A Mixed Methods Analysis of Environmental and Household Chaos: Implications for Childhood Obesity Prevention Through Toddlerhood

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Abstract

Background: Chaos has implications for child health that may extend to childhood obesity. Yet, results from studies describing associations between chaos and childhood obesity are mixed. Challenges to studying chaos-obesity relationships may include inconsistencies in how chaos is operationalized and reliance on caregiver perceptions. Furthermore, multiple pathways may link chaos to obesity, though few have been empirically examined.

Methods: We conducted a concurrent mixed methods analysis of quantitative and qualitative data describing home and neighborhood chaos among a diverse cohort of 283 caregiver-toddlers dyads from Ohio. We examined the underlying structure of environmental and household chaos using exploratory factor analysis then sought to validate the structure using qualitative field notes. We generated total scores for factors of chaos and described their distributions overall and according to cohort characteristics. Additionally, we conducted a thematic content analysis of brief ethnographies to identify potential pathways linking chaos to childhood obesity with the intention to direct future research efforts.

Results: Dyads varied according to household composition, income, education, and race/ethnicity. We found evidence for a multi-factor structure for chaos, which included disorganization and neighborhood noise. Household disorganization scores ranged from 8-18 and were on average 11.37 (SD = 2.58). Neighborhood noise scores ranged from 4-12 and were on average 6.93 (SD = 1.89). Both disorganization and neighborhood noise were associated with indicators of socioeconomic disadvantage, such as food insecurity and lower income-to-poverty ratio, though only disorganization was associated with additional social factors within homes, such as caregiver mental health and overall health. Finally, we identified unique themes from brief ethnographies which future contextualize the social and material environments in which chaos was observed, including child behavior and caregiver-child interactions.

Conclusions: Chaos is a complex construct composed of multiple factors and the mechanisms linking chaos to childhood obesity may be equally complex. Future studies of chaos-obesity relationships may require greater specificity when operationalizing chaos and empirical study of pathways, like child behavior and caregiver-child interactions, may inform future obesity prevention strategies.

1. Background

1.1 Childhood Obesity

Childhood obesity remains prevalent across the world, presenting one of the most challenging public health problems of this century[1]. Once established, obesity and related comorbid chronic conditions often persist into adolescence and adulthood[2]. The persistent nature of this condition may result from the establishment of obesity-related behaviors in early childhood, including poor diet, obesogenic eating behaviors, and physical inactivity, which often track through adulthood[3]. Therefore, infancy and early childhood (birth to 24-months) may be critical periods for obesity prevention efforts.

The health behavior patterns underlying development of childhood obesity are influenced by a complex ecology of factors[4]. Thus, interventions designed to change obesity-related behaviors require multilevel approaches with multiple component[5]. However, most childhood obesity interventions rely on single-strategy approaches[6], which in actuality, often fall short as they do not address the multiple social determinants implicated in the obesity epidemic[7], Currently, no compelling evidence advocates for one program or method for preventing childhood obesity. However, comprehensive approaches addressing both behavioral risk factors and psychosocial support within relevant contexts tend to offer more promising outcomes[8, 9]. For young children, family homes are promising settings for the implementation of childhood obesity preventions strategies[10–13]. Yet, more research is needed to understand how features of family homes influence interventions.

1.2 Chaos and Childhood Obesity

Chaos may be one feature of family homes with consequences for obesity prevention efforts. Chaotic environments are often described as noisy, crowded, and lacking organization[14]. Furthermore, both structural and temporal instability in the form of frequent changes in adults' romantic partners, residential mobility, loss of family income, and disrupted family routines and rituals may also contribute to chaos[15]. While greater levels of chaos are more likely to occur among households with fewer socioeconomic resources[14], chaos is more than a marker for poverty. In studies adjusting for the influence of socioeconomic status, chaos is consistently identified as an independent risk factor for less optimal outcomes of child health and development[14, 16]. Young children (≤ 5 years) exposed to greater levels of chaos are more likely to experience poorer cognitive development[17], less school readiness[17], increased behavioral problems[18], and poorer overall health[19], when compared to children living in less chaotic environments. Beyond these outcomes, chaos may be consequential for the development of obesity in early childhood[20].

1.3 Measuring Chaos in Childhood Obesity Research

A recent systematic review of chaos and structure in family home environments in relation to early childhood obesity found associations with child weight outcomes in the majority (10 of 14) of studies, but the direction of results was inconsistent, and measures of chaos differed substantially[20]. Specifically, within this review, chaos was operationalized as household routines, screen time limits, crowding, and environmental confusion. To date, no single measurement strategy has been adopted for studies investigating chaos-obesity relationships, limiting the conclusions that can be drawn about possible relationships between chaos and childhood obesity. Therefore, one potential solution to challenges associated with studying chaos-obesity relationships may include reconceptualizing aspects of chaos to determine which (if any) matter for childhood obesity risk.

One tool designed to measure household chaos is the Confusion, Hubbub, and Order Scale (CHAOS)[21, 22]. The CHAOS has been used as the measure of household chaos in at least five studies examining relationships between chaos and child weight outcomes[23–27], making it one of the most consistently used measure of chaos in the childhood obesity literature. Still, among these studies, results are

mixed[25, 26]. The CHAOS is a parent-reported survey consisting of 15-items which describe various conditions contributing to environmental confusion (e.g., *we almost always seem to be rushed* or *it's a real zoo in our home*)[21]. The tool offers a quick, low-cost approach to measuring parents' aggregate experiences within their home. However, the CHAOS may be limited by its reliance on caregiver perceptions, which tend to be subjective and influenced by factors such as parental coping strategies and personality traits[28]. Additionally, the CHAOS may characterize household and environmental chaos too broadly, inadvertently excluding important subdomains, such as disorganization and instability[22]. One study noted the association between children's exposure to poverty in early-life and academic achievement at kindergarten-age was mediated by chaos, in the form of household disorganization, but not instability[17]. Such findings suggest chaos as a construct may be more nuanced and aspects of chaos may matter for specific health outcomes. Therefore, obesity prevention researchers may benefit from revisiting the theoretical structure of chaos and considering more comprehensive measurement tools.

