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Parenting matters: Moderation of biological and community risk for obesity

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Abstract

Contributions of parental limit setting, negativity, scaffolding, warmth, and responsiveness to Body Mass Index (BMI) were examined. Parenting behaviors were observed in parent-child interactions, and child BMI was assessed at 5 years of age. Mothers provided demographic information and obtained child saliva samples used to derive cortisol concentration indicators ($N = 250$). Geospatial crime indices were computed based on publically available information for a subsample residing within the boundaries of a Pacific Northwest city ($N = 114$). Maternal warmth and limit setting moderated the association between child HPA-axis regulation and BMI. BMI was higher for children at lower cortisol concentrations with greater maternal warmth and lower for youngsters with mid-range cortisol values under high maternal limit setting. Maternal scaffolding moderated the effects of crime exposure, so that lower scaffolding translated into higher child BMI with greater neighborhood crime exposure. These parenting behaviors could be leveraged in obesity prevention/intervention efforts.

Keywords

Parenting behaviors BMI; HPA-axis; Neighborhood crime

Obesity represents a significant public health concern, and a growing interest in prevention has made identification of early risk factors critical to public health efforts in this area. Ogden et al. (2016) reported the prevalence of obesity was 17.0% in 2011–2014 for children and adolescents, with the rates of extreme obesity at 5.8% (2 to 19 years old). According to this recent report, the dramatic increase in obesity noted over the past 50 years (McAllister et al., 2009) has not been sustained in a uniform manner across different demographic subgroups. Despite some declines, a recent representative sampling of preschool-aged

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children conducted through a large health delivery system revealed non-negligible rates of obesity (11.2%; Lo et al., 2013). Thus, despite some evidence of decline in obesity rates, it continues to be imperative to understand contributing factors, starting in early childhood. The latter is of particular significance, given considerable stability of obesity from childhood to adulthood (Park, Sovio, Vinern, Hardy, & Kinra, 2013). Starting in the preschool period, markers of obesity begin to predict a variety of adverse health outcomes (Koebnick et al., 2010; Skelton, Cook, Auinger, Klein, & Barlow, 2009).

Increasing attention to precursors of childhood obesity has focused on factors such as socioeconomic status (SES), exercise, sedentary behavior, sleep, or candidate genes (Cecil et al., 2012; Craigie, Lake, Kelly, Adamson, & Mathers, 2011; Ejlerskov et al., 2015; Hart et al., 2011; Magee & Hale, 2012; Wang et al., 2011). By comparison, less emphasis has been placed on the variables addressed in this study, including cortisol concentrations, crime exposure, and the role of parenting behaviors. There is a complex interplay among factors contributing to children's unhealthy weight that can be represented via Bronfenbrenner's Ecological Systems Theory of development (Bronfenbrenner, 1979). According to Bronfenbrenner (1979; Bronfenbrenner & Evans, 2000), developmental outcomes result from a multitude of factors at different levels of influence including individual-biological, interpersonal, and macro-level contextual systems, and interactions within and between these factors contribute to development. Parenting behaviors, described next, occupy the interpersonal level in the bioecological model, and are thus engaged in transactions with both individual-biological and macro-contextual effects.

1. Parenting behaviors in context

Research addressing the influence of parenting on child functioning has provided ample evidence that parenting behaviors are important predictors of social, emotional and behavioral outcomes (e.g., Aunola & Nurmi, 2005; Olson, Sameroff, Kerr, Lopez, & Wellman, 2005). Both affective and control aspects of parenting behaviors known to predict children's behavioral and emotional adjustment are also likely relevant to children's BMI, and may operate to amplify or attenuate the effects of other factors that impact the risk for obesity. According to Bronfenbrenner's (1979) bioecological model, exchanges of energy between the developing organism and those in the immediately surrounding environment (e.g., in the context of parent-child interactions) represent the drivers of human development. Parental behaviors shape the quality of interactions with the child and play a pivotal role in this exchange, serving to encourage either a healthy developmental trajectory or one that deviates from the typical and expected, such as a high BMI score indicative of risk for obesity. The affective nature of parenting behaviors, including warmth, responsiveness and negativity, establishes the emotional quality of a parent-child relationship, and control-related aspects of parenting: scaffolding (i.e., supportive interactions, aimed at facilitating an outcome without resorting to a directive style) and consistent limit setting are important for supporting the development of self-regulation and for managing more challenging aspects of child behavior (Kiff, Lengua, & Zalewski, 2011). Both affective and control aspects of parenting behavior predict children's behavioral and emotional adjustment, and are also likely relevant to children's BMI, operating to amplify or attenuate effects of individual-level biological (e.g., HPA-axis functioning) and macro-level community (e.g., neighborhood

crime exposure) factors. This unique role is afforded by the fact that affective and control parenting behaviors are directly involved in what Bronfenbrenner described as proximal processes, facilitating or hindering exchanges between the organism and the environment ultimately resulting in either competence or dysfunction (Bronfenbrenner & Evans, 2000).

Previous research examining parental warmth, negativity, responsiveness, scaffolding and limit setting demonstrated that each of these dimensions contributed uniquely and differentially to children's social-emotional, behavioral and academic adjustment (Lengua et al., 2013; Zalewski, Lengua, Kiff, & Fisher, 2012), and are likely critical for consolidation of obesity-related risk in the preschool period (Mamun, Hayatbakhsh, O'Callaghan, Williams, & Najman, 2009; Narayan, Boyle, Thompson, Gregg, & Williamson, 2007). These parenting behaviors could prove as useful therapeutic targets for interventions aimed at decreasing the risk for obesity precisely because of this pivotal role anticipated by Bronfenbrenner's model. For example, limit setting could either decrease or escalate child obesity risk, via associated behaviors displayed in food and activity expenditure related contexts. Aspects of parenting related to emotional tone also likely contributing to either a positive climate and supportive relationships, or conflict and tension in the family affecting eating and obesity risk. Limit setting could also support children in the context of stress response regulation and with respect to mitigating neighborhood crime exposure, both contributing to child BMI and risk for obesity, as discussed below, starting with individual-level effects. Thus, parenting behaviors are critical to understanding different levels of influence in the bioecological model, from individual-biological to macro-contextual, that shape obesity related risk, through either direct or moderating effects. Yet, they have not been empirically examined in this context to date.

2. Parenting behaviors and obesity

The majority of studies considering links between parenting and weight status have focused on global indicators of parenting style, such as permissive versus authoritative parenting, or else specific parenting behaviors related to feeding and nutrition. Authoritative parenting style, reflecting a combination of high levels of caregiver expectations concerning rules and high responsiveness to the needs of the child, has been linked to a healthier home food environment (Johnson, Welk, Saint-Maurice, & Ihmels, 2012), relevant to childhood obesity. In a recent review of parenting, feeding practices, and weight status among 4- to 12-year-old children, associations between parenting style and child Body Mass Index (BMI) emerged as some of the most consistent and strongest effects (Shloim, Edelson, Martin, & Hetherington, 2015). Specific parenting behaviors related to nutrition (e.g., encouragement to eat versus restriction) are clearly important, and likely not independent from parenting in interactions with the child outside the food context, although the links among these two sets of parenting behaviors do not appear to have been empirically examined. Parenting in general interactions with children can be expected to contribute to childhood obesity, and it has been argued that an exclusive focus on eating/feeding related parenting behaviors in obesity interventions is inadequate (Power et al., 2013). Beyond parenting styles, it is important to understand the role of specific observable parenting behaviors in relation to children's weight and BMI. Both the affective quality of parenting behaviors, such as warmth, responsiveness and negativity, and control-related behaviors, such as consistent limit setting

and scaffolding, have potential relevance to children's health and nutrition, and ultimately BMI, as these have emerged as critical in shaping a variety of child behavioral, social, and emotional outcomes. Further, they represent specific therapeutic targets, which have been utilized to improve child behavioral health and could be leveraged to address weight status and obesity-related concerns as well, if demonstrated as relevant on their own, or in concert with other factors contributing to obesity, such as HPA-axis functioning.

3. Individual-level biological contributor to obesity: child HPA-axis functioning

The individual-level biological variable examined in this study is a marker of HPA-axis functioning, cortisol, which inherently sensitive to stress and largely responsible for the organism's response to challenging circumstances. Physiological and psychological stressors can lead to an increased secretion of corticotropin-releasing hormone (CRH), stimulating the anterior pituitary gland to release adrenocorticotropic hormone (ACTH), which in turn, activates the adrenal gland to release cortisol (Charmandari, Tsigos, & Chrousos, 2005). In a healthy situation, this system is flexible, wherein negative feedback to the pituitary gland and hypothalamus leads to inhibition of cortisol release. Dysregulation of the HPA-axis, evidenced by its end-product cortisol, has been linked to obesity. However, the direction of association between HPA-axis response and BMI has not been consistent. Higher cortisol concentrations were shown to contribute to an increase in BMI (Michels et al., 2015; Reinehr et al., 2013), yet negative associations between cortisol concentrations and weight status have also been reported (Chalew, Lozano, & Armour, 1991; Hillman, Dorn, & Loucks, 2012). Methodological differences could be responsible for these discordant results. For example, Reinehr et al. (2013) followed a group of children with obesity demonstrating basal cortisol concentrations decreased following weight loss, indicating a positive association between cortisol concentrations and BMI in this clinical sample. A “blunted” cortisol response for those with higher BMI values was also reported (Hillman et al., 2012), with baseline serum cortisol levels and cortisol reactivity following venipuncture examined in a group of healthy adolescents. Low cortisol concentrations (i.e., a ‘blunted’ response) have been described as indicative of chronic and pervasive stress exposure (Gunnar & Vazquez, 2001), and linked with more significant cumulative demographic and psychosocial adversity (Zalewski et al., 2012).

