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An Electronic Ecological Momentary Assessment Study to Examine the Consumption of High-fat/High-sugar Foods, Fruits/Vegetables and Affective States among Women

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Abstract

Objective—To examine the associations between high-fat/high-sugar foods (HFHS) and fruits/vegetables (FV) consumption and affective states in women.

Methods—Electronic ecological momentary assessment (EMA) was used to capture HFHS and FV consumption in the past 2 hours (predictor) and current affective states (outcome) across 1 week among 202 women. Multilevel linear regression was conducted. Weight status was tested as a moderator.

Results—FV consumption in the past 2 hours was positively associated with feeling happy ($p < .05$). Women who consumed more HFHS or fewer FV than others in the study reported higher average sadness ($p < .05$). Overweight/obese women who reported more frequent HFHS consumption than others had higher average stress than normal weight women ($p < .05$).

Conclusions and Implications—The association between HFHS consumption and stress might be stronger in overweight/obese than normal weight women. Future studies could further enhance the EMA method to explore other time-varying moderators/mediators of food consumption and affect.

Keywords

Dietary intake; stress; overweight; free-living; smartphones

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INTRODUCTION

Unhealthy eating is one of the major modifiable lifestyle risk factors that contributes to the development of chronic conditions such as cardiovascular diseases, diabetes, and cancer.¹ Some of the key components in healthy eating patterns include the consumption of a variety of fruits and vegetables (FV) and limiting high-fat and high-sugar foods (HFHS). However, more than 75% of Americans do not meet the FV recommendations and approximately 70% exceed the recommendations for added sugars and saturated fats.² Further, adherence to meeting the dietary guidelines has remained low for the past few decades.² Therefore, there is a need to help individuals improve dietary behaviors and achieve healthy eating patterns.

Previous research suggests food consumption could lead to improved mood and positive affect as a result of its nutritional and physiological effects³ and eating itself is a pleasurable experience.^{4,5} Food consumption could impact affective states through several potential physiological mechanisms. For example, consumption of energy-dense foods (e.g., HFHS) may increase positive affect due to the release of endorphins.⁶ However, frequent consumption of HFHS could induce plasticity-related changes in brain reward circuitry that are associated with depressive-like phenotype.⁷ Further, in comparison with HFHS, FV are believed to be conducive to increasing levels of brain-derived neurotrophic factors, which is thought to play a central role in negative mood states and depression.⁸ In addition to the physiological mechanisms, food consumption could influence affective states via cognitive expectations and perceptions of the health value of certain foods,^{9,10} which might differ across gender, weight status, and cultural background. For instance, in many western cultures, there is greater societal pressure for women to be physically attractive and thin compared to men.¹¹ HFHS could be considered as a threat to being thin and are associated with negative affect, especially among overweight/obese women who are trying to lose weight.¹² Previous studies have shown that overweight/obese women experience more intense negative affect than normal weight women after consumption of HFHS.¹³ A better understanding of the association between HFHS/FV consumptions and affective states in women could inform nutrition educators to help women recognize the possible consequences of consuming these foods and change their eating patterns to optimize physical and mental health.

Although several feeding studies (e.g., certain types of food were provided) have investigated the acute relationships between food consumption and subsequent affective states,^{5,13} these studies do not reflect the dynamic situations that individuals experience in their everyday lives (e.g., personal choices of foods in real-world situations). Understanding the association between HFHS/FV consumption and affective states could shed light on how to motivate individuals to avoid HFHS and consume more FV. Ecological momentary assessment (EMA), a real-time capture method that allows individuals to self-report their behaviors and experiences in their daily lives,¹⁴ is a useful method to study the acute relationships between everyday food consumption and affective states. Prior studies using this method found that eating large quantities of food subsequently led to greater negative affect in women.¹⁵ Nevertheless, the effects of different types of food was not investigated. The current study aimed to use EMA to (1) examine the association between consumption of HFHS and FV and affective states; and (2) explore the moderating effect of weight status on

these associations among middle-aged women. It is hypothesized that consumption of HFHS would positively associate with negative affect and consumption of FV would positively associate with positive affect.

