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# Family entropy: understanding the organization of the family home environment and impact on child health behaviors and weight

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## Abstract

Child obesity is a major public health issue with a high disease burden. Although numerous contributing factors have been identified, the family home environment is a central context of influence that requires deeper understanding. The level of organization in the family home environment may influence obesity and obesogenic behaviors, but the literature has suffered from the lack of a strong overarching construct and model to guide this area of research. Family entropy is a conceptual framework that fills this gap by representing the level of organization across the home environment. The current study empirically assesses family entropy using factor analysis in a longitudinal sample of 968 children measured yearly from Grades 3 to 6 as part of the NICHD Study of Early Child Care and Youth Development. Mixed modeling using MPLUS examined the influence of family entropy on child weight both directly and indirectly through weight-related health behaviors (i.e., sleep and physical activity), and considered the moderating role of socioeconomic status (SES). Results suggest that family entropy is comprised of distinct elements of household organization and disorganization, which are moderately related. Household disorganization may be particularly detrimental to child sleeping behavior both concurrently and over time in families of both high and low SES. The study concludes with recommendations for advancing understanding of the home environment by using nuanced measurement strategies, and incorporating support for household organization within child obesity prevention and intervention efforts.

## Keywords

Family entropy, Home environment, Organization, Child obesity, Sleep, Physical activity

**Implications**

**Practice:** Assessment of risk factors within the home environment can help identify high-risk families that may struggle to implement treatment recommendations.

**Policy:** Policymakers who want to decrease the incidence of child health disparities should consider supporting incentives that help to increase household organization and decrease environmental chaos.

**Research:** Future research should examine profiles of organization and disorganization related to health outcomes and should examine family entropy in low-income samples.

## INTRODUCTION

Despite an increased focus on prevention and intervention, rates of child obesity have remained stable, and some groups have risen, over the past 10 years [1]. Although many factors are implicated in the development and maintenance of child overweight and obesity, the family home environment is universally regarded as a central context of influence [2]. Within the family home environment, the level of family home organization is a lesser understood construct that may hold relevance for child overweight and obesity through influence on obesogenic behaviors, including eating patterns, sleep, physical activity (PA), and sedentary behavior.

The level of organization in the home has been studied, but not well-specified in relation to child obesity. A recent systematic review of organization of the family home environment and weight among children aged 2–12 found that household organization has been studied using an array of indicators including household routines, limit setting, chaos, and crowding [3]. The vast majority (84%) of studies indicated that the organization of the family home environment was associated with child weight, but the nature of the relation varied depending on the indicators. Family organizational behaviors, including mealtime routines, sleep routines, limit setting around screen time, were more likely to be related to lower zBMI and healthy weight status, whereas environmental disorganization, such as household crowding and chaos, were more likely

to be related to higher zBMI, overweight, or obesity among youth. These findings led Bates and colleagues [3] to propose a new overarching construct, family entropy, to capture the overall level of organization/disorganization within the home.

Family entropy is a novel term that borrows from thermodynamics to capture organization/disorganization across the family home environment [3]. In thermodynamics, entropy is "a measure of the amount of molecular disorder within a system" [4]. Accordingly, systems possessing a high degree of molecular disorder, such as a high temperature gas, have high entropy value, whereas systems with a low degree of disorder, such as ice, have low entropy value [4]. Drawing on this concept, high family entropy occurs in home environments that are disorganized and unstructured, whereas low family entropy occurs in home environments that are organized and structured.

Family entropy may be related to child weight through the influence of weight-related health behaviors. Few studies have clearly differentiated the influence of family routines around obesogenic behaviors (e.g., bedtime routine and screen time monitoring) from the behaviors themselves (e.g., child sleep duration and total screen time) on child weight [3]. Literature has proposed that family routines may mitigate obesity risk by supporting healthful behaviors [5], but there has been minimal empirical work to examine this notion. One study by Appelhans and colleagues [6] found that relations between caregiver screen time monitoring and weight status were mediated by total child screen time and sleep duration. To further explore pathways of influence, the current study also examined obesogenic behaviors (i.e., sleep and physical activity) as mediators of relations between family entropy and child weight.

