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Association of usual self-reported dietary intake with ecological momentary measures of affective and physical feeling states in children ★

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Abstract

Background—Little is known about the relationship between dietary intake and affective and physical feeling states in children.

Purpose—The current study used Ecological Momentary Assessment (EMA) to examine how usual dietary intake is cross-sectionally associated with both average affective and physical feeling state ratings and rating variability in children.

Methods—Children (N = 110, mean age = 11.0 ± 1.2 years, 52.5% male, 30.1% Hispanic/Latino) completed EMA measures of affective and physical feeling states 3–7 times per day for a full or partial day (weekday evenings and weekend days and evenings) over a 4-day period. Usual intake of pre-selected dietary components was measured prior to the EMA measurement period using the Block Kids Food Screener. Statistical analyses included mixed models and mixed-effects location scale models.

Results—Greater usual fiber intake was cross-sectionally associated with higher average positive affect (PA) ratings, lower variability of NA ratings, and higher variability of physical fatigue ratings. Lower usual glycemic load of diet was cross-sectionally associated with lower variability of NA ratings. Lower usual added sugar intake was cross-sectionally associated with higher average physical energy ratings and lower variability of NA ratings.

Conclusions—Although temporal precedence was not established by these findings, they indicate that characteristics of children's usual dietary intake are cross-sectionally associated with both the average and variability of affective and physical feeling states. EMA offers a promising avenue through which to explore the associations between affective states and diet and has the potential to provide insight into nuances of this relationship.

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Keywords

Dietary intake; Affective state variability; Ecological momentary assessment; Affect; Physical feeling state

Introduction

A growing body of evidence indicates that dietary intake may be related to psychological states. Laboratory-based studies on the short-term effects of food on affect have demonstrated that macronutrient composition of meals can have direct positive or negative influences on postprandial affect and alertness (Mac Evily & Kelly, 2001). For example, high-protein foods can increase alertness and high-carbohydrate foods can temporarily ameliorate negative affect (Mac Evily & Kelly, 2001), but can lead to an increase in fatigue and decline in feelings of energy over the longer-term (Cristensen, 1993; Mac Evily & Kelly, 2001; Thayer, 1987). Evidence from longitudinal research has shown that aspects of dietary intake can be prospectively linked to negative mood. For example, one study examining the impact of very-low carbohydrate diets versus low-fat, high-carbohydrate diets on mood in adults found that over the long-term, participants in the very-low carbohydrate condition had higher negative affect ratings than participants in the low-fat, high-carbohydrate condition (Brinkworth, Buckley, Noakes, Clifton, & Wilson, 2009). The relationship between food and affect has a biological basis such that macronutrients, including carbohydrates and protein, function as precursors for neurotransmitters and hormones that can impact affect (Mac Evily & Kelly, 2001; Prasad, 1998). While this illustrates that affect can be influenced by dietary intake, additional evidence indicates that this relationship is bi-directional such that affect can also affect food choice.

Much of the research on the impact of affect on dietary intake has focused on the influence that negative affect can have on food choice. Psychological stress, for instance, has been shown to be associated with increased consumption of highly-palatable, sweet and high-fat snack foods (Kandiah, Yake, Jones, & Meyer, 2006; Lowe & Fisher, 1983; Steptoe, Lipsey, & Wardle, 1998; Tice, Bratslavsky, & Baumeister, 2001; Wansink, Cheney, & Chan, 2003) even among those who tend to eat less than usual when stressed (Mac Evily & Kelly, 2001). Positive affect has also been associated with food choice. There is evidence that people choose more healthful foods (such as raisins over buttered popcorn) (Wansink et al., 2003) when experiencing positive affect, consistent with values some individuals place on maintaining a healthful diet (Christensen & Brooks, 2006). Changes in food preferences due to affect can be explained by the psychosomatic hypothesis and by affect regulation theories. The psychosomatic hypothesis states that overconsumption of food in some individuals represents an attempt to cope with negative affect (Kaplan & Kaplan, 1957). According to theories of affect regulation, an individual undergoing the aversive experience of negative affect will tend to seek ways to ameliorate the negative affect by consuming foods that are valued as hedonically pleasing or rewarding; conversely, an individual experiencing positive affect will tend to seek ways to maintain positive affect by avoiding consumption of less healthful foods that may be subsequently regretted (Andrade, 2005; Garg, Wansink, & Inman, 2007). Previous research and explanatory models lay out a link between affect and

