



The enriched home environment and dietary intake are related to percent overBMI in children

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ABSTRACT

Longitudinal research suggests that living in a cognitively enriched home environment, in which access to activities including hobbies and books are plentiful, can prevent excess weight gain and obesity in children. In order for the enriched home environment to influence weight it should influence energy and macronutrient intake and/or energy expenditure. To test this hypothesis, we used a cross sectional design to study aspects of the child's enriched home environment along with energy and macronutrient intake. A sample of 158 6–9-year-old children measured between February 2017 – April 2019 in Buffalo, NY were selected from a larger study based on criteria for accurate reporting of energy intake using the Block Kid's Food Frequency Questionnaire. Results showed that the Home Observation for Measurement of the Environment (HOME) subscales enriched environment, parental warmth and an integrated family structure were negatively related to child percent overBMI. Hierarchical regression showed that each of these factors improved variance in child percent overBMI accounted for beyond dietary intake or macronutrients, specifically accounting for a total of 18.2% variance in models controlling for total energy intake. These results provide the first demonstration that characteristics of a child's home environment are associated with lower energy intake and independently associated with percent overBMI beyond knowledge of diet. Enriching a child's home environment by providing alternative activities to eating, improving parental warmth and providing opportunities for parents to interact positively with their children may be novel ways to reduce childhood obesity that should be experimentally tested in future research.

1. Introduction

Research suggests that a cognitively enriched home environment, or one that provides access to and encourages engagement in a variety of cognitively enriching activities, is associated with a reduced risk of obesity (Solinas et al., 2010; Stairs and Bardo, 2009). Prospective epidemiological research has shown that children who grow up in homes with greater access to cognitively enriching activities, including encouragement of reading and hobbies, are less likely to have obesity than those with reduced access to an enriched environment (East et al., 2019; Strauss and Knight, 1999). While food is a powerful reinforcer for infants (Kong and Epstein, 2016), children (Temple et al., 2008) and adults (Epstein et al., 2011), a consistent body of research suggests that

providing alternative reinforcers can reduce energy intake and shift the choice from eating to non-eating (Giesen et al., 2010; Goldfield and Epstein, 2002).

Research examining the impact of alternative reinforcers on obesity in children has focused on cognitively enriching activities, including reading and physical activities, specifically examining their ability to directly compete with food reinforcers (Epstein et al., 1995; Temple et al., 2008). Basic behavioral economic research has shown that environmental access can make an impact on consumption or engagement in different activities (Epstein et al., 1991; Saelens and Epstein, 1998; Smith and Epstein, 1991). A change as small as moving sedentary behaviors to another room increased engagement in physical activities in adults (Raynor et al., 1998) and providing more choices of physical

Abbreviations: FFQ, Food Frequency Questionnaire; HOME, Home observation for Measurement of the Environment.

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activities increased energy expenditure for children in a gym class (Sanders et al., 2016). However, literature suggests that there are a wider range of environmental enrichment variables that can impact obesity and energy intake in children, including family stressors (Garasky et al., 2009), household stability (Schmeer, 2012), and other types of active stimulation, including social activities (Franzini et al., 2009).

To our knowledge, no research has studied the association between a child's home environment and their energy and macronutrient intake. One previous study examined intake of high energy dense foods and home environment in preschoolers (Østbye et al., 2013). Examining both energy intake, macronutrients and food group servings provides a way to identify home environment variables related to child percent overweight in addition to energy intake or intake of specific macronutrients. Examining individual macronutrient intake may be of interest, as macronutrient intake may be differentially related to obesity status (Brown et al., 2016). We characterized cognitive and emotional enrichment aspects of a child's home environment using The Middle-childhood Home Observational Measurement of Environment (HOME) Inventory (Bradley et al., 2001a, 2001b), which was used in the previous epidemiological studies that showed an enriched home environment was related to less pediatric and adult obesity (East et al., 2019; Strauss and Knight, 1999).

Using a cross-sectional design we studied 158 6–9-year-old children with valid energy intake data, who reported living in one household, across a wide range of zBMI values. We assessed relationships between the home environment and energy and macronutrient intake, as well as if the home environment adds variance to associations with child percent overBMI in addition to energy and macronutrient intake. We hypothesized that an enriched home environment would be associated with lower energy intake, and energy intake and enriched home environment would add unique variance to regression models of percent overBMI.

