler WV, et al. The US Department of Agriculture Automated Multiple-Pass Method reduces bias in the collection of energy intakes. Am J Clin Nutr. 2008; 88:324–332. [PubMed: 18689367]
16. [Accessed 9 December 2013] Key Concepts about NHANES Dietary Data Collection. http://www.cdc.gov/nchs/tutorials/dietary/SurveyOrientation/DietaryDataOverview/Info2.htm
17. Lee L, Kang SA, Lee HO, Lee B, Park JS, Kim J, et al. Relationships between dietary intake and cognitive function level in Korean elderly people. Public Health (Nature). 2001; 115:133–138.
18. Hercberg S, Preziosi P, Briançon S, Galan P, Triol I, Malvy D, et al. A Primary Prevention Trial Using Nutritional Doses of Antioxidant Vitamins and Minerals in Cardiovascular Diseases and

Cancers in a General Population: The SU.VI.MAX Study—Design, Methods, and Participant Characteristics. Control Clin Trials. 1998; 19:336–351. [PubMed: 9683310]

19. Kesse-Guyot E, Andreeva VA, Ducros V, Jeandel C, Julia C, Hercberg S, et al. Carotenoid-rich dietary patterns during midlife and subsequent cognitive function. Br J Nutr FirstView. 2013:1–9.
20. Kesse-Guyot E, Fezeu L, Andreeva VA, Touvier M, Scalbert A, Hercberg S, et al. Total and Specific Polyphenol Intakes in Midlife Are Associated with Cognitive Function Measured 13 Years Later. J Nutr. 2012; 142:76–83. [PubMed: 22090468]
21. Péneau S, Galan P, Jeandel C, Ferry M, Andreeva V, Hercberg S, et al. Fruit and vegetable intake and cognitive function in the SU.VI.MAX 2 prospective study. Am J Clin Nutr. 2011; 94:1295–1303. [PubMed: 21955649]
22. Kesse-Guyot E, Andreeva VA, Jeandel C, Ferry M, Hercberg S, Galan P. A Healthy Dietary Pattern at Midlife Is Associated with Subsequent Cognitive Performance. J Nutr. 2012; 142:909–915. [PubMed: 22457391]
23. Block G, Hartman AM, Dresser CM. A data-based approach to diet questionnaire design and testing. Am J Epidemiol. 1986; 124:453–469. [PubMed: 3740045]
24. Willett WC, Sampson L, Stampfer MJ. Reproducibility and validity of a semiquantitative food frequency questionnaire. Am J Epidemiol. 1985; 122:51–65. [PubMed: 4014201]
25. Subar AF, Thompson FE, Kipnis V, Midthune D, Hurwitz P, McNutt S, et al. Comparative validation of the Block, Willett, and National Cancer Institute Food Frequency Questionnaires: The Eating at America's Table Study. Am J Epidemiol. 2001; 154:1089–1099. [PubMed: 11744511]
