CHILD, FAMILY, AND NEIGHBORHOOD PREDICTORS OF CHILDREN'S BODY MASS INDEX: A LONGITUDINAL STUDY OF MODERATED MEDIATION

by

Katherine A. Hails

Bachelor of Arts, Hamilton College, 2010

Master of Science, University of Pittsburgh, 2016

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This dissertation was presented

by

Katherine A. Hails

It was defended on

June 8, 2020

and approved by

Michele Levine, Ph.D., Department of Psychiatry

Christina Mair, Ph.D., Graduate School of Public Health

Jennifer Silk, Ph.D., Department of Psychology

Elizabeth Votruba-Drzal, Ph.D., Department of Psychology

Dissertation Director: Daniel Shaw, Ph.D., Department of Psychology

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Katherine Hails, Ph.D.

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Childhood obesity is a widely prevalent public health concern that disproportionately affects children from low-income families (Cameron et al., 2015). The causes of child obesity and socioeconomic disparities in its prevalence are not well understood, but are likely because of co-occurring and interacting risk factors at multiple levels of influence on children (Harrison et al., 2011). In particular, aspects of children's early neighborhood environment, including food retailers and parks, may affect children's weight directly by influencing health behaviors (e.g., eating habits, physical activity). A neighborhood's social attributes (e.g., poverty levels, perceived danger) could also indirectly affect child weight by compromising self-regulation (SR), which could then influence eating behaviors. Additionally, parents may provide a buffering effect for children in the context of high levels of neighborhood risk (Supplee et al., 2007). The aims of the current study were to assess longitudinal relationships between the neighborhood environment in early childhood (the "built" environment and neighborhood social context) and growth in child body mass index (BMI) from age 5 to 10.5, to test child SR as a mediator of associations between neighborhood context and child BMI growth, and to test supportive parenting as a moderator of relationships between neighborhood and child SR and between child SR and child BMI growth. Study data came from the Early Steps Multisite Study, a sample of 731 predominantly low-income families from Oregon, Pennsylvania, and Virginia assessed when children were age 2 to 10.5. Overall, the current study provided little evidence for the proposed model. Neighborhood variables

and SR at preschool-age were both unrelated to growth in child BMI over time. Census-based neighborhood social disadvantage was found to interact with supportive parenting in relation to preschool-age SR, such that the relationship between supportive parenting and child SR was stronger in the context of lower levels of neighborhood disadvantage. Variability in neighborhood context and urbanicity across the three sites may have hindered the ability to detect associations. As child obesity is complex and influenced by many factors both proximal and distal, future research should continue to evaluate interactions and mediating mechanisms among variables at multiple levels of children's ecology.

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1.0 INTRODUCTION

Early life exposure to poverty is associated with heightened risk of later obesity (Lee, Andrew, Gebremariam, Lumeng, & Lee, 2014), which has important implications for socioeconomic health disparities across the lifespan. While conceptualizations and research on childhood obesity have established the critical influences of both physical activity (Must & Tybor, 2005) and nutritional intake (Berkey et al., 2000), recent research efforts have broadened this focus to include the quality of children's home and extra-familial contexts, including various facets of neighborhoods. Theoretically, neighborhood context may affect children's weight outcomes directly by influencing children's health behaviors and indirectly by leading to higher levels of psychological stress, thereby compromising children's ability to self-regulate their eating behaviors.

In terms of direct effects, neighborhood context is thought to be associated with health behaviors such as physical activity and food consumption that are crucial to maintaining a healthy weight. For example, the accessibility of public parks and the degree of safety in neighborhoods could reduce children's physical activity, and proximity to fast food restaurants and supermarkets could compromise the quality of children's nutritional intake. The term "built environment" refers to the human-made spaces in the communities where people live, work, and play, and may include characteristics such as walkability, residential density, mixed land use, and locations of grocery stores (Papas et al., 2007). Although theoretically plausible, empirical evidence linking characteristics of children's built environment to childhood obesity is still somewhat equivocal (Galvez, Pearl, & Yen, 2010).

In addition to the proposed direct effects of neighborhood context on child weight, recent conceptualizations and research also suggest potential indirect effects of children's neighborhood context. Exposure to stress and early adversity could *indirectly* increase risk of later excess weight gain by impairing children's physiological stress response and/or self-regulatory capacities (Evans & English, 2002). Empirically, exposure to early childhood adversity and chronic stress have been consistently found to influence obesity risk (Burke, Hellman, Scott, Weems, & Carrion, 2011), possibly by compromising children's self-regulation abilities (Evans, Fuller-Rowell, & Doan, 2012).