METHODS

Data Source

This study used data from the Mothers' and Their Children's Health (MATCH) study, which was a longitudinal observational dyadic study in a sample of mother-child pairs.¹⁶ The MATCH study included a 1-week free-living EMA monitoring period, which was repeated across 6 waves separated by 6 months each. The current study used mothers' EMA data from the first wave. The MATCH study protocol was reviewed and approved by the Institutional Review Board at the University of Southern California. The reporting of this study followed guidelines from the Adapted STROBE Checklist for Reporting EMA Studies (CREMA).¹⁷

Participants

Participants in the MATCH study were ethnically-diverse mothers and their 8–12-year-old children recruited from public elementary schools and after-school programs in the greater Los Angeles area. Eligibility criteria included: child in the 3rd–6th grade and resided with the mother at least 50% of the time, and both mother and child were able to read English or Spanish. All study materials (e.g., EMA surveys, instructions) were available in both English and Spanish. Mother-child pairs were excluded if they: were taking medications for thyroid function or psychological conditions, using oral or inhalant corticosteroids for asthma, had health issues that limit physical activity, child enrolled in special education programs or classified as underweight, mother currently pregnant or work >2 weekday evenings/week or >8 hours on any weekend day.

Procedures

Details about the design and protocol for MATCH study has been described elsewhere.¹⁶ All mothers attended an in-person data collection session to complete anthropometric measurements and paper-and-pencil questionnaires. They also received instructions on how to use study equipment, which included the smartphone EMA application (app).

EMA surveys were delivered via a custom Android app that was developed specifically for the study. Mothers who owned an Android smartphone downloaded the app on their own smartphone. For those who did not wish to use their own smartphone, who had an incompatible smartphone or no smartphone, a MotoG (Motorola Inc) was provided for the duration of the study period. EMA data were collected over 8 days following completion of the in-person data collection session. EMA prompts started after 5 pm on the day of the in-person data collection session (day 1), continued for the next 6 days (days 2–7), and up until 5 pm on the last day (day 8). EMA surveys were randomly prompted 4 times per day on weekdays between 3–9:30 pm and 8 times per day on weekend days between 7 am–9:30 pm. EMA data were wirelessly uploaded and stored on a secure Internet-accessible server during the monitoring period.

EMA Measures

Food consumption was assessed by asking women to indicate which of the following foods they had eaten over the past 2 hours (i.e., CHIPS or FRIES; PASTRIES or SWEETS; FAST FOOD; FRUITS or VEGETABLES). Women were instructed to choose all that applied. Each food item was then converted to a dichotomous response of yes/no. For the purpose of the current study, selection of chips or fries, pastries or sweets, or fast food was recoded as HFHS consumption (yes/no). EMA entries that indicated both HFHS and FV consumption were excluded from the analysis to examine the effects of these 2 food groups on affect separately.

For affective state, women were asked “Right before the phone went off, how (HAPPY, CALM/RELAXED, FRUSTRATED/ANGRY, STRESSED, SAD/DEPRESSED) were you feeling?” Response choices were “Not at all,” “A little,” “Quite a bit,” and “Extremely.” Each affect was analyzed separately as previous research showed distinct associations between single-item affect and eating.^{5,13} Composite scores for positive and negative affect were computed to explore the effect of food consumption on the 2 fundamental dimensions of affect. Positive affect was an average of happy and calm/relaxed (average Cronbach’s $\alpha=.75$). Negative affect was an average of frustrated/angry, stressed, and sad/depressed (average Cronbach’s $\alpha=.72$).

All EMA items were thoroughly pilot tested in the target population for comprehension and applicability. The supplemental figure shows an example of 1 woman’s EMA responses.

Anthropometric and Demographic Measures

Weight and height were measured in duplicate using an electronically-calibrated digital scale (Tanita WB-110A) and professional stadiometer (PE-AIM-101). Weight status was determined according to body mass index (BMI) as normal weight vs. overweight/obese.¹⁸ Participants self-reported their age, ethnicity (“Are you Hispanic or Latino?”), highest level of education, and annual household income through a paper-pencil survey.