Relations between family entropy on weight may be particularly important to understand among school-age youth. Obesity rates tend to climb within this developmental period, particularly when children are out-of-school [7] and even more so when out-of-school is spent in unstructured settings (e.g., at home under parental care) [8]. This may be owing to the fact that children engage in more obesogenic behaviors during unstructured out-of-school time, including increased sedentary time [9], decreased PA [10], and decreased sleep [11]. Indeed, in the same way that unstructured time is a risk factor for weight gain among school-age children [8], an unstructured, disorganized home environment (i.e., high family entropy) may be a risk factor for obesogenic behaviors and unhealthy weight status in this group.

A critical component to consider is the confounding influence of socioeconomic factors. Low-income status is associated with increased risk for obesity [12], and may contribute to family entropy through associations with household chaos, crowding, and disruption of family routines [13]. In addition to level of income, single-parent status has also been associated with higher levels of household disorganization [14] and obesity [15]. Importantly, indicators of family entropy (e.g., chaos, crowding) have been shown to be predictive of children's outcomes above and beyond the influence of socioeconomic status (SES) [16]. Socioeconomic factors are also important to consider for their influence on obesogenic behaviors. Factors such as inconsistent or demanding work schedules may limit families' abilities to participate in positive routines together [17], including bedtime and activity routines, which may then impact sleep duration and PA. While accounting for socioeconomic influences is important, more thorough examinations of the moderating impact of SES are needed to explore the varying influence of the home environment across levels of income and family structure. Knowing that obesity intervention programs often struggle with effectiveness in low-income samples [18, 19], examining the differential impact of family entropy on child health based on SES could lead to the identification of important barriers to intervention success, and highlight family entropy as an area to target in interventions for hard-to-reach families. Thus, the final analysis in this study examined family income-to-needs ratio as a moderator of relations between the family entropy and child health behaviors and weight.

## AIMS OF THE CURRENT STUDY

Utilizing a longitudinal sample of U.S. youth followed from third through sixth grade, this study sought evaluate family entropy and relations to child health behaviors and weight via four aims: (a) empirically evaluate the construct of family entropy in a large, longitudinal sample of school-age youth, (b) examine relations between family entropy and child weight, (c) examine children's health behaviors (i.e., sleep and PA) as mediators of relations between family entropy and child weight, and (d) examine the moderating role of socioeconomic factors on relations between family entropy, child health behaviors, and child weight. Drawing on a recent theoretical model of family entropy [3], the current study assesses family entropy by examining both organization (e.g., meal routines, sleep routines) and disorganization (e.g., household chaos).

## METHOD

### Participants and Procedures

Participants in this study were a part of the National Institute of Child Health and Human Development Study of Early Child Care and Youth Development (NICHD-SECCYD), a prospective longitudinal study conducted at 10 research sites

across the United States. Participant recruitment occurred at designated hospitals at the research sites in 1991 and children ($N$ = 1,364) were studied from birth until the end of high school. A conditionally random sampling was utilized to ensure that the recruited families: (a) included mothers who planned to work or go to school, either full time (60%) or part time (20%), and mothers who planned to stay at home with the child (20%) in the first year and (b) reflected the demographic diversity (economic, educational, and ethnic) of the sites. Families were excluded if they did not anticipate remaining in the catchment area for at least 3 years, if mother was younger than 18 years of age, if the child was born with medical concerns or required extended hospitalization after birth (i.e., 7 days), or if mothers were not conversant in English. At the time of recruitment, 26% of mothers had no more than a high school education, 20% had incomes no greater than 200% of the poverty level, and 22% were of color [20].

The current study draws on Phase III data, collected yearly in Grades 3–6 (G3–G6) via home visits, telephone calls, and participant visits to the research labs [20]. This study draws on a subsample of Phase III participants with complete home environment data at the third-grade time point ($n$ = 968). Participants were 52% female and identified as White (82%), Black (11.6%), Asian-American (1.4%), American Indian (0.2%), or Other race (4.8%). Most participants reported non-Hispanic ethnicity (94.1%). Mothers were married (74.0%), separated (12.1%), never married (5.9%), or partnered (5.9%). Mean household income-to-needs ratio was 4.36 (standard deviation [$SD$] = 3.68), with approximately 11% of participants living in poverty.