Self-regulation (SR) encompasses one's ability to modulate behavior and emotions in response to internal and external demands and is often conceptualized using a dual process model consisting of "hot," reactive processes (e.g., impulsivity) and a "cool," reasoned, cognitive system (Metcalfe & Mischel, 1999). As maintenance of healthy body weight involves appropriate SR of energy intake, it follows that SR has been found to predict child body mass index (BMI) (Graziano, Calkins, & Keane, 2010). As child weight and poverty have been associated with multiple components of SR, SR may be especially important in explaining how poverty and neighborhood context affect child weight.

Another piece of a child's ecology is the quality of the caregiving environment. Accordingly, supportive parenting could also serve as a protective factor for SR in the context of high neighborhood stress. Prior research suggests that positive parenting may be protective against the development of child externalizing problems in the context of neighborhood deprivation (Supplee, Unikel, & Shaw, 2007). Similarly, supportive parenting may also attenuate associations between children's SR and weight (Moding, Augustine, & Stifter, 2018).

The current study will assess longitudinal relationships between two specific domains of the neighborhood environment, namely the built environment and neighborhood social context, using objective methods such as data from the U.S. census and other publicly available data sources, parent reports of neighborhood quality, and child weight among a sample of low-income children assessed from child age 2 to age 10. Models will examine whether "hot" and "cool" measures of child SR mediate associations between two types of neighborhood context and child weight. It is anticipated that neighborhood indices of the built environment and neighborhood social context will be directly associated with growth in children's weight from early school-age (age 5) to middle childhood (age 10). It is also predicted that SR at age 5 will mediate relations between neighborhood social context and child weight. Finally, observed supportive parenting is expected to attenuate the strength of pathways from neighborhood social context to child SR and child SR to growth in weight. Refer to Figure 1 for a conceptual model depicting the specific pathways to be evaluated in the current project.

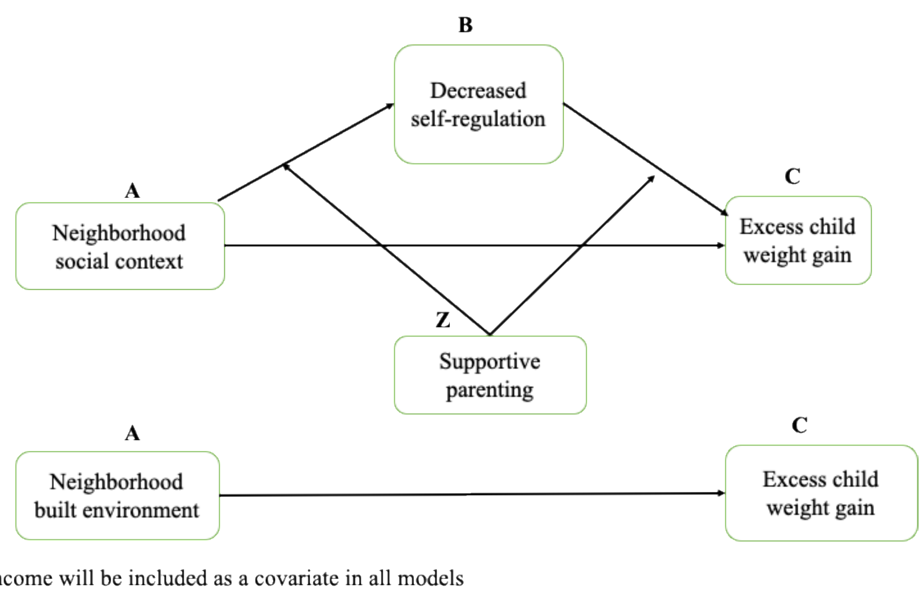

Figure 1. Proposed model of neighborhood influences on excess weight gain, operating through child self-regulation and moderated by supportive parenting

1.1 Literature Review

1.1.1 Conceptual perspectives linking childhood poverty to obesity

Childhood obesity is a widely prevalent public health concern (Ogden et al., 2016) that disproportionately affects children from low-income families (Alaimo, Olson, & Frongillo, 2001; Cameron et al., 2015). Pediatric obesity is associated with increased physical (Cote, Harris, Panagiotopoulos, Sandor, & Devlin, 2013; Sahoo et al., 2015) and mental (Waasdorp, Mehari, & Bradshaw, 2018) health problems in childhood that often persist through adolescence and into adulthood (Simmonds, Llewellyn, Owen, & Woolacott, 2016).