1.4 Potential Pathways from Chaos to Obesity

Multiple pathways may connect chaos to child health, but such pathways have not been fully considered in literature examining associations between chaos and childhood obesity risk. For example, the distracting and overstimulating nature of chaotic environments may impede children's developing self-regulatory skills. A recent meta-analysis concluded household chaos and executive functions, like self-regulation, are significantly and inversely related[29]. Such relationships are important, as self-regulatory skills, including inhibitory control and emotion regulation, may be protective against childhood obesity development[30].

Parenting practices and parent-child interactions may link chaos to child health[14]; such pathways may extend to child weight outcomes. For example, in chaotic environments, parents may perceive relationships with their children more negatively and exhibit less warmth or enjoyment[31], parents may be less verbally responsive to their children[32], and parents may demonstrate lower levels of responsivity or acceptance towards their children[18]. The quality of parent-child interactions in early-life has been noted as a potentially important determinant of child weight outcomes extending from preschool-age[33] to adolescence[34], but the role of chaos in such associations is poorly understood.

Finally, stress may be another process by which chaos is linked to child weight outcomes. While relationships between stress and childhood obesity are inconsistent, early-life stress is associated with overweight and obesity in adulthood[35]. Chaotic conditions are likely unsettling for young children and exposure to chaos may induce a stress-response that increases children's risk for obesity. Studies examining noise suggest cardiovascular stress indicators and neuroendocrine stress hormones may be sensitive to louder environments[36, 37], Additionally, other forms of chaos, such as "emotional chaos", may be associated with diurnal cortisol patterns among young children[23]. Such physiological responses to chaos may be implicated in stress responses that are consequential for child weight outcomes[35], but empirical evidence is limited.

1.5 Study Aims and Objectives

We aimed to characterize the home and neighborhood environments of a contemporary cohort of toddlers and explore potential contributors to chaotic environments. Our analyses utilized direct observations of family homes from 283 diverse families. To accomplish our aim, we examined chaos using a concurrent mixed methods research design, as such methods presented opportunities for triangulation, expansion of descriptions of chaos, and may better contextualize the broader social and material environments in which chaos occurs[38]. The objectives for this study were (1) to examine the underlying structure of environmental and household chaos using both quantitative and qualitative data, and (2) to conduct an exploratory analysis of qualitative fieldnotes to identify potential pathways that may link chaos to child weight outcomes. We hypothesized that more comprehensive and nuanced assessments of family home environments would provide evidence for a multi-factor structure of chaos, including disorganization, noise, and instability. Additionally, we anticipated that context offered from qualitative fieldnotes of family home environments will help inform obesity prevention efforts by underscoring potential pathways linking chaos to childhood obesity risk.

2. Methods

2.1 Study Population

Data are from the Play & Grow Study—a prospective cohort study of 299 parent-child dyads from central Ohio. Study design and cohort characteristics for the Play & Grow Study have been previously described[39] but are briefly summarized here. The target population for the Play & Grow Study included 18-month-old children (± 2 months) living in central Ohio. A sampling frame was constructed using patient medical records from Nationwide Children's Hospital (NCH) in Columbus, Ohio. Caregiver-child dyads were enrolled between December 2017 and May 2019. Dyads enrolled included primary caregivers (93% biological mothers) and children who were born singleton with gestational ages between 23 and 42 weeks. Enrolled dyads lived within 15 miles of NCH with no family plans to move beyond that radius during the study and the participating caregiver attested to taking part in the child's meals on a regular basis. Participants were excluded from recruitment if the child had deafness, blindness, food allergies (either child or potential participating caregiver), the child's recorded gestational age > 42 weeks, or if the child was tube-fed or a patient for a clinical feeding disorder.

The Play & Grow Study is ongoing, and we utilized data from the first and second assessments, which took place when children were approximately 18- and 24-months of age and include caregiver-reported survey data and direct observations of family homes. We limited or analyses to only records with complete data on the variables examined in this study (n = 283). The study was conducted in accordance with the Declaration of Helsinki and the Institutional Review Board of NCH approved study procedures. Researchers obtained written documentation of informed consent for all subjects.

2.2 Data Collection

We utilized Rapid Assessment Procedures (RAP)[40] to simultaneously collect quantitative and qualitative data describing neighborhood and household conditions. RAP make use of traditional anthropological techniques, such as participant observation, interviewing, and analysis of quantitative data, over a shortened and more focused period of fieldwork[40]. Typically, RAP are implemented by multidisciplinary teams across multiple sites, include prompt turn arounds on data analyses, and are participatory in nature[40, 41]. While RAP may never meet the methodological standards sought by most anthropologists, researchers across disciplines using RAP increasingly recognize the approach's ability to offer meaningful insight in complex social and material settings. For example, RAP have been used in disciplines including health education[42], pandemic response in clinical settings[43], and health information technologies[44]. Our RAP consisted of quantitative audits of neighborhood and household characteristics and participant observation techniques in neighborhoods and family homes.

Audit of Neighborhood and Household Environment. As part of the second wave of data collection (home visits) when children were aged 24-months, teams of trained research staff conducted mixed methods audits of neighborhood and household conditions. We designed a novel data collection tool by adapting existing environmental audits and questionnaires focused on neighborhood and household conditions[21, 22, 45–47]. A total of 32 items were selected for the audit to describe environmental conditions. Items were organized in relation to neighborhood features, neighborhood disorder, household features, and household disorder.

Fieldnotes of Neighborhood and Household Environments. We supplemented quantitative neighborhood and household audits with a rapid participant observation to describe conditions and interactions research staff observed in participants' neighborhoods and homes. Participant observation is a traditional anthropological technique often used when researchers aim to develop an understanding of participants' lived experiences amidst natural settings[38]. Because our research study lacked the time and resources to conduct extensive fieldwork typically associated with participant observation, we adapted key features of the anthropological technique to be implemented over numerous home visits lasting approximately 100 minutes each. During our visits, neighborhoods were observed for approximately 10 minutes, prior to the start of home visits, and homes were observed for the remainder of the scheduled visit (approximately 90 minutes). Staff were permitted to interact with participants in ways that helped build rapport as they implemented other study protocols but prioritized acting as an objective observer. Staff were trained to write descriptive notes to illustrate the physical and social environments they observed and practice critical self-reflexivity by writing fieldnotes reflecting on their experiences. Following visits, study staff returned to research offices where they logged their neighborhood and household audit and wrote a brief ethnography using their recorded fieldnotes.

