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Research report

Low socioeconomic status and eating in the absence of hunger in children aged 3–14

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ABSTRACT

A growing body of research indicates that one's early life experiences may play an important role in regulating patterns of energy intake in adulthood. In particular, adults who grew up under conditions characterized by low socioeconomic status (SES) tend to eat in the absence of hunger (EAH), a pattern that is not generally observed among higher-SES individuals. In the current study, we sought to examine (a) the environmental correlates of low SES that drive the association between low childhood SES and EAH and (b) whether the relationship between these variables is already manifest in children ages 3–14. Results of our study revealed that growing up in low-SES environments predicted less food security, diminished ability to meet financial needs, and less environmental predictability/safety. Further, the results indicated that reduced environmental predictability/safety in the children's environment interacted with children's current energy need to predict eating behavior. Consistent with patterns observed in adults, children from more predictable/safe environments ate food commensurate with their energy need, whereas those from less predictable/safe environments ate comparably high amounts of food across levels of energy need. These results offer needed insights into the development of environmentally-contingent energy-regulation strategies.

1. Introduction

Obesity increases one's risk for a constellation of health problems, including metabolic disorders (Wisse, 2004), cardiovascular disease (Van Gaal, Mertens, & Christophe, 2006), and certain types of cancer (Calle & Kaaks, 2004). Despite growing awareness of the health risks posed by this condition, obesity rates in the United States continue to climb (Hales, Fryar, Carroll, Freedman, & Ogden, 2018), suggesting that interventions aimed at reducing one's risk of unhealthy energy balance have not been effective. Indeed, the World Health Organization has cited obesity as being one of the most pressing public health challenges of the 21st century (World Health Organization, 2000).

While there are a variety of factors that contribute to high rates of obesity (Locard et al., 1992; McAllister et al., 2009; Weinsier, Hunter, Heini, Goran, & Sell, 1998), one factor that is known to impact one's risk is low childhood socioeconomic status (SES; Baum & Ruhm, 2009; Olson, Bove, & Miller, 2007). For example, longitudinal research examining environmental predictors of obesity in adolescents finds that time spent living in poverty before the age of nine is associated with higher body mass index (BMI) at age 17 (Wells, Evans, Beavis, & Ong, 2010), an effect that is mediated by greater exposure to factors such as crowding, noise, poor housing, separation from parents, exposure to violence, and family turmoil. Others find that parental education, a common proxy of childhood SES, is negatively related to adult obesity status, even after controlling for factors such as adult physical activity, consumption of vegetables, and achieved education level (Kestilä, Rahkonen, Martelin, Lahti-Koski, & Koskinen, 2009).

Results such as these highlight that the association between childhood SES and obesity risk is simultaneously robust and multicausal. At the neighborhood level, research suggests that reduced access to safe places to exercise and play (Pinter-Wollman, Jelić, & Wells, 2018; Suecoff, Avner, Chou, & Crain, 1999) and reduced access to healthy food options (Larson, Story, & Nelson, 2009) may each play a role in driving the low childhood SES – obesity link. At the family level, lack of parental education about healthful food practices may also contribute to this association (Conti, Heckman, & Urzua, 2010). At the individual level, people from lower-SES environments may develop food habits that contribute to unhealthy weight gain across the lifespan

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(Drewnowski & Specter, 2004). Although each of these factors undoubtedly plays a role in contributing to the heightened obesity risk exhibited among those from low-SES environments, they are by themselves incomplete. Interventions targeted at combating these contributing factors to obesity risk have met limited success (see e.g., Cummins, Flint, & Matthews, 2014; Hamid & Sazlina, 2019; Zhang et al., 2016), suggesting that our understanding of the mechanisms that mediate the relationship between childhood SES and energy balance in adulthood will likely require a deeper understanding of the day-to-day behavioral processes exhibitied by those from low-SES environments that impact body weight and energy balance over time.

In the current study, we sought to contribute to this research by examining the relationship between low childhood SES and the development of obesogenic energy-regulation strategies. Guided by insights from evolutionary models of life history theory (Brumbach, Figueredo, & Ellis, 2009; Ellis, Figueredo, Brumbach, & Schlomer, 2009; Kaplan & Gangestad, 2005; Rickard, Frankenhuis, & Nettle, 2014) and research showing that adults who grew up in low-SES environments eat in the absence of hunger (Hill, Prokosch, DelPriore, Griskevicius, & Kramer, 2016; Proffitt Leyva & Hill, 2018), we tested the following prediction: children living in less predictable and safe environments would eat independent of energy need, whereas children living in more predictable and safe environments would regulate food intake homeostatically using internal hunger and satiety cues. Although eating in the absence of hunger (EAH) is a pattern known to increase obesity risk in food-rich environments (e.g., Feig, Piers, Kral, & Lowe, 2018; Fisher & Birch, 2002; Fogel et al., 2018), this strategy may have historically helped to promote survival in environments that were resource deprived and unpredictable. The current research examines the developmental time course of energy regulation patterns found among low-SES children, as well as the environmental mediators through which low SES may affect energy regulation.

1.1. Life history theory, unpredictability, and regulation of energy intake

Life history theory is a well-established biological framework used to predict how and when organisms – including humans –allocate effort among the various tasks needed for survival and reproduction (Charnov, 1993; Kaplan & Gangestad, 2005; Roff, 1993; Stearns, 1992). Because somatic effort is inherently limited, organisms face important trade-offs in how they distribute these resources toward several competing life components – growth, maintenance, mating, and parental care – at any given point in time. For example, energy allocated toward immune system functioning cannot be used to concurrently attract a mate. Accordingly, throughout development, individual organisms must 'choose' how to divide up somatic resources toward achieving the various sub-goals required for successful reproduction (Ellis et al., 2009; Kaplan & Gangestad, 2005). These tradeoffs are manifested in an integrated suite of physiological and behavioral traits (e.g., timing of sexual development and reproduction, orientation toward more immediate versus future outcomes) that constitute the individual's *life history strategy*.

Working within a life history framework, researchers have hypothesized that developmental exposure to early-life adversity favors developmental tradeoffs that promote survival and reproduction under adverse conditions (Brumbach et al., 2009; Ellis et al., 2009; Griskevicius, Delton, Robertson, & Tybur, 2011a; Kaplan & Gangestad, 2005). Two key dimensions of the environment that regulate the development of life history strategies are extrinsic morbidity–mortality (external sources of disability and death that are relatively insensitive to the adaptive decisions of the organism) and predictability of environmental change (Ellis et al., 2009). In harsh environments characterized by relatively high age-specific rates of morbidity and mortality and unpredictability, life history strategies that maximize short-term gains (such as through future discounting, eating whenever food is available, and risky and aggressive behaviors that leverage access to mates) may increase the probability of reproducing prior to disability or death (for review see Ellis et al., 2012). Such strategies capitalize on presently-available opportunities, as it is uncertain whether such opportunities will be available into the future. Consistent with this theoretical perspective, environmental cues indicating higher extrinsic morbidity–mortality and unpredictability generally promote greater risk-taking (Griskevicius, Tybur, Delton, & Robertson, 2011b, 2013), as well as more risky sexual and aggressive behavior (e.g., Belsky, Schlomer, & Ellis, 2012; Doom, Vanzomeren-Dohm, & Simpson, 2016; James, Ellis, Schlomer, & Garber, 2012; Simpson, Griskevicius, Kuo, Sung, & Collins, 2012).