2. Methods

2.1. Participants

Participants were from an ongoing longitudinal study designed to prospectively assess relationships between aspects of home environmental enrichment, alternative reinforcers and child weight gain. From February 2017 – April 2019 Interested families in the Buffalo, NY area were recruited from a private database, online advertisements (e.g. Facebook, Craigslist), and flyers and postcards posted in the community and local school districts. Families were stratified by sex and income/education level (less than a college education, receiving/being eligible to receive federal assistance). About 27% of the sample (n = 43) had incomes <200% of the poverty line (ASPE, 2017), and 15% (n = 23) had incomes <130% of the poverty line). For the longitudinal study, participating children were required to report at least a moderate liking of the snack foods and activities offered in the study and would be willing to consume or partake in them, respectively. These represented a variety of popular and well-known snack foods (e.g. chocolate chip cookies, potato chips, pretzels, etc.) and activities (e.g. coloring, Legos, puzzles, etc.) for which children living in a wide range of socio-economic status households would have access. Exclusionary criteria included 1) dietary restrictions, including food allergies, religious/ethnic practices or medical conditions that could modify nutritional status and food absorption, 2) activity restrictions due to medical or physical problems, 3) psychopathology (e.g. childhood schizophrenia), developmental disabilities, and/or taking medications that could affect activity or appetite levels (e.g. methylphenidate), 4) zBMI score greater than 3 standard deviations from the mean (i.e. outside of the range of 99% of the population). Three-hundred and nine children enrolled in the study, four children were screen-failures (low zBMI, psychological diagnosis) and 14 families withdrew, citing time restrictions or loss of interest, for a

total of 291 children completing baseline appointments, with 288 children having complete dietary data. To examine relationships between dietary intake and the home environment, children were excluded if they lived in multiple households (n = 30). Given the common observation that energy intake is often underreported (Goldberg et al., 1991; Livingstone and Black, 2003), we only included children who provided valid energy intake data (n = 158). Methods for determining valid energy intake data are presented below. The participants were 158 (84 females and 74 males) children 6–9 years old.

2.2. Procedures

Eligible families were scheduled for three 90-minute laboratory visits and one 60-minute home visit. During the first lab visit, parents and children signed consent and assent forms. Both parent and child height, weight and percent body fat were then measured. During session two, parents completed the Block Kids 2004 Food Frequency Questionnaire (FFQ)(Cullen et al., 2008), and children completed the preference for activities questionnaire with the experimenter (Ullenhag et al., 2012) and the physical activity questionnaire with the help of their parent (Ellery et al., 2014). During the third session children indicated their enjoyment of their recent activities, and a physical activity questionnaire for their child.

The fourth appointment was a home visit, during which the experimenter used the HOME to assess the child's home environment. A home food inventory checklist was used to record the foods and drinks the families had in their home, followed by pictures taken for quality control of their fridges, freezers, cabinets, etc. At the end of these four appointments, participating children were compensated \$70 and the participating parent received \$30 through check or gift cards. Each family was entered in a raffle for a 10% chance to win an additional \$100 check upon completion of the study. Food reinforcement, child liking and frequency of engaging in selected activities, as well as Neighborhood Environment Walkability Scale were measured and are reported elsewhere. All procedures were conducted in accordance with the guidelines for the ethical conduct of human research and with the approval of the University at Buffalo Social and Behavioral Sciences Institutional Review Board.

2.3. Measurement

2.3.1. Demographics and medical history

The MacArthur Questionnaire was used to assess measures of socioeconomic status, including years of education and subjective measures of the family's social standing in the community, household income levels, household size and years of education for both parents (Adler et al., 2000; Giatti et al., 2012). Two families declined to report household income. Parents self-reported child race and ethnicity, and they completed a child medical conditions form including their current or a history of previous diagnoses of psychiatric disorders, developmental disorders, etc. and current medications.

