Research Article

Executive Functions and Dietary Behaviors in School-Aged Children

Christine A. Limbers,[1,*] Kaitlyn Egan,[2] and L. Adelyn Cohen[3]

[1]Ph.D., Department of Psychology and Neuroscience, Baylor University
[2]M.S., Department of Psychology and Neuroscience, Baylor University
[3]M.S., Department of Psychology and Neuroscience, Baylor University

[*]Corresponding author: Christine A. Limbers, Ph.D., Associate Professor, Department of Psychology and Neuroscience, Baylor University, One Bear Place #97334, Waco, TX 76798, U.S. Tel: +254-7102485, E-mail: christine_limbers@baylor.edu

Abstract

Background: Studies that have evaluated executive functions and dietary behaviors in school-aged children have found that deficits in executive functions are correlated with greater intake of high-caloric-low-nutritional foods and snacks and lower consumption of fruits and vegetables. However, since these studies analyzed executive functioning as a unidimensional outcome variable, the correlations between dietary behaviors and specific domains of executive functioning were not evaluated. The objective of the present study was to assess the associations between dietary behaviors and three domains of executive functioning (i.e., inhibition, working memory, planning/initiation skills) in a sample of school-aged children.

Methods: In this cross-sectional study, one-hundred-two, 8th grade students from a public middle school in the United States (mean age = 13.91; SD = 0.51; 62.7% female) completed a demographic questionnaire, a self-report measure of executive functioning (Behavior rating inventory of executive function-BRIEF), and self-report measures of dietary behaviors (adolescent food habits checklist, diet subscale of the summary of diabetes self-care activities questionnaire). Their parents completed the parent version of the BRIEF. Pearson correlations and multiple linear regression analysis were conducted.

Results: After controlling demographic factors (e.g., gender, race/ethnicity, parent education), self-reported planning/initiation skills were associated with healthier eating habits (unstandardized estimate = -0.16; P < 0.01).

Conclusions: These findings underscore the need for research evaluating the efficacy of techniques like implementation intentions that target planning/initiation skills in order to increase the consumption of healthy foods in school-aged children.

Keywords: Executive Functions, Diet, Youth

1. Background

Childhood obesity is a major public health concern (1). In 2015, over 42 million children worldwide were overweight or obese and this number is projected to rise to 70 million by 2025 (2). Obesity during childhood is associated with significant health complications including cardiovascular disease, hypertension, and type II diabetes (3). Diet is one factor that contributes to the development of obesity in children (4, 5). As such, concerted efforts are being made to identify modifiable cognitive and behavioral factors associated with children's dietary behaviors.

Executive functions are cognitive processes that facilitate top-down control over learned responses and play a pivotal role in the regulation of dietary behaviors (6, 7). Inhibition, working-memory, and planning/initiation skills have been among the most studied executive functions in relation to dietary behaviors (8). Studies in adults have demonstrated lower inhibition is correlated with unhealthy dietary behaviors such as overeating and consumption of high saturated fat foods (9-12). Greater initiation/planning skills are correlated with healthy dietary be-

haviors in adults including fruit and vegetable intake and eating breakfast (12, 13). The relationship between working memory and dietary behaviors is less clear, with one study indicating stronger working memory abilities are related to greater intake of fruits and vegetables (14), and another study finding no such association (12). Taken together, these studies indicate executive functions that promote healthy dietary behaviors may be distinct from those that lead to undesired eating behaviors in adults.

Relatively fewer studies have evaluated executive functions and dietary behaviors in school-aged children. These studies have found that deficits in children's executive functions are correlated with greater intake of high-caloric-low-nutritional foods and snacks (15-18) and lower consumption of fruits and vegetables (17). A major limitation of these existing studies is that all but one (16) analyzed executive functioning as a unidimensional outcome variable. As such, the associations between dietary behaviors and specific domains of executive functioning were not examined.

Wills et al. (2007) found that better initiation/planning skills were correlated with increased fruit and vegetable

consumption and deficits in inhibition were related to higher intake of saturated-fat foods in a multiethnic sample of 9th grade students [16]. Based on the results of Wills et al. (2007) and findings in the adult literature that indicate executive functions that predict healthy dietary behaviors and undesired eating behaviors are distinct, further research is needed to elucidate distinct facets of executive functioning that are associated with dietary behaviors in children. Such information may inform the development of cognitive-behavioral interventions for school-aged children that aim to alter dietary behaviors.