Although much of the early research employing a life history framework focused on outcomes related to sexual and reproductive outcomes, researchers more recently have applied insights from this theory to examine the lasting impact of early life environments on patterns of food intake exhibited in adulthood (Hill et al., 2016; Proffitt Leyva & Hill, 2018). In particular, these researchers hypothesized that early-life environments characterized by low SES may encourage the development of energy-regulation strategies that promote EAH. Such energy regulation patterns are reasoned to promote survival when energetic resources are scarce, even though these patterns are linked to obesity in modern, food-rich environments. Consistent with this hypothesis, adults who report that they grew up in relatively safe, resource-abundant environments tend to eat according to energy need, consuming more calories when they are hungry (i.e., high energy need) compared to when they are full (i.e., low energy need); by contrast, adults who report that they grew up in lower-SES environments tend to eat a comparably high amount of food, regardless of whether they are hungry or full (Hill et al., 2016; Proffitt Leyva & Hill, 2018; see also; Miller et al., 2018). These patterns suggest that one's early life environments may moderate the relationship between energy need and calorie consumption. This pattern was predicted to occur because extrinsic morbidity-mortality and unpredictability during childhood—key elements of low-SES environments—signal to the individual the likelihood of unreliable access to resources in the future, encouraging opportunistic rather than homeostatic eating (Hill et al., 2016; Proffitt Leyva & Hill, 2018).

Although these previous studies offer an important first step toward understanding how low childhood SES may promote EAH, many unanswered questions remain. The first question is one of etiology. What are the critical dimensions of low childhood SES that contribute to EAH in adulthood? Growing up poor often means a variety of different things for a child. These conditions are often characterized by unmet financial needs (Evans, 2004), food insecurity (Barrett, 2010; Coleman-Jensen, Rabbitt, M. P., Gregory, & Singh, 2016; Nord & Parker, 2010), and a lack of predictability and safety (Evans, Eckenrode, & Marcynyszyn, 2010, pp. 225–238). Accordingly, it is important to tease apart the different dimensions of low childhood SES to determine which of these factors contribute to the development of EAH. Identifying the specific environmental dimensions of low SES that drive the development of EAH, in addition to being important for the advancement of theory, has great practical importance, as it can be used to help identify the most effective interventions to promote healthy energy balance among those from low-SES environments.

The second question that remains is one of developmental time course. At what age do children's energy-regulation strategies begin to diverge as a function of their early life environmental circumstances? Research examining the impact of early life harshness and unpredictability on patterns of sexual development and risky sexual and aggressive behavior has found that exposure to harsh, unpredictable environments in the first 5–7 years of life is the best predictor of ecologically-contingent developmental strategies (Belsky et al., 2012; Evans, 2004; Lian et al., 2018; Simpson et al., 2012). We hypothesize that similar patterns will be observed with the mechanisms that govern energy intake, with the impact of early environments on energy regulation emerging early in life. Assessing the age at which differences in eating patterns begin to emerge is also of great practical importance for the development of interventions aimed at minimizing obesity risk, as much research indicates that the seeds of obesity risk are often sown in childhood (Biro & Wien, 2010; Deshmukh-Taskar et al., 2006; Gonzalez et al., 2012; Gordon-Larsen, Adair, Nelson, & Popkin, 2004; Poulton et al., 2002).

Finally, the current research extends past research on how low childhood SES may promote EAH by examing dimensions of low childhood SES *in children*. It is now well-documented that prospective and retrospective reports of stressful experiences in childhood are only weakly correlated (Hardt & Rutter, 2004; Newbury et al., 2018; Reuben et al., 2016). Thus, it is important to replicate past research on the role of childhood SES in regulating EAH (Hill et al., 2016; Proffitt Leyva & Hill, 2018), which employed adult retrospective measures, using contemporaneously obtained childhood measures.

1.2. The current research

The current research was designed to address these questions of etiology and developmental time course in a cross-sectional study of children ages 3–14 years old. Regarding critical dimensions of low childhood SES that contribute to EAH in adulthood, life history theory emphasizes extrinsic morbidity-mortality and unpredictability as being the drivers of divergent life history strategies (including potentially divergent patterns of eating among individuals growing up under different socioeconomic conditions). Here, we operationalized extrinsic morbidity-mortality in terms of safety (versus danger) at home, school, and in the neighborhood, and we measured predictability in terms of the child's life at home. We combined these constructs into an overarching measure of perceived predictability/safety.

Our conceptual model is presented in Fig. 1. Given the important role of predictability/safety in shaping environmentally contingent developmental patterns and behavioral strategies (e.g., see Ellis et al., 2009 for review; see also e.g., Maner, Dittmann, Meltzer, & McNulty, 2017; Simpson et al., 2012; Szepsenwol et al., 2017), as well as previous research linking perceived unpredictability and lack of safety to EAH in adults (Proffitt Leyva & Hill, 2018), we predicted that the link between lower-SES and greater EAH would be primarily *mediated* by variation in levels of predictability/safety in the environment (see Fig. 1).

Other potential mediators included in the model were unmet financial needs and food insecurity, which were assumed to be of secondary importance relative to predictability/safety (discriminant prediction). In turn, we predicted that the effect of predictability/safety in the environment (but not unmet financial needs or food insecurity) on calorie intake would be *moderated* by children's energy need. Specifically, we predicted that those from more predictable/safe environments would eat commensurate with energy need (eating more when hungry than when sated), whereas those from less predictable/safe environments would eat comparable amounts, regardless of energy need.

We designed the current study both to test the preceding predictions and to roughly assess the age at which SES-based differences in eating patterns begin to emerge. To this latter end, we initially ran the analyses with all participants (a sample of children ages 3–14), and then ran follow-up analyses using only data collected from participants who were 3–7 years old (to see if the link was already present in this earlier age range). This age cutoff is consistent with extant life history theory and research, which generally converges on the first 5–7 years as a sensitive period for the effects of exposures to harsh, unpredictable environments on the development of life history strategies (as originally proposed by Belsky, Steinberg, & Draper, 1991). Accordingly, we predicted that the SES – EAH link would already be present in this age group. Further, we conducted an additional follow-up analysis to examine whether a similar pattern of results would be found for older children (ages 8–14) as a test of the stability of the SES – EAH link across stages of childhood development.