2.3.2. Anthropometrics

The participating parent and child had their weight measured using a Tanita digital scale (Arlington Heights, IL) and height using a digital stadiometer (Quick Medical, Issaquah, WA). Percent body fat was determined by bioelectrical impedance through the digital scale (Tanita, Arlington Heights, IL). Two children did not have body fat percentage measured. Body mass index (BMI) was calculated according to the formula: $BMI = kg/m^2$. zBMI and BMI percentile values are standardized for the child's age and sex, so that zBMI values of 0 or BMI percentile values of 50 represent the midpoint of the distribution. Percent overBMI was calculated based on the percent the child is over the 85th BMI percentile (Løkkling et al., 2019).

2.3.3. Energy intake

The Block Kids Food Frequency questionnaire (FFQ) consists of 77 items that ask about the frequency and amount of specific foods that children have consumed in the last week. The Block FFQ has been validated for total energy intake against 24 h recalls (Cullen et al., 2008). The parents filled out the questionnaire on behalf of their children (Marshall et al., 2008) by identifying how many days in the last week they ate different foods, ranging from “none” to “everyday”. Children under the age of 10 are considered invalid self-reporters of energy intake (Livingstone and Robson, 2000), and similar FFQ have been validated with parental reporting (Del Pino and Friedman, 2011; Kobayashi et al., 2011). If the food had been consumed, parents selected the portion size and were provided images of different portions sizes. The foods included in the questionnaire consist of foods that children commonly eat identified by NHANES III. Dependent measures include total daily kilocalories and macronutrient consumption, categorized by grams of protein, fat, carbohydrate, and added sugar. Macronutrient intake was measured in total grams, as this is directly related to body weight, rather than percent macronutrient intake which relies on the total intake and may not be directly related to body weight. Questionnaires were scored and analyzed by NutritionQuest (Berkeley, CA). Missing items were not included in the calculations by NutritionQuest and this comprised < 1% of the data.

Since people underestimate their energy intake (Goldberg et al., 1991; Livingstone and Black, 2003), and parents underestimate children’s energy intake (Burrows et al., 2013; Livingstone and Robson, 2000), we attempted to address self-report bias by establishing an accepted level of accuracy of the parent reported child dietary intake. We used the approach recommended by the Institute of Medicine using regression equations to estimate energy requirements needed to maintain body weight (Food & Nutrition Board, 2005), and used physical activity levels that corresponded to low active versus higher active using the Physical Activity Questionnaire (Ellery et al., 2014; Voss et al., 2017). Black suggests using subject activity data, rather than the same PAL for everyone (Black, 2000). The cutoffs used by Jessri and colleagues (Jessri et al., 2016) to select under-reporters, which was <70% of the estimated value to maintain body weight, was selected. These investigators showed this cutoff was useful for removing under-reporters that influenced the relationship between self-reported intake and body weight. Using these criteria, 158 of 258 (61%) of the original sample was maintained. This was close to the percentage of the sample maintained in the validation paper (N = 11,748) of 57% (Jessri et al., 2016). There was a strong relationship between percent overBMI of the child and degree of under-reporting (energy intake to estimated energy expenditure ratio) in the complete sample ($r = -0.14$, $p = 0.022$), but this relationship was dramatically reduced and was not significant when only the valid reporters were included ($r = 0.037$, $p = 0.64$), consistent with the study by Jessri and colleagues (Jessri et al., 2016).

2.3.4. Physical activity

The Physical Activity Questionnaire (Ellery et al., 2014; Kowalski et al., 2004) was used to assess the child’s level of physical activity during the previous week and has been validated against accelerometers (Voss et al., 2017) and physical activity diaries (Kowalski et al., 1997). Information was collected about physical activity level during a normal school day, week night and weekend day. Parents were asked to select the number of days their child did different physical activities (e.g. skipping, rowing, skating, bicycling, etc.) ranging from 0 times to 7 or more times in the last week. A physical activity score was calculated ranging from 1 to 5, with higher numbers indicating more physical activity. Missing items were not included in the averaged score and this comprised < 1% of the data, with the greatest missing data for one child being 11%.