Statistical Analysis

Because each woman had multiple (up to 36) EMA responses, data was nested within individuals. The intraclass correlation coefficient (ICC) was small (ranged from .15 to .33) for all outcome variables, indicating large amount of variation within individuals.¹⁹ Therefore, multilevel linear regression modeling (MLM) was used to adjust the standard errors for the clustering of EMA responses within individuals. Between- subject (BS) and within-subject (WS) effects were separated (i.e., partitioning the variance). The BS effect represents the individual mean deviation from the group mean, and the WS effect represents deviation from one’s own mean (average level) at any given EMA prompt.²⁰ To test aim 1, MLM was fitted using current affective state (e.g., positive affect, negative affect, and each individual affect item) as the outcome and past 2-hour food consumption (i.e., HFHS/FV consumption vs. no consumption) as the predictor. Each predictor and outcome was tested in separate models. Because responses for each individual negative affect item and the composite negative affect score were not normally distributed, a log-transformation of the data was performed for those items. To test aim 2, interactions between each predictor and

weight status were created (i.e., weight status $\times$ WS and weight status $\times$ BS) and entered into all models described above. Age, ethnicity (Hispanic vs. non-Hispanic), day of the week (weekdays vs. weekend days) and time of the day (morning, afternoon, and evening) were controlled in all models.

RESULTS

Descriptive Statistics

A total of 453 women expressed interest in the MATCH study, and 299 of them completed eligibility screening. There were 237 women meeting the eligibility criteria and 202 of them attended the initial in-person data collection session and enrolled in the study. Of those who enrolled in the study, EMA data was lost for 2 women due to errors in server upload/manual backup. Another 2 women did not answer any EMA surveys during the monitoring period. One woman did not answer any food consumption EMA questions. These data losses resulted in a total of 197 women in the analytical sample. Women were on average 40.9 years old ($SD=6.2$). Forty-nine percent of the women were Hispanic, 43% were overweight or obese, and 60% completed college degree or above with a median annual household income of \$75,000.

Of the 6,895 possible EMA survey prompts, 1,136 were not prompted due to technical problems, outside of sleep schedule, phone being powered off, protocol change, or other unknown issues. On average, women answered 81% of the prompted EMA surveys ($SD=21\%$), yielding 4,730 EMA records. The likelihood of missing an EMA prompt was unrelated to women's age, weight status, time of day, or day of the week ($P>.05$); however, Hispanic women were more likely to have missed an EMA prompt than non-Hispanic women ($P=.03$).

A total of 301 EMA records were removed from the analyses due to an indication of consuming both HFHS and FV, leaving an analytical sample of 4,429 EMA records from 197 women. On average, women reported HFHS consumption in the past 2 hours in 12.8% of EMA prompts ($SD=11.4\%$). FV consumption was reported in 17.6% of EMA prompts ($SD=14.4\%$).

High-fat/high-sugar Foods Consumption and Affective States

Table 1 shows results from the MLM. Overall, the WS effect was not significant in any model, suggesting that consumption of HFHS in the past 2 hours was not associated with feelings of happy, calm/relaxed, frustrated/angry, stressed, sad/depressed, or the composite positive and negative affect scores at the end of the 2-hour window. However, at the BS level, women who reported more frequent consumption of HFHS compared to others in the study had greater overall negative affect (BS $\beta=.23$, $SE=.11$, $P=.04$, 95% CI [.015, .441]), particularly from feelings more stressed (BS $\beta=.44$, $SE=.16$, $P<.01$, 95% CI [.123, .749]) and more sad/depressed (BS $\beta=.22$, $SE=.11$, $P=.04$, 95% CI [.004, .434]).

Weight status only significantly moderated the association between HFHS consumption and stress at the BS level (BS $\beta=-.69$, $SE=.30$, $P=.02$, 95% CI [-1.288, -.087]), indicating a

positive association between frequency of HFHS consumption and average stress level among overweight/obese women only.