2. Method

2.1. Participants

One hundred forty-one children aged 3–14 (M_{age} = 7.12, *SD* = 2.75) and their parent/legal guardian (henceforth, *parent*) were recruited at the Fort Worth Museum of Science and History (FWMSH) during regular weekend hours and during free admission on weeknights for low-income families. See Table 1 for full participant characteristics and Table 2 for characteristics of the accompanying adults. The sample included 66 boys and 74 girls, with 49.3% White/Caucasian, 16.2% Hispanic, 5.6% Asian, 4.2% Black, and 9.2% multiracial. The participants included a diverse socioeconomic sample with a mean subjective SES of *M* = 4.14, *SD* = 0.73 (1 = Very poor, 4 = Middle class, 7 = Very wealthy).

2.2. Procedure and materials

This research was approved by the Texas Christian University Institutional Review Board and the Executive Board of the FWMSH. All data were collected in the museum's Research Learning Center, which is an area in the museum dedicated to community participation in science. Participants were processed two at a time by a team of four to six researchers. Each family began by providing written informed consent/assent or verbal assent (depending on child's age). After consent/assent was provided, the parent was asked to move to another table to allow the child to complete the remainder of the study alone with the researcher.

Children completed their portion of the study at one of two tables, situated approximately 10 feet apart. Tables were separated by a clear, 5′ X 8′ partition placed between the tables to reduce noise transference. Opaque table dividers were placed at the end of each table to obstruct vision to the other table (see Fig. S1 in the Supplemental Materials for a visual representation of the testing space). Parents completed their portion of the study while seated at a table approximately 25 feet behind the child. The location of the parent table was chosen so that the children's behavior would not be under the direct influence of their parents, but the children could turn around to see their parent if they wished. This was important, especially for the youngest children to feel comfortable while participating in the study. The parents were discouraged from interacting with the child while the child was participating in the study, and each child sat facing a researcher who was seated in front of a blank wall to avoid unnecessary distractions. In the case that siblings were processed, they were seated at opposite ends of the testing table facing the researcher.

2.3. Measures of socioeconomic status and its environmental correlates

A complete list of all scales used in the current research can be found in the supplemental materials. Parents were asked to respond to questions assessing: (a) subjective SES, (b) food insecurity in their household over the last two years (henceforth, *food insecurity;* Connell, Nord, Loften, & Yadrick, 2004), (c) the degree to which they struggle to afford shelter, clothing, and medical care (henceforth, *unmet financial needs*), and (d) environmental predictability/safety (henceforth, *predictability/safety*[1]). These categories were created based on theory (see e.g., Ellis et al., 2009) and empirical work (Brumbach et al., 2009). We assessed subjective SES by asking parents to respond to a single item:

[1] Although lack of unpredictability and safety are sometimes separated into separate constructs, a confirmatory factor analysis revealed these two dimensions of unpredictability are part of the same underlying construct. This suggests that these two variables are both feeding into a construct the measures environmental unpredictability, as lack of safety, particularly as described in our questionnaire, is marked by elements of unpredictability.

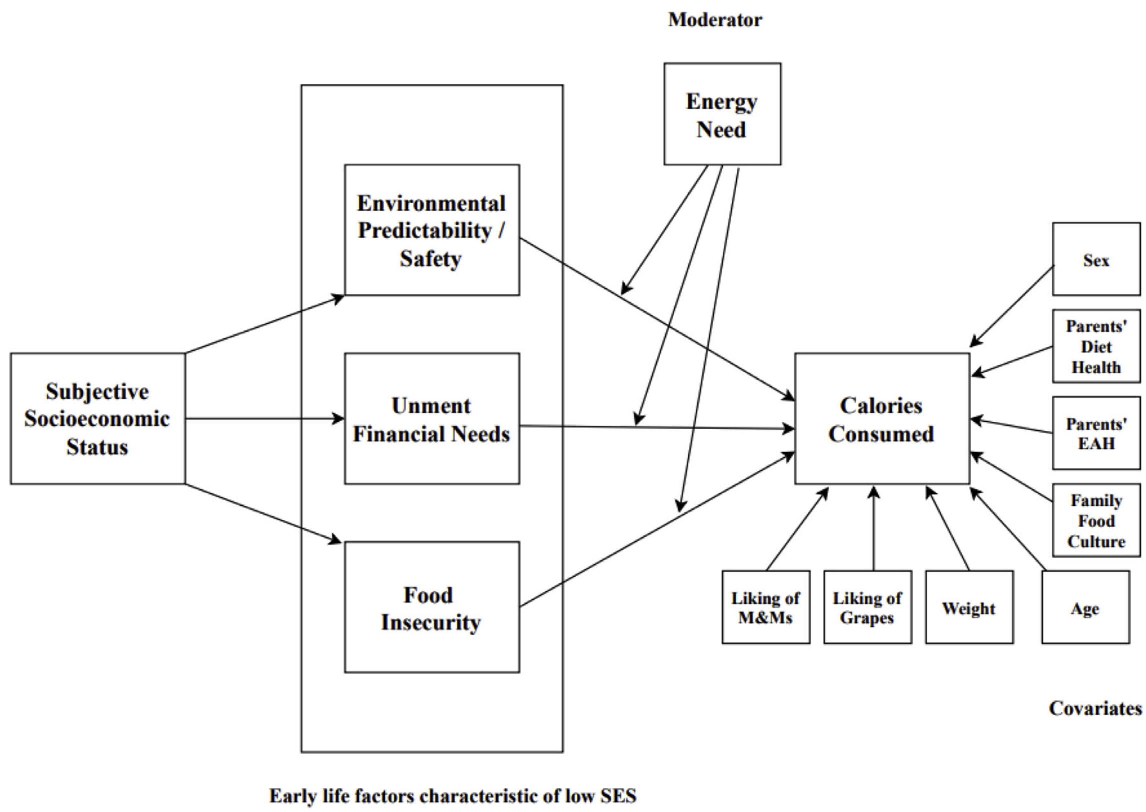

Fig. 1. Conceptual depiction of the statistical model. EAH = eating in the absence of hunger. SES = socioeconomic status.

Table 1
Characteristics of the sample (N = 141).

Sex: Boys = 66; Girls = 74
Age (3–14): *M* = 7.12, *SD* = 2.75
Race
White: 49.3% (*n* = 70)
Black: 4.2% (*n* = 6)
Hispanic: 16.2% (*n* = 23)
Asian: 5.6% (*n* = 8)
Multiracial/Other: 9.2% (*n* = 13)
Body mass index (12.30–34.80): *M* = 17.56, *SD* = 3.90
Body mass index percentile (1.00–99.00): *M* = 57.55, *SD* = 30.48
Subjective family SES: *M* = 3.86, *SD* = .73 (1 = Very wealthy, 4 = Middle class, 7 = Very poor)
Family yearly income: *M* = 5.48, *SD* = 2.02 (1 = $15,000 or less, 4 = $35,001-$50,000, 8 = $150,001 or more)
Parent education: *M* = 4.32, *SD* = 1.88 (1 = Some high school, 4 = Associate's degree, 8 = Professional degree (M.D., J.D., etc.)