2.3 Research Staff Training and Reliability

Prior to data collection, research staff received a half-day training involving a two-hour classroom session (discussing skills and techniques of ethnography[48]) and a two-hour field practice component. A second classroom-based review session was additionally conducted once data collection was underway. Photos of varying neighborhood and household conditions were rated and discussed. Detailed descriptions of

each rating were provided. Based on group consensus, definitions for ratings and descriptions were recorded and organized in a manual for reference and future trainings. During the field component, trainees traveled to the home of a research team member where each trainee completed and discussed the observation form. Trainees, who consisted mostly of college-educated, white, middle-class females under age 40 years, were required to demonstrate adequate inter-rater reliability (≥ 80%) from a minimum of five observations before they were certified to collect data.

2.4 Data Analyses

Analyses followed a mixed method design. Quantitative data from neighborhood and household audits were first analyzed to describe levels of chaos present in households during home visits. We then sought to validate and contextualize ratings of chaos using the brief ethnographies.

Quantitative Analysis. To describe levels of environmental and household chaos, we selected 21 items that were most relevant to environmental and household chaos from the audit of neighborhood and household conditions and respondent surveys (Table 1). Items from caregiver surveys were included to supplement measurements of household instability (often characterized by changes in parental romantic relationship status, household moves, changes in income or parental employment, and disruption to family routines)[15], as such indicators are not possible to observe during a 100-minute home visit. We reviewed the distributions of responses for the initial 21 items and chose to exclude two due to little variability in item responses. Thus, we sought to empirically derive measures of environmental and household chaos from a total of 19 items (Table 1).

Table 1
Description of items considered as indicators of neighborhood and household chaos

Item	Variable Name	Description	Min	Max	Mean	Median	Skewness Statistic	Standard Deviation
1	Interior Noise Rating	How would you rate the amount of noise inside the home? Focus on the noise produced by appliances, people, animals, etc. inside the home.	1	4	2.23	2.00	0.34	0.77
2	Hear Exterior Noise Inside (Y/N)	Is noise from outside the home audible when standing inside the home? Is there presence of loud ambient sounds (e.g., trains, construction, factories, traffic, people outside)?	1	2	1.49	1.00	0.02	0.50
3	Rating of Exterior Noise Audible Inside	How would you rate the amount of outside noise audible from inside the home?	1	4	1.70	2.00	0.91	0.81
4	Noise Pollution (Y/N)	Is there presence of loud ambient sounds? (i.e., can you hear trains, construction, factories, loud engines, etc.?)	1	2	1.39	1.00	0.44	0.49
5	Exterior Noise Rating	How would you rate the amount of noise overall?	1	4	2.34	2.00	0.28	0.80
6	Number of Changes to Household Roster[±]	Total number of household changes between 18- and 24-months (0, 1, 2 + changes)	1	3	1.22	1.00	2.36	0.54

Item	Variable Name	Description	Min	Max	Mean	Median	Skewness Statistic	Standard Deviation
7	Regular Mealtime Routine±	Mealtimes occur at the same time each day (1 = strongly disagree to 5 = strongly agree)	1	5	3.33	4.00	-0.62	0.92
8	Number of Adults in the Household±	Number of adults in the home at 24-month visit (1, 2, 3, 4 + children)	1	4	2.03	2.00	1.11	0.74
9	Number of Children in the Household±	Number of children in the home at 24-month visit (1, 2, 3, 4 + children)	1	4	1.97	2.00	0.78	1.05
10	Caregiver Marital Status Change±	Change in primary respondent's marital status between 18- and 24-months	1	2	1.04	1.00	4.57	0.20
11	Total Residential Moves±	Number of residential moves between child's birth and 24-months (0, 1, 2 + moves)	1	3	1.53	1.00	0.99	0.73
12	Regular Bedtime Routine±	Do you have a regular routine of things you do with child when you put him/her to sleep?	1	2	1.90	2.00	-2.64	0.30
13	Cluttered Interior (Y/N)	The house is reasonably clean and minimally cluttered	1	2	1.62	2.00	-0.51	0.49

Table 1
Continued...

Item	Variable Name	Description	Min	Max	Mean	Median	Skewness Statistic	Standard Deviation
14	Crowded with Furniture (Y/N)	Rooms are overcrowded with furniture	1	2	1.16	1.00	1.84	0.37
15	Commotion (Y/N)	There is very little commotion in the home	1	2	1.62	2.00	-0.49	0.49
16	Interruptions (Y/N)	Family members talk without interrupting one another	1	2	1.82	2.00	-1.67	0.39
17	Preparedness Rating	How prepared did the household appear for the home visit?	1	4	3.27	4.00	-0.83	0.88
18	Loud Speaking (Y/N)	Family members speak to one another in an elevated volume	1	2	1.19	1.00	1.61	0.39
19	Telephone Use (Y/N)	The telephone took up a lot of time in the home (e.g., ringing or active phone conversations)	1	2	1.12	1.00	2.30	0.33
20	Arguments (Y/N)*	Family members are drawn into other people's arguments in the home	1	2	1.04	1.00	4.57	0.20
21	Rushed (Y/N)*	Family members appear rushed	1	2	1.07	1.00	3.37	0.26

[±]Item is from the parent surveys

*Excluded from exploratory factor analysis due to little variation in item responses.

We developed scales describing chaos using exploratory factor analyses (EFA)[49] with unweighted least squares and oblique (Promax) rotation methods. All items considered for the EFA were ordinal or binary. Therefore, our factor analysis was based on polychoric correlations, rather than Pearson's correlations[50]. We chose to employ unweighted least squares for ordinal indicators, because it has been shown to be robust to smaller sample sizes, skewed data, and provides greater accuracy and less variability in estimates, when compared to diagonally weighted least squares[51].