## Measures

### *Family entropy*

Family entropy was assessed using a composite of selected items taken from the Confusion, Hubbub, and Order Scale [21] and the Middle Childhood Home Observation for Measurement of the Environment [22]. Selection of items was rooted in the theoretical conceptualization of family entropy [3], which includes several components of organization/disorganization within the home environment. Selected items assess aspects of the home environment and collectively indicate the overall level of family entropy.

*Confusion, Hubbub, and Order Scale (CHAOS).* Six selected family entropy items originated from the CHAOS scale [21]. The CHAOS scale is comprised of 15 items with a dichotomous True/False response that aim to assess the level of noise-confusion in the home, completed by the mother. The items are scored and summed for a total score in which a higher score represents a more chaotic, disorganized, and hurried home environment [21]. The current study used a subset of selected items representing family disorganization to assess family entropy (Table 1), along with selected items from the HOME-MC scale.

*Middle Childhood Home Observation for Measurement of the Environment (HOME-MC).* Six additional family entropy items were selected from the HOME-MC scale. The HOME-MC [22] was developed to capture the quality and quantity of support and stimulation, physical, and social aspects of the home environment and was administered using a combination of direct observation and a semi-structured interview with the mother at G3. Items had dichotomous Yes/No responses and were scored and summed

**Table 1** | Item frequencies for home environment measures ($n$ = 968)

| Item | No | (%) | Yes | (%) |
|---|---|---|---|---|
| *Items originally from CHAOS* | | | | |
| We can usually find things when we need them *(reverse scored)* | 139 | 14.4 | 829 | 85.6 |
| We almost always seem to be rushed | 408 | 42.1 | 560 | 57.9 |
| We are usually able to stay on top of things *(reverse scored)* | 128 | 13.2 | 840 | 86.8 |
| No matter how hard we try, we always seem to be running late | 619 | 63.9 | 349 | 36.1 |
| No matter what our family plans, it usually doesn't seem to work out | 905 | 93.5 | 63 | 6.5 |
| First thing in the day, we have a regular routine *(reverse scored)* | 86 | 8.9 | 882 | 91.1 |
| *Items originally from HOME-MC* | | | | |
| Family has a fairly regular and predictable schedule for child | 45 | 4.6 | 923 | 95.3 |
| Family requires child to carry out certain self-care routines (e.g., makes bed, cleans room, cleans up after spills, bathes self). (A "yes" requires three out of four.) | 105 | 10.8 | 863 | 89.2 |
| Parent sets limits for child and generally enforces them (curfew, homework, before TV, or other regulations for fit family pattern) | 65 | 6.7 | 903 | 93.3 |
| Parent is consistent in establishing or applying family rules | 184 | 19.0 | 784 | 81.0 |
| Child eats at least one meal per day, on most days, with mother and father (or mother and father figures) | 451 | 46.6 | 517 | 53.4 |
| There is at least 100 square feet of living space per person in the house | 48 | 5.0 | 920 | 95.0 |

into subscales or a total score in which a higher score represents a more supportive and stimulating home environment [22]. For the current study, a subset of selected items were used to assess family entropy along with selected items from the CHAOS scale (Table 1).

*Body mass index*

Weight and height measurements were collected during the third-, fifth-, and sixth-grade laboratory visit by trained research personnel. Using these height and weight measurements, BMI *z*-score (zBMI) was calculated by a program provided by the Centers for Disease Control by gender and age.

*Sleep*

Parent report of child sleep was collected at G3 and G6 using the Children's Sleep Habits Questionnaire [23], a measure designed to assess sleeping behavior in school-age children. Parents provided open-ended estimations of their child's bedtime, wake time, the amount of time that it takes their child to fall asleep at night, and amount of time they spend napping on a typical night. From this information, an estimate of total sleep duration was obtained [24].

*Physical activity*

Children wore a single channel accelerometer on a belt around the waist to assess PA at G3 and G6. Children were asked to wear the monitor for 7 consecutive days (5 weekdays, 2 weekend days), from the time they woke up in the morning until they went to bed at night (excluding showering/bathing, water sports, or high impact sports). Measures of activity intensity were recorded in 1-min epochs that were collapsed across days to obtain measures of children's daily activity [25]. Then, daily wear time was collapsed across all days of wear to obtain average minutes of daily moderate-to-vigorous physical activity (MVPA) at each time point [22].