Note. Information regarding race was only provided for 120 children.

Table 2
Characteristics of the adults.

Relationship to Child (N = 141)
Biological Mother: 56.3% (n = 80)
Biological Father: 22.5% (n = 32)
Stepmother: 1.4% (n = 2)
Stepfather: 1.4% (n = 2)
Adoptive Father: 2.1% (n = 3)
Grandparent: 9.2% (n = 13)
Aunt/Uncle: 5.6% (n = 8)
Older Sibling: 0.7% (n = 1)

"How would you rate your current socioeconomic status?" (1 = very poor; 7 = very wealthy). Food insecurity was measured using a modified, 8-item version the food insecurity scale (Connell, Nord, Lofton, & Yadrick, 2004; e.g., "I worried that my household would not have enough food"), which was scored per convention. Specifically, responses to the 3 questions that were measured on a Likert scale were each coded such that scores falling above the midpoint (midpoint: 4) were coded as "1" and all falling on the midpoint or below were coded as "0". These scores were then added to the summed "yes" responses given to the 5 questions utilizing a yes/no scale. Per USDA guidelines, we then used these sums to classify respondents as food secure (no affirmative responses), marginally food insecure (1–2 affirmative responses), or food insecure (3 or more affirmative responses) (Bickel, Nord, Price, Hamilton, & Cook, 2000). Six additional items were adapted for the purpose of the current study to assess the constructs of each unmet financial needs (Conger, Ge, Elder, Lorenz, & Simons, 1994; e.g., "You have enough money to afford the kind of home you need") and predictability/safety (e.g., "My child is safe and secure at home and at school"). See supplemental materials for all scales and items.

We conducted a factor analysis to ensure that our theoretically-derived constructs (unmet financial needs and predictability/safety) represented empirically distinct factors. Subjective SES and food insecurity were not included in this factor analysis as subjective SES was measured as a single item measure and food insecurity was categorized using a established scoring procedure. The results of a principal axis factor analysis using oblique rotation (direct oblimin) with Kaiser normalization yielded two distinct factors (see Table 3 for factor loadings). Factor 1 was labeled *unmet financial needs* due to high loadings of the following items: "Do you have enough money to afford the kind of home you need?", "Do you have enough money to afford the kind of clothing you need?", "Do you have enough money to afford the kind of medical care you need?" (items from the Unmet Financial Needs Scale; Conger et al., 1994), accounting for 44.43% of the variance, with an eigenvalue of 2.667. These items displayed high internal-consistency reliability (α = 0.88) and were reverse-scored so that higher scores indicated greater unmet financial need. The second factor was labeled environmental predictability/safety due to high loadings from the following items: "My child's home life is predictable.", "My child is safe

Table 3
Rotated Solution Correlations Demonstrating Factor loadings for the Exploratory Factor Analysis.

	Unmet financial needs[a]	Predictability/safety
You have enough money to afford the kind of home you need.	.938	
You have enough money to afford the kind of clothing you need.	.930	
You have enough money to afford the kind of medical care you need.	.844	
My child is safe and secure at home.		.780
My child's home life is predictable.		.734
My child lives in a safe neighborhood.		.759

[a] Reverse coded, so that higher scores indicate greater unmet financial need.

and secure at home and at school.“, and “My child lives in a safe neighborhood.” accounting for 25.54% of the variance, with an eigenvalue of 1.53. Although these items together yielded moderate reliability (α = 0.59), their factor structure was well-supported by the factor analysis, suggesting that they account for shared variance in our statistical model.

2.4. Energy need

As a proxy measure of children's energy need, we asked parents to report the number of hours and minutes it had been since the child last ate anything ($M_{\text{hours}} = 2.48$, $SD_{\text{hours}} = 2.21$). Similar measures of energy need have been used in several studies with adults (Hofmann, Rauch, & Gawronski, 2007; Prinsen, de Ridder, & de Vet, 2013; Seibt, Häfner, & Deutsch, 2007) and children (DeJesus, Gelman, Herold, & Lumeng, 2019; Harris, Bargh, & Brownell, 2009); this measure has been found to correlate with other indices of energy need (e.g., blood glucose levels and reported hunger, respectively: Hill et al., 2016; Wardle & Beales, 1987).

2.5. Alternative predictors of eating behavior

In addition to measuring the hypothesized environmental mediators of the relationship between low SES and EAH (e.g., unpredictability/unsafety), we measured alternative drivers of this relationship so that we could control for them, if necessary. These measures can be found in the supplemental materials. In particular, parents were asked questions assessing the healthiness of their own diets, whether they eat in the absence of hunger, and whether they encourage their children to finish all of the food on their plates, even when the child is no longer hungry (see supplemental materials for full details on scales used). Each of these measures is potentially important to account for, as parents from low-SES environments often exhibit unhealthy eating habits themselves (Vereecken, Keukelier, & Maes, 2004) and may encourage a food culture in their households which requires children to finish all of the food on their plates (Evans et al., 2011), both of which can contribute to EAH.

2.6. Eating task

The researcher presented the child with two snacks, each served in individual, identical white paper bowls. The snacks were 15 green seedless grapes sliced in half and a 1.69-ounce (47.9 g) package of M&M candies. Snacks were pre-weighed in their bowls by the researchers before being delivered to the children. After the snacks were placed in front of the child, the researcher asked the child to sample each snack and then rate the taste of the snack (rated on a 7-point picture-based scale; *1* = Yucky [written above a picture of a cartoon face making a disgusted face], *4* = Just okay [written above a picture of a cartoon face making a neutral face], *7* = Delicious [written above a picture of a cartoon face making a yummy face]). After rating the snacks, the children were given 5 min to eat as much or as little of each snack as they desired, while the researcher ostensibly completed paperwork across the room. After the 5 min was up, the bowls and any remaining food were removed by a different researcher who then weighed each bowl and any remaining food to calculate the total grams of each food that was consumed. The number of grams of each snack consumed was calculated by subtracting the amount of each type of food left over from the starting weight. Calories consumed were then calculated using nutrition information available online from M&M candies (M and M Milk Chocolate Candies Nutritional Information, 2018; www.mms.com/us/nutrition) and nutritional facts for green seedless grapes provided by the United States Department of Agriculture (USDA, 2018; https://www.ars.usda.gov/ARSUserFiles/80400525/data/hg72/hg72_2002.pdf).