2.3.5. Home environment

The Middle-childhood Home Observational Measurement of

Environment (HOME) Inventory (Bradley, Corwyn, Burchinal, et al., 2001; Bradley, Corwyn, McAadoo, et al., 2001) was used to measure the availability of cognitive and emotional enrichment in the child’s home. The Middle Childhood HOME consisted of 59 questions or observations made during an in-home interview and has been used in a variety of developmental research (Totsika and Sylva, 2004). The items were divided into 8 different subscales; responsivity (10 items, e.g. does parent answer child’s questions during visit, sample range 2–10), encouragement of maturity (7 items, e.g. does parent require child to complete simple household tasks, sample range 0–7), parental warmth (8 items, e.g. has parent used physical punishment in the past month, sample range 3–8), learning materials and opportunities (8 items, e.g. does child have at least 10 age-appropriate books, sample range 2–8), cognitive enrichment (8 items, e.g. does parent encourage child to develop hobbies, sample range 2–8), family integration (4 items, e.g. does family eat meals together, does child have contact with second parent/parent figure, sample range 0–4), family companionship (6 items, e.g. how often do you visit friends or relatives, sample range 3–6) and physical environment (8 items, e.g. is the house reasonably clean, sample range 0–8). Some items were adjusted to fit more modern practices (e.g. reading news in the newspaper vs an online subscription). Items were scored on a 0/1 scale by a trained staff member. Missing items were not included in the summed subscales and this comprised < 1% of the home environment data.

2.4. Analytic plan

Analysis of variance was used to examine differences between the accurate reporters and the under-reporter groups on demographic and anthropometrics. Relationships between measures of the environment from the HOME with eating (total energy intake, protein, fat, and carbohydrates) and percent overBMI were established using zero-order Pearson Product moment correlations. Measures significantly correlated with percent overBMI were then used in the hierarchical regression analysis. Hierarchical regression models were used to assess the relationship between energy intake and percent overBMI controlling for child sex, age, minority status, physical activity score and household education. Characteristics of the home environment were examined to see if they added unique variance to the model above the contribution of energy intake. Step 1 included the covariates of child sex, age, minority status, physical activity and highest parental education (as a measure of socioeconomic status), and step 2 added calorie or macronutrient measures. Parental education was chosen as an index of household socioeconomic status, as it is highly correlated with income and parental education has been found to be more strongly associated with child obesity than income (Vazquez and Cubbin, 2020). In the final steps, characteristics of the home environment measures that were correlated with percent overBMI were added in steps 3, 4 and 5, from smallest to largest environmental enrichment variables were added in separate steps to examine each variable’s incremental increase in variance. Incremental F-tests were used to determine if the change in incremental variance was significant. These models were repeated to study dietary protein, fat, carbohydrate and sugar intake. A sensitivity analysis was conducted comparing the results from the larger dataset (n = 258) to examine differences in the relationship between percent overBMI, dietary intake and home environment if invalid dietary data were included.

3. Results

Child characteristics, dietary intake, and enriched home environment measures and their relationship to child percent overBMI and total energy intake for the accurate reporters are shown in Table 1 (mean, standard deviation and confidence intervals reported). Appendix Table 1 shows the correlations between the child characteristics, enriched home environment and macronutrient intake. For the accurate

Table 1
Participant characteristics and correlations with energy intake and percent overBMI.