Factor extraction was informed by a scree plot[52] and our theoretical understanding of chaos. Our final factor structure required factors to have a minimum of three items, as fewer than three items generally results in weak factors[52]. Following previously published work, we assigned an item to a factor if the primary loading was ≥ 0.50[51] and the item did not cross-load (loading was < 0.32 for other factors)[52]. Finally, we generated factor scores by summing the items assigned to each factor.

Variables to describe cohort characteristics were predominantly derived from the caregiver survey administered at the baseline assessment (when children were approximately 18-months old). Descriptive statistics (means, standard deviations (SD), and P values from one-way ANOVA) described how measures of chaos distribute across characteristics of the sample, including child, household, and caregiver characteristics. Quantitative analyses, including the EFA, were conducted using SAS (version 9.4, SAS Institute, Cary, NC).

Qualitative Analysis. Due to the large number of households visited by researchers during the 24-month assessment, we chose to examine and compare qualitative records from a randomly selected subset of families. To do this, we categorized factor scores into quartiles and randomly selected records from the highest quartile and records from the lowest quartile of factor scores. A thematic content analysis[53] was conducted using the brief ethnographies to describe participants' immediate neighborhood and home environments. Informed by our theoretical interest in chaos, we used a deductive approach to develop codes, though an initial round of open coding was completed to assess patterns in the data and codes missing from our *a priori* coding structure[54]. A final codebook was constructed with code definitions to ensure consistency across coding and coding was completed by one researcher. We coded records until thematic saturation[38] was achieved and codes were managed electronically using *QSR NVivo* (Version 12, QSR International, Victoria, Australia). In total, 87 records were coded for our thematic content analysis.

3. Results

3.1 Quantitative Findings

Of the 299 caregiver-child dyads in the cohort, field observations were completed at 283 family homes. Compared to families with complete observation data, the proportion of families missing field observations was higher among those who had the lowest household income, lowest educational

attainment, were food insecure, and whose primary respondent identified as non-Hispanic Black (data not shown).

The scree plot suggested two to four factors would optimally fit our data. We examined the factor loadings for each of the three structures and determined a two-factor solution was best. Eight items were assigned to the first factor. Factor one was labeled *household disorganization* and included items describing interior household conditions and household dynamics, such as interior noise, clutter, commotion, overcrowding with furniture, excessive telephone use, communication between household members, and overall preparedness for the study visit. Our second factor, labeled *neighborhood noise*, consisted of four items describing the types and amount of noise heard outside participants' homes (Table 2).

Table 2
Factor loadings from exploratory factor analysis of environmental and household chaos indicators

		Factor 1:	**Factor 2:**
Item No.	Item Name	*Household Disorganization*	*Neighborhood Noise*
1	Interior Noise Rating	**-0.79**	0.16
13	Cluttered Interior (Y/N)	**0.51**	-0.31
15	Commotion (Y/N)	**0.84**	-0.04
16	Interruptions (Y/N)	**0.61**	-0.05
17	Preparedness Rating	**0.78**	-0.11
18	Loud Speaking (Y/N)	**-0.61**	0.09
14	Crowded with Furniture (Y/N)	**-0.40**	0.06
19	Excessive Telephone Use (Y/N)	**-0.47**	0.30
2	Hear Exterior Noise Inside (Y/N)	0.08	**0.75**
3	Rating of Exterior Noise Audible Inside	-0.05	**0.84**
5	Exterior Noise Rating	-0.26	**0.65**
4	Noise Pollution (Y/N)	-0.13	**0.45**
6	Number of Changes to Household Roster	-0.20	0.05
7	Regular Mealtime Routine	0.23	-0.02
8	Number of Adults in the Household	0.07	-0.03
9	Number of Children in the Household	-0.26	-0.06
10	Caregiver Marital Status Change	-0.31	-0.11
11	Total Residential Moves	-0.31	0.06
12	Regular Bedtime Routine	0.34	-0.06

Note: N = 283; Exploratory factor analysis using unweighted least squares and Promax rotation; Inter-factor correlations are as follows: factors 1 & 2 = 0.17, $p = 0.005$; Cronbach's Alpha 0.73 and 0.67 for household disorganization and neighborhood noise, respectively.

Scores were generated by summing the items assigned to each factor and internal consistency estimates were calculated (Cronbach's Alpha = 0.73 and 0.67, respectively). Observed scores for household disorganization ranged from 8–18 and the mean score was 11.37 (SD = 2.58). Observed scores for

neighborhood noise ranged from 4–12 and the mean score was 6.93 (SD = 1.89). Characteristics of the cohort were provided in Table 3.

Table 3
Descriptive statistics for child, household, and primary respondent characteristics and measures of chaos

	Overall		**Household Disorganization (Range: 8–18)**			**Neighborhood Noise (Range: 4–12)**		
	n	%	Mean	(SD)	P Value	Mean	(SD)	P Value
Overall	283	-	11.37	(2.58)		6.93	(1.89)	
Child Characteristics								
Sex								
Boy	162	57.2	11.29	(2.46)	0.52	6.94	(1.88)	0.90
Girl	121	42.8	11.49	(2.73)		6.91	(1.91)	
Household Characteristics								
Housing Type								
Single Family Home	194	68.6	10.87	(2.41)	< 0.0001	6.60	(1.83)	< 0.0001
Duplex or Condo	26	9.2	12.73	(2.49)		7.92	(2.02)	
Apartment or Other	63	22.3	12.37	(2.66)		7.51	(1.76)	
Number of Household Members								
2 members	17	6.0	11.82	(2.51)	< 0.0001	7.60	(1.85)	0.43
3 members	93	32.9	10.74	(2.36)		7.17	(1.90)	
4 members	83	29.3	10.81	(2.13)		6.82	(1.98)	
5 or more members	90	31.8	12.47	(2.83)		6.74	(1.80)	
Food Insecurity								
Food Secure	239	84.5	11.18	(2.53)	< 0.01	6.84	(1.84)	0.03
Food Insecure	44	15.6	12.43	(2.59)		7.45	(2.06)	
Income-to-Poverty Ratio								
Less than 0.50	41	14.6	13.24	(2.60)	< 0.0001	8.07	(2.05)	< 0.0001
0.50–0.99	48	17.1	12.91	(2.67)		7.10	(1.39)	