After completing the eating task, the child's height and weight were measured and the children were allowed to choose a toy as a token of appreciation for their participation. The child's parent received a document with their child's height, weight, calculated BMI, and resources for maintaining a healthy weight in children based on recent CDC guidelines.

3. Data preparation, analysis plan, and results

3.1. Data preparation

Data were double-entered from paper questionnaires into SPSS by two independent research assistants blind to the research hypothesis. All errors were corrected by the first author to ensure perfect reliability (α = 1.0) for each variable.

3.2. Data analysis plan

See Fig. 1 for a conceptual depiction of the hypothesized model. Data were analyzed using hierarchical linear modeling (HLM) in MPlus statistical software (MPlus 7.4; Muthén & Muthén, 2012). Because many of our participants were siblings ($n = 33$ sets of siblings), all sibling data were treated as non-independent observations. To control for this non-independence, data were structured as clusters of observations, with each cluster representing participants who were processed together during the time of the study (and those processed individually being alone in their ‘cluster’). For all models, model fit was assessed using four fit indices: χ^2 test of model fit, the comparative fit index (CFI), the root mean square error of approximation (RMSEA), and the standardized root mean square residual (SRMR). Adequate model fit is determined by a non-significant χ^2 value ($p > .05$), a CFI value > 0.95, an RMSEA value < 0.08, and an SRMR statistic < 0.08 (Kline, 2016). Missing data were handled via maximum likelihood estimation.

Per convention, standardized parameter coefficients for each effect were estimated using robust full maximum likelihood estimation (Kline, 2016; Muthén & Muthén, 2012). As an additional test of parameter reliability, we also generated credibility intervals (CIs) for each effect (interpreted in the same manner as confidence intervals) in the primary model using Bayesian estimation in MPlus, a Markov chain Monte Carlo process (Muthén, 2010; Van de Schoot et al., 2014; Zyphur & Oswald, 2015). Effects were considered significant only when both $p < .05$ and the CIs for the given effect did not contain 0.

To be consistent with past research (Hill et al., 2016; Proffitt Leyva

& Hill, 2018), and to address potential alternative explanations for the predicted effects, we first tested for the inclusion of the following variables as covariates in our model: sex, parents' tendency to eat in the absence of hunger, parents' dietary health, family food culture, child's weight, child's age, and reported liking of each food item (grapes, M& Ms). Only statistically significant covariates were retained in the main model; however, we also report the results of the main model without these covariates included in the supplementary materials.

The first set of paths in our primary structural path model (see Fig. 1) assessed whether SES predicts the three related, but conceptually distinct potential mediators of the link between low childhood SES and EAH: food insecurity, unmet financial needs, and predictability/safety. The second set of paths tested whether food intake (calories consumed) was predicted by (1) each of the three potential mediators, (2) energy need (i.e., time since child last ate), and/or (3) an interaction between energy need and each of the potential mediators. Based on theory (Ellis et al., 2009; Maner et al., 2017; Simpson et al., 2012; Szepsenwol et al., 2017) and the results of previous research (Proffitt Leyva & Hill, 2018), we predicted that predictability/safety would interact with energy need to predict food intake. Specifically, we predicted that children from homes that are characterized by higher levels of predictability/safety would eat a greater number of calories when hungry than when full. Conversely, we predicted that children from homes that are characterized by low levels of predictability/safety would consume a comparable number of calories, regardless of energy need.

3.3. Results: test of covariates

Descriptive statistics are displayed in Table 4. First, we examined whether any of our covariates (i.e., sex, parents' tendency to eat in the absence of hunger, parents' dietary health, family food culture, weight, age, and liking of the two snacks) had an influence on participants' calorie intake or interacted with energy need to predict calorie intake. As expected, the children's liking of both the M&Ms, $\beta = 0.26$, $SE = 0.07$, $t = 3.77$, $p < .001$, and the grapes, $\beta = 0.16$, $SE = 0.08$, $t = 2.04$, $p = .04$, predicted calorie intake, with greater liking predicting higher calorie consumption. Additionally, child age also predicted calorie intake, $\beta = 0.31$, $SE = 0.15$, $t = 2.08$, $p = .04$, with older children consuming more calories than younger children. Liking of each of the food items and child's age were therefore included as covariates in the target analysis. No relationship between calorie consumption and the remaining proposed covariates reached significance (sex, parents' tendency to eat in the absence of hunger, parents' dietary health, family food culture [i.e., rules for eating all of the food on one's plate], or child's weight) (all $ps > .08$). Therefore, these variables were not included in subsequent models. Moreover, there were no significant interactions between any of the proposed covariates and energy need in predicting calorie consumption (all $ps > .47$).

Table 4
Descriptive statistics for key variables.

Key Variables	Mean (*SD*)	Range
Subjective SES	3.86 (0.73)	1–6
Environmental Predictability/Safety	6.36 (0.85)	1–7
Unmet Financial Needs	2.12 (1.50)	1–7
Food Insecurity	1.16 (0.50)	1–3
Energy Need (Hours Since Last Ate)	2.48 (2.21)	0.17–16.00
Calories Consumed	150.08 (85.92)	0–320.61
Parents' Diet Health	4.68 (1.29)	1–7
Parents' EAH	3.68 (1.37)	1–7
Family Food Culture	4.98 (1.97)	1–7
Liking of M&M's	6.44 (1.33)	1–7
Liking of Grapes	6.09 (1.65)	1–7
Child Bodyweight (lbs.)	64.48 (29.20)	26–154
Age	7.12 (2.75)	3–7

3.4. Preliminary analyses: conceptual replication of previous findings

Before testing the primary structural path model, we first conducted analyses to examine whether there was a significant relationship between low childhood SES and EAH. We did this to test whether we would be able to conceptually replicate the pattern observed in adults from low-SES environments (see Hill et al., 2016) in our sample fo children ages 3–14.

Results revealed that, consistent with previous research (Hill et al., 2016), there was a significant interaction between childhood SES and energy need, $\beta = -0.13$, $SE = 0.06$, $t = -2.16$, $p = .03$, with children from high-SES environments eating a greater number of calories when energy need was high (compared to when low), $\beta = 1.86$, $SE = 0.76$, $t = 2.44$, $p = .02$, but those from low-SES environments eating a comparable number of calories irrespective of energy need, $\beta = 0.03$, $SE = 0.12$, $t = 0.24$, $p = .81$.

