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# Executive Cognitive Function and Food Intake in Children

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## INTRODUCTION

The neuro-circuitry involved in the self-regulation of food intake is receiving increased research attention, due in large part to a link between behavioral dysregulation and food intake and both increased energy intake and energy imbalance.[1,2] Executive cognitive function (ECF) skills are those considered to be higher-order, cognitive processes necessary for goal-directed problem solving behavior, and which are associated with prefrontal cortical integration with emotion processes in the limbic system.[3,4] Examples of ECF are inhibitory control, emotional control, planning, sequencing, and working memory, all of which are critical for youth behavioral development.[3–5] Previous studies have linked executive cognitive dysfunction to dysregulated behavior in domains such as conduct problems, antisocial behavior, and substance use disorders.[6,7] However, to date, very little research has investigated a potential role of ECF in the dysregulation of food intake.

Executive cognitive function may be linked to dysregulated food intake via multiple mechanisms. Inhibitory control may play a role in inhibiting food related thoughts and/or appetitive behaviors in the face of situational cues for (over)consumption of snack foods.[8] The ability to cognitively control emotion may also play a role in overweight and obesity as negative mood states have been shown to increase food intake.[9,10] Working memory also appears to assist in the execution of healthy behavior by allowing youth to hold nutritious plans "on-line."[11] That is to say that once a healthy plan and its sequence of steps drop "off-line" there may be a greater likelihood that this plan falls apart, especially if these plans have not yet become routine or habit.

### Executive Cognitive Function as a Gatekeeper for Food Intake and Selection of Food Types

The relation between ECF and food intake may vary by type of food.[12] For example, high calorie, or "snack food," may be extremely rewarding for young children and place high emotional and/or motivational drives on their still developing executive cognitive systems, similar to that which is produced by some drugs.[13,14] As a result, motivation to eat highly palatable foods may be especially difficult for young children to inhibit. It might be expected that youth with more advanced executive skills are better equipped than those less skilled to inhibit intake of snack food in the face of strong impulses. If so, one would expect a negative relationship between ECF and snack food intake. However, the relation between emotional



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aspects of highly palatable food and specific executive cognitive functions is not well understood.

Conversely, the relatively lower palatability of vegetables, and to a lesser extent fruit, may result in a decreased emotional load and motivation to consume. However, the consumption of vegetables and fruit is critical to long-term health. In the absence of a strong drive to eat vegetables and fruit it may become important for youth to engage higher order ECF skills critical for developing long-term goals for physical health including vegetable and fruit consumption. It might be anticipated that youth with greater ECF skills would be more proficient in formulating long-term healthy plans, and as a result there may be a positive relationship between ECF and vegetable and fruit intake.

### Hypotheses

Currently, few if any nutrition education programs for youth account for the fact that much of food intake is impulsive or emotionally driven.[8-10] Findings confirming a link between neuro-cognitive skills related to control over impulsive, emotionally-driven food intake might suggest areas where additional content can be developed that may improve the effectiveness of nutrition education programs. The current study investigates concurrent relationships among ECF and three categories of food intake; snack food (e.g., soda, potato chips), vegetables, and fruit. Hypothesis 1 was that self-reported ECF would be negatively associated with the intake of snack food. Hypothesis 2 was that ECF would be positively associated with vegetable and fruit intake.

## METHOD

### Research and measurement designs

All data were drawn from a school-based obesity prevention pilot study entitled Pathways to Health (Pathways).[15] The dual purposes of the pilot were to compare the psychometric properties of executive cognitive function, food intake, and physical activity measures, as well as to develop and test the 4th grade intervention component of a multi-component obesity prevention program. Youth completed one of four survey versions at both baseline (pre-intervention) and immediate follow-up. The current study utilized baseline data collected from all youth who received the survey version with both ECF and food intake items. All procedures were approved by the University of Southern California Institutional Review Board.

### Participants

Pathways pilot participants were 353 consented 4th grade students, from 17 classrooms, in five schools, from Southern California. The mean age of participants was 9.4 years, 54% were female, and 91% were Latino, which represented each school’s population demographic characteristics. Four percent of the participants were African-American, with no other racial or ethnic group making up more than 2% of the sample. Seventy-four percent reported receiving a free lunch at school. One hundred percent of these participants completed one of four survey versions. Of the 353 participants, 107 completed a survey version that included both ECF and food intake items. It is these participants that make up the study sample. There were no significant differences by age, ethnicity, gender, or free lunch between those 107 who completed the survey version with study variables of interest and those 246 who completed alternative versions of the survey.