Importantly, Hillman et al. (2012) described potential mechanisms responsible for this inverse relationship between child BMI and cortisol concentrations, focusing on an established link between obesity and overweight status with insulin resistance, apparent as early as childhood (Daniels, Morrison, Sprecher, Khoury, & Kimball, 1999). As cortisol stimulates insulin activity, resulting in increased blood glucose levels, lower cortisol concentrations may reflect an early adaptive mechanism to assist in the maintenance of glucose/metabolic homeostasis in the face of emerging insulin resistance. That is, a blunted cortisol response could provide an effective means of suppressing insulin activity, facilitating glucose management for those at risk of insulin resistance. Inconsistent links between a predictor (in this case, cortisol concentrations) and a dependent variable (i.e., childhood obesity/BMI) could also be indicative of omitted interactions, for example,

parenting behaviors moderating child HPA-axis effects with respect to BMI, considered in this study. In addition to individual biological contributors, such as HPA-axis functioning, multiple environmental factors have been linked with obesity or BMI, including neighborhood crime.

4. Macro-level environmental contribution to obesity: community crime exposure

The impact of crime exposure has not been sufficiently investigated in relation to childhood obesity or overweight status, despite considerable odds of crime exposure in the US and emerging evidence linking crime exposure to an increased risk for obesity (32% increase in risk; Sumner et al., 2015). Among many other potential mechanisms, neighborhood crime impacts the risk for obesity via increased sedentary behaviors in childhood (Brown, Pérez, Mirchandani, Hoelscher, & Kelder, 2008), wherein apprehension related to victimization results in decreased physical activity (Lumeng, Appugliese, Cabral, Bradley, & Zuckerman, 2006), as children spend less time outdoors engaged in active pursuits. This influence may be especially powerful in early childhood, when parents are able to direct their children to a greater extent, and parents' concerns regarding community crime can significantly limit youngsters' exposure to physical activity. For example, if parents respond to children in a more negative tone (e.g., due to their own apprehension), or otherwise limit or express tension with respect to outdoor activities, such parental reactions could result in lower calorie expenditure for children residing closer to more serious incidents of crime. Alternatively, more responsive parents may modulate their own emotional reactions to crime, thereby attenuating the effects of crime proximity relevant to child BMI, optimizing opportunities for active play despite the risk. Associations between exposure to community crime, parenting behaviors, and child BMI can be expected to play an especially important role in the preschool years, a developmental period critical to obesity, with significant weight gains translating into long-term risk (Mamun et al., 2009; Narayan et al., 2007). This time period is also optimal for considering moderation by parenting behaviors, which continue to represent critical proximal processes, capable of filtering more distal influences, as well as modulating individual-level variables (Bronfenbrenner & Evans, 2000). That is, preschool-age children still rely on their parents to structure their stress response, and at the same time caregivers take on the responsibility of negotiating neighborhood effects, as youngsters begin to engage in community activities. We recently demonstrated that exposure to community crime contributes to child BMI jointly with HPA-axis response (Gartstein, Seamon, Thompson, & Lengua, 2017), and the present study expands this research, considering parenting as a moderator of neighborhood crime risk with respect to child obesity in the same sample.

5. Parenting behaviors as moderators of risk for obesity

Parenting behaviors, such as limit setting and warmth, can be expected to play a protective or a risk-exacerbating function with respect to both individual-level biological and community-level risk factors for obesity in childhood. Aspects of parenting have been shown to moderate child HPA-axis effects, for example, in the context of predicting executive

functions (Tu et al., 2007; Wagner et al., 2016), and sensitivity/responsiveness was linked with child cortisol reactivity (Blair et al., 2015). It may be that parental behaviors directly reduce physiological reactivity, such as when a warm or responsive parent cuddles a child, or otherwise established physical proximity. Parental structuring of exchanges with the child can also induce, or serve to cue, more effective self-regulation or coping strategies on the part of the child, modulating physiological reactivity (i.e., the HPA-axis response).

Parenting behaviors can be expected to function as moderators with respect to the influence of macro-level community effects, namely neighborhood crime exposure, as well. In older children, parental monitoring was consistently shown to alter relations between youth's exposure to neighborhood crime or violence and behavioral outcomes (Bacchini, Miranda, & Affuso, 2011; Pettit, Bates, Dodge, & Meece, 1999). Parental monitoring becomes important as children function more independently in their neighborhoods. However, limit setting, negativity, scaffolding, warmth, and responsiveness are likely more relevant in the preschool period, and will be examined as moderators of links between community crime exposure and BMI in this study. To our knowledge, these parenting behaviors have not been previously examined in the context of community crime or childhood BMI, although scaffolding was demonstrated as a mediator of cumulative family risk with respect to executive control in the preschool period (Lengua, Fisher, Zalewski, & Moran, 2013). Overall, the existing literature suggests parenting behaviors serve as moderators of individual-level biological and macro-level community effects, and their roles should be examined with respect to HPA-axis functioning and neighborhood crime exposure, associated with risk for obesity. The present study addresses an important gap in research considering both contextual and biological risk factors for obesity, as well as their joint effects with parenting behaviors, and it is also unique with respect to the measurement of specific parenting behaviors and community crime exposure.

6. Present study

In this study, we set out to examine affective (warmth, responsiveness, negativity) and control (limit setting, scaffolding) aspects of parenting as independent contributors to risk for childhood obesity, along with indicators of child HPA-axis functioning and proximity of neighborhood crime. Because multiple family stressors have been linked with community crime exposure, parenting, child HPA-axis functioning, as well as BMI (Attar, Guerra, & Tolan, 1995; Lengua, Fisher, et al., 2013; Plybon & Kliewer, 2001; Zalewski et al., 2012), cumulative family stress was considered as a covariate. Demographic (e.g., mother education, single parent status) and contextual (e.g., household density, residential instability) factors along with psychosocial risk, such as negative life events (e.g., changing schools, death of a family member or friend) and maternal depression, jointly contribute to child and family adversity. Indices that account for the number or accumulation of such risk factors predict important early childhood developmental outcomes, such as behavior problems and academic achievement (Evans, Li, & Sepanski Whipple, 2013). Thus, rather than considering each of these contributing factors in turn, a cumulative score was constructed, as previously described (Lengua et al., 2015; Zalewski et al., 2012), to capture the overall burden of risk experienced by children and families (Vernon-Feagans & Cox, 2013).

Importantly, parenting behaviors were examined as moderators of individual-level biological and macro-level contextual risk factors with respect to preschool-age children's BMI. It was hypothesized that a dysregulated diurnal cortisol pattern, evidenced by lower concentrations, and greater community crime exposure would be associated with higher child BMI scores. High limit setting, responsiveness, scaffolding, and warmth were expected to be associated with lower child BMI, thus a decline in risk for obesity. Parenting behaviors were also expected to modify effects of the individual-level biological and macro-level contextual factors. It was hypothesized that higher limit setting, responsiveness, scaffolding, and warmth would attenuate links of HPA-axis dysregulation and community crime exposure with child BMI. On the other hand, higher levels of negativity in parent-child exchanges were predicted to accentuate the risk conferred by individual and macro-level predictors.

7. Method

7.1. Participants

The present study was based on a portion of a dataset collected in the context of a larger, longitudinal investigation of the effects of income, family adversity, parenting and physiological stress responses on the development of preschool-age children's self-regulation (Lengua, Fisher, et al., 2013; Lengua, Kiff, et al., 2013; Zalewski et al., 2012). The larger study included 306 mothers and their 36–39-month-old children ($M = 37$, $SD = 0.84$ mos.) at the initial time point recruited from birth registers, daycare centers, health clinics, and community organizations serving low-income families. For the purposes of this study, data collected when the children were 5 years of age were utilized, as these were contemporaneous to the crime exposure index developed based on publically available crime information for the City of Seattle.