ratings and ranked intake data for pre-selected dietary variables: fruits, vegetables, whole grains, fiber, saturated fat, and added sugar, as well as glycemic load of diet. Based on evidence from previous studies (Christensen & Brooks, 2006; Cristensen, 1993; Kandiah et al., 2006; Lowe & Fisher, 1983; Lyman, 1982; Steptoe et al., 1998; Tice et al., 2001; Wansink et al., 2003) we hypothesized that children with the highest levels of fruit, vegetable, whole grain, and fiber intake, lowest levels of saturated fat and added sugar intake, and lowest level of glycemic load of reported dietary intake would have greater subject-level or WS mean PA and physical energy ratings, whereas children with the lowest levels of fruit, vegetable, whole grain, and fiber intake, the highest levels of saturated fat and added sugar intake, and the highest level of glycemic load of reported dietary intake would have greater average NA and physical fatigue ratings and higher subject-level or WS variability of PA, NA, physical energy, and physical fatigue ratings.

Methods

Participants and recruitment

Participants were drawn from Healthy PLACES, a larger trial that is examining the effects of the built environment on family obesity prevention, specifically the use of smart growth principles in community planning (Jerrett et al., 2013; Pentz, Almanza, Dunton, & Berrigan, 2010). The current study, Mobile Healthy PLACES, examined the relationships between children's neighborhood environments, physical activity, dietary intake, and health on a representative sub-sample of children who were administered an ecological momentary assessment measure in addition to other measures as part of the parent Healthy PLACES trial (Dunton, Intille, Wolch, & Pentz, 2012). A sample of children was recruited using informational flyers that were distributed at community events, residences, schools, community clinics, and churches. Participants were required to meet the following inclusion criteria: (a) live in Chino, California or surrounding communities within a 30 minute drive of Chino, California, (b) be in 4th–8th grade, (c) have an annual household income of < \$165,000, and (d) have the ability to complete questionnaires in English. Parental consent and child assent were collected prior to any study-related procedures. This study was approved by the Institutional Review Board at the University of Southern California.

Study design and protocol

The analytic data were the first of two EMA data collection waves. Subsequent to screening, eligible participants completed a data collection visit at home or at a local community site. Anthropometric and dietary intake measures were collected during this visit. For the next four consecutive days after the data collection visit, Ecological Momentary Assessment (EMA) was used to measure real-time affective and physical feeling states during weekday evenings and weekend days and evenings. EMA data were collected using a T-Mobile HTC Shadow mobile phone. The phone included a custom software program for EMA (<http://myexperience.sourceforge.net/>) and did not have calling or Internet capabilities. No data were collected during the months of January–February and July–August.

Measures

Dietary intake—Typical dietary intake was measured prior to the EMA data collection using the Block Kids Food Screener (version 2, NutritionQuest). This tool collects self-reported recall measures of the frequency and amount of food consumed over the past 7 days. It includes a 41-item food list and provides estimates of typical food group consumption. Frequency of consumption is measured by a 6-point scale (“none” to “every day”) for the question “How many days last week did you eat or drink it”, and amount consumed is measured using a 3-point scale (“a little”, “some”, “a lot”) for the question “How much in one day” for each food item. Examples of dietary variables that are generated from this instrument include average daily intake estimates of macronutrients such as grams of protein and food groups such as ounces of whole grains. The Block Kids Food Screener has been shown to have good validity for intake of food groups (Hunsberger, O’Malley, Block, & Norris, 2012).

All participants in the analytic sample had complete dietary data. Dietary data were screened for improbable caloric intake using a lower cutoff of 500 kilocalories per day (Willett, 1998). No upper cutoff was needed as the greatest reported daily caloric intake was below the previously used cutoff of 5000 kilocalories (Willett, 1998). Participants who reported improbable caloric intake of less than 500 kilocalories per day were excluded from this analysis ($n = 8$), resulting in a final analytic sample of 110 participants. There were no differences in age, gender, BMI percentile, ethnicity, or household income between those participants who were excluded from and those who were included in the analysis. Dietary variables (excluding pre-standardized glycemic load) were standardized for total daily caloric intake using a ratio to 1000 kilocalories in order to provide a relative estimate of the contribution of each of the dietary variables to overall dietary intake (Willett, 1998). Children were then ranked into tertiles (the lowest tertile [LT], the middle tertile [MT], and the highest tertile [HT]) for each of the dietary intake variables in order to further account for potential measurement error from underestimated reporting.