Measure	Mean ± S.D.	% overBMI		Energy intake	
		r	95% CI	r	95% CI
N	158				
Age	7.69 ± 1.15	-0.12	(-0.27, 0.04)	0.08	(-0.08, 0.23)
zBMI	0.27 ± 1.02	0.91***	(0.88, 0.93)	0.27***	(0.12, 0.41)
Percent OverBMI	-6.52 ± 15.57	—	—	0.27***	(0.12, 0.41)
Percent body fat	18.5 ± 7.6	0.87***	(0.82, 0.90)	0.24**	(0.09, 0.38)
Parent education (years)	17.1 ± 2.5	-0.09	(-0.24, 0.07)	-0.17*	(-0.31, -0.01)
Household Income (\$US)	103406 + 67230	-0.13	(-0.28, 0.03)	-0.27***	(-0.41, -0.11)
% minority	22.8%	0.05	(-0.11, 0.20)	0.15	(-0.004, 0.30)
Gender (m/f)	74/84	-0.04	(-0.55, -0.29)	-0.10	(-0.25, 0.06)
Physical activity	2.74 ± 0.54	-0.01	(-0.17, 0.15)	0.28***	(0.13, 0.42)
Dietary intake					
Energy intake	1685.0 ± 441.9	0.27***	(0.12, 0.41)	—	—
Protein (g)	58.0 ± 17.6	0.25**	(0.10, 0.39)	0.86***	(0.81, 0.89)
Fat (g)	63.0 ± 17.8	0.26***	(0.11, 0.40)	0.90***	(0.86, 0.92)
Carbohydrates (g)	229.1 ± 66.8	0.24**	(0.08, 0.38)	0.93***	(0.90, 0.95)
Total Sugar (g)	116.4 ± 45.2	0.19*	(0.03, 0.34)	0.79	(0.72, 0.84)
HOME Scores					
Parental Warmth	5.96 ± 1.12	-0.16*	(-0.31, -0.003)	0.01	(-0.14, 0.17)
Cognitive Enrichment	5.89 ± 1.34	-0.19*	(-0.33, -0.03)	-0.16*	(-0.31, -0.01)
Environment	7.35 ± 1.18	-0.13	(-0.28, 0.03)	-0.18*	(-0.33, -0.03)
Family Communication	5.11 ± 0.79	-0.14	(-0.29, 0.02)	0.01	(-0.15, 0.16)
Family integration	2.90 ± 1.09	-0.24**	(-0.38, -0.09)	-0.27***	(-0.41, -0.11)
Learning opportunities	5.30 ± 1.28	-0.06	(-0.21, 0.10)	0.001	(-0.15, 0.16)
Maturational tone	5.28 ± 1.38	-0.03	(-0.19, 0.12)	-0.06	(-0.22, 0.09)
Parental responsiveness	8.89 ± 1.54	-0.12	(-0.27, 0.04)	-0.19*	(-0.33, -0.03)

Data was collected between February 2017 – April 2019 in Buffalo, NY.

*p < 0.05, **p < 0.01, ***p ≤ 0.001.

reporters, energy, protein, fat and carbohydrate intake were associated with child percent overBMI (r's 0.19–0.27, Table 1). Three HOME scales were related to child percent overBMI, including cognitive enrichment, parental warmth and family integration (r's -0.16 to -0.24, Table 1), with higher scores being associated with lower percent overBMI. Several HOME environment scales were associated with total energy intake, including cognitive enrichment, physical environment, family integration and parental responsiveness (r's -0.16 to -0.27, Table 1), with higher scores associated with lower energy intake.

The hierarchical model is shown in Table 2. Results show energy intake is associated with percent overBMI, and increases variance

accounted for by 7.8 percent beyond demographics and activity. For total energy intake and carbohydrate intake home parental warmth and family integration were significantly associated with percent overBMI and contributed significant additional variance above energy and carbohydrate intake. For protein and fat intake, cognitive enrichment and family integration were significantly associated with percent overBMI and contributed significant variance above the macronutrients. The three HOME measures together accounted for an additional 7.5 percent of the variance in the model controlling for total energy intake. The HOME variables increased variance accounted for beyond protein (Δr² = 7.7%), fat (Δr² = 7.3%), carbohydrate (Δr² = 8.2%) and sugar (Δr² =

Table 2
Hierarchical regression models for child percent overBMI with energy and macronutrient intake.

Effect					Total Calories (kcal)		Protein (g)		Fat (g)		CHO (g)		Sugar (g)		
	b	95% CI	SE	t	r ²	Δr ²	r ²	Δr ²	r ²	Δr ²	r ²	Δr ²	r ²	Δr ²	
Step 1															
Constant	18.67	(-9.10,46.44)	14.06	1.33	0.029		0.029		0.029		0.029		0.029		
Child sex	-1.57	(-6.56,3.41)	2.52	0.62											
Child age	-1.78	(-3.98,0.42)	1.11	1.60											
Physical activity	-0.83	(-5.48,3.83)	2.36	0.35											
Minority status	2.47	(-3.59,8.53)	3.07	0.81											
Parental education	-0.53	(-1.51,0.46)	0.50	1.05											
Step 2					DF(1,151)										
Energy intake	0.01	(0.01,0.02)	0.003	3.64***	F_{INC}	0.107	0.078	0.093	0.065	0.100	0.071	0.086	0.057	0.062	0.033
Step 3					DF(1,150)										
Cognitive Enrichment	-1.90	(-3.82,0.03)	0.97	1.95	F_{INC}	0.129	0.022	0.123	0.029	0.124	0.024	0.107	0.021	0.085	0.024
Step 4					DF(1,149)										
Home Parental Warmth	-2.22	(-4.43,-0.01)	1.12	1.99*	F_{INC}	0.152	0.023	0.139	0.016	0.143	0.019	0.131	0.024	0.104	0.019
Step 5					DF(1,148)										
Home family integration	-2.82	(-5.20,-0.45)	1.20	2.35*	F_{INC}	0.182	0.030	0.170	0.032	0.173	0.030	0.168	0.037	0.143	0.039