## RESULTS

### Descriptive statistics

Results indicated low variability in responses to family entropy items (Table 1). Means, standard deviations, and correlations for all continuous study variables are shown in Table 2. The sample evidenced healthy weight status on average at both G3 and G6. Parents reported a decline in child sleep duration by approximately 32 min from G3 to G6. There was also a steep drop in activity over time, from 89.96 min/day of MVPA at G3 to only 5.70 min/day of MVPA at G6. Correlations demonstrated that lower family income-to-needs ratio was significantly associated with higher zBMI at G3 and G6, and shorter sleep duration at G3. More min/day of MVPA at G3 was associated with lower child zBMI at both G3 and G6. Shorter sleep duration at G3 was associated with higher zBMI at G6 only.

### Evaluating a model of family entropy

To empirically evaluate the construct of family entropy, confirmatory factor analysis (CFA) compared the fit of two models: (a) a one-factor model in which all 12 home environment items loaded onto one latent factor representing family entropy, and (b) an oblique two-factor model in CHAOS scale items loaded onto a first-order latent factor representing household disorganization and HOME-MC items loaded onto a first-order latent factor representing household organization. The total sample was divided into random halves (*development* sample: $N$ = 484 and *confirmation* sample: $N$ = 484) that were stratified by income ($n$ = 53 participants living below the poverty line in each random half) [26]. Analyses used diagonally weighted least squares with robust standard errors to avoid distortions caused by non-normality [27]. Model fit was assessed using the Sattora-Bentler scaled diagonally weighted least squared chi-square (SB $\chi^2$). The original scaled difference in

**Table 2** | Correlations and descriptives for continuous study variables, using the longitudinal complete sample ($n$ = 473)

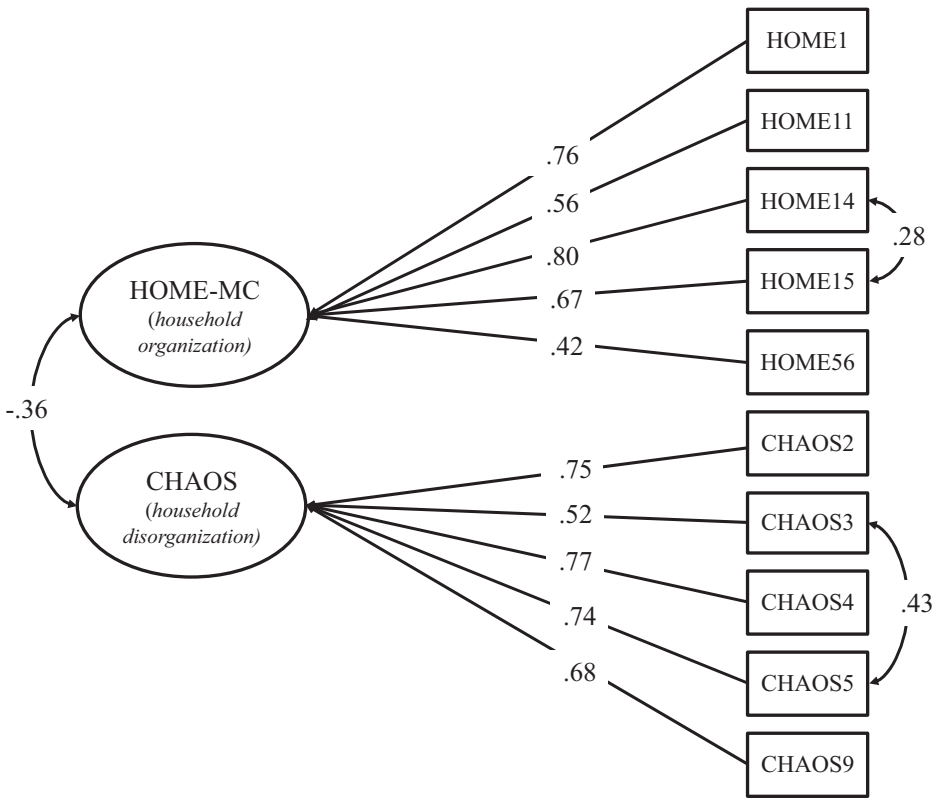
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 1. Income-to-needs ratio | – | | | | | | | | |
| 2. zBMI G3 | −.13** | – | | | | | | | |
| 3. pBMI G3 | −.12* | .97** | – | | | | | | |
| 4. Sleep G3 | .14* | −.07 | −.06 | – | | | | | |
| 5. MVPA G3 | −.03 | −.17** | −.15** | −.05 | – | | | | |
| 6. zBMI G6 | −.19** | .89** | .87** | −.11* | −.16** | – | | | |
| 7. pBMI G6 | −.18** | .86** | .87** | −.09* | −.15** | .96** | – | | |
| 8. Sleep G6 | .03 | −.08 | −.07 | .53** | .03 | −.08 | −.06 | – | |
| 9. MVPA G6 | .02 | −.07 | −.06 | .03 | .32** | −.09 | −.06 | .08 | – |
| *M* | 4.03 | .56 | 65.2 | 571.15 | 89.96 | .56 | 65.00 | 536.07 | 5.55 |
| *SD* | 3.13 | .99 | 27.5 | 45.82 | 33.32 | 1.10 | 29.07 | 53.57 | 3.31 |