26. Solfrizzi V, Panza F, Frisardi V, Seripa D, Logroscino G, Imbimbo B, et al. Diet and Alzheimer's disease risk factors or prevention: the current evidence. Expert Rev Neurother. 2011; 11:677–708. (2011). [PubMed: 21539488]
27. Jenab M. Biomarkers in nutritional epidemiology: applications, needs and new horizons. Hum Genet. 2009; 125:507–525. [PubMed: 19357868]
28. Lloyd AJ, Fave G, Beckmann M, Lin W, Tailliart K, Xie L, Mathers JC, Draper J. Use of mass spectrometry fingerprinting to identify urinary metabolites after consumption of specific foods. Am J Clin Nutr. 2011; 94:981–991. [PubMed: 21865330]
29. Heinzmann SS, Brown IJ, Chan Q, Bictash M, Dumas M- Kochhar S, et al. Metabolic profiling strategy for discovery of nutritional biomarkers: Proline betaine as a marker of citrus consumption. Am J Clin Nutr. 2010; 92:436–443. [PubMed: 20573794]
30. O'Sullivan A, Gibney MJ, Brennan L. Dietary intake patterns are reflected in metabolomic profiles: potential role in dietary assessment studies. Am J Clin Nutr. 2011; 93:314–321. [PubMed: 21177801]
31. Bouchard-Mercier A, Rudkowska I, Lemieux S, Couture P, Vohl MC. The metabolic signature associated with the Western dietary pattern: A cross-sectional study. Nutrition Journal. 2013; 12:158. [PubMed: 24330454]
32. Dullemeijer C, Durga J, Brouwer IA, Van De Rest O, Kok FJ, Brummer R-M, et al. n-3 Fatty acid proportions in plasma and cognitive performance in older adults. Am J Clin Nutr. 2007; 86:1479–1485. [PubMed: 17991662]
33. Heude B, Ducimetière P, Berr C. Cognitive decline and fatty acid composition of erythrocyte membranes--The EVA Study. Am J Clin Nutr. 2003; 77:803–808. [PubMed: 12663275]
34. Bowman GL, Silbert LC, Howieson D, Dodge HH, Traber MG, Frei B, Kaye JA, Shannon J, Quinn JF. Nutrient biomarker patterns, cognitive function, and MRI measures of brain aging. Neurology. 2012; 78:241–9. [PubMed: 22205763]
35. Friedenreich CM, Slimani N, Riboli E. Measurement of Past Diet: Review of Previous and Proposed Methods. Epidemiol Rev. 1992; 14:177–196. [PubMed: 1289112]
36. Smith AF. Cognitive processes in long-term dietary recall. National Center for Health Statistics. Vital Health Stat. 1991; 6
37. Smith AF, Jobe JB, Mingay DJ. Retrieval from Memory of Dietary Information. Applied Cognitive Psychology. 1991; 5:269–296.
38. Haraldsdottir J, Jonneland AT, Overvad K. Validity of individual portion size estimates in a food frequency questionnaire. Int J Epidemiol. 1994; 23:787–796.