*p < 0.05, **p < 0.01, ***p < 0.001, DF Degrees of Freedom for Incremental F-test, F_{INC} incremental F test.

Calories and macronutrients were assessed in separate linear regression models.

Data was collected between February 2017 – April 2019 in Buffalo, NY.

8.2%) intake.

To assess whether these results are sensitive to exclusion of under-reporters, these analyses were repeated with the full sample. Comparison of accurate versus under-reporters showed significant differences in zBMI ($F(1,256) = 9.41, p = 0.002, 0.68$ for under-reporters versus 0.27 for accurate reporters) and percent overBMI ($F(1,256) = 10.02, p = 0.002, 0.66$ for under-reporters versus -6.52 for accurate reporters). While 11% of the accurate reporters met obesity criteria (95th BMI percentile), 23% of the under-reporters met obesity criteria ($\chi^2(1) = 7.00, p = 0.008$). No differences were found between accurate and under-reporters for age, sex, minority status, home environment, parent zBMI, household education or income. Models with the full sample ($n = 258$) showed home environment variables, with the exception of parental warmth ($b = -0.07, 95\% \text{ CI} = -2.13, 2.00, p = 0.95$) remained significantly related to child percent overBMI (cognitive enrichment $b = -1.94, 95\% \text{ CI} = -3.72, -0.15, p = 0.03$; family integration $b = -2.45, 95\% \text{ CI} = -4.64, -0.27, p = 0.03$) and significantly increased the variance accounted for in the hierarchical regressions (cognitive enrichment $F(1,250) = 4.58, p = 0.033$; family integration $F(1,248) = 4.90, p = 0.03$). However, energy intake and dietary macronutrients were not related to child percent overBMI in the full sample (calorie intake $b = 0.002, 95\% \text{ CI} = -0.003, 0.007, p = 0.43$; Carbohydrates $b = 0.01, 95\% \text{ CI} = -0.03, 0.04, p = 0.86$; fat $b = 0.07, 95\% \text{ CI} = -0.05, 0.19, p = 0.24$; protein $b = 0.10, 95\% \text{ CI} = -0.03, 0.22, p = 0.12$; Sugar $b = -0.01, 95\% \text{ CI} = -0.06, 0.05, p = 0.90$).

4. Discussion

The results show that aspects of the enriched home environment are negatively correlated with child energy intake, and account for a significant amount of variance in child percent overBMI beyond energy and macronutrient intake. This extends previous research that showed cognitively enriching environments are related to child relative weight (East et al., 2019; Strauss and Knight, 1999). While it is expected that energy intake would be related to percent overBMI, characteristics of the home environment were associated with percent overBMI when accounting for energy intake. The unique variance accounted for by characteristics of the enriched home environment were similar to the amount accounted for by energy or macronutrient intake, with a total variance accounted for of 18.2% in child percent overBMI for total energy intake. Parental warmth and family integration accounted for additional variance in child percent overBMI beyond energy intake and carbohydrates, and cognitive enrichment and family integration accounted for additional variance in child percent overBMI beyond protein, fat and sugar intake. These results suggest that aspects of the home environment may influence child percent overBMI through mechanisms distinct from energy intake or macronutrients. Our data also suggest that cognitive enrichment is not independently related to child percent overBMI from carbohydrates, while parental warmth is not independently related to child percent overBMI from protein and fat intake.