Ecological momentary assessment—EMA prompts were used to assess real-time PA, NA, physical energy, and physical fatigue during weekday evenings and weekend days and evenings. Participants carried a mobile phone and answered EMA prompts for a full or partial day over a four-day period from Friday at 4:00pm through Monday at 8:30pm, excluding school hours. A total of 20 EMA surveys (3–7 prompts per day) were prompted, each at a random time within a pre-programmed time interval (e.g., 8am–10am, 10am–12pm, 12pm–2pm). Participants were instructed to stop their activities and answer a short survey on the mobile phone when an EMA prompt was received. Each survey was available for a total of 10 minutes. If the survey was incomplete or unanswered after 3 minutes, a reminder prompt was sent. A second reminder prompt was sent after another 3 minutes if the survey was still incomplete or unanswered. After 10 minutes total, the survey closed and could not be accessed until the next prompting period. Participants were instructed to ignore surveys prompts during incompatible activities (e.g., sleeping, bathing). Participants received compensation of \$30.00 for participating in the study, and an additional \$1.00 for responding to each of the 20 EMA prompts (up to \$50.00 total).

The affective state items used in this study represent the fundamental dimensions of affect postulated by the circumplex model, which include valence (ranging from pleasure to displeasure) and arousal (ranging from activation to deactivation) (Posner, Russell, & Peterson, 2005). Based on relevance to the study aims, items that represent activated pleasure (HAPPY, JOYFUL) were used to assess PA. Items that represent activated (NERVOUS OR ANXIOUS, STRESSED) and deactivated (SAD, MAD) displeasure were used to assess NA. PA was measured using a two item scale including the following questions – “How JOYFUL were you feeling just before the beep went off?” and “How HAPPY were you feeling just before the beep went off?” Scores for these two items were averaged to create a combined PA score (reliability = 0.80). NA was measured using a four item scale including the following questions – “How STRESSED were you feeling just before the beep went off?”, “How MAD were you feeling just before the beep went off?”, “How NERVOUS OR ANXIOUS were you feeling just before the beep went off?” and “How SAD were you feeling just before the beep went off?” Scores from these four items were averaged to create a combined NA score (reliability = 0.70). The EMA affect items were based partially upon the Positive and Negative Affect Schedule for Children (Ebesutani et al., 2012; Laurent et al., 1999) and the results of previous EMA studies (Dunton, Atienza, Castro, & King, 2009).

The physical feeling states physical energy and physical fatigue were each measured using one item – “How ENERGETIC were you feeling just before the beep went off?” and “How TIRED were you feeling just before the beep went off?” For each affective and physical feeling state item, participants chose one response from four response options “Not at all”, “A little bit”, “Quite a bit”, or “Extremely” (the scale ranged from 1 “Not at all” to 4 “Extremely”). To reduce participant burden, items measuring physical energy, physical fatigue, PA, and NA appeared in a randomly programmed 12 out of the 20 question sequence (60% of sequences). All EMA items were thoroughly pilot tested in the target population for comprehension and applicability (Dunton, Liao, Intille, Spruijt-Metz, & Pentz, 2011).

Demographics and anthropometrics—Demographics and anthropometrics were collected at the data collection visit. Age and sex were self-reported by participants. BMI percentile was calculated with CDC age- and sex-specific growth curves from height and weight measured in duplicate by trained study staff via stadiometer (PE-AIM-101, Perspective Enterprises, Portage, MI) and digital scale (Tanita WB110-A, Tanita Corporation of America, Inc., Arlington Heights, IL) respectively.