	Overall		Household Disorganization (Range: 8–18)			Neighborhood Noise (Range: 4–12)		
1.00-1.84	50	17.8	11.52	(2.43)		7.08	(1.98)	
1.85–2.99	60	21.4	10.98	(2.19)		6.32	(1.71)	
3.00 or greater	82	29.2	9.67	(1.45)		6.55	(1.84)	
Missing	2	0.7	-			-		
Primary Respondent Characteristics								
Race/Ethnicity								
Non-Hispanic white	149	52.7	10.58	(2.28)	< 0.0001	6.56	(1.82)	< 0.001
Non-Hispanic Black	104	36.8	12.48	(2.64)		7.48	(1.98)	
Non-Hispanic other (includes multiple races)	17	6.0	11.94	(2.33)		7.24	(1.20)	
Hispanic	13	4.6	10.92	(2.33)		6.23	(1.48)	
Educational Attainment								
High school diploma/GED or less	50	17.7	12.66	(2.41)	< 0.0001	7.96	(1.78)	< 0.0001
Some college	93	32.9	12.51	(2.73)		7.06	(1.92)	
Bachelor's degree	66	23.3	10.23	(1.73)		6.29	(1.74)	
Post-graduate degree	69	24.4	10.00	(2.01)		6.55	(1.75)	
Missing	5	1.8	-			-		
Endorsed Symptoms of Depression								
No	257	90.8	11.27	(2.57)	0.03	6.89	(1.86)	0.28
Yes	26	9.2	12.42	(2.48)		7.31	(2.19)	

Table 3
Continued…

	Overall		Household Disorganization			Neighborhood Noise		
	n	%	Mean	(SD)	P Value	Mean	(SD)	P Value
Self-reported general health								
Excellent	40	14.1	11.25	(2.48)	0.03	7.30	(2.00)	0.21
Very Good	104	36.8	11.06	(2.49)		6.81	(1.89)	
Good	99	35.0	11.23	(2.63)		6.76	(1.78)	
Fair/Poor	39	13.8	12.46	(2.60)		7.33	(2.00)	
Missing	1	0.4	-			-		

Note: Description of disorganization and neighborhood noise were derived from assessments in family homes when children were approximately 24-months of age. Higher scores are indicative of higher levels of chaos. SD = standard deviation; Household disorganization scores summarizes ratings assigned to eight items: (1) interior noise rating, (2) cluttered interior (y/n), (3) commotion (y/n), (4) interruptions (y/n), (5) preparedness rating, (6) loud speaking (y/n), (7) crowded with furniture (y/n), (8) excessive telephone use (y/n). Neighborhood noise scores summarized ratings from four items: (1) exterior noises heard from inside the home (yes/no), (2) the volume of exterior noises heard from inside the home, (3) the rating of noise heard while outside the home, and noise pollution (y/n). Food insecurity was assessed using the U.S. Department of Agriculture Food and Nutrition Service's guidelines for measuring food security. We coded families as having food insecurity if they indicated experiencing any level food insecurity in the 12-months prior to them completing our surveys. Income-to-poverty ratio was calculated using the 2018 U.S. poverty guidelines according to household size. Depression symptomology was determined using the Center for Epidemiological Studies Depression Survey, with a score ≥ 16 indicated symptoms of depression.

3.2 Qualitative Findings

Household Disorganization. Concurrent with our quantitative ratings of disorganization, family homes with the highest levels of disorganization were described by researchers as environments where household members often spoke loudly or over one another or households were ill-prepared for the study visit (e.g. families were late for the visit, did not follow instructions for visit preparation, or it was apparent participating caregivers did not communicate with household members that the study visit had been scheduled to occur). Furthermore, home interiors were often cluttered, and households were tumultuous, which was often attributed to crowding (i.e., more people that the space appeared to accommodate) and heavy foot traffic in and out of the home. Example passages from ethnographies include,

"… [It] took a lot of coaxing from study staff to get any confirmations and survey/[food] orders from mom [prior to the visit]. Grandma answered the door and seemed surprised we were there. [She] spent at least 3 minutes wrangling the dogs to get them out of the way while we waited outside. There were friends of the

family (according to [grandma, the friends were] 2 or 3 new moms [they were helping out]…) making noise upstairs… Grandma [said] they were either living… there temporarily… During measurements and study activities, grandma ran in and out of the room multiple times- seemingly multitasking at opposite ends of the house. Grandma would sometimes interrupt mom during measurements or had many questions for staff. Mom and grandma yelled at each other from opposite ends of the house about changing target child's diaper for measurements…"

"The first thing I noticed upon walking in the front door was…how cluttered everything was… There were boxes of diapers, laundry, miscellaneous papers… crammed against walls and made it very difficult to get around… There were several sofas crammed into the small space, one of which was overflowing with laundry and blankets. We had to step around several kid's toys scattered across the living room floor. The kitchen… counter surfaces were completely covered in dishes, food, papers, laundry…"

Brief ethnographies also revealed themes that helped contextualize the social and material environments observed in both disorganized and organized homes (Table 4). In nearly all ethnographies from homes with high disorganization, staff wrote about children's behaviors or energy levels. In many cases, researchers described children as being "very active" or having "a lot of energy". Sometimes study staff noted children "running around the home" or climbing on study materials or furniture. Some children were described as "crying/screaming out of excitement…" or "demand[ing] a lot of attention from [study] staff and [caregivers]". Such descriptions of child behavior were often coupled with staff observations of situations when caregivers attempted to bring order to the home environment unsuccessfully using approaches, such as speaking at elevated volumes or yelling across rooms to get a child's attention. In contrast, descriptions of child behavior were mostly absent from ethnographies from homes with the lowest disorganization. However, among the most organized homes, researchers portrayed moments when caregivers were observed using specific behaviors or strategies to successfully mitigate potential disorganization within the home. This was often noted when caregivers were described as "encouraging" and "supportive" of their children as they worked through study tasks or when they responded to energetic or uncooperative children in ways that successfully calmed the child without introducing additional sources of disorganization. In one household, a mother was described as asking her excited daughter to "pause, take a deep breath, and then speak…" so she could better understand her needs.

