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Cover Page Footnote

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Research article

Self-reported nutritional status, executive functions, and cognitive flexibility in adults

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Abstract

Objectives. The purpose of this study was to investigate the relationship between nutrition status, executive cognitive functions, and cognitive flexibility; and to analyze the role of gender, age, and nutrition status in the prediction of executive cognitive functions and cognitive flexibility in a sample of Iranian adults. *Background*. This study is based on the hierarchy of needs, health beliefs, developmental, cognitive and psychophysiological conceptualizations of nutrition and their plausible influences on human cognitive functions and cognitive flexibility.

Materials and Methods. The randomly selected sample consisted of 200 adult participants (M=99 and F=101) from Eghlid City, the north of Fars province, Iran. A demographic questionnaire, the Nutrition Assessment Inventory (NAI), the Amsterdam Executive Function Inventory (AEFI), and the Cognitive Flexibility Scale (CFS) were used.

Results. Findings showed significant positive relationships between healthy nutrition (diet-oriented nutrition and high fat foods subscales of Nutrition Assessment Inventory), the evaluation coping subscale, and the total score of Cognitive Flexibility Inventory. In addition, age and nutritional status had a significant impact with regards to predicting cognitive flexibility and executive cognitive functions.

Conclusions. Given the significant positive relationship between nutrition status and cognitive flexibility, and the role of gender and nutrition status on executive cognitive functions and mental flexibility, this study may offer beneficial approaches for nutrition and cognitive health programs by clinicians and health education professionals.

Keywords : nutrition status, executive cognitive functions, cognitive flexibility, gender, age.

Highlights

- ✓ Healthy nutrition is significantly related to cognitive flexibility in adults
- ✓ Gender and nutrition status are influential factors on executive cognitive functions and mental flexibility

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Introduction

A critical factor in the physiological maintenance, regulation, and survival of individuals is the environmental input received from an optimal nutritional diet. A balanced nutritional diet provides the 24 elements (e.g., nitrogen, potassium, and manganese) required by the human body and generally obtainable through various food sources. Optimal nutrition is important as it plays a critical role in the development, maintenance, and regulation of physiological functioning across an individual's life span. However, for numerous reasons including financial costs, restricted food resources, and the importance of size and beauty, dietary components have changed significantly over the years (1).

The concept of a healthy diet is defined as eating natural products which ensure sufficient nutrients and a balanced caloric intake for a healthy body (2). Nutritional food intake can be considered in terms of its basic constituents: carbohydrate, protein, starches, and fat. Healthy eating requires a well-balanced intake from available food sources across five food categories that include: (a) fruits and vegetables, (b) bread, pasta, other cereals, and potatoes, (c) meat, fish, and alternatives, (d) milk and dairy products, and (e) fatty and sugary foods (1). Altogether, a healthy diet can protect against the development of illness in general, while an unhealthy diet may contribute to disease and mental dysfunctions. The purpose of this study was to investigate the relationships between self-reported nutritional status, executive functions, and cognitive flexibility based on the influences of gender and age in a sample of Iranian adults.

Nutrition, executive functions and cognitive flexibility

Research indicates that carbohydrate meals can impair performance on cognitive tasks and may induce sleepiness (3). Several studies have reported improved cognitive function following the consumption of either fat or sugar (4). A cross-sectional study of a middle-aged population demonstrated that high saturated fat (SF) intake was associated with an increased risk of impaired cognitive functions, including memory, speed, and flexibility (5). Barnes and Joyner demonstrated that a diet high in saturated fats and refined sugars such as sucrose and fructose can contribute to cognitive impairment and general physiological decline (6). Bodnar and Wisner proposed a number of mechanisms through which nutritional intake could be effective in improving mental health. For example, modifying dietary intake or supplementing diets with single or multiple vitamins and minerals may correct existing nutrient deficiencies that contribute to poor mental health (7). Gomez-Pinilla indicated that the consumption of vitamins and minerals can positively affect cognitive status whilst the consumption of, for example, saturated fats, can have a negative effect on both neural plasticity and cognitive function. He hypothesized that understanding the molecular basis of the effects of food on cognition will help determine how best to manipulate diet in order to increase the resistance of neurons to insults and to promote mental fitness (8).

Spaccavento, Del Prete, Craca and Fiore showed that nutrition is also related to clinical mental outcomes, such as dysfunctions in cognition, autonomy, and behavior. They demonstrated a relation between nutritional intake and functional, cognitive, and neuropsychiatric deficits in patients with neuropsychiatric disorders (9). When cognitive assessment was performed pre- and post-HF diet consumption, results showed significantly reduced attention following diet intervention (10).