3.5. Target analysis: factors characterizing low SES and eating in the absence of hunger

We next tested the primary structural path model in which we assessed the indirect impact of low childhood SES on EAH through each predictability/safety, food insecurity, and lack of financial resources, all of which are inherent in low-SES environments. Number of hours since last having eaten (energy need) was positively skewed, and thus natural log-transformed to normalize the distribution and improve model fit (see Table 5 for fit statistics); this transformation normalized the distribution and improved all model fit indices, but did not change the pattern or significance of the results. After this transformation, results revealed good model fit. As predicted, higher-SES children were exposed to more predictable, safer environments, $\beta = 0.18$, $SE = 0.06$, $t = 2.98$, $p = .003$, 95% CI = [0.01, 0.34], had fewer unmet financial needs, $\beta = -0.46$, $SE = 0.06$, $t = -7.37$, $p < .001$, 95% CI = [-0.57, -0.29], and were less food insecure, $\beta = -0.20$, $SE = 0.010$, $t = -2.04$, $p = .04$, 95% CI = [-0.34, -0.03], than lower-SES children.

Next, results revealed that there was a main effect of energy need on calorie intake, $\beta = 0.15$, $SE = 0.07$, $t = 2.17$, $p = .033$, with children who went longer without eating prior to the session consuming more calories than those who had eaten more recently. The CIs for this main effect, however, were not significant, 95% CI = [-0.02, 0.29]. The main effects were also not significant for predictability/safety, $\beta = -0.05$, $SE = 0.07$, $t = -0.64$, $p = .52$, 95% CI = [.-0.21, 0.11], unmet financial needs, $\beta = -0.02$, $SE = 0.09$, $t = -0.23$, $p = .82$, 95% CI = [.-0.20, 0.15], or food insecurity, $\beta = 0.03$, $SE = 0.07$, $t = 0.47$, $p = .64$, 95% CI = [-0.13, 0.20]. However, as predicted, there was a significant interaction between energy need and predictability/safety on children's food intake, $\beta = 0.21$, $SE = 0.08$, $t = 2.63$, $p = .008$, 95% CI = [0.03, 0.36] (see Fig. 2 for interaction effect).

To probe this interaction, two sets of simple slopes analyses were conducted. The first examined the impact of predictability/safety on calorie intake at high (+1 *SD*) and low (−1 *SD*) levels of energy need. The second examined the impact of energy need on calorie intake at high (+1 *SD*) and low (−1 *SD*) levels of environmental predictability/

Table 5
Summary of model fit statistics.

Model	χ^2 (*df*)	CFI	RMSEA	SRMR
Primary Model –Untransformed	119.75 (44)*	.57	.11	.14
Primary Model – Transformed	35.84 (44)	1.00	.00	.07
Primary Model without Covariates	17.07 (24)	1.00	.00	.07

Note. CFA = confirmatory factor analysis; CFI = comparative fit index; RMSEA = root mean square error of approximation; SRMR = standardized root mean square residual. 'Transformed' refers to a natural log-transformation to the energy need variable. *$p < .05$.

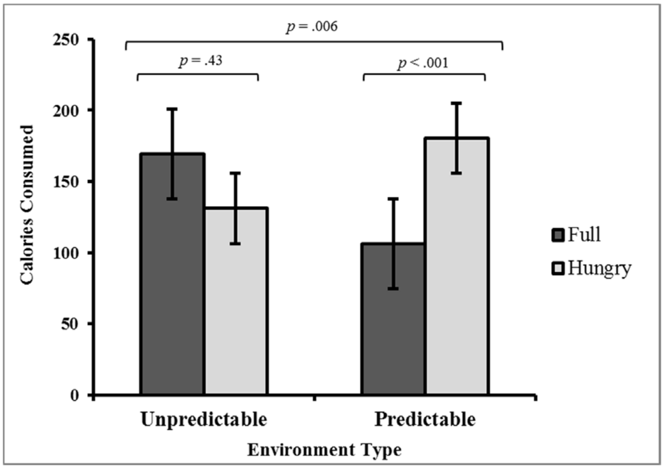

Fig. 2. The impact of environmental predictability/safety on eating behavior at different levels of energy need. "Hungry" and "Full" refer to the amount of time that had passed since participants had last easten anything (+and – 1 standard deviation above/below the mean, respectively, on the measure "How long has it been since your child has last eaten anything?").

safety. Examining the impact of predictability/safety at high and low levels of energy need revealed that, for children who were hungry (i.e., energy need was high), environmental predictability/safety did not impact the number of calories consumed, $\beta = 0.09$, $SE = 0.09$, $t = 0.99$, $p = .32$. However, for children who were full (i.e., energy need was low), lower environmental predictability/safety significantly predicted greater calorie intake, $\beta = -0.46$, $SE = 0.13$, $t = -3.66$, $p < .001$, with those from more predictable/safe environments eating fewer calories than those from unpredictable/unsafe environments.

The impact of energy need on calorie intake at different levels of environmental predictability/safety was next examined. Results revealed that, for children from more predictable, safer environments, energy need significantly predicted calorie consumption, $\beta = 0.45$, $SE = 0.13$, $t = 3.57$, $p < .001$, with children eating more calories when energy need was high compared to when energy need was low. There was no such relationship found for children from environments lower in predictability/safety, however, $\beta = -.07$, $SE = 0.09$, $t = -0.78$, $p = .43$. In other words, children from more predictable, safer environments were eating according to energy need, while children from more unpredictable, unsafe environments ate a comparable number of calories regardless of whether energy need was high or low. Neither unmet financial needs ($p = .33$, 95% CI = [-0.27, 0.12]) nor food insecurity ($p = .07$, 95% CI = [-0.05, 0.30]) interacted with participant energy need to predict food intake (see Supplemental Analysis S1 in supplemental materials for more details).

Overall, the primary model accounted for 19.8% of the variance in calorie intake with significant covariates including in the model, and 11.5% of the variance in this outcome when these covariates were excluded. Excluding covariates did not, however, change the pattern or significance of any effects in the primary model (see Supplemental Analysis S2 in supplemental materials for results without covariates).

3.6. Follow-up analysis: factors characterizing low SES and eating in the absence of hunger for children younger than eight years old ($n = 77$)

We performed a targeted follow-up analysis to examine whether the interaction between environmental predictability/safety and energy need predicted calorie consumption in children younger than eight years old ($n = 77$). As in the primary model, there was a significant two-way interaction between predictability/safety and energy need on participants' calorie intake, $\beta = 0.26$, $SE = 0.10$, $t = 2.63$, $p = .009$, 95% CI = [0.05, 0.45].

To probe this interaction, we conducted two sets of simple slopes analyses; the first was conducted at both high (+1 *SD*) and low (−1 *SD*) levels of the energy need variable and the second at high (+1 *SD*) and low (−1 *SD*) levels of environmental predictability/safety. Examining the effect of predictability/safety on calorie consumption at high and low levels of energy need revealed that, for children who were hungry (i.e., energy need was high), environmental predictability/safety did not impact the number of calories consumed, $\beta = -0.03$, $SE = 0.09$, $t = -0.30$, $p = .77$. However, for children who were full (i.e., energy need was low), lower environmental predictability/safety significantly predicted greater calorie intake, $\beta = -0.33$, $SE = 0.12$, $t = -2.73$, $p = .006$, replicating the pattern observed in the full sample.