These results replicate cross-sectional relationships observed between child percent overweight and cognitive enrichment (East et al., 2019; Strauss and Knight, 1999), family companionship (East et al., 2019), family mealtimes (family integration item) and screen-time restrictions (cognitive enrichment item) (Bates et al., 2019) and a global cognitive-emotional score with child consumption of junk food (den Bosch and Duch, 2017). Our data consists of cross-sectional associations, and we are unable to determine directionality, i.e. low environmental enrichment may predict child percent overBMI, or child percent overBMI may elicit low environmental enrichment. However, two previous longitudinal studies suggest environment is associated with later obesity (East et al., 2019; Strauss and Knight, 1999). East et al. (2019), examined changes in obesity from ages 10 – 21, showing relationships for home learning environment, parental warmth and family companionship. In our sample, only parental warmth was related to child percent

overBMI. Several models of childhood obesity, including the Family Ecological model (Davison et al., 2013) and the developmental systems perspective (Birch and Anzman, 2010), suggest that environment confers risk, or protection, against childhood obesity, and developmental periods are impacted by different aspects of the environment. It is possible that family companionship, an index of family activity engagement outside of the home, was not seen as a significant correlation in our sample, as the previous work focused on 10-year old children and activity engagement outside of the home may have a greater effect on obesity as children become more autonomous in selecting activities. Our sample included a significant portion of children younger than 9, which may have weakened the possible relationship between family companionship and obesity.

Aspects of the enriched home environment may have unique pathways to impact body weight. First, a greater enriched home environment suggests that children have access to a variety of stimulating and enriching activities which may compete with eating. Behavioral economic theory recognizes that as the reinforcing value of food depends on what alternatives are available, and a variety of laboratory (Giesen et al., 2010; Goldfield and Epstein, 2002), observational (East et al., 2019; Strauss and Knight, 1999) and clinical (Buscemi et al., 2014) research has shown that access to reinforcing alternatives to food is associated with decreased energy intake (Temple et al., 2008), body weight (East et al., 2019; Strauss and Knight, 1999) and increased weight loss (Best et al., 2012). This data points to the possibility that improving child's access to alternative behaviors other than eating may reduce risk of obesity.

Parental warmth and acceptance was also associated with child percent overBMI independently from energy intake and carbohydrate intake, but not protein and fat intake. This follows previous observational research in children that showed parental warmth and acceptance was significantly associated with BMI change and rate of change from age 10 to 21-years (East et al., 2019). The pathway from parental warmth to obesity may be through reducing negative emotions and stress in the family environment. Emotional eating and stress are known to influence energy intake in children (Hill et al., 2018; Michels et al., 2012), and parental stress is related to parenting behaviors such as using food to soothe moods (Stifter et al., 2011) and pressure to eat (Berge et al., 2017; Mitchell et al., 2009). Educational information about how parenting may influence eating and behavioral training to increase opportunities for positive parent-child interactions may improve both the child's environment and percent overBMI by providing enriching alternative activities to eating. An alternative explanation is that positive interactions with parents is an alternative reinforcer to food for children. Research has shown that adults are more effective social reinforcers when the child had previous positive interactions (McCoy and Zigler, 1965) and parents are effective social reinforcers in young children (Patterson et al., 1964). Younger ages may benefit more from positive parental interactions, as peers gain social reinforcing value as children age (Patterson and Anderson, 1964).

The influence of family integration on obesity may include two behavioral pathways. First, the family integration subscale assesses regular family meals, which can influence childhood obesity (Hammons and Fiese, 2011). In addition, family integration assesses the family structure and the number of opportunities for a child to interact with a parent. The more time a child spends interacting with a parent, the greater the opportunity for the child to see the parent as a model for their behavior, and modeling has been shown to influence child eating (Brown and Ogden, 2004). The family structure can moderate obesity outcomes in children, with children from two parent households less likely to have obesity (Craigie et al., 2012). Family integration assesses opportunities for the child to learn gross motor skills from parent interactions, and research has suggested that single parent homes are related to lower physical activity due to fewer opportunities for children to engage in physically activities with their parents (Wong et al., 2017).