Data analyses—Analyses were conducted using SAS v. 9.1 (SAS Institute, Cary, NC). Descriptive statistics were conducted for the analytic sample. Bivariate associations between demographic characteristics and affective and physical feeling states were examined. Estimates of between-person reliability for PA and NA were calculated using a generalizability analysis approach (Hedeker, Mermelstein, Berbaum, & Campbell, 2009). Mixed models were conducted for all hypothesis testing with level 1 (EMA prompts or occasions) nested with level 2 (individuals). PROC MIXED was used to examine the cross-sectional associations between intake tertiles of dietary variables and subject-level or WS

mean of affective and physical feeling states. Mixed-effects location scale models were then conducted using PROC NLMIXED (Hedeker & Mermelstein, 2007; Hedeker et al., 2009; Hedeker, Mermelstein, & Demirtas, 2008) to examine the cross-sectional associations between intake tertiles of dietary variables and subject-level or WS variability of affective and physical feeling states. The outcome variables (i.e., WS mean and WS variability) were examined in terms of differences between people.

PROC MIXED and PROC NLMIXED require that the outcome variable be measured at level 1 (EMA prompts or occasions in the current study). Given our usual dietary intake variable was measured at level 2 (the individual), these models required affective and physical feeling states to be entered as the outcome and usual dietary intake as the predictor. Therefore, the models tested cross-sectional associations and could not establish temporal relationships between the variables of interest. The primary outcomes of these analyses included WS means and WS variability of PA, NA, physical energy, and physical fatigue. A-priori predictor dietary variables included: glycemic load of typical dietary intake and cup equivalents of fruit, cup equivalents of vegetables, ounces of whole grains, grams of fiber, grams of saturated fat, and teaspoons of added sugar reported per 1000 kilocalories (all calculated by Nutrition Quest based on self-reported answers to Block Kids Food Screener items) (NutritionQuest). The food group dietary variables were chosen because they are often the focus of nutrition interventions in youth and are potentially modifiable (Donnelly et al., 1996; Hoelscher, Evans, Parcel, & Kelder, 2002; Vandongen et al., 1995). Glycemic load provides a measure of the quantity and quality of carbohydrate and quantifies the expected glycemic response to a serving of food (Foster-Powell, Holt, & Brand-Miller, 2002). This was chosen as a predictor because previous research has demonstrated associations between glycemic load and affective states (Cheatham et al., 2009; Micha, Rogers, & Nelson, 2011).

Each model included an affective or physical feeling state dependent variable and a single dietary predictor variable; a priori covariates included age, sex, and BMI percentile. All participants with any proportion of answered EMA prompts were included in the analyses. The random scale for models for NA and physical fatigue were not included in the mixed effects location scale models because the random scale portion of the models failed to converge due to low levels of WS variability in these variables. Twenty-eight mixed models and twenty-eight mixed-effects location scale models were run (one for each affective or physical feeling state outcome and dietary predictor). To minimize the probability of Type I error, more conservative significance levels were applied at $p = 0.002$ using a Bonferroni adjustment for multiple comparisons ($7 \text{ dietary variables} \times 4 \text{ affective outcomes}$; $p = 0.05/28$).

Results

A sample of 118 participants was included in the study, and a sample of 110 participants (mean age = 11.0, SD = 1.2 years; mean BMI percentile = 63.4, SD = 31.0; 47.5% female) was included in this analysis ($n = 8$ participants excluded for improbable caloric intake). Sample characteristics are shown in Table 1. On average, participants answered 77.9% of the EMA prompts (compliance range = 25%–100%). EMA prompt non-compliance did not

differ by sex, ethnicity, or BMI percentile. Affective and physical feeling states differed by demographic characteristics. Higher PA was associated with younger age ($r = -0.13$, $p < 0.0001$). Higher NA was associated with older age ($r = 0.11$, $p = 0.001$) and female gender ($r = 0.19$, $p < 0.0001$). Greater physical fatigue was associated with female gender ($r = -0.09$, $p = 0.008$).

Dietary intake and between-subject mean levels of affective and physical feeling states

The results from the mixed models examining the cross-sectional association between levels of dietary intake and WS mean levels of affective and physical feeling states are shown in Table 2.

Positive affect

PA ratings differed by fiber intake such that, on average, the PA ratings for children in the lowest tertile (LT) of fiber intake were lower than the PA ratings of those in the highest tertile ($b_{LT} = -0.46$, $p = 0.002$).

Physical energy

Physical energy ratings differed by added sugar intake such that, on average, the physical energy ratings of children in the lowest tertile of added sugar intake were higher than the physical energy ratings of those in the highest tertile ($b_{LT} = 0.45$, $p = 0.002$).

Dietary intake and within-subject variability of affective and physical feeling states

Table 3 shows the results from the mixed-effects location scale models testing the cross-sectional associations between dietary intake tertiles and WS variability of affective and physical feeling states.