All children with cortisol data were included in analyses addressing hypotheses related to HPA-axis functioning. However, fifty six families did not return usable saliva samples, resulting in valid cortisol values for 250 preschoolers. The subsample with available cortisol data demonstrated the following income composition: 29% at or near poverty ($N = 73$, 150% federal poverty threshold); 26% lower income ($N = 64$, >150% poverty threshold and < local *median* income of \$58 K); 27% middle- to upper-income ($N = 67$, > *median* income to \$100 K); and 18% affluent ($N = 46$, >\$100 K). Analyses addressing exposure to community crime were based on a subsample of the original group of families residing within the boundaries of the City of Seattle, where crime-related information was available ($N = 114$). This subsample was somewhat more representative of both disadvantaged and affluent portions of the distribution, with 31% at or near poverty ($N = 37$, 150% federal poverty threshold); 26% lower income ($N = 31$, >150% poverty threshold and < local *median* income of \$58 K); 18% middle- to upper-income ($N = 21$, > *median* income to \$100 K); and 26% affluent ($N = 31$, >\$100 K). The flat distribution of income across subsamples ensures variability for indicators of risk, providing a robust test of the associated effects examined in this study.

7.2. Procedures

Families were assessed in research offices on the university campus. Following the guidelines stipulated by the Social and Behavioral Sciences Institutional Review Board at the University of Washington, both active parental consent and child assent were secured prior to data collection. Assessments included physiological and questionnaire measures administered by a team of trained experimenters, and families were compensated \$130 for this visit. Mothers joined children to engage in parent–child interactions after other measures, not included in this study, were obtained.

Mothers were trained in the collection of child cortisol and were given a home-collection kit that included instructions with specific collection times and procedures to obtain the saliva samples, along with labeled tubes and data recording forms. Specifically, mothers were instructed to collect their child's saliva 30 min after the child woke in the morning and 30 min prior to bedtime, for three consecutive days. Mothers were to place a sorbette (Salimetrics, LLC State College, PA) under the child's tongue for 1 min and then place the sorbettes into a prelabeled swab storage tube, repeating this process with another sorbette to ensure adequate saliva volume. Collection times were recorded directly on collection tube labels at the time the samples were taken, and mothers completed a daily questionnaire regarding their children's health, medication use, eating times, and napping on sampling days, reviewed to ensure compliance. A staff member called families on the first night to ensure proper collection and to answer questions, reminding to avoid sampling when children were using steroid based medications or were ill. A reminder call was placed on the third evening to prompt mothers to return the packets by mail. Mailing saliva was shown not to influence subsequent cortisol analyses (Clements & Parker, 1998) and used successfully with child samples (Bruce, Davis, & Gunnar, 2002). Parents were paid an additional \$30 for all cortisol packets returned.

7.3. Measures

7.3.1. Body Mass Index (BMI)—BMI was calculated from the children's weight and height ($BMI = \text{weight [kg]} / [\text{height (m)}^2]$) measured by trained research assistants. A standard procedure that included having a scale in a set place on a hard floor and a wall-mounted measuring stick was employed using identical instruments and assessment room. Research staff were instructed to ensure that the child was still on the scale before recording the number and that the child was standing with her back to the measuring stick with feet together and straight for the height measurement. Height and weight data were checked for unlikely values. Mean, standard deviation, as well as range statistics all indicated values were within the expected range. Categorical weight status was established using standardized growth charts and the following definition: Underweight < 5th%; Overweight > 85th% and < 95th%; Obese > 95th % (CDC, 2000). The sample included in the HPA-axis functioning analyses ($N = 250$) formed the following weight distribution: 20% underweight; 10% overweight; 5% obese. The sample with available geospatial indicators ($N = 114$) also distributed in a similar fashion with respect to weight status categories: 21% underweight; 8% overweight; 5% obese. Although a conclusive explanation for the number of underweight children cannot be provided, this category was not over-represented in the

lower income bracket, as indicated by a non-significant χ^2 test, $\chi^2(9, N = 114) = 13.56, p = 0.14$. The overall mean BMI value (Table 1) was in the Healthy range (>5th% and < 85%).

7.3.2. Parenting behaviors—Mothers and children engaged in 4 activities (7 min each of parent-directed play, child-directed play, instructional activity, and 3 min cleanup; Kerig & Lindahl, 2001). In mother-directed play, mothers were instructed to choose an activity and engage the child in this activity. In child-led play, mothers were instructed to allow the child to choose the activity and follow the child's lead. Next, mothers were instructed to help children build a challenging Lego figure. Finally, mothers were to obtain children's assistance in cleanup.

Warmth, negativity, limit setting, scaffolding, and responsiveness were coded in 1-minute epochs for all activities (segments), and then averaged across epochs and segments in order to derive more robust parenting behavior constructs (Rushton, Brainerd, & Pressley, 1983). Parenting was coded from video recordings using ratings adapted from established systems (Cowan & Cowan, 1992; Lindahl & Malik, 2000; Rubin & Cheah, 2000). All behaviors were rated on 6-point scales (0 = *absent/lowest*, 5 = *highest*). Warmth was a combination of positive affect, that is, frequency and level of behavioral and verbal expressions of happiness, comfort, connection, and warmth toward the child, and interactiveness, which was operationalized as the quantity of verbal and non-verbal engagement. Negativity reflected the negative tone or tension expressed by the mother, including verbal and non-verbal expressions of irritation with the child that were critical, rejecting, or invalidating. Limit setting included clarity and consistency of directions, and follow-through of directives when children were non-compliant, oppositional, or disruptive. Scaffolding was a combination of guidance/structuring, autonomy granting, and low intrusive control, reflecting the parent's ability to intervene when the child needed help and disengage when the child was functioning independently. Responsiveness to children's expressions of negativity indicated mothers' sensitivity/responsiveness to cues of child distress or negative affect. Interrater reliability was assessed by independent recoding of 20% of the observations. Intraclass correlations (*ICCs*) for warmth, negativity, scaffolding, limit setting, and responsiveness were 0.80, 0.75, 0.81, 0.73, and 0.67, respectively.

7.3.3. Diurnal cortisol pattern: a marker of child HPA-axis functioning—Cortisol assay samples were sent to the university's Biobehavioral Nursing and Health Systems laboratory for processing, where they were stored at $-70\text{ }^{\circ}\text{C}$. until extraction of cortisol. The concentration of cortisol in each sample was extrapolated from a standard curve generated in each test plate and the results were averaged, as previously described (Ashman, Dawson, Panagiotides, Yamada, & Wilkinson, 2002).

7.3.3.1. Cortisol salivary enzyme: Immunoassay Kit provided by Salimetrics LLC (State College, PA, USA), with sensitivity ranging from 0.005 to 2.5 $\mu\text{g}/\text{dl}$, was utilized. All samples from the same participant were included in the same assay batch to minimize inter-assay within-subject variability. Intra-assay reliabilities were obtained using high and low cortisol controls provided by Salimetrics: mean cortisol value (MCV) for the high concentration sample = 0.950 $\mu\text{g}/\text{dl}$; MCV for the low concentration sample = 0.083 $\mu\text{g}/\text{dl}$.

The intra-assay CV was 6.3%, for the high cortisol concentration, and for low concentration, the intraassay CV was 5.4%; all acceptable values.

Assay results that were over 2.0 µg/dl were deemed biologically implausible and the values were not used, consistent with methods employed in other studies (Ashman et al., 2002). Only one case was fully discarded because all cortisol values were over 2.0 µg/dl. Average latencies to collect the morning samples ranged from 27 to 40 min after awakening. Average evening samples collections were between 31 and 49 min before bed. Values in samples that had been collected 90 min after waking up or prior to bedtime were also discarded. Overall, this study was able to maintain a higher cortisol collection rate compared to other preschool samples in which parents also collected morning and evening data at home (Dougherty, Klein, Olino, Dyson, & Rose, 2009).

Within each time point, the associations of raw morning and evening values were examined to determine if it was appropriate to average across days, as done in other studies to create a more reliable measure (Bruce, Fisher, Pears, & Levine, 2009). For morning levels within a time point, cortisol values were all significantly correlated, with an average $r = 0.35$ (0.14–0.48), all $p < 0.05$. For evening levels, all but two associations were significant, with an average $r = 0.26$ (0.08–0.56). Thus, cortisol levels refer to the average across the 3 days of sampling, based on these results.

7.3.3.2. Cortisol measure: Regulation of the HPA-axis can be indicated by the diurnal pattern of cortisol levels. A regulated diurnal pattern is suggested by higher morning levels that decrease across the day, therefore, a measure of HPA-axis regulation was calculated as the average of morning level and diurnal slope. Assay results for all three mornings and evenings were averaged to create a summary measure of morning and evening levels (Ashman et al., 2002; Lengua, Fisher, et al., 2013). A diurnal slope value was computed by subtracting the average evening from the average morning value. The average morning score was 0.29 ($SD = 0.21$), average evening was 0.13 ($SD = 0.18$), and average diurnal slope was 0.16 ($SD = 0.20$). As is common with cortisol data, values were positively skewed, and log transformations were applied to the average morning and evening variables prior to calculating the diurnal pattern. A mean of the averaged morning and slope values served as an indicator of overall regulation of the HPA-axis system, and this variable was centered and squared to test for curvilinear or quadratic effects (Bush, Obradovi, Adler, & Boyce, 2011). Specifically, this quadratic representation was deemed optimal given considerable evidence of promotive and suppressive effects for cortisol, in associations with multiple outcomes. Bush et al. (2011) argued that the pattern of demonstrated cortisol effects suggests this variable represents an ideal candidate for modeling curvilinear relationships.