*zBMI* BMI z-score; *pBMI* BMI percentile.
**Correlation is significant at the 0.01 level (two-tailed).
*Correlation is significant at the 0.05 level (two-tailed).

chi-squared test [28] was used to compare the fit of nested models. Other indices of absolute fit (root mean square estimation [RMSEA], standardized root mean square residual [SRMR]) and relative fit (comparative fit index [CFI], Tucker Lewis index [TLI]) were also examined to assess model fit, with acceptable fit defined as RMSEA <.10 [29], SRMR <.08 [30], CFI >.90, and NNFI/TLI >.90 [31].

Results showed that the originally hypothesized one-factor model did not provide an acceptable fit to the data in the development sample. The oblique two-factor model demonstrated a significantly better fit to the data than the one-factor model as evidenced by the scaled difference chi-squared test [$\chi^2(1) = 45.48$, $p < .001$], but demonstrated unacceptable fit based on the SRMR index (SRMR > .08). Analyses proceeded with model modification based on theory, examinations of modification indices, and factor loadings, but modified models did not yield an acceptably-fitting solution. Thus, a model-building approach was implemented. Exploratory factor analysis (EFA) was performed using maximum likelihood estimation and Oblimin rotation. A two-factor EFA solution demonstrated significantly better fit than a one-factor solution using the scaled difference chi-square test [$\chi^2(11) = 91.91$, $p < .001$]. EFA analyses using PROMAX rotation confirmed these results. Factor loadings were inspected in the two-factor solution, and items were retained if standardized loadings were above .40 on the underlying factor [32]. Five items from the HOME-MC loaded onto the first factor, and five items from the CHAOS scale loaded onto the second factor.

The fit of the 10-item oblique two-factor model was then examined using CFA analyses and additional theory-based model modifications were made. The final and best-fitting solution (Fig. 1) was an oblique two-factor model utilizing five HOME-MC items (latent factor 1: *household organization*), and five CHAOS items (latent factor two: *household disorganization*), with two pairs of correlated items reflecting similar concepts: (a) HOME-MC items 14 & 15, asking about family limit setting, and (b) CHAOS items 3 & 5 asking about feeling rushed and running late. Correlating these error terms significantly improved model fit in the development sample [$\chi^2(2) = 9.76$, $p < .01$], and demonstrated the best fit to the data of all models. The fit was finally confirmed in the confirmation ($n = 484$) and full




| df | $\chi^2$ | RMSEA <.10 | SRMR <.08 | CFI > .90 | TLI>.90 |
|---|---|---|---|---|---|
| 32 | 53.76 | .03 | .076 | .98 | .97 |

**Fig 1** | Final two-factor oblique confirmatory factor analysis model of family entropy with standardized parameter estimates.

samples ($n$ = 968), and the model demonstrated acceptable fit based on all metrics in the full sample (Fig. 1). Thus, the oblique two-factor model was utilized in subsequent analyses.