In homes with high disorganization, staff frequently described caregivers as passive towards other household members or unengaged in visit activities. For example, one caregiver was described as "mostly passive" when she did not intervene when one child in the household was "throwing things or picking up and swinging around… three young [household] pets". Another caregiver was described as only directly engaged with the participating child when "[complying] with the visit activities," but not during other points of the study visit, such as transitions between activities or during preparation for mealtime. Furthermore, ethnographies from the most disorganized homes illustrated strained interactions between caregivers and children. Specifically, caregivers visibly, or audibly, expressing frustration towards their child's actions (e.g., "mom shout[ed] 'why?!' several times… when [child] was crying and refusing to be measured on the stadiometer"). Other study staff wrote that caregivers "seemed to be stressed" or were

"visibly frustrated" when their child struggled during the visit. These descriptions from highly disorganized homes directly contrasted with descriptions of interactions between parents and children in organized homes. In the most organized homes, staff described interactions between caregivers and children using language that was mostly positive in sentiment. For instance, one dyad seemed to enjoy shared activities as the "child giggled, or mom laughed in response to something… the child was doing". Another family was observed "communicat[ing] a lot with one another and happily discuss[ing] their many shared interests." One dad made comments to research staff about "how [he and the mother] were proud of the kids". Research staff suggested that such interactions made homes feel "calm and relaxing".

Competing caregiver responsibilities were noted in households described as highly disorganized. In such cases, caregivers shared with study staff they were rushing to get to or come from places like work, school, doctor's visits, or were balancing other family priorities, such as medical challenges. For example, one mother shared that she "scheduled a far-away appointment 90 minutes after the set visit start time and asked [staff] at the start of the visit how long it would take to complete [the visit]". In comparison, staff ethnographies from the most organized homes often contained passages describing preparation and prioritization of the study visit. On staff member wrote, "[the] family was very prepared for the study visit. All family members were aware we were coming and greeted us upon first interaction…. [the family] dog was put away upstairs as we had asked." Finally, staff noted clearly defined play spaces for children within some of the homes that had the lowest ratings of disorganization. Such spaces included separate playrooms or designated spaces within a family room that was clearly marked by child play-structures, such as a small table, or a soft padded mat or rug distinguishing a space for toys and play.

Neighborhood Noise. Qualitative descriptions of neighborhood noise paralleled the quantitative scale derived from the EFA. To illustrate,

"[The] neighborhood and [the participant's home] was very close to a very busy highway that was very loud [throughout our observation]. There was also a construction site nearby, contributing to the noise with their dump trucks that drove by-at least 3 large dump trucks went past in the 15 mins that we sat there… [While inside the home,] We could also hear noise from the highway and construction outside, especially the large trucks going by."

"Though no cars drove through the lot during our observation, there was a constant stream of traffic down that main road and accompanying sounds of traffic. Police and ambulance sirens persisted for a few minutes and were intermittently present throughout the entire observation."

Sources of neighborhood noise were similar across households, despite the ratings of neighborhood noise assigned by researchers. Sources included car traffic, such as distant highway noise or engines, sirens (e.g., ambulance or police sirens) and alarms (e.g., beeping from construction vehicles), air traffic, speech from people in the neighborhood, and other noises, such as dogs barking. However, among homes described as having the lowest neighborhood noise, researchers more frequently described noise as being noticeable to a lesser degree. They did this by conditioning their descriptions using words like "faint" or "muffled" or described noise as being "sporadic", rather than persistent.

We noted two themes that were unique to households in the loudest neighborhoods (assigned to the highest quartile of neighborhood noise) (Table 4). First, in especially noisy neighborhoods, researchers more frequently described being able to hear loud ambient noises from the surrounding neighborhood while inside the participant's home. These descriptions often included noises such as vehicles driving by, airplanes, and sirens from emergency response vehicles. In fewer instances staff described hearing neighbors talking or yelling outside. The second theme, unique to the noisiest neighborhoods, was the presence of loud music from passing vehicles. Researchers described neighborhood environments where drivers' music was so loud, they could "feel the vibrations" from the music being played. Loud music from cars was observed when researchers were outside homes and inside homes.

We also noted two themes that were unique to the quietest neighborhoods (assigned to the lowest quartile of neighborhood noise). Researchers described neighborhood settings where geography appeared to play a role in attenuating environmental noise. Examples of geographic features include trees surrounding the neighborhood which buffered against noise, distance from the metropolitan airport, or a large parking lot or dead-end street separating the participant's home from major sources of traffic noise. Finally, in homes that were describe as being the quietest, research staff described an overall lack of loud ambient noise. In such cases, researchers often noted the inability to hear exterior noise while inside the home.

Table 4
Codes and supporting excerpts describing social and material conditions observed during rapid participant observation

Factor	Parent Code	Supporting Excerpts
High Disorganization		
	Child Behavior	*I endorsed commotion in the home because the [target child] had a LOT of energy and was running around the home from one end to the other, grabbing toys, riding his truck, and crying/screaming out of excitement/motioning for staff or parent to do things for him.*
	Passive or Unengaged Caregivers	*Mom and children were still in pajamas and there was clutter on the floor making it difficult to navigate our things inside... Children's faces were dirty, and they went back and forth from living room to kitchen and were occasionally shouting. Mom spent most of our visit looking at her phone and playing with the youngest baby. She called the oldest over once or twice, but for the most part, he was interested in and getting into our materials. Mom did not pay much attention to what was going on in her home. She provided minimal engagement with the children and even less with us.*
	Strained Parent-Child Activities	*Even when the non-preferred activities stopped, child continued to want to run around or sit in the puzzle box and resisted when we tried to direct his attention elsewhere. Mom became even more visibly frustrated during the meal but would quickly get over it and laugh it off at times. The more mom reacted to the child's outbursts, the more chaotic the environment felt.*
	Unsuccessful Strategies to Create Order	*For book, child was very interested in the measurement tools still and our suitcase in the kitchen. He became very upset when Mom would not let him come to the kitchen. She became louder and louder in her requests to sit and look at the book. She sent Dad to the kitchen for a piece of candy in hopes that child would calm down. He did not. Eventually she gave in and let him come to the kitchen to see. She brought him back but was not able to get him to focus on the book much. The puzzles were a similar scenario. Mom got louder and louder to try to keep him engaged in the activity, but he still ran to the kitchen several times and she would yell for him to come back.*
	Competing Caregiver Responsibilities	*Dad was very difficult to get a hold of due to his crazy work hours. Mom tried to reschedule and cancel the visit on his behalf multiple times. After some prompting and a few Saturday calls, dad confirmed a date and did the survey before the visit.*
Low Disorganization		