The objective of the present study was to evaluate the associations between dietary behaviors and specific domains of executive functioning (i.e., inhibition, working memory, planning/initiation skills) in sample of 8th grade students. Based on the extant literature with adults [9-13] and children [16], we hypothesized (a) stronger inhibitory control would be associated with lower consumption of foods high in saturated fat, (b) stronger initiation/planning skills would be associated with greater consumption of fruits/vegetables and healthier eating habits, and (c) working memory abilities would not be associated with intake of foods high in saturated fat or greater consumption of fruits/vegetables and healthier eating habits.

2. Methods

2.1. Participants

This cross-sectional study sample consisted of 102, 8th grade students attending a public middle school in the Southern United States.

2.2. Measures

The behavior rating inventory of executive functioning (BRIEF) is a standardized rating scale that evaluates everyday behaviors associated with specific domains of executive functions in children and adolescents [19]. Participants completed the self-report form of the BRIEF, which contains 80 items that make up eight clinical scales (inhibit, shift, emotional control, monitor, working memory, plan/organize, organization of materials, task completion) and two summary index scales (behavioral regulation index, metacognition index). Parents also completed the parent form of the BRIEF, which contains 86 items that make up similar clinical scales. All scores are reported on a T-score scale (M = 50, standard deviation (SD) = 10), with scores $\geq$ 65 considered clinically significant. The BRIEF self-report and parent forms have demonstrated internal consistency reliability, convergent validity, and construct validity in school-aged populations [19]. Consistent with the adult literature in which inhibition, working-memory,

and initiation/planning skills have been among the most studied executive functions in relation to dietary behaviors [8] the following subscales were used in the present study: inhibition, working memory, and plan/organize.

Dietary behaviors: the diet subscale of the summary of diabetes self-care activities (SDSCA) questionnaire was used to assess consumption of fruit and vegetables as well as saturated fat intake [20]. Participants answered the following two questions: (a) On how many of the last 7 days did you eat five or more servings of fruits and vegetables? (b) On how many of the last 7 days did you eat high-saturated fat foods such as red meat or full-fat dairy products? Responses ranged from 0 to 7. These items have demonstrated strong psychometric properties across multiple studies [21].

Participants also completed the adolescent food habits checklist [22]. The 23-item self-report instrument provides an overall measure of healthy eating behaviors in adolescents. Items pertain to consumption of fats and fibers, simple sugars, and fruits and vegetables and are scored true, false, or not applicable. The dietary behavior score was used in the present study [22]. It was calculated by assigning a one point value to healthy food choices and adjusting the final score for not applicable and missing responses utilizing the following formula: number of healthy response choices x (23/number of items completed). Higher scores are indicative of healthier eating behaviors [22]. The adolescent food habits checklist has demonstrated good psychometric properties [22].

Body mass index (BMI): graduate research assistants objectively measured height and weight for each student. BMI was computed by entering the student's height, weight, age, and sex into centers for disease control and prevention (CDC) pediatric growth charts for children between the ages of 2 and 19. BMI, BMI percentile rank, and BMI z-score were calculated and recorded on a paper with the participant's ID number. A BMI below the 5th percentile was considered underweight, a BMI at the 5th and below the 85th percentile was classified as normal weight, a BMI at the 85th and below the 95th percentile was considered overweight, and a BMI at or greater than the 95th percentile was classified as obese.

Demographic information: participants completed a brief demographic questionnaire that gathered information about their gender, age, race/ethnicity, and parental highest educational attainment. Gender, race/ethnicity, and parental highest education were used as control variables in the current study.