### Relations between family entropy and child weight

Cross-sectional analyses using path models revealed no significant associations between either the latent HOME-MC factor (household organization) or CHAOS factor (household disorganization) and G3 zBMI. Longitudinal analyses using path models similarly revealed no significant impact of the latent HOME-MC factor (household organization) or latent CHAOS factor (household disorganization) on G6 zBMI, when controlling for the influence of G3 zBMI. Additional analyses examined cross-sectional and longitudinal relations between household organization, disorganization, and child zBMI in the context of G3 socioeconomic factors (i.e., family income-to-needs ratio, mother's marital status), but analyses revealed no significant associations.

### Health behaviors as mediators of family entropy and child weight

Path models examined the mediating role of health behaviors within relations between family entropy and child weight cross-sectionally and over time (Aim 3). Sleep duration and minutes of MVPA were examined as mediators. Models used measured subscales of family entropy (i.e., HOME-MC subscale and CHAOS subscale), a bias-corrected bootstrapping approach, and full information maximum likelihood estimation [33, 34]. Results of the cross-sectional mediation were not suggestive of significant mediation. Some direct effects were uncovered within the model, including a negative direct effect of household disorganization (CHAOS subscale) on G3 sleep duration ($\beta = -.14$, $p < .001$), and a positive direct effect of household organization (HOME-MC subscale) on G3 sleep duration ($\beta = .14$, $p < .001$). Finally, G3 MVPA evidenced a negative direct effect on G3 zBMI ($\beta = -.14$, $p < .01$). Longitudinal results were not suggestive of significant mediation. There was, however, a negative direct effect of the CHAOS subscale on G6 sleep duration ($\beta = -.11$, $p < .01$), even when accounting for the influence of G3 sleep duration ($\beta = .45$, $p < .001$).

### Socioeconomic status as a moderator of relations between family entropy, health behaviors, and child weight

Simultaneous regressions were conducted examine SES as a moderator of relations between subscales of family entropy and (a) zBMI, (b) sleep duration, and (c) MVPA. Cross-sectional simultaneous regression analyses uncovered a significant main effect of family income-to-needs ratio on G3 zBMI ($\beta = -.16$, $p < .001$), such that children from homes with lower family income-to-needs ratio had higher zBMI scores. There were no other significant main effects or interaction effects. Longitudinal analyses revealed a significant interaction effect of CHAOS and family income-to-needs ratio on G6 zBMI ($\beta = -.05$, $p < .05$) above and beyond the influence of G3 zBMI ($\beta = .87$, $p < .001$), revealing that the impact of household chaos on G6 zBMI differed based on participant SES. Post hoc probing using tests of simple slopes [35, 36] revealed a significant impact of the CHAOS subscale on zBMI in the high SES sample only [slope: $y = -.15x + .29$; $t(799) = .-2.38$, $p = .02$]. Unexpectedly, higher levels of household disorganization predicted lower G6 zBMI among higher SES participants. There were no significant moderation effects detected in models predicting sleep or MVPA.

## DISCUSSION

With increasingly high rates of overweight and obesity among school-age youth, it is important to identify factors that may influence the development and maintenance of this condition, as well as pose challenges to prevention and intervention. The premise of the current study was that the level of organization/disorganization within the family home environment may play a role in the development of overweight and obesity by shaping children's health behaviors. To date, household organization and disorganization have only been examined a piecemeal fashion, studying one or a few indicators at a time. A recent comprehensive review of the literature proposed an overarching conceptual framework of the organization/disorganization in the family home environment, known as family entropy [3]. Building on this work, the current study is the first empirical examination of family entropy. The study evaluated the construct of family entropy and examined relations between family entropy, child health behaviors, and child weight. Results contribute a nuanced perspective on organization in the family home environment and its influence on obesity and obesogenic behaviors among school-age youth.