Negative affect

The variability of NA ratings differed by tertiles of fiber and added sugar intake and by tertiles of glycemic load of diet. Children in the lowest tertile of fiber intake showed greater WS variability in NA ratings relative to those in the highest tertile ($\tau_{LT} = 0.46$, $p = 0.0002$); those in the highest tertile (HT) of added sugar intake showed greater WS variability in NA ratings relative to those in the lowest tertile ($\tau_{HT} = 0.37$, $p = 0.002$); and those in the highest tertile of glycemic load of diet showed greater WS variability of NA ratings than those in the lowest tertile ($\tau_{HT} = 0.88$, $p < 0.0001$).

Physical fatigue

The variability of physical fatigue ratings differed by tertiles of fruit and fiber intake. Children in the lowest tertile of fruit intake showed lower variability in physical fatigue ratings relative to those in the highest tertile ($\tau_{LT} = -0.68$, $p < 0.0001$), and those in the lowest tertile of fiber intake showed lower variability in physical fatigue ratings relative to those in the highest tertile ($\tau_{LT} = -0.45$, $p = 0.0002$).

Discussion

The current study used ecological momentary measures of affective and physical feeling states to examine the cross-sectional associations of usual dietary intake with average levels and variability of affective and physical feeling states during weekday evenings and weekends in children. This study could not establish temporal relationships between usual dietary intake and average levels and variability of affective and physical feeling states in this sample. However, findings from this study indicated that there were cross-sectional associations between usual dietary intake and usual affective and physical feeling states. Fiber and glycemic load of diet showed more consistent cross-sectional associations with mean levels and variability of affective and physical feeling states than fruits, vegetables, whole grains, and saturated fats. Although a causal association cannot be derived from these findings, it is possible that this observation may be explained by the impacts of fiber and glycemic load of diet on physiological pathways that can influence affective states. Consumption of high glycemic load meals causes increased fluctuations in blood glucose, whereas fiber consumption leads to a more stable rise in blood glucose (Ludwig et al., 1999; McIntosh & Miller, 2001; Owens & Benton, 1994; Pittas et al., 2005). Previous studies have shown poor glycemic control to be associated with negative affective states (Benton, 2002; Cheatham et al., 2009; Lieberman, Wurtman, & Chew, 1986), which may lend support to our findings that lower fiber was associated with lower mean positive affect and greater variability in negative affect, and higher glycemic load of diet was associated with greater variability of negative affect. However, future research is necessary to determine if the observed relationships are causal in order to understand whether these potential mechanisms are valid explanations. Added sugars also appeared to be particularly relevant to children's mean levels and variability of affective and physical feelings states. Findings from previous research support the notion of a "sugar crash", characterized by feelings of low energy and low activity, following consumption of high amounts of added sugar (Pasman, Blokdijk, Bertina, Hopman, & Hendriks, 2003; Spruijt-Metz et al., 2009). This may provide support for our finding that higher added sugar intake was associated with lower physical energy and greater variability of negative affect. Again, however, further research is necessary to determine if the observed relationships between added sugar intake and affective and physical feeling states are causal.

Healthful dietary characteristics, including greater fruit intake and greater fiber intake, were cross-sectionally associated with greater variability of physical fatigue. It is possible that the observed findings could be explained by factors that were not measured in this study, such as individual characteristics or dynamic environmental contexts. For example, it is possible that children with more healthful dietary intake patterns also engage in greater physical activity, sports, classes, lessons, or other enrichment or extracurricular activities that would make them feel more fatigued at certain times – especially immediately after these activities. It is also possible that other variables may drive the observed findings. For example, the family environment may influence a child's affect as well as access to and thus consumption of foods. Parenting practices determine children's dietary intake (Ventura & Birch, 2008). Parenting behavior can also influence children's affective states (Mills-Koonce et al., 2007). The current study did not control for participation in the aforementioned types of activities,

other potential trait-like confounders, or factors such as parenting practices. Overall, these findings provide preliminary evidence of the linkages between dietary intake and affective and physical feeling states in children, and highlight the need for future research to understand the temporal nature of these linkages.