7.3.4. Community crime exposure—Crime data were acquired for 2008 from the city of Seattle's publically available data portal (data.seattle.gov), with 911 incident calls (approximately 183,000) grouped into seven major crime areas: homicide, assault, larceny/stolen property, robbery, burglary, car theft/car prowling, and lastly, nuisance crimes (e.g., disturbance, narcotics), and weighted in order of severity, as previously described (Chainey & Ratcliffe, 2005; Gartstein et al., 2017; Gartstein, Seamon, & Dishion, 2014). Our approach included an examination of spatial autocorrelation for crime incident data - the

degree to which a set of spatial features and their associated data tend to cluster in space (Craglia, Haining, & Wiles, 2000), because of potential for such clustering to inflate Type I error (Longley, Longley, Goodchild, Maguire, & Rhind, 2001). *Local Morans I* and *Ord Getis Gi* indices of local and global autocorrelation, respectively (Longley et al., 2001), were computed and resulted in extremely low p-values (e.g., $p < 0.001$) – indicating that autocorrelation was present, and was likely considerable. Given the large number of crime incidents (+180,000), this situation was remedied by randomly sampling our crime incidents to approximately 10% of the original (+18,000), as recommended (Rowland, Mohamied, Yean Chooi, Bailey, & Weinberg, 2015). This resampling resulted in lowering the number of significant autocorrelation effects, with considerably fewer “hot” and “cold” spots after the implementation of this procedure (Fig. 1).

The Crime Proximity Index (CPI), a *nearest neighbor-weighted index*, was defined as:

$$\text{CPI} = \frac{1 + N(\text{Distance to crime event} * \text{crime severity factor})}{\text{Total number of crime events within 1000 feet of participant residence}}$$

Crimes (i.e., homicide, assault, larceny/stolen property, etc.) were weighted in a linear progression – from least severe (e.g., car theft) to most severe (e.g., homicide), according to a previously reported procedure, summarizing all crimes within 1000 ft of the residence (Chainey & Ratcliffe, 2006; Gartstein et al., 2014). Thus, the CPI represents a weighted distribution of crime reflecting exposure at each participant's location (Fig. 2; Gartstein et al., 2017).

7.3.5. Cumulative family risk—Low maternal education, single parent status, divorce, adolescent parenthood, maternal depression, negative life events, residential instability, and household density were jointly considered as risk factors. Mothers reported concerning their age when the child was born, education, marital status, changing households, and number of individuals residing in the home. Maternal responses to the General Life Events Schedule for Children (Sandler, Ramirez, & Reynolds, 1986) addressing negative life events, and the Center for Epidemiological Studies–Depression Scale (CES-D; Radloff, 1977), were also included in the cumulative risk score. Correlations among these ranged from 0.02 to 0.50, indicating that variables were related but not redundant. An average cumulative risk score was the sum of dichotomous risk factors (scored 0 = *not present*, 1 = *present*) and continuous scores, converted into proportions of the total possible score, so that they ranged from 0 to 1, weighted equally with the dichotomous variables without loss of their continuous scale ($M = 1.01$; $SD = 0.83$; $range = 0-4$; Lengua et al., 2015).

7.4. Analytic strategy

Analyses comparing responders and non-responders for cortisol and crime related variables were computed first, followed by descriptive statistics for all of the variables included in this study, as well as simple correlations among these. Two hierarchical multiple regressions were subsequently performed to examine parenting behaviors as moderators of the associations between HPA-axis functioning, exposure to crime, and BMI, along with main effects of these variables. Child gender and cumulative risk indicators were initially

considered as covariates, and retained if statistically significant contributions were observed. Interaction terms were computed as products of each of the parenting behavior variables (limit setting, responsiveness, scaffolding, warmth, and responsiveness, and negative emotional tone) and the cortisol concentration index (i.e., squared daily average), as well as the geospatial crime index, in turn (Aiken & West, 2013). All predictors were centered prior to computing interaction terms. The cortisol concentration index was entered following the cumulative risk covariate, as the effects of this individual-level biological variable are more proximal to child BMI, relative to those associated with parenting. The quadratic nature of our HPA-axis regulation variable required that a number of additional predictors be considered. Namely, the average cortisol concentration values were included in the equation prior to the squared values, and interaction effects involving average cortisol concentrations were accounted for as well, prior to considering interaction effects of interest reflecting hypothesized moderation. Thus, the regression equation addressing moderation of the HPA-axis functioning included all five parenting behaviors in a single step of entry, followed by interactions between parenting behaviors and average cortisol concentrations, then parenting behaviors and squared cortisol indicators, entered together in turn. A parallel strategy was implemented in evaluating parenting behaviors as moderators of neighborhood crime exposure, with the exception that the main effect of crime proximity was entered after the five parenting predictors (i.e., limit setting, responsiveness, scaffolding, warmth, and negativity), as the latter were more proximal in their effects on child BMI, and thus prioritized in terms of the entry into the equation.

A statistically significant test of the interaction effect (i.e., significant F , β coefficient) was interpreted as indicative of moderation, with follow-up including plots of effects. Simple slope analyses were conducted at three levels to follow-up effects related to neighborhood crime exposure, with parenting behavior moderators (Z) considered at the mean ($Z = 2$), one standard deviation below ($Z = 1$) and above ($Z = 3$) the mean (Aiken & West, 2013; Preacher, Curran, & Bauer, 2006). As the HPA-axis functioning was indexed by a quadratic cortisol concentration term, the analytic scheme was tailored accordingly. First, variability in the shape of the curve as a function of parenting behavior moderators was examined, subsequently considering whether or not the strength of the relationship between child diurnal cortisol pattern and BMI was altered as a function of limit setting, responsiveness, scaffolding, warmth, and negative emotional tone (Dawson, 2014).

8. Results

8.1. Comparison of responders and non-responders

Independent group t-tests were used to compare responders and non-responders on all of the independent and dependent variables. Children missing cortisol data demonstrated higher cumulative risk scores ($M = 1.56$, $SD = 1.02$) compared to children without missing cortisol ($M = 0.86$, $SD = 0.78$), $t(304) = 2.93$, $p < 0.01$. Although the association between missing cortisol and cumulative risk, $r = -0.21$, $p < 0.01$, was also significant, it is below the threshold deemed to introduce bias (Collins, Schafer, & Kam, 2001), and cortisol missingness was not related to family income. Comparisons of cortisol responders and non-responders with respect to parenting behaviors resulted in two statistically significant tests:

negativity, $t(304) = -2.07, p < 0.05$; responsiveness, $t(304) = 2.62, p < 0.05$. Caregivers failing to provide cortisol samples were rated as more negative (Responders $M = 0.55, SD = 0.43$; Non-responders $M = 0.74, SD = 0.59$) and less responsive (Responders $M = 4.46, SD = 0.54$; Non-responders $M = 4.15, SD = 0.72$), compared to those who complied with cortisol data collection. For the CPI, no significant differences were noted between the full sample and those with available crime data on cumulative risk, or any of the five parenting behaviors.

8.2. Descriptive statistics and correlations

Descriptive statistics (Table 1) and simple correlations (Table 2) were computed next. A number of significant correlations emerged, perhaps most notably between the CPI, reflective of community crime exposure, cumulative risk, and child BMI, in the positive direction. In addition, parent responsiveness and scaffolding were related to lower BMI.

8.3. HPA-axis functioning: diurnal cortisol pattern

In hierarchical multiple regressions predicting BMI, cumulative family risk, but not child gender, was associated with a statistically significant contribution, and thus retained in the analyses. The first two, and the final full model, with all of the interaction terms of interest in the equation, $F(5, 232) = 3.36, p < 0.01$, produced statistically significant changes in explained variance (Table 3). In the final model, warmth was associated with a significant main effect in the positive direction, $\beta = 0.21, p < 0.05$, as well as a significant interaction with the quadratic diurnal cortisol pattern predictor, $\beta = -0.45, p < 0.01$, indicative of moderation. Significant interactions were also observed for limit setting, $\beta = 0.26, p < 0.05$, and scaffolding, $\beta = 0.33, p < 0.05$.¹ Significant interaction effects that involved a quadratic diurnal cortisol pattern term, warmth, limit setting, and scaffolding, were considered along with those based on average cortisol concentration values, and tested with respect to their incremental contribution to child BMI. These analyses addressed the question of whether the strength of the relation between HPA-axis functioning and BMI changed as a function of relevant parenting behaviors.