Fruits/vegetables Consumption and Affective States

As shown in Table 1, FV consumption in the past 2 hours was positively associated with feeling happy at the end of the 2-hour window (WS $\beta=.06$, SE=.03, $P=.03$, 95% CI [.004, .111]). This significant positive association was also found at the BS level. Women who reported more frequent FV consumption compared to others in the study reported feeling happier in general (BS $\beta=.55$, SE=.25, $P=.02$, 95% CI [.066, 1.035]). Further, women who reported more frequent FV consumption compared to others reported feeling less sad in general (BS $\beta=-.21$, SE=.09, $P=.02$, 95% CI [-.377, -.035]). Weight status was not a significant moderator in any of the models.

DISCUSSION

The current study used electronic EMA through a smartphone app to examine the associations of HFHS and FV consumption with affective states in a sample of middle-aged women's daily lives. Previous studies have used EMA to capture eating episodes in obese adults²¹ and binge eating.²² However, those studies only assessed the frequency of eating, not the types of food being eaten. This study also had high EMA compliance rate (81%) compared to the average EMA compliance rate (71%) in diet and physical activity research.¹⁷

The positive associations between happiness and consumption of FV but not HFHS found in this study might be partly explained by the potential mental health benefit effect of FV beyond just the intake of food. Previous studies have shown that FV but not HFHS consumption was associated with greater positive affect the next day.²³ FV consumption could have a positive effect on one's mental state through various physiological mechanisms via the nutrients found in FV (e.g., B vitamins' effect on the synthesis of neurotransmitters, antioxidant's defense mechanism against oxidative stress).²⁴ Further, the perception of consuming healthier foods could provoke positive emotions such as feeling satisfied, happy, or proud.¹⁰ It is also possible that women who in general feel happier tend to choose FV over HFHS foods.

The null WS associations between the consumption of HFHS and feelings of anger or sadness were consistent with previous studies that examined affective states immediately after energy-dense food intake in lab settings¹³ and affective states 5-min to 90-min after chocolate intake in free-living settings.⁵ However, it is possible that consumption of HFHS could invoke other negative affective states (e.g., guilt, shame) that are not measured in this study. This study also did not find any association between HFHS consumption and positive affective states. There might be other unexplored time-varying or contextual moderators (e.g., place, social context) that impact the association between affective states and HFHS consumption.

This study showed that women who consumed more HFHS or fewer FV compared to others in the study reported feeling more depressed in general. This is consistent with previous

cross-sectional findings that high frequency of snacks and fast food intake and low frequency of FV intake were correlated with higher (trait) depression.^{25,26} Further, overweight/obese women who reported more frequent HFHS consumption than others in the study had a higher average stress than normal weight women. It is possible that overweight/obese women might be more emotionally vulnerable to consequences of frequent HFHS consumption when compared to normal weight women. It is also possible that on average, overweight/obese women might experience higher levels of stress than normal weight women, that, in turns is associated with higher likelihood of consuming HFHS for emotional comfort.

Although this study is one of the first attempts to use electronic EMA to examine the association between HFHS and FV consumption with affective states in daily lives, there are some limitations. First, the EMA questions did not measure portion size. Further, some eating events may not have been captured if the participants did not feel the pre-set food category applied to what they have consumed. Nevertheless, this study attempted to capture and distinguish between HFHS and FV broadly. Second, this study assessed eating events within the past 2 hours but did not specify the exact time of the eating event (e.g., eating a food 2 hours ago vs. 10 minutes ago may differentially impact affective states). Eating could also happen at the time of the EMA prompt, resulting in the capture of affective states during eating. Additionally, because the parent study focused on mother-child dyads, EMA surveys were only prompted when they were likely spending time together (i.e., after-school hours on weekdays and weekend days). Third, some other affective states that might be related to food consumption (e.g., guilt, energetic) were not measured. Although the current study used affect items that were from well-established scales²⁷ and have been utilized in previous EMA studies,²⁸ it is possible that potential between-person variations exist when rating affective states. Further, this study did not examine mood change before and after food consumption. Therefore, it is unclear whether food consumption altered mood states. The current study design also could not distinguish the potential effects of mood states on food consumption. Fourth, this sample only included middle-aged women thus findings might not be generalizable to younger or older women. Results from this study might not be applied to men because the relationships between food consumption and affect tend to differ by gender. Lastly, because Hispanic women in the study were more likely to miss an EMA prompt than non-Hispanic women, their experiences may be underrepresented in this study. Nevertheless, all models have controlled for the effect of Hispanic vs. non-Hispanic.