Factor	Parent Code	Supporting Excerpts
	Positive Parent-Child Interactions	*The home feels extremely inviting and a nurturing place for young children to grow. Mom listened to child throughout their meal and asked child questions as if they were engaged in a discussion. Mom genuinely laughed with child and genuinely seems to enjoy her time with child- and child with mom. Mom calmly redirected behaviors when child behaved less favorably. All interactions were positive and in a respectable tone.*
	Successful Strategies to Create Order	*[The target child] was still asleep from the car ride home. Dad and Mom chatted a bit and Dad held [target child] until he had to get ready to leave. [Target child] was hard to measure, but Mom was very persistent in trying to get him to be cooperative. She calmly talked to him and encouraged him, while also responding to his desires and frustrations.*
	Visit Preparation	*Mom did everything ahead of time and even prepped a supplementary meal… The cat was also put away before we got there… Mom remembered [staff] from their first visit… dad greeted [staff]…and introduced himself.*
	Designated Space for Children	*[The] house has front playroom for kids, lots of toys but very organized - toys were in colored bins, stacked on bookshelves, arranged in specific areas. Small teepee the child received for her birthday recently, small child's table & tea-set.*

Table 4. Continued…

Factor	Parent Code	Supporting Excerpts
High Noise		
	Neighborhood Noise Heard while Inside the Home	*Some noise from the freeway was persistently audible throughout the visit. It got slightly more noticeable towards the end and I could feel the vibrations from the cars from inside the home*
	Loud Music from Passenger Vehicles	*Two cars pulled in at different times that had their music turned up very loud so that we could hear it out of the vehicle and feel the bass.*
Low Noise		
	Geographic Barriers to Noise	*Since the home was in a cul-de-sac, there were no cars that had to drive by unless they were from that street and coming/going. I felt like this really contributed to the fact that it was very quiet.*
	Lack of Loud Ambient Noises	*…cars [could not] be heard from the back of the home or the front where we were seated during mealtime. No outdoor sounds whatsoever [were] noticeable.*

4. Discussion

4.1 Summary of Findings

With the goal to inform future childhood obesity prevention strategies, we examined detailed descriptions of environmental and household chaos using a concurrent mixed methods approach. Our analyses re-examined the underlying structure of chaos using EFA and found evidence for a two-factor solution consisting of disorganization and neighborhood noise, but not instability. Moreover, qualitative fieldnotes describing family homes and neighborhoods supported factors identified in the EFA. Finally, we sought to describe the context in which observed chaos occurred, and in doing so, identified codes describing social and material conditions that varied according to the level and type of observed chaos.

Our multi-factor structure of chaos aligns with methodological approaches and results described by Vernon-Feagans et al (2012). In their analysis, ten indicators of chaos were collected via five direct observations of participant homes over children's first three years of life; factor analyses identified two factors: disorganization and instability[22]. Our EFA did not identify instability as an independent factor contributing to chaos. However, methodological differences in study designs may explain such discrepancies. While the indicators selected to represent instability in our study closely aligned with those previously assessed,(e.g., residential moves)[22], we conducted a single-assessment when children were approximately 24-months of age, rather than multiple assessments over time. Unlike other aspects of chaos, which tend to occur regularly, instability often occurs periodically. Therefore, our lack of support for instability as a factor of chaos may be due to our limited assessment timeline. Additionally, the sample examined by Vernon-Feagan et al (2012) was drawn from a target population comprised of families living in low-income rural regions of the U.S.[55], which differs from families included in the Play & Grow cohort. Such differences, especially regarding socioeconomic position, may contribute to instability being unidentifiable in our EFA. Still, our findings build upon previous work by suggesting chaos may be comprised of important subdomains. Thus, assessments of environmental and household chaos may require greater nuance when discussed as a potential correlate of childhood obesity.

Our scale describing disorganization closely aligns with what Matheny and colleagues labeled *environmental confusion*, in the development of the CHAOS[21]. This suggests the CHAOS may provide a foundation for developing measurement tools designed for structured, direct observations of disorganization in family homes. We believe direct observations may be necessary to avoid potential bias often associated with parent-reported measures[56]. For example, one study examining parent and adolescent perceptions of household chaos using the CHAOS (N = 261 parent-adolescent dyads) found perceptions of chaos in shared home environments were only moderately correlated (r = 0.32), implying individual differences in perceptions of chaos[57]. Another analysis examined associations between maternal personality characteristics and perceptions of chaos using the CHAOS (N = 94). Results indicated mothers with high stimulus sensitivity perceived home environments as more chaotic than what was objectively measured by trained observers[28]. While parent-reported measures offer quick, cost-effective alternatives to direct observations, disentangling caregiver characteristics from measures of chaos may be impossible without more objective assessments. Still, direct observations conducted by trained researchers also have notable shortcomings, including vulnerability to bias resulting from observers' personality, knowledge, beliefs, and experiences. We were mindful of this limitation when designing our data collection procedures. To mitigate potential bias in our direct observations, staff were

trained to collect both descriptive and reflecting fieldnotes which facilitated staff engagement in reflexivity as they assigned ratings. Never-the-less, individual biases may have played a role in our observations.

We identified neighborhood noise as a unique factor contributing to our ratings of chaos. In early research investigating associations between chaos and child development, noise was the primary aspect of studied[14], but current definitions of chaos include little specificity around types and sources of noise[14, 21]. Interestingly, one item describing the level of interior noise was highly correlated with our factor of disorganization, but minimally correlated with our factor of neighborhood noise. Such distinction may suggest noise typologies are a necessary level of nuance for measuring environmental and household chaos, with different implications for intervention development. For example, our quantitative analysis found neighborhood noise was associated with indicators of socioeconomic disadvantage, such as not living in a single-family home and income-to-poverty ratio but was not associated with characteristics more closely linked to social environments within homes (e.g., number of household members or caregiver health). Therefore, neighborhood noise may be one aspect of chaos more closely tied to structural disadvantage and may require multifaceted interventions designed to address a variety of upstream social inequalities.