Consistent with Dawson (2014), regression models with interaction terms that reflect moderation by warmth, limit setting, and scaffolding, and those excluding these effects, were compared via F-tests. Warmth, $F(2, 232) = 3.81, p < 0.05$, and limit setting, $F(2, 232) = 3.23, p < 0.05$, made statistically significant contributions, altering the strength of association between HPA-axis regulation and child BMI, along with the form of the curve. A non-significant (trend-level) effect was noted for scaffolding, $F(2, 232) = 2.51, p < 0.10$. Two significant interaction effects observed for the quadratic cortisol concentration indicator were plotted (Figs. 3, 4), and probed further with respect to the strength of moderation, as recommended by Dawson (2014). Greater maternal warmth was associated with higher child BMI at lower values of the diurnal cortisol pattern term, with the intercept of BMI indicating values in the overweight range (Fig. 3). Higher levels of maternal limit setting were associated with lower child BMI at mid-level cortisol concentrations, however, none of the

¹Additional covariates were considered: Child Ethnicity; Child Nutrition Composite; Physical Activity; Television Exposure; Neighborhood Social Organization Composite, but did not account for significant variance, or alter the nature of observed associations. Results available from the first author upon request.

BMI values were at levels indicating overweight or obesity (Fig. 4). Multicollinearity indices were inspected and did not suggest problems in this regard, (*Tolerance* > 0.20, *VIF* < 10; Hair, Anderson, Tatham, & Black, 1995; Menard, 1995).

8.4. Crime exposure

Neither cumulative risk nor child gender were retained in the hierarchical multiple regression analysis of neighborhood crime, failing to make a significant contribution. The first model was statistically significant overall, $F(1, 113) = 2.36, p < 0.05$, yet none of the parenting predictors made significant individual contributions. The second model accounted for a change in explained variance with the entry of the crime proximity predictor, $F(6, 108) = 18.46, p < 0.01$, as did the final full model, $F(5, 102) = 2.57, p < 0.05$, with all interaction terms included (Table 4). Crime proximity accounted for significant variance in child BMI, $\beta = 0.38, p < 0.05$, contributing to higher values, when first considered as a predictor. Limit setting, $\beta = 0.25, p < 0.05$, and scaffolding, $\beta = -0.30, p < 0.05$, emerged as significant predictors in the final model, with limit setting associated in a positive, and scaffolding in the negative direction.

The significant crime proximity-by-scaffolding interaction, $\beta = 0.45, p < 0.05$, was followed by simple slope analyses (Preacher et al., 2006). A statistically significant simple slope was observed at $Z = 1$ (-1 *SD* scaffolding): $5.53(0.21), t = 26.06, p = 0.01$; but not for $Z = 2$ (M scaffolding): $11.05(10.94), t = 1.01, p = 0.31$; or $Z = 3$ ($+1$ *SD* scaffolding): $0.10(0.35), t = 0.28, p = 0.78$ (Fig. 5). At lower levels of maternal scaffolding, children exposed to greater community crime presented with higher BMI values in the overweight/obese range. Multicollinearity indicators raised concern regarding this issue for the CPI (*Tolerance* = 0.08, *VIF* = 12.33), once the interaction terms were entered into the regression equation. Although these indices of multi-collinearity exceeded traditional “rules of thumb” for *Tolerance* and *VIF*, more recent studies suggest such markers do not necessarily cast doubt on analyses, especially if the models are justifiable on theoretical grounds (O'Brien, 2007).

9. Discussion

The primary goal of this investigation was to examine parenting behaviors as moderators of individual-level biological and macro-level community effects with respect to childhood BMI, during a period deemed critical to long-term obesity risk (Mamun et al., 2009; Narayan et al., 2007). These parenting behaviors were conceptualized as involved in proximal processes, described in Bronfenbrenner's bioecological theory of human development. Specifically, these factors were viewed as essential to the energy exchange (for example, in the context of parent-child interactions) between the developing organism and the environment, or “engines of development” (Bronfenbrenner & Evans, 2000; *p.* 118), modulating growth and adjustment across diverse areas of child functioning (e.g., behavioral, health-related, etc.). Results of this study extend the existing literature, as the observed pattern of results supports the critical role of parenting behaviors, indicating that warmth, limit setting, and scaffolding in mother-child interactions moderate effects associated with the child's HPA-axis functioning and exposure to community crime with

respect to the risk for obesity. Moderation effects are addressed first because these significant interactions condition observed direct effects, discussed in turn.

9.1. Maternal warmth moderates HPA-axis effects

Results of this study provided evidence that parental warmth served to increase the risk for obesity, and children at the lower range of the cortisol concentration distribution demonstrated higher BMI when parent-child interactions were characterized by greater warmth. Recent investigations demonstrated blunted HPA reactivity was associated with increased obesity/overweight risk, even in preschool-age children (Kjølhede, Gustafsson, Gustafsson, & Nelson, 2014; Miller et al., 2013), and the present study contributes to the existing literature by indicating that parenting behaviors can moderate this risk. According to Gunnar and Vazquez (2001), the HPA-axis down-regulates after chronic periods of elevated stress responding, a condition referred to as “hypocortisolism” (Heim, Ehler, & Hellhammer, 2000; Tarullo & Gunnar, 2006), signaling HPA dysregulation. Such dysregulation is likely important to child BMI, and parental warmth appears to have detrimental effects for youngsters with lower diurnal cortisol pattern values. Hillman et al. (2012) suggested lower cortisol concentrations could serve as an early adaptive mechanism, facilitating maintenance of glucose and metabolic homeostasis in the face of emerging insulin resistance. This blunted cortisol response may not effectively suppress insulin activity if particularly warm parents are solicitous around health behaviors such as allowing predominantly sedentary behaviors (e.g., television watching) or making high calorie foods readily available, disrupting glucose management. The warmth variable in this study may serve as a proxy of solicitousness around health behaviors or food consumption, or it might be associated with use of food for comfort and relationship building. Based on these possibilities, it would be valuable to examine both general warmth-related parenting behaviors and specific health behavior and food related behaviors simultaneously.

Future studies should explore the mechanisms behind this effect, especially if warm interactions translate into lower physical activity or higher intake of calorically dense foods, resulting in BMI elevations for preschooler with lower cortisol values, a potential marker of biological vulnerability. Although “high involvement and supportive” parenting in a food-related context was associated with lower children's intake of high calorie energy snacks (Gevers, Kremers, de Vries, & van Assema, 2015), it may nonetheless contribute to higher BMI, possibly through consumption of more calorically dense regular meals. Additional research is needed to examine links between parental warmth and specific behaviors related to child food intake, and the present findings suggest links between warmth and higher BMI for children exhibiting a cortisol profile potentially reflective of a chronic stress response or HPA-axis dysregulation. Another novel set of findings contributing to the current literature speaks to child HPA-axis functioning association with BMI being contingent on limit setting, considered next.

9.2. Limit setting moderates HPA-axis effects

Although the main effect of limit setting from the crime exposure analyses indicated higher levels were associated with higher BMI scores, follow-up of the interaction effect involving limit setting and HPA-axis functioning indicated that more consistent limit setting was

associated with lower BMI at mid-level cortisol concentrations. There were no specific a-priori expectations concerning these mid-range cortisol values, yet an obesity risk-lowering effect was anticipated for parental limit setting, operationalized as clarity of communication and follow-through on directives with the child. Limit setting was shown to buffer against an array of behavior problems (Bates, Pettit, Dodge, & Ridge, 1998; Renk, 2011), and the present findings suggest this parental contributor to proximal processes is also associated with lower obesity risk, dependent on child HPA-axis regulation. This rule-oriented and clear parental communication style was associated with lower BMI only for youngsters with mid-range diurnal cortisol pattern values. Unfortunately, results of this study do not clarify exactly why this beneficial effect was only noted at mid-range cortisol values. However, it may be that children with these mid-range concentrations are in fact most effectively regulated with respect to their HPA-axis functioning, which in turn makes it possible for them to benefit from the structure afforded by more consistent limit setting. That is, higher cortisol values were described as reflective of a dysregulated acute reaction to stress (Dickerson & Kemeny, 2004), whereas lower values were characterized as 'blunted', and linked with chronic stress exposure (Gunnar & Vazquez, 2001; Heim et al., 2000). Thus, results of this study suggest that the mid-range values may be most adaptive, enabling greater responsiveness to context (i.e., parental limit setting), which expands the current thinking about this HPA-axis marker. The latter possibility requires exploration in future studies, which should also examine whether it is limit setting specific to food and energy expenditure activities that is most critical to consider. Scaffolding also played a role of a moderator, primarily with respect to the macro-level community crime exposure predictor.

9.3. Scaffolding moderates crime exposure effects

The present study contributes to the literature addressing neighborhood effects, indicating that parenting behaviors other than monitoring youngsters' activities (e.g., Bacchini et al., 2011) moderate effects of community exposure to crime. Initially considered in a problem-solving context (Rogoff, 1990; Vygotsky, 1978), the importance of parental scaffolding has been extended to understanding the development of self-regulation or executive functions (e.g., Hammond, Muller, Carpendale, & Bibok, 2011; Lengua, Kiff, et al., 2013), as well as behavior problems (Gartstein & Fagot, 2003). In this present study, scaffolding represents a balance of autonomy granting and structure, that appears relevant to children's health behaviors and BMI, as lower levels of scaffolding were particularly problematic with respect to child obesity risk in the context of greater community crime exposure. Specifically, BMI of children experiencing most severe and frequent neighborhood crime exposure was highest when parents demonstrated lower levels of scaffolding. One potential explanation is that parents exhibiting high levels of scaffolding were effective in providing structure for their children (e.g., remaining child-focused and non-intrusive), while ensuring safe physical activity. It may be that children whose parents are able to offer this type of guidance benefit by maintaining physical activity even in greater proximity to community crime, which is in turn reflected in lower child BMI, and future research should examine this possibility directly. Results of this study contribute to the literature demonstrating scaffolding as an important filter of neighborhood effects with respect to child health.