39. Schatzkin A, Kipnis V, Carroll RJ, Midthune D, Subar AF, Bingham S, et al. A comparison of a food frequency questionnaire with a 24-hour recall for use in an epidemiological cohort study: results from the biomarker-based Observing Protein and Energy Nutrition (OPEN) study. Int J Epidemiol. 2003; 32:1054–1062. [PubMed: 14681273]
40. Bartali B, Turrini A, Salvini S, Lauretani F, Russo C, Corsi A, et al. Dietary intake estimated using different methods in two Italian older populations. Arch Gerontol Geriatr. 2004; 38:51–60. [PubMed: 14599704]
41. Van Staveren WA, de Groot LC, Blauw Y, van der Wielen R. Assessing diets of elderly people: Problems and approaches. Am J Clin Nutr. 1994; 59:221S–223S. [PubMed: 8279429]
42. de Vries J, de Groot L, van Staveren W. Dietary assessment in elderly people: experiences gained from studies in the Netherlands. Eur J Clin Nutr. 2009; 63:S69–S74. [PubMed: 19190649]
43. Morris MC, Colditz GA, Evans DA. Response to a Mail Nutritional Survey in an Older Bi-Racial Community Population. Ann Epidemiol. 1998; 8:342–346. [PubMed: 9669617]
44. Morris MC, Tangney CC, Bienias JL, Evans DA, Wilson RS. Validity and Reproducibility of a Food Frequency Questionnaire by Cognition in an Older Biracial Sample. Am J Epidemiol. 2003; 158:1213–1217. [PubMed: 14652307]
45. Folstein M, Folstein S, McHugh P. «Mini-mental state». A practical method for grading the cognitive state of patients for the clinician. J Psychiatr Res. 1975; 12:189–98. [PubMed: 1202204]
46. Arsenault LN, Matthan N, Scott TM, Dallal G, Lichtenstein AH, Folstein MF, et al. Validity of Estimated Dietary Eicosapentaenoic Acid and Docosahexaenoic Acid Intakes Determined by Interviewer-Administered Food Frequency Questionnaire Among Older Adults With Mild-to-Moderate Cognitive Impairment or Dementia. Am J Epidemiol. 2009; 170:95–103. [PubMed: 19433614]
47. Poslusna K, Ruprich J, de Vries J, Jakubikova M, van't Veer P. Misreporting of energy and micronutrient intake estimated by food records and 24 hour recalls, control and adjustment methods in practice. Br J Nutr 101 Suppl. 2009; 2:S73–85.
48. Westerterp KR, Goris AHC. Validity of the assessment of dietary intake: Problems of misreporting. Curr Opin Clin Nutr Metab Care. 2002; 5:489–493. [PubMed: 12172471]
49. Pope SK, Kritchevsky SB, Morris MC, Block G, Tylavsky FA, Lee JS, et al. Cognitive ability is associated with suspected reporting errors on food frequency questionnaires. J Nutr Health Aging. 2007; 11:55–58. [PubMed: 17315081]
50. Jia X, Craig LCA, Aucott LS, Milne AC, McNeill G. Repeatability and validity of a food frequency questionnaire in free-living older people in relation to cognitive function. J Nutr Health Aging. 2008; 12:735–741. [PubMed: 19043649]
51. Bowman GL, Shannon J, Ho E, Traber MG, Frei B, Oken BS, et al. Reliability and validity of food frequency questionnaire and nutrient biomarkers in elders with and without mild cognitive impairment. Alzheimer Dis Assoc Disord. 2011; 25:49–57. [PubMed: 20856100]
52. Klipstein-Grobusch K, Den Breeijen JH, Goldbohm RA, Geleijnse JM, Hofman A, Grobbee DE, et al. Dietary assessment in the elderly: Validation of a semiquantitative food frequency questionnaire. Eur J Clin Nutr. 1998; 52:588–596. [PubMed: 9725660]
53. Subar A. Improving food frequency questionnaires: A qualitative approach using cognitive interviewing. J Am Diet Assoc. 1995; 95:781–788. [PubMed: 7797809]
54. Carroll RJ, Midthune D, Subar AF, Shumakovich M, Freedman LS, Thompson FE, et al. Taking Advantage of the Strengths of 2 Different Dietary Assessment Instruments to Improve Intake Estimates for Nutritional Epidemiology. Am J Epidemiol. 2012; 175:340– 347. [PubMed: 22273536]
55. Prentice RL, Mossavar-Rahmani Y, Huang Y, Van Horn L, Beresford SAA, Caan B, et al. Evaluation and Comparison of Food Records, Recalls, and Frequencies for Energy and Protein Assessment by Using Recovery Biomarkers. Am J Epidemiol. 2011; 174:591–603. [PubMed: 21765003]
56. Prentice R, Huang Y, Tinker L, Beresford S, Lampe J, Neuhouser M, et al. Statistical Aspects of the Use of Biomarkers in Nutritional Epidemiology Research. Stat Biosci. 2009; 1:112–123. [PubMed: 19841649]