2.3. Procedure

Participants were a convenience sample of students recruited through health and lifestyle courses offered at

their middle school. To be eligible to participate in the study, students had to be in middle school, be able to read and write in English, and not have a developmental or intellectual disability that would prevent them from reliably completing the study questionnaires. The primary investigator and a graduate research assistant provided a short explanation of the study to eight classes, distributed an information packet to those interested in participating, and answered any questions or concerns. The information packets contained written informed consent and assent paperwork and the parent version of the BRIEF. Students were instructed to look over the information with their parent or guardian for approval and return the packet with a parent or guardian's signature and a completed parent BRIEF form. Approximately, one week following the first visit, the researchers returned to the middle school classes to collect returned and completed packets. After it was verified that written consent and assent were obtained and study eligibility criteria was met, the student was provided with a packet that contained the demographic questionnaire, the BRIEF self-report form, the adolescent food habits checklist, and the diet subscale of the summary of diabetes self-care activities questionnaire. The student was asked to complete the packet of questionnaires in their classroom at that moment as their teacher provided quiet time for the entire class. After the participant completed the measures, a graduate research assistant measured height and weight individually in a private hallway outside the classroom to ensure privacy. Data collection occurred during three separate visits. Each participant took approximately 30 minutes to complete the questionnaires and have their height and weight measured. The university's institutional review board (IRB) approved the study procedures before data collection began.

2.4. Statistical Analysis

Pearson's product moment correlations were calculated between the BRIEF Inhibit Score, BRIEF working memory score, BRIEF planning/organization score, adolescent food habits checklist dietary behavior score, and fruit/vegetable intake and high-saturated fat food consumption items on the summary of diabetes self-care activities questionnaire. Pearson's Product Moment Correlation coefficient effect sizes were designated as small (0.10 - 0.29), medium (0.30 - 0.49), and large (> 0.50) (23).

Multiple linear regression analysis was conducted with 6 separate models. Fruit and vegetable consumption (summary of diabetes self-care activities questionnaire) was the outcome for two models. Saturated fat intake (summary of diabetes self-care activities questionnaire) was the outcome for two additional models. Finally, the adolescent

food habits checklist dietary behavior score was the outcome for the final two models. Each model used hierarchical entry with demographics (e.g., gender, race/ethnicity, parent education) entered in the first block as control variables. The 3 BRIEF-A self-report clinical scales were entered in the second block of three models; the 3 BRIEF-A parent proxy-report clinical scales were entered in the second block of the three remaining models. In each model the increment in variance accounted for by executive functions entered in the second block was tested for statistical significance ($P < 0.05$). Statistical analyses were conducted in SPSS Version 19 for Windows (24).

3. Results

3.1. Sample Demographics

The mean age of the 102 students was 13.91 years (SD = 0.51; Range = 13.0 - 15.0 years). The sample was predominantly female (62.7%). The majority of the sample identified as White (61.8%), followed by 12.7% other, 11.8% Latino, 7.8% Black, and 5.9% Asian. Most of the participants (72.6%) reported that at least one of their parents had received a college degree. The majority of participants (68.6%) had a BMI that fell in the normal range, followed by 18.6% obese, 9.8% overweight, and 2.9% underweight.

3.2. Descriptive Statistics

For the current sample, mean T scores on the BRIEF self-report version were as follows: BRIEF inhibition = 48.60 (SD = 11.56; range = 34 - 78), BRIEF working memory = 52.87 (SD = 12.96; range = 33 - 94), BRIEF planning/organization = 48.70 (SD = 10.49; range = 31 - 80). Mean T scores on the BRIEF parent version were as follows: BRIEF inhibition = 53.65 (SD = 12.55; range = 41 - 91), BRIEF working memory = 55.88 (SD = 11.70; range = 40 - 87), BRIEF planning/organization = 53.34 (SD = 10.41; range = 38 - 82). The mean score on the item pertaining to fruit/vegetable consumption in the last 7 days was 3.77 (SD = 2.05; Range = 0 - 7); for the item pertaining to intake of high-saturated fat foods in the last 7 days, the mean score was 3.76 (SD=2.02; Range = 0-7). On the Adolescent Food Habits Checklist Dietary Behavior Total Score, the mean score for the sample was 10.74 (SD = 3.87; Range = 2 - 18.82).

3.3. Pearson Correlations

Table 1 presents the intercorrelations among the BRIEF inhibit score, BRIEF working memory score, BRIEF planning/organization score, adolescent food habits checklist dietary behavior score, and fruit/vegetable intake and high-saturated fat food consumption items on the summary of diabetes self-care activities questionnaire.

The intercorrelation between self-reported BRIEF planning/organization score and adolescent food habits checklist dietary behavior score approached statistical significance ($r = -0.19$; $P = 0.05$). Better self-reported planning/organizational skills on the BRIEF were associated with healthier eating behaviors. None of the correlations between the parent BRIEF scores, the adolescent food habits checklist dietary behavior score, and fruit/vegetable intake and high-saturated fat food consumption items were statistically significant.