Though a single factor solution was hypothesized, results of factor analysis suggest that family entropy is comprised of distinct elements of household organization and disorganization, which are moderately related. Family entropy remains a unifying conceptual framework, though underlying components of family entropy (i.e., household organization and disorganization) may be empirically distinct. Relatively few studies have considered how household organization and disorganization are related, but Miller and colleagues [37] theorized that routines and chaos may operate differently based on to the role of caregivers. Specifically, routines involve one-on-one interactions with caregivers (i.e., in context of bedtime, mealtime, or other regular activities involving caregiver engagement or attention). In contrast, disorganization at the household level may reflect

processes outside of the caregiving relationship, and possibly outside of caregivers' control. This distinction posits that household organization and disorganization may capture unique facets of the home environment, as opposed to representing "different sides of the same coin," and suggests that caregivers may be able to establish and promote regular routines in the context of challenging economic circumstances. Recently, research has explored behavioral phenotypes, or genetic predispositions that interact with environmental contexts (including the home environment) to place youth at risk for obesogenic behaviors and obesity [38, 39]. Understanding the risks and benefits associated with different profiles of family entropy could identify modifiable environmental factors and intervention mechanisms for high-risk phenotypes.

Although factor analysis supported a two-factor model of family entropy, measurement- and dataset-related factors may have impacted model fit. First, it is possible that the two underlying factors of organization and disorganization were influenced by differing administration and reporting strategies for the HOME-MC and CHAOS scales. Second, limitations of the current dataset may have restricted sample and measurement variability. The sample was relatively high-income and exhibited low variability in reported household organization and disorganization. It is possible model fit would differ in a sample with more diversity in SES, organization, and disorganization. Finally, the dichotomous nature of item responses may have also impacted model fit by truncating within-item variability.

Contrary to hypotheses, household organization and disorganization were not significantly related to zBMI. Several studies have established the relevance of specific components of household organization (i.e., family routines and limit setting) and household disorganization (i.e., chaos and crowding) to child weight [3], but pooled subscales of organization and disorganization did not demonstrate a significant influence on weight in this sample. Findings did, however, corroborate the cross-sectional and longitudinal relevance of components of family entropy, particularly household disorganization, to child sleep duration. Household disorganization was detrimental sleeping behavior concurrently and over time in both high and low SES families. Indeed, home environments with high levels of disorganization may struggle to consistently implement healthy sleep hygiene habits (e.g., regular bedtimes and routines) that have been shown to promote high-quality sleep [5]. Household disorganization may also impact sleep through pathways of stress and vigilance. Sleep and vigilance are opposing processes [40], and home environments that are chaotic and unpredictable may induce children's heightened arousal and hypervigilance, thereby disrupting sleep [41]. Longitudinal relations between household disorganization and child sleep duration support that relations between sleep and family functioning are ongoing and transactional [40].

Though not a central aim of the current study, a consideration of the longitudinal stability and developmental trends of health behaviors and weight in the current sample helps contextualize study findings. Consistent with trends observed in other population-representative samples of youth [42–44], zBMI was highly stable from third through sixth grade, whereas sleep and MVPA were moderately stable. The stability of health behaviors and weight in this sample highlight that longitudinal relations between family entropy and sleep are robust, since relations were consistent even when controlling for prior levels of sleep duration. Moreover, from the third- to sixth-grade time points, both sleep duration and PA evidenced predictable developmental declines. Parent-reported child sleep duration declined by 35 min/night from third to sixth grade, and PA saw a steep decline of 83 min/day, with children obtaining only 5 min/day of MVPA on average in sixth grade. Declines in sleep duration of this magnitude or greater are commonly observed in literature across samples [43, 45]. In contrast, this notable drop in MVPA has been previously documented in this sample [46], but other studies have failed to replicate such extreme declines and have instead evidenced moderate declines in MVPA during the same developmental stage [47, 48]. Studies have identified several possible contributors to PA decline during early adolescence, including reduced social support for PA engagement, lower perceived athletic competence, and decreased access to organized activities [16]. Parenting factors, including monitoring, encouragement, and parents' own level of physical activity, have additionally demonstrated associations with decline in MVPA in this sample [49].