57. Prentice RL, Tinker LF, Huang Y, Neuhouser ML. Calibration of Self-Reported Dietary Measures Using Biomarkers: An Approach to Enhancing Nutritional Epidemiology Reliability. Curr Atheroscler Rep. 2013; 15:353. [PubMed: 23881548]

58. Haubrock J, Nöthlings U, Volatier J- Dekkers A, Ocké M, Harttig U, et al. Estimating usual food intake distributions by using the multiple source method in the EPIC-Potsdam calibration study. J Nutr. 2011; 141:914–920. [PubMed: 21430241]

59. Illner A, Freisling H, Boeing H, Huybrechts I, Crispim S, Slimani N. Review and evaluation of innovative technologies for measuring diet in nutritional epidemiology. International Journal of Epidemiology. 2012; 41:1187–1203. [PubMed: 22933652]

60. Falomir Z, Arregui M, Madueño F, Corella D, Coltell Ó. Automation of Food Questionnaires in Medical Studies: A state-of-the-art review and future prospects. Comput Biol Med. 2012; 42:964–974. [PubMed: 22898338]

61. Ngo J, Engelen A, Molag M, Roesle J, García-Segovia P, Serra-Majem L. A review of the use of information and communication technologies for dietary assessment. Br J Nutr. 2009; 101:S102–S112. [PubMed: 19594959]

62. Kristal AR, Peters U, Potter JD. Is It Time to Abandon the Food Frequency Questionnaire? Cancer Epidemiol Biomarkers Prev. 2005; 14:2826–2828. [PubMed: 16364996]

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Table 1

Impact of Cognitive Function on Validity and Reliability of Diet Assessment Methods

Author/Year	Sample	Measures of Cognitive Function	Diet Assessment Method	Reliability/Validity Assessment	Results
Morris et.al 2003 (44)	118 Black and 114 White participants of the Chicago Health and Aging Project Mean age = 77.8 y Frequency Questionnaire	Global cognitive score = averaged z-scores from four tests: East Boston Tests of Immediate Memory, Food Delayed Memory, Mini-Mental State Examination and Symbol Digit Modalities Test	Self-administered, modified version of the Harvard Youth/Adolescent	Reliability: FFQ completed at month 1 and month 12. Validity: Multiple 24-hour dietary recall interviews (mean=3.6 recalls)	Reliability and validity correlations for average of 15 nutrients did not vary across tertiles of global cognitive score.
Arsenault et. al 2009 (46)	273 community-dwelling adults in the Nutrition, Aging, and Memory in Elders Study Mean age = 73.4 y	Mini-Mental State Examination and clinical consensus diagnoses	Interviewer-administered Harvard FFQ	Reliability: Not Assessed Validity: Plasma phospholipid fatty acid profiles	Validity: Consistent across categories of cognitive function stratified by MMSE scores and clinically diagnosed categories of cognitive functioning
Pope et. al 2007 (49)	2,706 community-dwelling older adults in the Health, Aging, and Body Composition Study Mean age = 73.6	Modified Mini-Mental State Exam (3MS)	Block FFQ	Reliability: Not assessed Validity: Reporting errors defined as extremely low or high numbers of reported solid foods per day and caloric intake outside gender-specific normal ranges.	Validity: Reporting errors inversely associated with cognitive ability. 5-point increase in 3MS scores associated with decreased likelihood of reporting errors (OR=0.86)
Jia et. al 2008 (50)	189 free-living older adults from the MAVIS trial (Effect of multivitamin and multimineral supplements on morbitity from infections in older people) Mean age = not reported Age Range = 64–80 y	Digit span forward test (short-term memory) and verbal fluency test (executive function)	175-item Scottish Collaborative Group FFQ	Reliability: FFQ completed on two occasions 3 months apart. Validity: 4-day weighed food record	Reliability: Similar across tertiles of short-term memory and executive function test scores. Validity: Lowest correlation coefficients in the low-score tertile of short-term memory and executive function.
Bowman et. al 2011 (51)	Older adults with amnestic-mild cognitive impairment (n=19) or nonimpaired (n=19) Mean age = 74 years	Consensus diagnosis by neurologists and neuropsy-chologists after cognitive and functional examinations.	Plasma nutrient biomarkers (26 nutrients) and National Cancer Institute Diet History Questionnaire	Nutrient Biomarkers Reliability: plasma estimates collected at baseline FFQ Reliability: FFQ completed at baseline and 1 month Validity: Nutrient biomarkers and 1 month Validity: Not assessed	Nutrient Biomarkers Reliability: Good reliability in both groups, but greater variability in MCI. FFQ Reliability: Lower in nonimpaired individuals Validity: More negative correlation coefficients in MCI than nonimpaired individuals.