9.4. Direct effects of HPA-axis, parenting and crime exposure

Results of a hierarchical multiple regression analysis demonstrated that greater warmth was associated with higher BMI. Thus, parents who responded to their children in a more emotionally positive, engaged, and supportive manner had children with higher BMI scores. As already noted, this association between maternal warmth and higher child BMI was not uniform, but rather informed by an interaction that indicated obesity-related risk for children at the lower end of cortisol concentration values. Nonetheless, this direction of effect was not consistent with our hypotheses, casting maternal warmth as associated with lower BMI. That is, we expected maternal warmth to lower risk related to obesity similar to its role in behavioral development, wherein for example warmth in mother-child interactions was protective with respect to callous-unemotional child attributes (Waller et al., 2014). It is also important to note that the effects of warmth were independent effects above the contributions of the other parenting variables. Thus, accounting for the effects of the other affective and control aspects of parenting, and other study variables, may alter the direction or magnitude of the association of warmth with BMI, as suggested by the bivariate correlation between warmth and BMI which was negative. Results of this study suggest conditioned protective effects for maternal warmth, not observed in a child health related context here. Average cortisol concentration values predicted child BMI in the negative direction (i.e., lower cortisol associated with higher BMI), as anticipated (Hillman et al., 2012), until other variables were allowed into the equation, which weakened the contribution of this independent variable.

Three significant direct effects emerged in the hierarchical multiple regression analysis addressing community crime exposure. More proximal/severe crime incidents were associated with higher BMI, consistent with our hypotheses and existing research (Brown et al., 2008; Sumner et al., 2015). However, the CPI was a significant predictor only when first entered in the regression equation. This contribution was subsequently diminished when other variables were considered, possibly in part due to multicollinearity-related issues. Scaffolding also made a unique contribution to predicting child BMI in the final model, only when all of the variables being considered were entered. As expected, higher levels of scaffolding were associated with lower BMI scores, with a significant interaction effect that further informed this link. Although scaffolding has not been previously examined in this context, it has been shown to play a protective function, for example supporting the development of effortful control responsible for flexible self-regulation (Lengua, Kiff, et al., 2013), and the present study expands these findings, indicating a protective role with respect to child health.

Limit setting was associated with higher BMI, in contrast to our expectations, insofar as it was hypothesized that higher levels of limit setting would be associated with lower BMI, consistent with a reduction in the risk for obesity. As already noted, an anticipated protective direction of the maternal limit setting effect was only observed for children with mid-range cortisol concentration values. It may be that greater limit setting amounts to less physical activity outdoors, and thus higher BMI values. It is also possible that higher limit setting translates into more controlling behaviors around food, with children gravitating toward forbidden items as a result (Vereecken, Legiest, De Bourdeaudhuij, & Maes, 2009),

accounting for the association with higher BMI. Regardless of the exact mechanism behind this effect, it appears to circumvent children at mid-range cortisol values, who present with lower BMIs when their parents engage in more limit setting. Significant effects just discussed were largely consistent with our expectations based on Bronfenbrenner's Ecological Systems Theory of development, which casts parenting behaviors in a unique role interfacing with individual and macro levels of influence. However, two parenting behaviors (i.e., responsiveness and negativity) hypothesized to contribute to child BMI did not produce statistically significant results.

9.5. Responsiveness and negativity in interactions with the child

Responsiveness, thought to contribute to reduced risk for obesity, did not emerge as a significant predictor, nor did negative parenting behaviors, either in the context of main effects of interaction terms. Negative parental behaviors (e.g., coercive parent-child interactions, negative affect, intrusive behaviors) were shown to play an important role in predicting behavior problems (e.g., Belsky, Hsieh, & Crnic, 1998; Gartstein & Fagot, 2003), yet did not present as equally relevant when examined in relation to risk for obesity in the present investigation. Thus, negative affectivity in parenting may be less critical in this health-related context.

The observed pattern of results could also be a function of the developmental period, as, for example, sensitivity or responsiveness may be most essential to child wellbeing during infancy, linked with multiple positive outcomes, such as attachment security and development of attentional skills (Beijersbergen, Juffer, Bakermans-Kranenburg, & van IJzendoorn, 2012; Bornstein & Tamis-LeMonda, 1997; Gartstein, Crawford, & Robertson, 2008). An alternative explanation involves the pattern of missing data observed in this study, wherein parents who provided cortisol samples for their children were lower in negativity and higher in responsiveness. It is possible that range restriction, a result of non-responses to the cortisol portion of this study, contributed to the lack of significant results observed for maternal negativity and responsiveness.

10. Summary

Overall, warmth, limit setting, and scaffolding appeared to be particularly important to proximal processes operating for preschool-age children, as these parenting behaviors made significant contributions to explaining child BMI independently and/or as a function of HPA-axis regulation and neighborhood crime exposure. Notably, warm exchanges did not lower the risk for obesity, but rather were associated with higher BMI scores for children, especially at the lower end of the cortisol concentration distribution. Limit setting was linked with lower obesity risk (i.e., lower BMI) given mid-range diurnal cortisol pattern values only, and was otherwise associated with higher BMI. Scaffolding was most critical to child BMI in the context of community crime exposure, with lower levels exacerbating risk for those in greatest proximity to more dangerous incidents. Together, the present findings support the importance of parenting behaviors to child physical health, extending the existing literature addressing behavioral outcomes. This pattern of results was anticipated by the bioecological model insofar as this framework incorporates individual-level biological

attributes (e.g., HPA-axis functioning), psychosocial or interpersonal aspects of the child's environment (e.g., parenting behaviors), and more macro-level community effects, such as exposure to community crime, in predicting child development. Although not typically considered in the context of health-related outcomes, such as child BMI, the importance of parenting behaviors and their interrelationships with individual and macro-level variables can be expected on the basis of Bronfenbrenner's theory, which stipulates that salient proximal processes involve combinations of factors that serve to elevate or decrease adversity for a given developmental outcome. The present study further extends the implications of this bioecological approach, outlining mechanisms that involve moderation by several parenting behaviors (i.e., warmth, limit setting, and scaffolding), emerging as key to proximal processes shaping obesity risk in the preschool period.

Results of this study also have clinical implications, as reduction of BMI is a likely therapeutic target, even for preschool-age children. Specifically, the nuanced pattern of results observed in this investigation suggests that most optimal approaches may differ based on individual-level biological and macro-level community factors. These conditional effects are relevant to prevention and intervention efforts targeting parenting as a means of mitigating child obesity risk. In particular, although the observed pattern of results requires replication and extension, the present study makes a contribution by indicating that a nuanced strategy targeting parental warmth, limit setting and scaffolding is indicated.

11. Limitations

This work is associated with several limitations, starting with the cross-sectional nature of our data, admittedly not optimal for examining moderator relationships. Although the parent project from which these data were derived is longitudinal, we were limited by the timing of crime data collection for the City of Seattle geospatial law enforcement indicators, and thus constrained to cross-sectional analyses. Future research should attempt replication, conducting longitudinal evaluations. Geographic constraints to the City of Seattle caused exclusion of multiple cases, limiting our samples size, power and generalizability, and represent another limitation to be remedied by future research. As such, our sample size did not permit an examination of 3-way interactions (or moderated moderation), testing joint effects of child HPA-axis functioning, community crime, and parenting behaviors on child BMI. This work should be undertaken in the future, given that interactions between crime exposure and cortisol concentrations were recently shown as important in predicting BMI (Gartstein et al., 2017). Interactions among parenting behaviors should be examined in the future as well, as for example, jointly high levels of scaffolding and limit setting, or scaffolding and warmth, may have unique consequences in terms of child health behaviors and BMI. Our aggregation of parenting behavior scores across assessment episodes could also be construed as a limitation, insofar as a more fine-grained look at dimensions of parenting (i.e., examining these separately across tasks), would be informative due to contextual differences across task demands, for example, cleanup and free-play. It should be noted that research is also required to empirically examine links between parenting in a general parent-child interaction context and in food-related situations. In addition, communities that afford greater exposure to crime likely present with additional BMI related effects (e.g., food insecurity), and tend to be disproportionately composed of households

experiencing adversity related to low SES and/or minority status. Some of these contributing factors may not have been adequately captured by the measurement strategy and study design, even with the effort to control for cumulative family stress, and should be addressed in future research. The fact that not all families complied with the cortisol data collection, resulting in missing data, represents a limitation given significant differences between responders and non-responders reported earlier. Further, mothers' recordings of saliva collection times were not confirmed with an objective measurement, and this lack of fidelity data concerning collection efforts also represents a limitation. Finally, there are limitations associated with the approach to measuring BMI, in that an average of three different measurements of height and weight was not taken, rather relying on a single set of values. Thus, results obtained in this study should be replicated utilizing more rigorous procedures for cortisol data collection, assessing and ensuring reliability of child BMI measurement.