4.2 Implications for Childhood Obesity Prevention

Our content analysis of qualitative fieldnotes contextualized disorganization and neighborhood noise within family environments and alluded to possible pathways by which chaos may influence obesity[58]. For example, while our staff were not trained in rigorous protocols for coding children's behaviors[59], nearly every qualitative assessment of highly disorganized homes included staff descriptions of children's behaviors. Parent- and teacher-reported characteristics of child behavior, such as being impulsive, playing carelessly or recklessly, and or becoming out of control relative to playmates, are included in validated measures of children's self-regulation[58]. In toddlerhood, self-regulation develops rapidly[60] and poor self-regulation in early life may influence short-term obesity development[30], and obesity in adulthood[61]. To the best of our knowledge, only one study has examined the joint effect of chaos and self-regulation on child weight outcomes[26]. In this study, 132 parent-child dyads from a Head Start program in Michigan provided caregiver-reported perceptions of household chaos and children's self-regulation was evaluated according to their performance in the snack delay task when children were approximately 24-months Results indicated a three-way interaction of household chaos, child self-regulation, and child sex on BMI z-score when children were approximately three years old. Specifically, for boys with moderate to low self-regulation, BMI z-score was higher when exposed to greater levels of household chaos; no association was found among girls[26]. The association between self-regulation and childhood obesity has been shown to differ among boys and girls[62] and self-regulation may be a promising target for childhood obesity prevention efforts[30]. However, our observed differences in child behavior-related fieldnotes between organized and disorganized homes builds upon emerging evidence suggesting chaos may act as a moderator for obesity outcomes relative to children's

self-regulation. Therefore, chaos should be considered in future interventions designed to improve child self-regulation.

Fieldnotes describing interactions between caregivers and children from our rapid participant observations diverged between households with the highest and lowest ratings of disorganization. Coding and characterizing aspects of parent-child interactions requires years of training and expertise not acquired by our research staff. Therefore, our descriptions of caregiver-child interactions do not replace more rigorous, objective protocols employed by developmental and behavioral scientists[63]. However, the consistency and contrary nature of language used by staff to describe caregiver-child interactions according to levels of disorganization suggests caregiver-child interactions may be important context for studies of chaos-obesity relationships. Moderated parent-child interactions and relationship quality have been linked to childhood obesity development. For example, in a nationally representative sample of U.S. children, toddlers demonstrating low security of attachment to their primary caregiver also had greater BMI at preschool age[33]. Other studies examining parent-child food-related interactions suggest interactions characterized by low responsivity may also increase children's risk for developing obesity by promoting obesogenic eating behaviors[64]. Improving parent-child relationship quality and interactions may be a promising childhood obesity prevention strategy[30]. However, previous literature underscores the deleterious effects of chaos on parent-child relationships[14, 18, 31, 32]. Therefore, obesity prevention strategies designed to promote high quality parent-child relationships and food-related interactions may also require intervention components which address chaos. To support such intervention development, future research is needed to examine whether parent-child dyadic pathways mediate or moderate relationships between chaos and childhood obesity risk.

Our study has limitations that must be considered. Observations of chaos were conducted during a single visit in participant's homes. As some aspects of chaos may be acute while others are chronic, we may not have observed the true variation of environmental and household chaos. Furthermore, the presence of study staff and execution of study protocols during the visit may have contributed to an unusual home environment that factored into our staff's ratings. Future studies incorporating objective measure of chaos should strive for repeated assessments to ensure what is measured is "typical" for households. Our data collection tool for measuring household chaos was novel and data collection relied on multiple research staff members who were predominantly non-Hispanic white, middle-class, women. Though protocols and trainings attempted to overcome systematic error, without more rigorous testing of psychometric properties, construct validity of our tool may be limited, and observations may incorporate individual bias from observers. Furthermore, most observers interacted and built rapport with families at previous assessments. It is known whether these previous interactions influence ratings and fieldnotes. Finally, though we included two items on household routines in our quantitative assessment, household routines were largely neglected from our observations of chaos. Family routines may be key aspects of chaos with important implications for childhood obesity[65, 66]. Future research should combine factors, such as disorganization and noise, with measure of family routines to understand how best to operationalize chaos.

5. Conclusions

Chaos represents a complex, multifaceted risk factor with research implications spanning various disciplines[67], including public health research focused on early childhood obesity prevention. Unfortunately, empirical evidence examining chaos-obesity relationships in childhood is limited by heterogenous definitions and subjective parent-reported instruments. As obesity prevention researchers look to family home environments as preferred settings for prevention efforts[68], more contemporary measures, such as those relying on direct observations which account for multiple underlying factors of chaos, may yield valuable insight on factors contributing to a global public health issue. We demonstrated methods for improving measures of chaos and underscore potential mechanisms linking chaos to early childhood obesity, such as child self-regulation and caregiver-child interactions, which deserve greater attention in the literature.

Abbreviations

CHAOS: The Confusion, Hubbub, and Order Scale; NCH: Nationwide Children's Hospital; RAP: Rapid Assessment Procedures; EFA: Exploratory Factor Analysis

Declarations

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Authors' Contributions

KLK designed and conceptualized this research, led data collection, led analyses and interpretation of data, and wrote the manuscript. AP participated in the design and conceptualization of data collection methods, assisted with data collection, assisted with analyses, and critically revised the manuscript. RA advised the conceptualization of analytic methods, supervised data analyses, and critically reviewed the manuscript. BZ participated in early development of the data collection methods and critically reviewed the manuscript. SAK supervised data collection and critically reviewed the manuscript. SEA supervised the design and conceptualization of this research, supervised analyses, and interpretation of data, and critically revised the manuscript.

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Availability of Data and Materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethics Approval and Consent to Participate

The study was approved by the Institutional Review Board at Nationwide Children's Hospital (IRB16-00826) and participants provided written informed consent.

Consent for Publication

Not Applicable

Competing Interests

The authors declare that they have no competing interests.

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