### Measures

The survey consisted of 143 items and took approximately 45-50 minutes to complete. The survey was administered aloud by a trained data collector, with a second data collector available to answer individual student questions about comprehension. As with other school-based studies[16,17], we were constrained to one class period, approximately 45 minutes, for data collection. Due to these constraints of survey length, we were forced to use abbreviated versions of some food intake scales. The limitation of this strategy is that the validity of the abbreviated scales, relative to the original scales, has not been assessed. However, there is support in the psychometric literature for using abbreviated scales[18] and the practical reality of school-based prevention research is that assessment tools must be administered within the restrictions of time for school-based assessment.

Items from 4 of 8 clinical sub-scales of the BRIEF, Self-Report[19] were included. The four sub-scales included emotional control (e.g., “I yell, scream, or cry for no reason”), inhibitory control (e.g., “I do things without thinking first”), working memory (e.g., “I forget what I’m doing in the middle of things”), and organization of materials (e.g., “My desk is a mess”). Item response choices ranged from 1 = Never, 2 = Sometimes, 3 = Often. Scores were subsequently reversed such that higher scores represented greater ECF proficiency. Internal consistencies for BRIEF scales are moderate to high (range .72-.96).[19]

Food intake items were taken from validated food frequency questionnaires. Fruit and vegetable intake items were adapted from the Youth Risk Behavior Survey (YRBS).[20] Two of these items assess fruit intake over the past week (e.g., “How often did you eat any fruit, fresh, or canned”), and four assess vegetable intake (e.g., “How often do you eat green salad”). Since the YRBS does not ask questions regarding snack food intake, 5 items (e.g., “How often do you drink soda – not diet (1 can or glass)) were taken from a validated open-source food frequency questionnaire.21 The choice to select a subset of items from this questionnaire was based on constraints of survey length. The five items were selected by project investigators who have used these items in previous studies22, and were compared to school teacher reports of snack food intake of their students, and results of the California Healthy Kids Survey. Abbreviated versions of food frequency questionnaires have demonstrated validity for $4^{th}$ grade youth[18] and these specific items have been used with younger populations.[22] Response choices for food intake items were 1 = “Less than once a week,” 2 = “Once a week,” 3 = “2-3 times a week,” 4 = “4-6 times a week,” 5 = “Once a day,” and 6 = “2 or more of these a day.”

### Data analytic strategy

All analyses were conducted using SAS (SAS. version 9.1. SAS Institute., Cary, NC, 2005) unless otherwise noted. First, principal components analyses with promax rotation were conducted for food intake items. Promax rotation was employed due to the likelihood that resulting factors would be correlated. Mean scores were then constructed by taking the mean among items within the resulting factors. Since ECF factors were likely to be at least moderately correlated, a confirmatory factor analysis was conducted with AMOS (AMOS. Version 17.0. SPSS., Inc., Chicago, IL, 2008) in order to determine whether there was a single higher-order ECF factor. In the case that the CFA confirmed a single higher-order factor a mean score for this factor would be calculated by taking the mean of each individual BRIEF item. In the case that a single higher-order factor did not fit the data a mean score would be calculated for each individual clinical scale.

Previous studies have shown some differences in obesity risk by gender, ethnicity, and socioeconomic status23, although the causal relationships are still not well understood and in some cases the findings are mixed. In addition, studies on child development have shown that executive cognitive function may be related to academic achievement.[24] Thus, our preliminary analyses explored the use of all four of these factors as potential covariates in analyses. To yield the most parsimonious model, we first analyzed whether any of these factors were significantly related to our variables of primary interest. Those factors that showed no significant relationships were eliminated from further analyses. School grades ranged from

"Mostly 4s" which were roughly equivalent to As to "Mostly 1s" which were roughly equivalent to Ds. Covariates for which significant differences were found were retained for subsequent analyses. Finally, regression models were conducted with food intake factors included as dependent variables and the ECF scale(s) as well as retained covariates included as independent variables.

## RESULTS

Internal consistency coefficients of the BRIEF scales were .78 for inhibitory control, .63 for emotional control, .78 for working memory, and .66 for organization of materials. As expected these scales were moderately inter-correlated (Table 1). As a result a confirmatory factor analysis (CFA) was conducted to determine whether a higher order factor structure among ECF factors was present. The excellent fit of the CFA model (Chi-Square = 0.36, DF = 2; NFI = .998, CFI = 1.000; RMSEA = .000) confirmed a single ECF factor. Therefore, a single ECF score was computed that represented the mean of each BRIEF item. Principal components analysis yielded an expected three-factor solution of food intake in which factors had eigenvalues of greater than 1.0. These factors were snack food intake (5 items), vegetable intake (4 items) and fruit intake (2 items).