12. Conclusions

Despite these limitations, the present study makes a unique contribution, examining how parenting behaviors including limit setting, responsiveness, scaffolding, negativity and warmth, were associated with childhood BMI, jointly with child HPA-axis functioning and community crime exposure. Moderation effects considered for the physiological stress response marker and the geospatial community-level measure of crime indicated parenting behaviors altered the nature of relationships between HPA functioning, neighborhood crime exposure, and child BMI. Contributions of warmth, limit setting, and scaffolding in parent-child interactions, considered as predictors of child BMI for the first time, emerged as most prominent. Although prior research has focused on weight status categories presented in this study for descriptive purposes, BMI scores have the advantages associated with continuous variables, permitting the use of more powerful statistical tests and preventing loss of information (MacCallum, Zhang, Preacher, & Rucker, 2002). Nonetheless, this difference in metric should be considered when interpreting the present findings. Results of this study are particularly notable given the multi-method approach that included a biomarker of child stress response, municipality-reported crime statistics in a geo-spatial platform, and observations of parent-child interactions. Parenting effects are important in their own right, and provide key avenues for intervention, especially with younger children not able to engage in treatment independently. Results obtained in this study have the potential to inform prevention and intervention services, especially important given a downward extension of extreme obesity that effects progressively younger children (Lo et al., 2013; Ogden, Carroll, Kit, & Flegal, 2014). In fact, preventative programs are already being implemented as early as infancy (Machuca et al., 2016), and results of the present investigation can inform these efforts.

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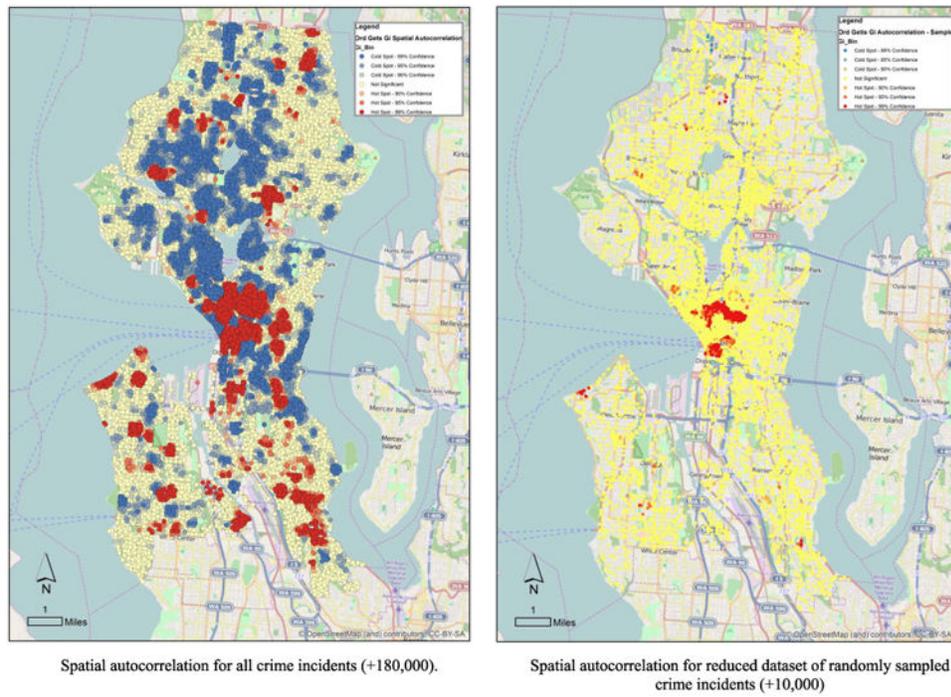


Fig. 1. Comparison of spatial autocorrelation before reducing observations thru random resampling (left), and after (right).

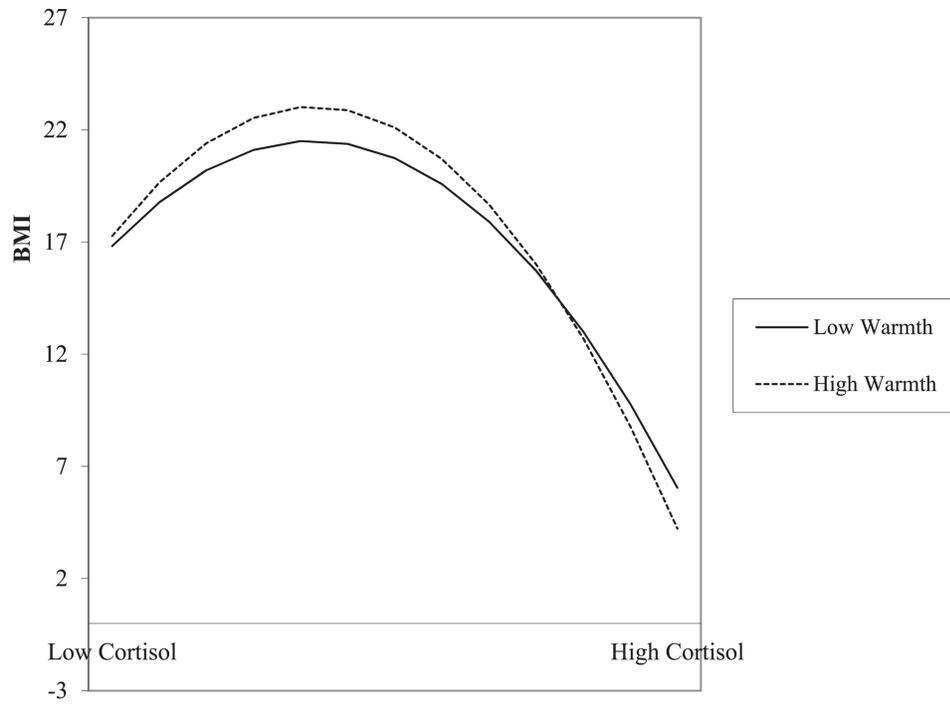


Fig. 3. Schematic representation of warmth in parent-child interactions as a moderator of the child Diurnal Cortisol Pattern and BMI association.

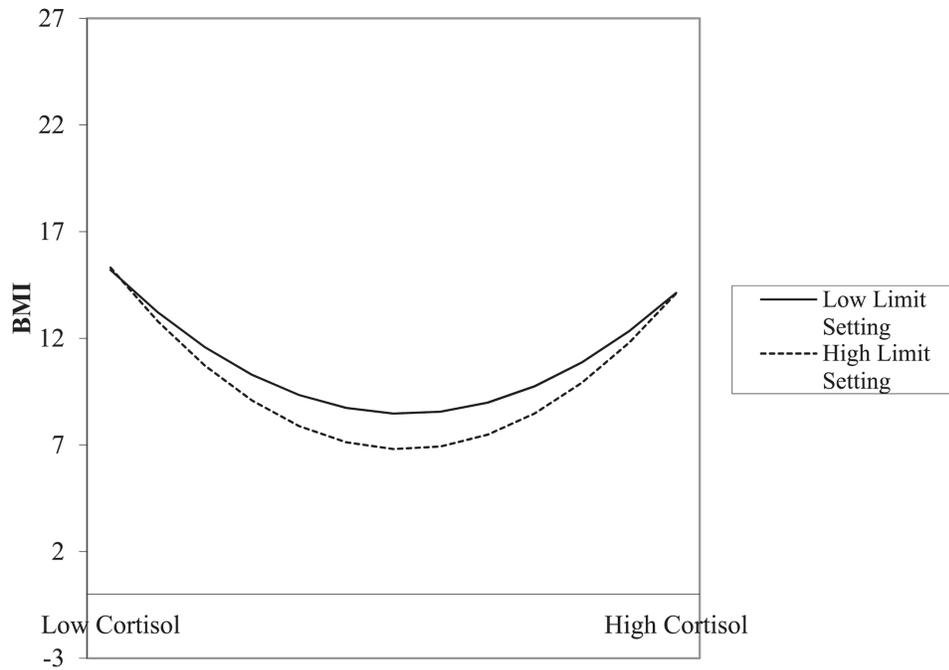


Fig. 4. Schematic representation of limit setting in parent-child interactions as a moderator of the child Diurnal Cortisol Pattern and BMI association.