Tangney and Scarmeas noted that a growing body of evidence is supportive of an influence of nutritional factors on cognitive health (11). Bowman et al. found connections between diet and brain health, showing that high levels of omega-3 fatty acids, the B family of vitamins, and vitamins C, D and E correlated with higher cognitive test scores (12). Similarly, Francis and Stevenson showed an association between a diet high in saturated fat and refined carbohydrates (HFS) and impaired cognitive function. Research data have thus provided a growing understanding of how HFS diets can disrupt brain function, particularly episodic memory, attention, and inhibition, not only suggesting a causal link between an HFS diet and impaired brain function in humans, but also that HFS diets contribute to the development of neurodegenerative conditions. Therefore, a healthy diet seems essential for psychological health, particularly for optimum performance in cognitive functions (13). Smith and Scholey demonstrated that nutritional status, diet, and the ingestion of a range of nutrients impact upon neurocognitive development, executive function, and performance (14). In addition, Dauncey concluded that optimal executive functions may be influenced by highly complex interactions between numerous genetic and environmental factors, including food intake, physical activity, age, and stress (15). Meeusen revealed that dietary factors can affect multiple brain processes, including memory, learning, and executive cognitive function, by regulating the neuro-transmitter pathways and synaptic transmission, signal-transduction pathways and membrane fluidity. For example, flavonols are part of the flavonoid family and are found in various fruits, cocoa, wine, tea and beans (16). Best and Dye provided an innovative scientific summary of nutrition–cognition research which provides valuable information regarding nutrition and lifestyle choices for cognitive health (17).

Although much literature on nutrition and cognitive functions exists, the extent to which diet plays a role in cognitive flexibility has received little attention. A recent study showed that children consuming diets higher in saturated fats and cholesterol exhibit compromised ability for flexibility and the ability to modulate their cognitive operations, particularly when faced with cognitive challenges (18). Tandon et al. indicated that physical activity and healthy diets in early childhood are associated with better cognitive flexibility outcomes in young children (19).

Theoretical frameworks

The model of human motivation for eating and for the palatability of foods and beverages intake has its origin in Maslow's hierarchy of needs (20). This theory predicts that the satisfaction of eating is related to the palatability of foods and beverages, and that the palatability of foods and beverages is affected by our physiological states, our psychological and social contexts, and people's belief structures (21).

A developmental perspective related to food choice emphasizes the importance of experience/ learning and focuses on the development of preferences of food in childhood (1, 22-26). The developmental model emphasis is on exposure, the social model, and the associative learning of choice of food intake by people.

A cognitive approach to food choice focuses on an individual's cognitions and highlights the relationship between a person's beliefs about the ability to control health and dietary behavior (1, 27-29) Attitudes, social norms, perceived control, and ambivalence are basic cognitive components that determine how a person makes a choice with regard to intentional behavior in relation to food intake. For example, the Health Belief Model (HBM) posits that six constructs predict health behavior: risk susceptibility, risk severity, benefits to action, barriers to action, self-efficacy, and cues to action (30, 31). This model focuses on perceptions individuals have of the threat posed by a health problem (susceptibility, severity), the potential benefits of avoiding the threat, and factors influencing the decision to act (barriers, cues to action, and self-efficacy). Jones and colleagues suggested that the Health Belief Model (HBM) posits that messages achieve optimal behavior change if they successfully target perceived barriers, benefits, self-efficacy, and threat (32). This cognitive approach assists in understanding and predicting how food choices can be influenced by an individual's functions in general.

The psychophysiological perspective on food choice focuses on hunger and satiety (1, 33) and explores the interplay between cognitions, behavior, and an individual's physiology. For instance, it considers the metabolic model of eating with a focus on the role of the hypothalamus and the impact of psychopharmacological drugs and neurochemicals on hunger and satiety (1). The psychophysiological model of food choice helps to examine the effect of food on cognitions and behavior in different age groups.

The present study

This study is based on the hierarchy of needs, health beliefs, developmental, cognitive and psycho-physiological conceptualizations of nutrition and its plausible influences on human cognitive functions and cognitive flexibility (1, 20-22, 24, 26-29, 30-33). With regard to the aforesaid conceptualizations in the field of eating and nutrition, the present study hypothesizes that a balanced diet is essential for cognitive functions and cognitive flexibility, despite a lack of evidence on the possible role of nutrition in the latter. The present study examines the concurrent relationships between nutritional status, cognitive functions, and cognitive flexibility whilst considering the potential role of gender and age in an Iranian adult sample. The first hypothesis is that nutritional status, cognitive functions, and cognitive flexibility are significantly related in Iranian adults. The second hypothesis is that gender, age, and nutrition status significantly predict executive cognitive functions and cognitive flexibility.