Table 2 illustrates means and standard errors for the ECF factor and food intake scales. The mean ECF score indicates that children reported having ECF problems between "never" and "sometimes." Mean scores on the two fruit intake items approached "4-6 times per week." Mean scores on the 4 vegetable intake items was "2-3 times per week." Finally, mean scores on the 5 snack food intake items was slightly greater than "Once a week."

Table 3 illustrates bivariate correlations among major study variables. A negative correlation at the $p < .001$ level was found between ECF function and snack food intake. No significant correlations were found between ECF factors and fruit or vegetable intake. Among the food intake factors, only a significant positive correlation between fruit intake and vegetable intake was found ($p < .05$). Initial general linear models demonstrated that only one potential covariate was associated with any of the independent or dependent variables. Here school grades were positively associated with ECF ($\beta = .19$, $SE = .04$).

Table 4 illustrates the results from regression models testing the association between ECF and food intake. Presented in Table 4 are standardized betas and standard errors after taking into account school grades as a covariate. ECF was significantly and negatively related to snack food intake, indicating that children with greater ECF proficiency ate fewer snack foods. However, ECF was not significantly related to either fruit or vegetable intake.

## DISCUSSION

Results of this pilot study supported the hypothesis that ECF skills in children are related to snack food intake, which is one risk factor related to obesity. Potential explanations include that youth with enhanced cognitive inhibitory and emotional control skills are better at inhibiting the rewarding cognitive and emotional characteristics of snack foods, and that youth with greater working memory capacities can keep healthy goals "on-line" in the face of competing motivation to eat snack food. It is likely the case that multiple executive functions interact in an ultimate association with snack food intake, which would support the inclusion of a single higher-order ECF construct. Future studies with larger sample sizes may be able to tease apart the unique associations between individual executive cognitive functions and food intake.

Further research should also be conducted with more heterogeneous populations. One of the strengths of the current study is that it was conducted on a largely Latino sample, one that is a rapidly increasing segment of the population in general, and one that was representative of the local community. However, the current sample can not be considered representative of a national sample. In fact, since the majority of students received free lunch this sample may be considered to be relatively disadvantaged compared to a national sample. As a result some of these children may be exposed to limited amounts of fruits and vegetables at home and a greater proportion of their food intake may be driven by modeling and experience, rather than ECF skills.

Contrary to hypotheses, there were no significant relationships between ECF and vegetable or fruit intake. There are at least a few potentially interacting explanations for this lack of significant relationships. First non-significant relationships may reflect a relatively lower motivational and/or emotional load of these less palatable foods. Vegetables and perhaps fruit may have fewer inherently rewarding properties, making them less desirable to youth than high-calorie foods.[25] In turn, the lower motivational and emotional load of these foods may not require 4th grade children to employ ECF skills in decisions to eat these foods.

Culture may also play a role in food choices. For example, the early home environment for fruit and vegetable availability and preferences affect food intake into adulthood, and this availability can vary by ethnic group.[26] This potential explanation introduces the important point that children's neurocognitive functioning interacts in complex ways with other ecological contexts (e.g., family, school, and community) known to influence food intake. For example parents may facilitate executive cognitive development and health with positive parent-child communication and by setting clear rules for behavior at home, at school, and in other environments. Furthermore, the relationship between executive cognitive development and food intake may be related to several factors in the school environment including availability of healthy choices on lunch menus and in vending machines.

Current results should be considered in light of study limitations. One is the relatively small sample size. The lack of power associated with the small sample size may have obscured ECF relationships that might otherwise have been significant in larger studies and prohibited multi-group analyses or analysis of moderating effects. Larger-scale studies will be necessary in order to delineate more detailed relationships among individual ECF capacities and food intake. A second study limitation was the cross-sectional nature of the data. Because of the study design it was not possible to draw any causal conclusions as to the effect of ECF on snack food intake. Instead, the main contribution of the current analyses is the demonstration that the association exists. It may be the case that greater ECF contributes to less high-calorie food intake, or snack food intake may lead to ECF dysfunction. Future research can determine the (bi)directionality of the correlation between ECF and snack food intake.

The cross-sectional design also did not allow for examination of mediators, or a third, unmeasured variable, that could be responsible for the relationship between ECF and snack food. Perhaps snack food intake functioned as a proxy for an individual's access to health care, parental characteristics, or education. However, if this was the case in the current study, we might also expect to have seen significant positive associations among ECF and potential proxies of positive cardiovascular health such as vegetable and fruit intake, which was not the case.