CONCLUSIONS AND IMPLICATIONS

The current study demonstrated that electronic EMA is a feasible tool for capturing everyday HFHS/FV consumption and related factors such as affective states. In nutrition education, findings from the WS effect could be useful to set personalized behavioral targets (e.g., eat half serving more FV than average intake) while BS findings could help to identify health disparities in populations (e.g., overweight/obese women might have more negative experience from frequent HFHS consumption than normal weight women). The EMA method could be further enhanced by optimizing the prompting schedules and survey questions. Other time-varying moderators and mediators of the relationships between food

consumption and affective states (e.g., social context, intentions, stressful events) could also be explored.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Associations between Consumption of High-fat/high-sugar Foods and Fruits/vegetables and Affective States in a Sample of 197 Women

Table 1

Outcome	Predictor				Weight Status Interaction	Fruits/vegetables Consumption	Coefficient Estimate (SE)
	High-fat/high-sugar Foods Consumption	Weight Status Interaction	Fruits/vegetables Consumption	Weight Status Interaction			
Happy	WS Effect	0.035 (0.030)	<i>n.s.</i>	0.057 (0.027) *	<i>n.s.</i>		
	BS Effect	-0.289 (0.312)	<i>n.s.</i>	0.551 (0.246) *	<i>n.s.</i>		
	AIC	8586.5	8590.3	8582.0	8579.2		
Calm/relaxed	WS Effect	0.023 (0.035)	<i>n.s.</i>	0.039 (0.032)	<i>n.s.</i>		
	BS Effect	-0.571 (0.309)	<i>n.s.</i>	0.340 (0.249)	<i>n.s.</i>		
	AIC	9752.3	9754.5	9752.6	9756.4		
Positive affect	WS Effect	0.029 (0.028)	<i>n.s.</i>	0.049 (0.023)	<i>n.s.</i>		
	BS Effect	-0.426 (0.294)	<i>n.s.</i>	0.450 (0.234)	<i>n.s.</i>		
	AIC	8083.3	8086.7	8079.0	8082.8		
Frustrated/angry	WS Effect	-0.007 (0.016)	<i>n.s.</i>	-0.010 (0.014)	<i>n.s.</i>		
	BS Effect	0.197 (0.0104)	<i>n.s.</i>	-0.140 (0.083)	<i>n.s.</i>		
	AIC	3275.5	3276.2	3275.8	3277.6		
Stressed	WS Effect	0.015 (0.019)	0.003 (0.035)	-0.014 (0.018)	<i>n.s.</i>		
	BS Effect	0.436 (0.159) **	-0.687 (0.304) *	-0.207 (0.152)	<i>n.s.</i>		
	AIC	3524.3	3524.3	3526.8	3528.0		
Sad/depressed	WS Effect	0.014 (0.011)	<i>n.s.</i>	-0.003 (0.010)	<i>n.s.</i>		
	BS Effect	0.219 (0.109) *	<i>n.s.</i>	-0.206 (0.087) *	<i>n.s.</i>		
	AIC	92.6	96.6	92.9	96.2		
Negative affect	WS Effect	0.007 (0.012)	<i>n.s.</i>	-0.016 (0.011)	<i>n.s.</i>		
	BS Effect	0.228 (0.108) *	<i>n.s.</i>	-0.126 (0.087)	<i>n.s.</i>		
	AIC	1120.6	1121.3	1121.0	1123.3		

Note: WS = within-subject, BS = between-subject, AIC = Akaike Information Criterion. *n.s.* = not significant.

* *P* < .05.

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^{**} $P < .01$. Multilevel linear regression was used. All models controlled for age, ethnicity (Hispanic vs. non-Hispanic), day of the week (week days vs. weekend days) and time of the day (morning, afternoon, and evening).

Study sample included 197 middle-aged women (mean = 40.9 years old, SD = 6.2), 49% Hispanic and 43% overweight/obese, and 60% completed college degree or above with a median annual household income of \$75,000.