Interestingly, among higher-income families, high levels of household disorganization predicted lower child zBMI. This suggests that higher levels of household disorganization may not pose the same risk to child weight in higher-income families as would be expected in mid-to-low income samples. Household chaos has typically been studied in lower-income samples, and findings consistently report that lower-income homes evidence higher levels chaos than higher-income homes [21, 50] It is possible that "high disorganization" looks qualitatively different in higher-income households than lower-income households. For example, high-income families reporting high levels of household disorganization may be overburdened by numerous obligations, such as children's extracurricular activities, which may in themselves be beneficial to child weight, or may utilize coping strategies, such as employing additional childcare, that buffer the impact of disorganization on child behaviors and weight.

Although other moderated effects between family entropy and child weight were not significant in current study, there are reasons to further examine SES as a moderator of relations between the home environment and children's health behaviors. Lower family income-to-needs ratio was associated with higher zBMI and shorter sleep duration in this sample. Thus, low-income families continue to represent a population at high-risk for chaotic home environments, high weight status, and short sleep durations, and it is critical to understand how these outcomes are related. No study to date has examined moderating pathways between aspects of the home environment and child weight in a predominantly low-income sample.

### Limitations and future directions

This study is not without limitations. The participant sample was large, longitudinal, and geographically diverse, but was limited in diversity of race, income, and family structure (i.e., one- versus two-parent families). In addition to the effects of attrition, exclusionary criteria at the time of data collection may have limited SES variability in the sample. The dichotomous measurement of family entropy items limited nuance in measurement and predictive power. The use of parent report for measures of children's nightly sleep duration is not as accurate as the gold-standard wrist-worn actigraphy for sleep measurement. Finally, data collection occurred nearly 20 years ago, which may impact the generalizability of some of the results, especially given changes in culture and technology that may impact the family and home environment. However, the size and longitudinal nature of the sample is an asset, and Phase III data continues to be published in recent literature [51, 52]. Finally, the current study did not examine dietary behavior due to measurement limitations.

Acknowledging limitations, this study is nevertheless the first to comprehensively examine the total level of organization and disorganization in the home environment through an empirical assessment of family entropy. The study brings together previously separate areas of the literature to advance a cohesive conceptualization of family entropy and to examine relations between family entropy, child health behaviors, and child weight. Although the hypothesized one-factor model of family entropy was not supported, the examination sheds light on critical areas of family and home environment research that require further exploration. First, more sensitive measurement strategies are needed that allow for greater depth of understanding organization and disorganization in the home environment. Second, future studies may benefit from examining profiles of organization and disorganization to uncover whether certain patterns appear to buffer or exacerbate obesity and obesogenic behaviors among school-age youth. Finally, it may be worth replicating an examination of family entropy in different samples, particularly low-income samples who may experience disorganization due to a number of poverty-related influences, in order to finally rule out family entropy as a cohesive construct.

## CONCLUSION

Organization within the family home environment may influence child health behaviors and weight, but literature to date has suffered from the lack of a strong overarching construct and model to guide this field of research. Family entropy is a conceptual framework that fills this gap by representing the overall level of organization across the home environment. This study is the first to empirically assess family entropy in a school-aged sample and examine influence on child weight both directly and through weight-related health behaviors. The study suggests that family entropy is comprised of distinct elements of household organization and disorganization, which are moderately related. Household disorganization may be particularly detrimental to child sleep among families of both high and low SES. Increased awareness of family entropy among health care providers may facilitate identification of families that are at high-risk for struggling to implement consistent health behaviors, particularly around sleep duration. Additional family-centered problem-solving strategies may be necessary to promote optimal sleep and health outcomes for youth in these home environments.

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### Compliance with Ethical Standards

**Conflicts of Interest:** The authors declare that they have no conflicts of interest.

**Authors' Contributions:** CB conceived of the study, performed analyses, and wrote the manuscript. AB assisted with study development and manuscript writing. JB assisted with study development. DV is a principal investigator of the initial NICHD-SECCYD study and assisted with study development. KL assisted with data analyses. FB assisted with study development and analyses.

**Ethical Approval:** All procedures performed in studies involving human participants were in accordance with the ethical standards of the Institutional and/or National Research Committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. The study was approved by the Institutional Review Boards of the University of California, Irvine, and Loyola University Chicago.

**Informed Consent:** Informed consent was obtained from all individual participants included in the study.

**Welfare of Animals:** This article does not contain any studies with animals performed by any of the authors.

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