This study supports findings from previous research in adults, which demonstrate a relationship between positive affective state and more healthful dietary intake and of negative affective state and less healthful dietary intake. For example, in a study conducted by Lyman & Bernard in 1982, participants were asked to imagine experiencing positive and negative affective states and to report the types of foods they perceived they would prefer during those affective states (Lyman, 1982). The authors found that participants perceived their preference for unhealthy snack foods would increase during negative affective states and that preference for healthful foods would increase during positive affective states (Lyman, 1982). These findings reportedly suggested that people use food to regulate affective states by consuming unhealthy foods to relieve negative affective states and healthful foods to maintain positive affective states (Garg et al., 2007). These findings, along with results from the current study, are consistent with affect regulation theories including mood management theory (Andrade, 2005; Zillmann, 1988) and mood-maintenance hypothesis (Andrade, 2005; Clark & Isen, 1982).

The current study extends previous work by offering insight into the relationship between dietary intake and affective state stability using a novel analytic approach. Affective state variability has previously been examined using repeated measures data in research by Hedeker et al. (2009) to characterize the association of smoking and affective state variability in adolescents. Additionally, a recent study used EMA to reveal that physical activity was associated with greater affective state stability in children (Dunton et al., 2014). However, this is the first study to examine the cross-sectional relationship between diet and variability of affective states over time. Furthermore, to the best of our knowledge, this cross-sectional study is also the first study in children to examine the association between typical dietary intake and affective states using real-time measures of affect and physical feeling states from EMA observations, which offer improved ecological validity (Shiffman & Stone, 1998; Smyth & Stone, 2003). Using EMA to collect affective and physical feeling state data allowed us to examine associations between usual affective state tendencies and typical dietary intake in this sample. Despite the strengths of the current study, there are limitations that should be acknowledged. Even though EMA was used to assess repeated measures of affective and physical feeling states in real-time, dietary intake was assessed at a single time point through a recall-based food frequency instrument, which measured food intake over the week prior to the EMA. We were unable to conduct 24-hour dietary recalls due to the scope of the study, so the dietary assessment did not overlap with the EMA assessment. Nonetheless, the instrument used provides a measure of usual food intake (Hunsberger et al., 2012), so the dietary intake reported from the week prior to the EMA measurement was likely similar to dietary intake during the period of EMA measurement. We did not screen for dietary constraints or allergies, and did not assess for household food insecurity. The Block Kids Food Screener has been validated for children ages 10 to 17 years old (Hunsberger et al., 2012). While the majority of the sample was composed of children within this age range, some participants were as young as 8 years old. However, this

instrument has been previously used in studies with samples including children younger than 10 years (Davis, Ventura, Cook, Gyllenhammer, & Gatto, 2011; Garcia-Dominic et al., 2012; Wright et al., 2013).

There were also limitations to the use of EMA for assessing affective and physical feeling states. EMA data were collected over the course of four days, rather than a longer period of time. Additionally, participants completed twenty EMA surveys over the course of the study. A greater number of EMA surveys may have provided a different assessment of typical affective and physical feeling states. The EMA measures were collected during weekday evenings and weekend days and evenings, so we cannot determine from these findings whether recalled dietary intake is associated with affective and physical feeling states during other periods of time, such as school hours. Due to the model limitations of PROC mixed and PROC nlmixed, which require that the lowest level of data serve as the dependent variable, we were not able to test dietary intake as an outcome variable in the current study. As previously mentioned, this fact prevented us from establishing the temporal relationship for the associations between dietary intake and affective states. Therefore, whether dietary intake truly influenced affective states or affective states actually influenced dietary intake in this sample could not be tested. Furthermore, as the data were conceptualized to be cross-sectional, the analyses were conducted to test associations rather than causality.

Our findings support the notion that average levels and variability of affective and physical feeling states might have trait-like associations with typical dietary intake, as average levels and variability of affective and physical feeling state ratings did not vary much from day to day. However, while the EMA data collection method enabled us to assess participants' usual affective and physical feeling state tendencies, the affective and physical feeling states reported during the EMA data collection may not have been representative of usual affective state tendencies for all participants (for instance, if an unusual event occurred during the period of data collection that impacted a participant's affective state). Affect and physical feeling states were assessed using one to four items. Although use of additional items may have strengthened these measures, short scales were necessary in this EMA study to avoid over-burdening participants (Dunton et al., 2014). The mean BMI percentile of the sample included in this study was below the average BMI percentile for children, which may indicate that the participants were from a more health-conscious population and thus limit the generalizability of these findings. Finally, the random scale portion of the mixed effects location scale models for NA and physical fatigue were excluded because they did not converge, possibly due to low variance of these outcomes. This issue has been observed in previous studies that have used mixed effects location scale models (Dunton et al., 2014; Hedeker et al., 2008).