Materials and Methods

Participants

The sample consisted of 99 males and 101 females from Eghlid City, Fars province; Iran. The mean and standard deviation of age for men and women was 38.02 (S=11.65) and 39.69 (S=21.70) respectively. The educational level included preschool (N=2), elementary (N=14), guidance (N=17), high school (N=24), diploma (N=52), associate or skill degree (N=33), bachelor degree (N=50), master degree (N=7), and doctorate degree (N=1). The ethnicity of the sample included Fars (N=159), Lour (N= 20), and Turkish (N=17). All participants were Muslims.

Instruments

The demographic questionnaire included participants' age, gender, educational level, and ethnicity questions. Three inventories were applied: (a) the Nutrition Assessment Inventory (NAI), (b) the Amsterdam Executive Function Inventory (AEFI), and (3) the Cognitive Flexibility Scale (CFS).

The Nutrition Assessment Inventory (NAI): The NAI is a 23-item inventory (e.g. I use seafoods in my diet). Response options are presented on a 5-point Likert scale with the choice options 5 = "Always," to 1 = "Never." In the present study, an exploratory factor analysis was conducted to evaluate the construct validity of the NAI. Principal analysis factor with varimax rotation was introduced in order to determine construct validity, agreeing an Eigenvalue higher than 1. Factor analysis specification was satisfactory; KMO = .74, Bartlett's Test of Sphericity = 16.77, df = 253, p = .0001, and the rotation sums of squared loadings = 61.18. It was found a significantly rotated correlation of higher than .30 for 23 items in 14 iterations. Factor analysis indicated that the NAI consisted of six factors, with eigenvalues for the six factors ranging from 13.83 to 61.18. These factors explained 61.18% of variance and were "Healthy Nutrition (HN)", "Diet Oriented Nutrition (DON)", "Fast Food Tendency (FFT)", "Use of Complementary Nutrients (UCN)", "Coping with High Fat Foods (CHFF)", and "High Fat Food Assumption (HFFA)" (Table 1). The total score of the NAI represents the sum of these five subscales. The reliability of all subscales ranged from .78 to .91. The reliability of the NAI was established using Cronbach's alpha, .89.

The Amsterdam Executive Function Inventory (34): The AEFI is a 13-item inventory. The first executive component can be verbally labeled "Attention" and consists of cognitive abilities such as selective and sustained attention (e.g. I am not able to focus on the same topic for a long period of time). The second executive function factor can be verbally labeled "Self-Control and Self-Monitoring" and consists of abilities such as working memory and self-monitoring (e.g. I often lose things). The third factor can be verbally labeled "Planning and Initiative" and consists of abilities such as the initiating and planning of behavior (e.g. I can make fast decisions). The responses for the AEFI items were presented on a 3-point Likert scale with the choice options 1 = "Not true," 2 = "Partly true," and 3 = "True." Psychometric analyses have shown that construct validity and reliability of the AEFI were adequate (Van der Elst, Ouwehand et al. 2012).

The Cognitive Flexibility Scale (35): The CSF is a 12-item scale (e.g. I avoid new and unusual situations). Cognitive flexibility is a general mental function that helps coordinate thought and action. Cognitive flexibility refers to a person's awareness of communication alternatives, willingness to adapt to the situation, and self-efficacy in being flexible. The responses for the CFS were presented on a 5-point Likert scale with the choice options 1 = "Strongly Disagree" to 5 = "Strongly Agree." Three studies have affirmed the validity and reliability of the Cognitive Flexibility Scale (35, 36).

Results

To examine the first hypothesis, correlation coefficients were computed for nutritional status, cognitive functions, and cognitive flexibility in an effort to assess how the total score and subscales of these constructs were significantly related. The Bonferroni approach was used to control for Type I error across the 14 correlations (Table 2).