Households with low education or low income are associated with

low parental warmth and cognitive enrichment (Totsika and Sylva, 2004), and are more likely to be single parent homes, providing fewer opportunities for family integration (Sarsour et al., 2011). These aspects of the enriched home environment likely influence each other, as increased cognitive enrichment may offer more opportunities for the parent to interact with the child in a positive manner, or may allow the child to remain engaged in fun and safe activities, limiting potential negative interactions and punitive control from parents. Single parent households may have fewer monetary and time resources (Waldfogel et al., 2010) to provide children with cognitively enriched activities or opportunities to spend time with a parent. In addition, a recent study showed that energy balance and socio-economic factors, including age, sex, and household socioeconomic status, were both associated with adolescent obesity status accounting for similar amounts of variance (Pila et al., 2021). Ideally, understanding how aspects of the home environment are complementary could identify intervention targets that would influence both low environmental enrichment in a child's home and other obesity related behaviors.

While these results may provide new insights into factors that impact childhood obesity, there are several limitations to this study. First, this sample only included children for whom there was complete home enrichment data, and did not include children living in multiple households. The study included families who did not under-report their child's dietary behavior and this differentially excludes heavier children (Collins et al., 2010). Approximately 11% of the children with valid energy data met criteria for obesity (95th BMI percentile), while 23% of the children who were under-reporters met obesity criteria. While the relationship between obesity and under-reporting is expected (Collins et al., 2010), excluding under-reporters restricts the variability in percent overBMI and reduces the magnitude of the relationship between energy intake and percent overBMI. While we did not see significant differences on other characteristics between families who did and did not under-report dietary behavior, it is possible that there are differences in unmeasured factors, including greater environmental stressors or executive function abilities that limit generalizability. Second, this was a cross-sectional study and whether home environment influences child weight or if child weight elicits differences in home environment cannot be differentiated. While this sample included a wide range of household incomes and educations, the number of households at or below poverty level represent a small percentage. It is possible that, for families who are under-resourced, there may be different relationships between energy intake, child percent overBMI and home environment, including the possibility of a floor effect of measures of enriched home environment. We recommend that future research study these relationships using a randomized controlled trial designed to increase aspects of an enriched home environment.

Another limitation is that the dietary intake was assessed by a food frequency questionnaire, which has been shown to have low to moderate correlations with other measures of energy intake (Kolodziejczyk et al., 2012). Food frequency questionnaires are useful in large studies as they are low burden for the family in comparison to 24 h recalls or food weight records, and they provide a window into usual eating over a longer period than other approaches, however some resolution may be lost (Collins et al., 2010). For example, we are not able to identify energy or macronutrient intake in relationship to snacks versus meal, which may be relevant if home enrichment is associated with obesity through providing non-food alternative reinforcers for snacks. We also used parental report of young child intake, which was necessary as young children are unreliable reporters of energy intake for time spans longer than one day (Livingstone et al., 2004), but there is the possibility that a parent may not know all the foods their child eats, particularly in school or other supervised environments (Baranowski et al., 1991). The sensitivity analysis showed that the enriched home environment variables were correlated with child percent overweight, but energy intake and percent overBMI were not related when examining both accurate and under-reporters. If under-reporting was not considered, energy intake

and home environment variables would not have been found to add significantly to the model for child percent overBMI.

These data provide evidence of cross-sectional relationships and novel insights into factors that relate to percent overBMI beyond energy intake, but future studies are needed to assess the prospective effects of home environment characteristics and energy intake on the trajectory of weight change. These cross-sectional results complement prospective studies on the changes in relative weight (East et al., 2019; Strauss and Knight, 1999), but it is important to replicate these results in prospective studies. This study points to novel associations with child obesity and novel, non-food related interventions to prevent childhood obesity.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Author contributions

LHE, KAC and JLT designed the research and LHE provided the funding acquisition. LHE wrote the original draft and LHE and KAC analyzed the data and revised the original draft for review. LHE provided supervision, KAC and CG provided project administration, CG and LS conducted the research, LAL and LHE provided methodology, CG provided study resources and KAC completed the data curation. All authors reviewed the manuscript and approved the final version.

LHE has primary responsibility for the final content.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.pmedr.2021.101440>.

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