Table 1. Intercorrelations Among BRIEF, Adolescent Food Habits Checklist Dietary Behavior Score, and Fruit/Vegetable Intake and High-Saturated Fat Food Consumption[a,b]

	Fruit/Vegetable	High-Saturated Fat Food	Dietary Behavior Score
Self-Report BRIEF Scales			
Inhibit	0.06	0.11	0.03
Working Memory	0.08	0.13	-0.03
Planning/Organ	-0.10	0.12	-0.19¤
Parent-Report BRIEF Scales			
Inhibit	0.06	0.03	0.01
Working Memory	0.03	-0.08	-0.02
Planning/Organ	-0.05	-0.03	-0.13

[a]$P = 0.05$.
[b]Effect sizes are designated as small (0.10), medium (0.30), and large (0.50) for Pearson's product moment correlations.

3.4. Multiple Linear Regression Analysis

Table 2 contains unstandardized estimates and standard errors for the three models for which the primary outcomes were fruit/vegetable consumption, saturated fat intake, and the adolescent food habits checklist dietary behavior score. After controlling for demographic variables (e.g., gender, race/ethnicity, parent education) in the first model, the correlation between the self-report BRIEF Planning/Organization Scale and fruit and vegetable consumption approached statistical significance (unstandardized estimate = -0.06; $P = 0.05$). Self-reporting better planning/organization skills on the BRIEF was associated with greater consumption of fruits and vegetables in the last 7 days. In the second model, none of the BRIEF self-report scales were associated with consumption of high-saturated fat foods. However, the correlation between race/ethnicity and consumption of high-saturated

fat foods approached statistical significance (unstandardized estimate = -0.82; $P = 0.05$) in that identifying as White was associated with lower consumption of high-saturated fat foods in the last 7 days. After controlling for demographic variables (e.g., gender, race/ethnicity, parent education) in the third model, the self-report BRIEF planning/organization scale was significantly correlated with the adolescent food habits checklist dietary behavior (unstandardized estimate = -0.16; $P = 0.00$). Self-reporting better planning/organizational skills on the BRIEF was associated with healthier eating behaviors. In the third model, the addition of the 3 BRIEF self-report scales in block 2 significantly increased the variance accounted for by the independent variables ($P < 0.01$).

Table 3 contains unstandardized estimates and standard errors for the three models for which the primary outcomes were fruit/vegetable consumption, saturated fat intake, and the adolescent food habits checklist dietary behavior score. None of the parent proxy-report BRIEF scales were significantly correlated with fruit/vegetable consumption, intake of high-saturated fat foods, or the adolescent food habits checklist dietary behavior score.

4. Discussion

The objective of the present study was to evaluate the associations between dietary behaviors and specific domains of executive functioning (i.e., inhibition, working memory, planning/initiation skills) in a sample of 8th grade students. Consistent with our hypothesis, working memory abilities were not associated with any of the dietary outcome variables in our sample. In line with previous literature (9-13), planning/initiation skills were associated with healthier eating habits in our sample of 8th grade students. This finding was consistent across two separate self-report measures of dietary behaviors and was present after controlling for demographic variables (e.g., gender, race/ethnicity, parent education). It is noteworthy that these findings are consistent with a study conducted by Wills et al. (2007) with multiethnic adolescents in a different region of the United States, despite methodological differences including different questionnaires and statistical analytic procedures.

Taken together, these findings provide further evidence for the association between planning/initiation skills and healthy diet choices among school-aged children and are consistent with research on implementation intentions (i.e., the use of if-then plans to help people articulate the ways they will accomplish a targeted goal). In their systematic review, Adriaanse and colleagues (2011) found implementation intentions were an effective method for

Table 2. Multiple Linear Regression Analysis for Self-Report BRIEF[a]