To investigate the second hypothesis in this study, a multiple hierarchical regression analysis using the "enter" procedure was performed to evaluate the role of gender, age, and nutrition status as predictors of cognitive flexibility across the entire sample. The gender variable, $b = .80$, $t(200) =.70$, $p < .48$, did not predict the total score of cognitive flexibility, $R2= .003$, $F =.501$, $p < .48$. The age variable, $b = .116$, $t(200) =2.42$, $p < .016$, predicted the total score of cognitive flexibility, $R2= .031$, $F =3..191$, $p < .043$. The nutrition status variable, $b = .112$, $t(200) =2.76$, $p < .006$, predicted the total score of cognitive flexibility, $R2= .068$, $F =4.742$, $p < .003$. This analysis included gender as a "dummy" variable (with 0 and 1 values): first block, the gender, second block, the age, and the third step: nutrition status. Again, this analysis showed significant effects for age and nutrition status but not gender in predicting cognitive flexibility (Table 3).

A multiple hierarchical regression analysis with the "enter" procedure was used to evaluate the role of gender, age and nutrition status on the prediction of executive cognitive functions. The gender variable, $b = .49$, $t(200) =.808$, $p < .42$, did not predict the total score of executive cognitive functions, $R2= .003$, $F =.652$, $p < .42$. The age variable, $b = .069$, $t(200) =2.66$, $p < .008$, predicted the executive cognitive functions' total variability, $R2= .038$, $F =3.896$, $p < .022$. The nutrition status variable, $b = .027$, $t(200) =1.206$, $p < .229$, predicted the total of executive cognitive functions' variability, $R2= .045$, $F =3.088$, $p < .028$. Again, this analysis showed a significant effect for age and nutritional status, but not gender, in predicting executive cognitive function (Table 4).

Table 1. Factors and Items of the Nutrition Assessment Inventory (NAI)

Factors	Items	% of Variance	Cumulative %
1. Healthy Nutrition (HN)	1,10,11,14,15,16,18,20,21	13.839	13.839
2. Diet Oriented Nutrition	2,4,5,6	13.495	27.334
3. Fast Food Tendency	19,22,23	10.145	37.479
4. Use of Complementary	8,9,12	9.024	46.503
5..Coping with High Fat	3,13	7.393	53.896
6. High Fat Food	7,12	7.290	61.185

Table 2. The Relationships of Nutritional Status, Cognitive Functions and Cognitive Flexibility

Variables	NAI2	NAI3	NAI4	NAI5	NAI6	NAI	CFS1	CFS2	CFS	AEFI1	AEFI2	AEFI3	AEFI
NAI1	.261**	.362**	.236**	.418**	.236**	.874**	.246**	.046	.194**	-.067	.109	.096	.052
NAI2		.093	.343**	-.061	.343**	.555**	-.021	.175*	.096	-.010	.002	.004	.023
NAI3			-.028	.121	-.028	.479**	.080	-.065	.036	-.041	.022	.112	.026
NAI4				.279**	1.000**	.445**	.012	-.002	.001	.038	.032	-.062	-.003
NAI5					.279**	.472**	.158*	-.045	.076	.054	.104	.077	.097
NAI6						.445**	.012	-.002	.001	.038	.032	-.062	-.003
NAI							.190**	.075	.169*	-.048	.116	.097	.062
CFS1								.551**	.879**	-.074	-.076	.032	-.046
CFS2									.828**	-.073	.005	-.075	-.038
CFS										-.114	-.066	-.038	-.072
AEFI1											.581**	.402**	.767**
AEFI2												.491**	.836**
AEFI3													.692**

Note: NAI1= Healthy Nutrition, NAI2= Diet Oriented Nutrition, NAI3= Fast Food Tendency, NAI4=Use of Complementary Nutritients, NAI5= Coping with High Fat Foods, NAI6= High Fat Food Assumption, NAI=Nutrition Assessment Inventory, CFS1= Evaluation Coping, CFS2= Adaptive Coping, CFS=Cognitive Flexibility Inventory, AEFI1= Attention, AEFI2= Self-Control and Self-Monitoring, AEFI3= Planning and Initiative, AEFI= Amsterdam Executive Function Inventory, *p < .05. ** p< .01.

Table 3. Summary of Hierarchical Regression Analysis for Variables Predicting Cognitive Flexibility in the Total Sample (N = 200)

Variable	Model 1 (Gender)				Model 2 (Gender + Age)				Model 3 (Gender+ Age+			
	B	*SE B*	*β*	Power	*B*	*SE B*	*β*	Power	*B*	*SE B*	*β*	Power
Gender	.800	1.130	.050	.48	0.028	1.139	.038	.58	.891	1.106	.056	.42
Age					.116	.048	1.170	.01	.128	.047	.187	.008
Nutrition									.112	.041	.191	.008
R^2	.003			0.003	.031			0.031	.068			0.072
F for	.501				3.191*				4.743**			

Note : *p < .05. ** p< .01.