We next examined the impact of energy need on food intake at different levels of environmental predictability/safety. Results revealed that, for children from more predictable, safer environments, energy need significantly predicted calorie consumption, $\beta = 0.44$, $SE = 0.18$, $t = 2.44$, $p = .02$, with children eating more calories when energy need was high compared to when energy need was low. There was no such relationship found for children from more unpredictable, unsafe environments, $\beta = -.22$, $SE = 0.12$, $t = -1.77$, $p = .08$. These results also replicated the pattern observed in the full sample. However, it is worthy of nothing that, although not conventionally significant, children under eight in relatively unpredictable, unsafe environments trended toward actually eating more when their energy need was low compared to when it was high. Overall, these results provide initial evidence that environmental unpredictability leads to EAH, even in children younger than eight.

3.7. Follow-up analysis: factors characterizing low SES and eating in the absence of hunger for children eight years and older ($n = 64$)

We performed a second follow-up analysis to examine whether the interaction between environmental predictability/safety and energy need predicted calorie consumption in children eight years and older ($n = 64$). Similar to the primary model, as well as the model tested in children younger than eight years old, the two-way interaction between predictability/safety and energy need trended toward significance, $\beta = 0.29$, $SE = 0.17$, $t = -1.76$, $p = .08$, 95% CI = [-0.35, 0.73].

We again probed this interaction using two sets of simple slopes analyses; first at both high (+1 *SD*) and low (−1 *SD*) levels of the energy need variable and again at high (+1 *SD*) and low (−1 *SD*) levels of environmental predictability/safety. Results revealed that, for children who were hungry (i.e., energy need was high), environmental predictability/safety did not impact the number of calories consumed, $\beta = -0.21$, $SE = 0.16$, $t = -1.33$, $p = .18$, 95% CI = [-0.55, 0.18]. However, for children who were full (i.e., energy need was low), lower environmental predictability/safety predicted greater calorie intake, $\beta = -0.42$, $SE = 0.21$, $t = -1.97$, $p = .049$, 95% CI = [-0.97, 0.35], similar to the patterns observed both in the full sample and in younger children. Note that the creditbility interval for this effect did contain 0.

We next examined the impact of energy need on food intake at different levels of environmental predictability/safety. Results revealed that, for children from more predictable, safer environments, energy need predicted calorie consumption, $\beta = 0.56$, $SE = 0.20$, $t = 2.89$, $p = .004$, 95% CI = [-0.10, 0.94], with children eating more calories when energy need was high compared to when energy need was low. Note that, again, while the *p*-value was significant, the credibility interval contained 0. At low levels of predictability/safety, higher energy need did not predict caloric intake, $\beta = -0.03$, $SE = 0.23$, $t = -0.11$, $p = .91$, 95% CI = [-0.74, 0.79].

While the interaction was not statistically significant (as was true for the previous models), these results replicated the patterns observed in the full sample and in children younger than eight years old. The lack of statistical significance here may have been due to inadequate power to detect the predicted relationships in this relatively small sub-sample of children ($n = 64$).

4. Discussion

Research indicates that low childhood SES is a major predictor of obesity in adulthood (Gonzalez et al., 2012; Poulton et al., 2002; Wells et al., 2010). We proposed that, in addition to the sociological factors known to contribute to this association (Baltrus, Everson-Rose, Lynch, Raghunathan, & Kaplan, 2007; Laitinen, Power, & Järvelin, 2001), low childhood SES would also calibrate the mechanisms that guide food intake in ways that motivate EAH. Such mechanisms are hypothesized to be favored in these environments because they would help promote survival in harsh and unpredictable environments. Support for this hypothesis has been found across several studies in adult participants utilizing retrospective accounts of childhood environments as the key moderator of calorie intake under different levels of energy need (Hill et al., 2016; Proffitt Leyva & Hill, 2018). The current research was designed to build on this previous work, predicting that (a) contemporaneously measured childhood SES would predict EAH in children ages 3 to 14 and (b) that the link between low childhood SES and EAH would be driven by variation in levels of predictability/safety in home and neighborhood environments.

The results of the present study supported our predictions. Specifically, we found that children from higher-SES households were exposed to more predictable, safer environments, had fewer unmet financial needs, and had less food insecurity. In turn, environmental predictability/safety, but not other correlates of SES, interacted with energy need to predict calorie intake. Specifically, children from more predictable, safer environments ate according to energy need, consuming a greater number of calories when energy need was high compared to when it was low. On the other hand, children from more unpredictable, unsafe environments exhibited EAH. That is, they ate a similar number of calories irrespective of energy need. This same pattern of results was found in a follow-up analysis using only children in our sample younger than eight years old.

These results advance theory in several key ways. First, they demonstrate that SES-based differences in calorie regulation emerge early in life, as they were already manifest in our subsample of children ages 3 to 7. This is noteworthy because it indicates that energy-regulation strategies are likely sensitive to environmental cues that are present very early in development, a finding consistent with life history models of development (Belsky et al., 2012; Doom et al., 2016; Simpson et al., 2012). Secondly, the current results suggest that, rather than being driven by food insecurity or unmet financial needs, which are perhaps more intuitive mediators of the link between low SES and EAH, this link was mediated by environmental predictability/safety. This is conceptually consistent with past research on energy regulation patterns observed in adults (Proffitt Leyva & Hill, 2018) and likely reflects developmental attunement to cues that have historically played an important role in minimizing energy shortfalls and starvation. Historically (and currently, in contemporary hunter-gatherer groups), the primary means by which individuals have buffered themselves against energy shortfalls has been through their social networks (Gurven & Kaplan, 2007; Kaplan, Gurven, Hill, & Hurtado, 2005; Petersen, Aarøe, Jensen, & Curry, 2014). The current results suggest that our energy regulation mechanisms may reflect this legacy, with their developmental trajectory being most sensitive to cues bearing on the predictability and safety of one's immediate environments. Our findings highlight that environmental unpredictability associated with low-SES environments, especially early in life, may be a critical intervention target for developing healthy energy-regulation strategies. For example, the results of the current research suggest that interventions focused on promoting home stability and neighborhood safety may be especially beneficial in facilitating healthy eating behaviors. Such inverventions may complement existing strategies for reducing childhood overweight and obesity status, such as those designed to increase access to healthy food options in low-income communities.

Our findings provide insight into a possible mechanism linking early life environments with adult overweight and obesity status (for a similar hypothesis, see Dhurandhar, 2016). For example, research indicates that children who grow up in financially unstable families, particularly between the ages of 0–3, are at a significantly greater risk of obesity, even if their families moved out of poverty in later childhood (Li, Mustillo, & Anderson, 2018). Conversely, they found that children growing up in financially stable families, but who later become poor, are not at a greater risk of overweight and obesity. Because patterns of eating behavior observed in childhood are relatively stable over time (Fogel et al., 2018), the results of the current research suggest that EAH may be a behavioral mediator of the low childhood SES-obesity link. Future research is needed to examine, longitudinally, the relationship between early life environments, EAH, and energy balance and weight gain over time.