Further research is required to untangle the complex association between diet and affective states in children. Future field-based studies could collect time-varying dietary data concurrent with EMA affective state data in order to examine the relationship between affective states and WS mean levels and WS variability of dietary intake. Such data could be applied to establish the naturally-occurring temporal relationship between food intake and affective states. Additionally, observations collected over a longer period of time may provide greater insight into how long-term dietary patterns are associated with affective state

stability. Findings from future research have the potential to have important clinical and policy implications, and could be relevant for school menu planning. Previous research has focused on the impacts of school meals on cognitive performance in children (Hoyland, Dye, & Lawton, 2009). Future research could use EMA to examine the impact of the dietary profiles of school meals on affect in children. If dietary intake influences affective and physical feeling states, the dietary profiles of school meals may have consequences for how effectively children can participate in learning during the school day (Micha et al., 2011). This may be important for determining the types of meals served in the school environment. Future research examining relationships between time-varying dietary data concurrent with EMA affective state data may also have important clinical implications for mood disorders in children, which are common among children but often undertreated (Wells, Kataoka, & Asarnow, 2001). While the findings from this study cannot provide direct insight into this issue, future research could reveal whether dietary intake can provide an important approach for managing such conditions in youth.

To conclude, this study used EMA to collect real-time repeated measures of affective and physical feeling states in order to examine the relationship between typical dietary intake and affective states in children. The results from this study indicated that overall average ratings of affective states and within-person variability of affective states over the observation period were associated with typical dietary intake. These findings contribute to a growing body of evidence demonstrating a link between diet and affective states. Our results show that EMA offers a promising avenue through which to explore the associations between affective states and diet and that it has the potential to provide insight into nuances of this relationship. Further work is needed to unravel the complexities of the causal relationships between diet and affective states.

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Table 1

Sample characteristics (n = 110).

Variable	n (%) or M (SD)
Sex	
Male	57.7 (52.5%)
Female	52.3 (47.5%)
Age	11.0 (1.2)
BMI percentile	63.4 (31.0)
Race/ethnicity ^a	
White	10.6 (9.6%)
African American	15.6 (14.2%)
Hispanic/Latino	33.1 (30.1%)
Asian	26.7 (24.3%)
Biracial/mixed	18.9 (17.2%)
Other	5.1 (4.6%)
Dietary intake ^b	
Total daily kilocalories	1264.7 (622.6)
Fruit (ce)	1.6 (0.9)
Vegetables (ce)	0.6 (0.4)
Whole grains (oz)	0.4 (0.3)
Fiber (g)	9.1 (2.8)
Saturated fat (g)	12.0 (2.4)
Added sugar (tsp)	5.3 (2.5)
Glycemic load	72.8 (35.5)
Affective and physical feeling states ^c	
Positive affect (n = 982) ^d	1.8 (0.9)
Negative affect (n = 981) ^d	0.4 (0.5)
Physical energy (n = 974) ^d	0.8 (0.9)
Physical fatigue (n = 965) ^d	1.4 (1.0)

ce = cup equivalents; oz = ounces; g = grams; tsp = teaspoons.

^a race/ethnicity information was missing for 1 participant.^b fruit, vegetables, whole grains, fiber, saturated fat, and added sugar adjusted for total daily energy intake and are reported per 1000 kilocalories.^c possible score range was 1 to 4.^d total number of observations.