Variables	Fruit and Vegetables		Foods High in Saturated Fat		Dietary Behavior Score	
	Estimates	S.E.	Estimates	S.E.	Estimates	S.E.
Block 1						
Gender	0.27 (P = 0.52)	0.42	-0.72 (P = 0.09)	0.41	0.93 (P = 0.27)	0.78
Race/Ethnicity	0.00 (P = 0.87)	0.44	-0.82 (P = 0.05)	0.43	-0.11 (P = 0.99)	0.80
Parent Education	-0.10 (P = 0.73)	0.43	0.11 (P = 0.84)	0.43	0.97 (P = 0.21)	0.80
Block 2						
Self-Report Inhibition	0.01 (P = 0.95)	0.02	0.01 (P = 0.67)	0.02	0.04 (P = 0.36)	0.04
Self-Report Working Memory	0.05 (P = 0.08)	0.03	0.00 (P = 0.94)	0.03	0.09 (P = 0.07)	0.05
Self-Report Planning Skills	-0.06 (P = 0.05)	0.03	0.02 (P = 0.49)	0.03	-0.16 (P = 0.00)	0.05

Abbreviation: S.E., standard error.
[a] Estimates presented are unstandardized for the full model.

Table 3. Multiple Linear Regression Analysis for Parent Report BRIEF[a]

Variables	Fruit and Vegetables		Foods High in Saturated Fat		Dietary Behavior Score	
	Estimates	S.E.	Estimates	S.E.	Estimates	S.E.
Block 1						
Gender	0.33 (P = 0.47)	0.44	-0.72 (P = 0.10)	0.42	0.85 (P = 0.34)	0.84
Race/Ethnicity	0.03 (P = 0.80)	0.45	-0.89 (P = 0.03)	0.43	0.27 (P = 0.65)	0.85
Parent Education	-0.06 (P = 0.62)	0.46	-0.13 (P = 0.47)	0.44	1.25 (P = 0.14)	0.87
Block 2						
Parent Report Inhibition	0.02 (P = 0.41)	0.02	0.01 (P = 0.73)	0.02	0.03 (P = 0.43)	0.04
Parent Report Working Memory	0.02 (P = 0.55)	0.03	-0.02 (P = 0.50)	0.03	0.06 (P = 0.36)	0.04
Parent Report Planning Skills	-0.03 (P = 0.38)	0.03	0.01 (P = 0.92)	-0.09	-0.24 (P = 0.16)	0.06

Abbreviation: S.E., standard error.
[a] Estimates presented are unstandardized for the full model.

increasing consumption of healthy foods across 23 empirical studies (Cohen's d = 0.51). Only one of the studies included in this systematic review involved children (25). The present findings underscore the need for additional research examining the efficacy of techniques like implementation intentions that target planning/initiation skills in school-aged children in order to increase the consumption of healthy foods.

Contrary to our hypothesis and previous literature (9-12, 16), inhibition was not associated with intake of high-saturated fat foods in our sample. This finding may in part be a result of methodological differences between the studies, particularly in how consumption of high-saturated fat foods was measured. For example, Wills et al. (2007) used a 14-item measure of saturated-fat food consumption over the past year in their sample of 9th grade students. In the present study, we utilized a single-item

measure of saturated-fat food intake in the last 7 days. There is a critical need for a "gold standard" in the measurement of dietary behaviors in school-aged children as this will facilitate comparison of findings across empirical studies (26). Other methodological differences between the current study and previous studies (9-12) that may have contributed to dissimilar findings include use of different measures of inhibition, differences in sample size, and differences in age and racial/ethnic composition of the samples. While the present study did not support an association between inhibition and saturated-fat intake in school-aged children, it will be important for future research with school-aged children to investigate this relationship.

In the current study, the child self-report BRIEF scores generally correlated stronger with dietary outcomes (in comparison to the parent report BRIEF scores). This finding may in part be explained by the shared variance of

the reporters. Studies that have examined agreement between child and parent reports of child executive functioning on behavioral rating scales have generally found low agreement (27). It would be valuable for future research with school-aged children to also include parent reports of child dietary behaviors to examine whether these measures demonstrate stronger associations with parent reports of child executive functioning.

There were a number of limitations to the present study. The cross-sectional design precludes us from inferring causation. We used a convenience sample and did not perform a power analysis to calculate a pre-determined sample size. As such, our small sample may have lessened the likelihood of detecting statistically significant correlations. Our measures of dietary behaviors were exclusively self-report and as a result may have been affected by self-report bias. Finally, our sample was comprised predominantly of White, middle to upper middle class, normal weight school-aged children. As such, our findings may have limited generalizability.

Footnote

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