Although the current research did not find a correlation between food insecurity and EAH, others have observed a relationship between these variables (e.g., Godsell, Randle, Bateson, & Nettle, 2019; Kral, Chittams, & Moore, 2017; Nettle et al., 2019). For example, in one study, researchers found that, in women, retrospectively-reported childhood food insecurity interacted with adult food insecurity to predict higher adult BMI, calorie intake, and greater liking ratings of chocolate (Nettle et al., 2019). Results such as this suggest that childhood food insecurity may be an important pathway to adult BMI, obesity, and energy-regulation strategies – particularly among those who remain food insecure as adults. The mixed results on the impact of food insecurity on EAH suggest that future research is needed to better understand how food insecurity over the lifespan impacts energy regulation.

An unanticipated pattern of results that was found in our study was that, for young children (our subsample of children ages 3–7), there was a trend indicating less food intake in the context of hunger than fullness. Although this pattern needs to be further explored in a larger sample of children under eight before any conclusions can be drawn from the observed pattern, it may indicate that energy dysregulation manifests itself in different ways in young children. That is, it is possible that early in development, children's eating reflects their lack of attunement to their body's hunger and satiety signals, but is not yet opportunistic (eating when food is available). Future research will be necessary to establish how EAH develops over time, as well as the mechanisms guiding its development.

There current research has important limitations that should be considered when interpreting the meaning of the presented results. First, our study was limited by our relatively abbreviated measures of each of the reported environmental measures. This was a limitation imposed by the nature of our data collection procedure (i.e., all data were collected in a museum setting and the number of questions that we were allowed to ask participants were strictly limited). For example, the current research used only a single-item measure of childhood SES and a three-item measure to assess predictability/safety. While we did replicate the findings of previous research that used a broader range of measures to assess the impact of childhood SES on EAH (Hill et al., 2016), it is possible that a greater number of measures to assess each predictability and safety may have revealed a unique role for each in predicting EAH. Future research would benefit from asking participants a broader range of questions assessing each unpredictability (without including measures of unpredictability stemming from a lack of safety) and safety. Such research would allow for a more precise test of the relative importance of each of these dimensions on the development of environmentally-contingent energy-regulation strategies.

Next, it is important to note that, because we collected data at a single point in time to assess children's tendencies towards EAH, these results may not reflect children's approach to food over time. A variety of factors may have influenced children's desire to eat snacks at this specific time, although we exercised great care to minimize these through our research design. As behavior can vary across contexts, a single measurement of tendencies towards EAH may not fully capture the energy-regulation strategies of an individual. Moreover, EAH may also vary across food types. That we only offered two snacks to participants during the eating task is another potential limitation to consider. Future research may find that links between childhood environmental factors and EAH differ across foods varying in caloric content or gustatory properties.

Additionally, we aimed to determine the timing at which energy-regulation strategies may be calibrated by one's early-life environment. While we found that these effects were present in our sample of children ranging from age 3–14, and in a subsample of our sample targeting those who were younger than eight years old, we were unable to analyze these effects for each individual age of children due to limited sample size and power concerns. Future research utilizing larger sample sizes would be invaluable in shedding light on the specific ages in which early life unpredictability may begin to reliably calibrate energy-regulation strategies. In addition to examining links between childhood environmental factors and EAH across a broader age range, future research would also benefit from examining these relationships in a more racially diverse sample. Although the current research included a relatively diverse sample of children from a range of racial, ethnic, and socioeconomic backgrounds, the numbers of children in each category were too small to make meaningful comparisons between children based on variables such as race and enthicity. Such comparisons would provide needed inight into whether the observed relationship between predictability/safety and EAH operate across levels of race and ethnicity, which is a critical test to ensure the generalizability of the present findings to a sample more representative of the population as a whole.

Other researchers have also found sex differences in the effects of one's early-life environment on adult obesity outcomes (Kestilä et al., 2009; Nettle et al., 2019). These differences may stem from sex differences in developmental timing, differences in environmental susceptibility during sensitive periods, or differences in stress response systems. While we did not find reliable sex differences in our sample, examining sex differences in the timing and etiology of one's early-life environment's impact on EAH and adult obesity should be a goal of future research.

Lastly, it is important to emphasize that the link between low early-life SES and obesity risk is one that has many mediating variables. Accordingly, although it is possible that EAH plays a role in the low childhood SES-obesity link, it is likely one of many variables influential to this relationship. For example, others have proposed explanations for the relationship between low childhood SES and obesity that emphasize the impact of child insecurity, general stress, emotional turmoil, family strain and dysfunction, low self-esteem, and mental health issues (Hemmingsson, 2018). While these midlevel factors may all influence energy-regulation strategies, many of these factors could also be considered to contribute to, or be an outcome of, environmental unpredictability.

Despite its limitations, the results of the current research have important implications for understanding the impact of environmental and social stressors on the development of children's eating strategies, which can lead to excessive calorie consumption, overweight status, and obesity. Considering that eating patterns established early in childhood often persist across time, this work has important public health implications for understanding that the obesity epidemic goes beyond basic nutritional choices. In particular, the results of the current research suggest that energy dysregulation emerges early in childhood – long before children are making food choices on their own – and these patterns are fueled more by psychosocial factors (predictability/safety) than resource availability, per se. These patterns should be taken seriously as we consider the future for interventions targeted at deceasing rates of obesity among children from low- and middle-income families. For example, the present research suggests that interventions should target features of a child's environment can be made to feel safer and more predictable. Additionally, they suggest that these interventions need to begin early (prior to early childhood). Although the development and implementation of such interventions may seem daunting, the overall message is one of hope. The link between low childhood SES and obesity is not inevitable. It is an association that can be severed by thoughtful interventions.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.appet.2020.104755.

Author contributions

R.P·P.L. and S.E.H conceived the idea, designed the project, collected the data, and wrote the paper. S.M. and J.G. assisted in writing the paper and analyzed the data. E.M.R. and R.P·P.L. also assisted in conducting data analyses. B.J.E. assisted in designing the study and writing the paper. All authors discussed the results and contributed to the final manuscript.

Ethics statement

This research was approved by the Texas Christian University Institutional Review Board and the Executive Board of the FWMSH. All data were collected in the museum's Research Learning Center, which is an area in the museum dedicated to community participation in science. Each family began by the parent/legal guardian providing written informed consent and the child providing written assent or verbal assent (depending on child's age).

Each of the researchers have no conflicts of interest to disclose.

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