Table 2Results from mixed models for affective and physical feeling states.^a

	<u>Positive affect</u> <u>WS mean level</u>	<u>Negative affect</u> <u>WS mean level</u>	<u>Physical energy</u> <u>WS mean level</u>	<u>Physical fatigue</u> <u>WS mean level</u>
Tertiles	b (SE)	b (SE)	b (SE)	b (SE)
Fruit intake				
Lowest	−0.14 (0.14)	0.12 (0.08)	−0.02 (0.15)	−0.12 (0.12)
Middle	0.06 (0.14)	0.05 (0.08)	0.14 (0.14)	−0.02 (0.12)
Highest (ref)				
Vegetable intake				
Lowest	−0.19 (0.15)	−0.01 (0.08)	−0.14 (0.15)	−0.10 (0.12)
Middle	−0.08 (0.15)	0.01 (0.08)	0.02 (0.15)	−0.02 (0.12)
Highest (ref)				
Whole grain intake				
Lowest	−0.18 (0.14)	0.10 (0.08)	−0.07 (0.15)	0.03 (0.12)
Middle	−0.18 (0.15)	0.04 (0.08)	−0.21 (0.15)	0.04 (0.12)
Highest (ref)				
Fiber intake				
Lowest	−0.46 (0.14)*	0.17 (0.08)	−0.16 (0.15)	−0.10 (0.12)
Middle	−0.11 (0.14)	0.16 (0.08)	−0.08 (0.15)	0.10 (0.12)
Highest (ref)				
Saturated fat intake				
Lowest	0.08 (0.14)	−0.08 (0.08)	0.03 (0.15)	0.12 (0.12)
Middle	−0.10 (0.15)	0.08 (0.08)	0.06 (0.15)	0.15 (0.12)
Highest (ref)				
Added sugar intake				
Lowest	0.05 (0.15)	−0.10 (0.08)	0.45 (0.14)*	−0.04 (0.12)
Middle	−0.04 (0.15)	−0.04 (0.08)	0.08 (0.14)	0.13 (0.12)
Highest (ref)				
Glycemic load of diet				
Lowest	−0.02 (0.15)	−0.22 (0.08)	0.03 (0.15)	−0.14 (0.11)
Middle	0.06 (0.15)	−0.12 (0.08)	−0.05 (0.15)	0.09 (0.12)
Highest (ref)				

WS = within- subject; SE = standard error; ref = reference group;

^aModels were adjusted for age, sex, and BMI percentile.*
p 0.002.

Table 3Results from mixed-effects location scale models for affective and physical feeling states.^a

	<u>Positive affect WS variability</u>	<u>Negative affect WS variability^b</u>	<u>Physical energy WS variability^b</u>	<u>Physical fatigue WS variability</u>
Tertiles	τ(SE)	τ(SE)	τ(SE)	τ(SE)
Fruit intake				
Lowest	-0.07 (0.20)	0.19 (0.12)	-0.01 (0.14)	-0.68 (0.11)*
Middle	-0.03 (0.20)	0.09 (0.12)	0.15 (0.14)	-0.30 (0.12)
Highest (ref)				
Vegetable intake				
Lowest	-0.24 (0.21)	0.01 (0.11)	0.14 (0.14)	-0.38 (0.12)
Middle	-0.21 (0.21)	-0.10 (0.12)	-0.06 (0.14)	-0.29 (0.12)
Highest (ref)				
Whole grain intake				
Lowest	0.39 (0.20)	0.18 (0.12)	-0.002 (0.14)	-0.08 (0.12)
Middle	0.48 (0.21)	0.44 (0.13)	0.02 (0.15)	-0.18 (0.13)
Highest (ref)				
Fiber intake				
Lowest	0.44 (0.21)	0.46 (0.12)*	0.12 (0.14)	-0.45 (0.12)*
Middle	0.42 (0.20)	0.51 (0.12)*	0.25 (0.14)	0.16 (0.12)
Highest (ref)				
Saturated fat intake				
Lowest (ref)				
Middle	0.07 (0.20)	0.31 (0.12)	-0.01 (0.14)	-0.40 (0.12)
Highest	0.11 (0.19)	-0.06 (0.12)	0.11 (0.14)	0.02 (0.12)
Added sugar intake				
Lowest (ref)				
Middle	0.22 (0.20)	0.43 (0.12)*	-0.11 (0.08)	0.21 (0.12)
Highest	0.08 (0.20)	0.37 (0.12)*	-0.17 (0.12)	0.13 (0.12)
Glycemic load of diet				
Lowest (ref)				
Middle	0.08 (0.20)	0.54 (0.13)*	0.15 (0.14)	0.35 (0.13)
Highest	0.38 (0.20)	0.88 (0.13)*	0.15 (0.14)	0.23 (0.12)

WS = within subject; SE = standard error;

^a models were adjusted for age, sex, and BMI percentile.^b model did not include the random scale.

* p = 0.002.