A third potential limitation is the reliance on child self-report data. Since the main trial is conducted with approximately 1,500 students, clinical and observational data on the entire sample is prohibitive, and self-report surveys are used as the primary assessment method. Furthermore, the food intake scale was abbreviated to fit within the time restrictions associated with school-based assessment, which can raise some questions related to the validity of the scales. It should be noted however that the challenges of validating food frequency questionnaires is generally based in terms of the ability to measure total energy intake, which can be extremely difficult particularly in young children. However, the purpose of the current study was to examine the relationship between ECF and specific types of food intake, not total energy intake.

As with the vast majority of school-based prevention trials, youth were assessed throughout the entire school day based on research staff and teacher schedules. Schools and classrooms within schools were scheduled to represent the full range of teaching periods, in order to minimize any potential bias due to time of measurement. The limitation here is that this strategy potentially introduces variation in youth hunger/fullness when completing the survey.

A final potential limitation is that we focused on 4th grade students. It is not known yet whether ECF skills that appear to be associated with snack food intake in 4th graders may also be associated with vegetable and fruit choices as youth mature and gain more decision-making power. With the development of the frontal cortex, which starts in early childhood and continues into early adulthood, comes greater cognitive control over the emotion centers of the brain. As a result behavior becomes less emotionally-driven and more influenced by higher-order cognitive processing skills. As children exercise greater cognitive control over behavior they are better able to organize and execute healthy plans. This might manifest over time in significant correlations between ECF and behaviors that are less emotionally-driven and more related to cognitive decision-making skills (e.g., perhaps vegetable intake and physical activity) where there were no such correlations earlier in life. In addition, future research including that which will be conducted in the main Pathways trial will allow for these tests of possible ECF application shifting across types of food intake and food choices from 4th through 6th grade. The shifts could occur in types of ECF skills that relate to obesity risk and/or shifts in relationships to types of food intake.

## IMPLICATIONS FOR RESEARCH AND PRACTICE

If confirmed by future large-scale and more heterogeneous samples, the primary implication for the development of child nutrition education is that program developers may consider adding content that targets the promotion of ECF skills. This can be done by providing focused and sequenced curricula/activities that allow youth to practice emotion regulation and problem solving skills in contexts where they will be making nutrition related decisions. This may be particularly important during periods of rapid structural and functional development of the brain related to ECF, which begin in childhood and continuing through late adolescence.[28]

With this combined approach, youth may: a) be armed by traditional nutrition education content with a cognitive understanding of the nutrition content of foods, and b) be able to regulate their consumption of food intake when emotionally or impulsively driven. Although this strategy has not yet been applied to nutrition education programs, it has been successfully applied to programs that enhance youth social-emotional, educational, and behavioral development.[29,30]

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**Table 1**

Correlations among executive cognitive function scales (n = 107).

| | 1 | 2 | 3 |
|---|---|---|---|
| 1. Inhibitory Control | | | |
| 2. Emotional Control | .45*** | | |
| 3. Working Memory | .57*** | .55*** | |
| 4. Organizational Skills | .59*** | .52*** | .67*** |

*** = $p < .001$,

**Table 2**

ECF and food intake means and standard deviations.

| | X | SD |
|---|---|---|
| ECF | 2.3 | .3 |
| Snack Food Intake | 2.3 | 1.0 |
| Vegetable Intake | 3.1 | 1.1 |
| Fruit Intake | 3.8 | 1.3 |

ECF = Executive Cognitive Function, range 1-3. Food intake ranges = 1-6.

**Table 3**

Correlations among main study variables (n = 107).

| | ECF | Junk Food Intake | Vegetable Intake |
|---|---|---|---|
| 1. ECF | | | |
| 2. Snack Food Intake | 39*** | | |
| 3. Vegetable Intake | .08 | .17 | |
| 4. Fruit Intake | −.03 | .09 | .23* |

ECF = Executive Cognitive Function.

*** = $p < .001$,

* = $p < .05$.

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**Table 4**

General linear models predicting food intake.

| | Snack Food | | Vegetable | | Fruit | |
|---|---|---|---|---|---|---|
| **Independent Variable** | **β** | **SE** | **β** | **SE** | **β** | **SE** |
| Grades | .09 | .10 | .17 | .11 | .11 | .11 |
| ECF | $-.41^{***}$ | .10 | .01 | .11 | .07 | .11 |

ECF = Executive Cognitive Function. Grades range from 1-4.

$^{***}$ = $p < .001$.