Table 4. Summary of Hierarchical Regression Analysis for Variables Predicting Executive Cognitive Functions in the Total Sample (N =200)

Variable	Model 1 (Gender)				Model 2 (Gender + Age)				Model 3 (Gender+ Age+ Nutrition Status)			
	B	*SE B*	*β*	Power test	*B*	*SE B*	*β*	Power test	*B*	*SE B*	*β*	Power test
Gender	.495	.613	.057	.42	0.380	.606	.044	.53	.448	.608	.052	.46
Age					.069	.028	.187	.008	.072	.026	.194	.006
Nutrition status									.027	.022	.085	.22
R^2	.003			.003	.038			.039	.045			0.047
F for change in R^2	.652				3.896 *				3.08 8*			

Note: *p < .05. ** p< .01.

Discussion

Analysis related to the first hypothesis showed significant positive relationships between the Healthy Nutrition subscale of the Nutrition Assessment Inventory, the Evaluation Coping subscale, and the total score of the Cognitive Flexibility Inventory. The Diet Oriented Nutrition subscale of Nutrition Assessment Inventory was significantly correlated with the Evaluation Coping subscale of the Cognitive Flexibility Inventory. The Coping with High Fat Foods subscale of the Nutrition Assessment Inventory was significantly correlated with the Evaluation Coping subscale of the Cognitive Flexibility Inventory.

These findings are consistent with the current literature which supports the role of nutrition in healthy cognitive functioning and cognitive flexibility among adults and children (11, 17-19). Consistent with a cognitive approach to food choice (1, 27-29), this study indicated that food choices and diet influence cognitive flexibility. As Sakai noted, the relationship between nutrition and cognitive flexibility can be explained in light of psychological and social contexts (21). For example, people currently have more concern about eating healthy foods and the role of nutrition on physical and cognitive health in Iranian culture. This study suggests that people have more opportunity for awareness about a healthy life style and its impact on their mental functioning via information sources such as the internet, satellite, and social networks. However, there were no significant correlations between the Nutrition Assessment Inventory, the Amsterdam Executive Function Inventory, and their subscales in this sample. This finding differs from previous research which has supported the role of nutritional intake in executive cognitive functioning (13, 14, 16). This lack of relationship in our sample might be explained by moderating variables such as hunger and satiety motives of food choice or environmental factors such as norms of food intake, low physical activity, and stress (1, 15, 33).

Finally, a careful investigation of the roles of gender, age, and nutrition status on executive cognitive functions and cognitive flexibility in the second hypothesis, utilizing hierarchal multiple regression, has rejected a role for gender in the prediction of cognitive flexibility and executive cognitive functions. However, results did reveal a significant effect of age and nutrition status on the prediction of cognitive flexibility and executive cognitive functions. However, both age and nutritional status had only mild predictive roles for the explanation of cognitive flexibility and executive cognitive functions variation in this study. Such results are congruent with earlier studies on nutrition and cognitive functions (7-11, 13-16). Also, the predictive roles of age and nutritional status on cognitive flexibility and executive cognitive functions may be explained in light of the hierarchy of needs, health belief, developmental, cognitive, and psychophysiological conceptualizations of nutrition (1, 20-22, 24-33). With regard to such conceptualizations, this study suggests that many people would like to choose a balanced diet to improve cognitive function and flexibility, and to realize the benefits on overall health, although this task is often difficult in real life.

Conclusions

This study demonstrates significant positive relationships between nutrition status and cognitive flexibility, the role of gender and nutrition status on executive cognitive functions and mental flexibility, and the lack of a gender influence within an Iranian adult sample. These findings may be useful for promoting positive physical and mental health programs through governmental policies, non-governmental organizations; and community-based programs by clinicians and health education professionals.

The present study has limitations in that it represented a correlational study and therefore could not delineate cause-and-effect relationships among the study variables. Future research might attempt to control the moderating effects of these variables so as to better understand the relationships between nutrition, executive cognitive functions, and cognitive flexibility in clinical and non-clinical samples.

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List of abbreviations

- Amsterdam Executive Function Inventory (AEFI)
- Cognitive Flexibility Scale (CFS)
- Coping with High Fat Foods (CHFF)
- Diet Oriented Nutrition (DON)
- Fast Food Tendency (FFT)
- High Fat Food Assumption (HFFA)

- Healthy Nutrition (HN)
- Nutrition Assessment Inventory (NAI)
- Saturated Fat (SF)
- Use of Complementary Nutritients (UCN)

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