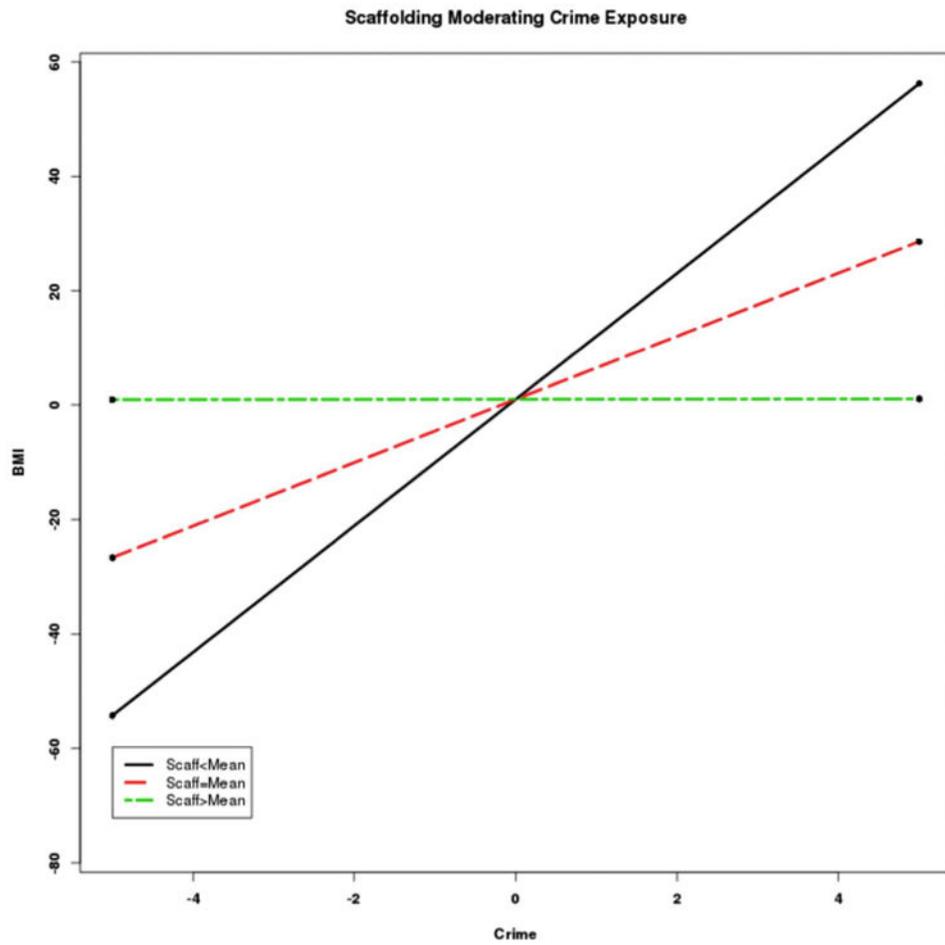


Fig. 5. Schematic representation of scaffolding in parent-child interactions as a moderator of crime exposure and BMI association.

Table 1

Descriptive statistics: demographics, BMI, parent-child interactions, HPA-axis functioning, and crime exposure ($N = 250$).

Variable	Mean	SD	Min	Max
Cumulative Risk Index ^a	0.85	0.64	0.18	3.51
Child BMI	15.13	2.45	8.06	27.18
Limit setting ^b	4.60	0.55	1.50	5.50
Negativity	0.58	0.46	0.10	2.60
Responsiveness	4.41	0.58	1.50	5.17
Scaffolding	3.61	0.36	2.04	4.80
Warmth	3.59	0.36	1.75	4.39
Diurnal cortisol pattern ^c	0.03	0.33	-0.87	0.56
Crime Proximity Index ^d	709.49	1080.89	37.00	1,0515.00

Note. Body Mass Index (BMI); Hypothalamic-Pituitary-Adrenal (HPA).

^aCumulative Risk Index included: demographic (mother education, single parent status) and contextual (household density, residential instability) factors contributing to adversity and psychosocial risk, including negative life events (changing schools, death of a family member or friend) and maternal depression (Lengua et al., 2015).

^bParenting behavior scores reflect observational codes based on 4 activities: parent-directed play, child-directed play, instructional activity, and cleanup (Kerig & Lindahl, 2001).

^cMarker of HPA-axis functioning measured via average cortisol concentration (combined morning level and diurnal slope), centered and squared.

^dCrime Proximity Index descriptives based on a subsample within Seattle city limits ($N = 114$).

Table 2

Correlations: demographics, child BMI, diurnal cortisol pattern, parent-child interactions, and crime exposure ($N = 250$).

Scale	1	2	3	4	5	6	7	8	9	10
1 Child gender	-									
2 Cumulative Risk Index	-0.08	-								
3 BMI	-0.02	0.24*	-							
4 Limit setting	-0.08	0.13	0.16	-						
5 Negativity	0.05	0.25*	0.02	-0.18	-					
6 Responsiveness	0.10	-0.38**	-0.22*	0.02	-0.18	-				
7 Scaffolding	0.15	-0.38**	-0.23*	0.05	-0.05	0.55**	-			
8 Warmth	0.09	-0.21*	-0.17	0.24*	-0.02	0.44**	0.49**	-		
9 Cortisol ^a	0.12	0.13	0.14	0.00	0.07	0.01	0.02	-0.08	-	
10 Crime Proximity Index ^b	-0.03	0.19*	0.39**	0.08	-0.02	-0.01	0.08	-0.09	0.29**	-

Note. Body Mass Index (BMI); Hypothalamic-Pituitary-Adrenal (HPA).

^aHPA-axis functioning indexed via the Diurnal Cortisol Pattern, combined morning level and diurnal slope.

^bCrime Proximity Index correlations based on a subsample within Seattle city limits ($N = 114$).

** $p < 0.01$.

* $p < 0.05$.

Table 3
Hierarchical multiple regression predicting child BMI: Parenting behaviors and HPA-axis ($N = 250$).

	Model 1: Cumulative risk	Model 2: Cortisol ^a	Model 3: Cortisol ^b	Model 4: Parenting Behaviors	Model 5: Moderator Effects ^c	Model 6: Moderator Effects ^d
R ²	0.05	0.07	0.07	0.09	0.12	0.18
R ²	0.05	0.02	0.00	0.01	0.03	0.07
F	12.66**	4.72*	0.22	0.58	1.49	3.36**
Model F	12.66**	8.79**	5.91**	2.56*	2.16*	2.58**
β cumulative risk	0.23**	0.21**	0.20**	0.18*	0.17*	0.15*
Cortisol		-0.14*	-0.12	-0.12	-0.09	-0.09
Cortisol ^b			0.04	0.03	0.03	-0.03
Limit setting (LS)				-0.12	0.06	-0.14
Negativity				-0.05	0.01	-0.02
Scaffolding				-0.02	-0.01	-0.13
Warmth				0.03	0.04	0.21*
Responsiveness (Resp)				-0.12	-0.12	-0.13
Cortisol * LS					-0.19	-0.03
Cortisol * negativity					0.03	0.04
Cortisol * scaffolding					-0.00	0.21
Cortisol * warmth					0.02	-0.14
Cortisol * resp					0.01	-0.03
Cortisol ^b * LS						0.26*
Cortisol ^b * negativity						0.08
Cortisol ^b * scaffolding						0.33
Cortisol ^b * warmth						-0.45**
Cortisol ^b * resp						0.11

Note. Body Mass Index (BMI); Hypothalamic-Pituitary-Adrenal (HPA).

^aDiurnal cortisol pattern measured via average cortisol concentration (combined morning level and diurnal slope).

^bDiurnal cortisol pattern (average cortisol concentration) centered and squared, representing curvilinear or quadratic effects.

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^c Parenting behaviors: limit setting (LS), negativity, scaffolding, warmth, and responsiveness (Resp) were considered as moderators of the average cortisol concentration levels first, with interaction terms considered simultaneously.

^d Parenting behaviors were tested as moderators of the squared average cortisol concentration levels, to test our hypotheses, with interaction terms considered simultaneously.

** $p < 0.01$.

* $p < 0.05$.

Table 4Hierarchical multiple regression predicting child BMI: Parenting behaviors and crime ($N = 114$).

	Model 1: Parenting behaviors	Model 2: Crime Proximity Index	Model 3: Moderation effects ^a
R ²	0.11	0.25	0.35
R ²	0.11	0.15	0.09
F	2.36 [*]	18.46 ^{**}	2.57 [*]
Model F	2.36 [*]	5.40 ^{**}	4.36 ^{**}
β limit setting	0.20	0.15	0.25 [*]
Negativity	-0.08	-0.07	-0.08
Scaffolding	0.02	-0.23 [*]	-0.33 [*]
Warmth	-0.16	-0.03	-0.06
Responsiveness	-0.11	-0.07	-0.14
Crime Proximity Index (CPI)		0.39 ^{**}	0.45
CPI * Limit Setting			0.28
CPI * Negativity			-0.33
CPI * Scaffolding			-0.47 [*]
CPI * Warmth			-0.14
CPI * Responsive			-0.06

Note. Body Mass Index (BMI).

^aParenting behaviors: limit setting, negativity, scaffolding, warmth, and responsiveness were tested as moderators of community crime exposure via interaction terms considered simultaneously.

**
p < 0.01

*
p < 0.05.