Child obesity, defined by the Centers for Disease Control and Prevention (CDC) as having a body mass index (BMI) at or above the 95^{th} percentile for age (Ogden et al., 2002), is caused by an individual's prolonged energy imbalance (i.e., a surplus of calories ingested compared to calories expended). However, this most basic explanation leaves much to be understood about etiological factors related to obesity and thus fails to address who is most susceptible to obesity. Similar to many behavioral health problems, risk for obesity is thought to be influenced by both biological and environmental factors, as well as interactions between them.

One established environmental risk factor for child obesity is exposure to poverty (Phipps, Burton, Osberg, & Lethbridge, 2006). The reasons for socioeconomic disparities in the prevalence of child obesity for middle- and high-income countries are complex and multifaceted (Lipina & Colombo, 2009), with research suggesting that the association between poverty and child obesity is likely operating through several, often co-occurring mechanisms, such as low levels of physical activity, lack of parental monitoring, and dietary content and habits (Gebremariam, Lien, Nianogo, & Arah, 2017; Lee, Harris, & Gordon-Larsen, 2009). These and other hypothesized mechanisms, which may appear at the level of the individual family (e.g., low family income affecting quality of food in the home) and/or the larger context in which families reside (e.g., low-income neighborhoods lacking grocery stores to purchase high-quality food and parks for physical activity), tend to focus on risk factors that may directly or indirectly affect children's energy balance for prolonged periods of time (Hilmers, Cullen, Moore, & O'Connor, 2012; Lee, 2012; McCurdy, Gorman, Kisler, & Metallinos-Katsaras, 2014). Such a chronic energy imbalance, where calories ingested exceed calories expended, may be attributable to excessive caloric intake, sedentary behavior, or both.

Other than the possible direct effects of the environment of poverty on children's energy intake or expenditure (e.g., food environment in the home, lack of green spaces in the neighborhood), another major theory of how poverty affects child weight focuses on the potential effect of poverty-related stress on children's weight regulation (Miller & Lumeng, 2018). Children living in poverty are frequently exposed to stressors in and outside of the home, some of which may be a direct result of poverty (e.g., residential crowding, a parent's financial stress), and some that commonly co-occur with poverty (e.g., life stressors such as exposure to parental mental illness, exposure to violence in the neighborhood). Such stressors have been found to be associated with deficits in children's self-regulatory skills (Evans & Kim, 2013) , and self-regulation has been both concurrently and longitudinally related to child overweight and/or obesity (Miller, Rosenblum, Retzloff, & Lumeng, 2016; Seeyave et al., 2009). In addition, poverty-related stress, particularly when it is related to family food insecurity, could also affect parenting quality in ways that adversely affect children's health behaviors (Bauer et al., 2015).

1.1.1.1 BMI, obesity, and child health

For children and teens from age 2 to 19 years of age, BMI is first calculated in the same manner as it is for adults (weight in kilograms / (height in meters)^2), and then transformed into an age- and gender-specific BMI percentile based on growth charts from the CDC. Children whose BMI falls between the 85th and 94th percentile are described as "overweight," and children whose BMI is at or above the 95th percentile are considered "obese." In the pediatric obesity literature, the outcome of interest is typically either BMI scaled as a continuous measure or categorical weight status (e.g., Graziano, Kelleher, Calkins, Keane, & Brien, 2013). As higher child BMI has been found to be related to medical complications associated with obesity (e.g., obstructive sleep apnea, musculoskeletal pain) in a linear, continuous manner (L. M. Bell et al., 2006), higher BMI is typically considered to represent greater risk for poor health outcomes. In addition, studies that assess BMI longitudinally often test trajectories of BMI growth, with more rapid BMI growth having been found to predict later overweight/obesity (Willers et al., 2012).

1.1.2 Neighborhood social context and child weight outcomes

It is crucial to consider children's broader environmental context to fully understand influences on children's psychological and physical development (Bronfenbrenner & Morris, 1998), including obesity. Neighborhood influences on child health have been a focus of considerable prior research (E. Chen & Paterson, 2006; Crespi, Wang, Seto, Mare, & Gee, 2015). Theories addressing the influence of neighborhood social context on child weight outcomes have tended to focus on how aspects of a neighborhood could be directly related to children's eating and physical activity (Keita, Casazza, Thomas, & Fernandez, 2009; Kimbro, Brooks-Gunn, & McLanahan, 2011).

1.1.2.1 The neighborhood food environment and child BMI

Living in an impoverished neighborhood may affect the food that children consume. Access to supermarkets that carry fruits and vegetables is often limited in low-income neighborhoods (i.e., "food deserts") (Gordon et al., 2011; Moore & Diez Roux, 2006). Specifically, living a farther distance from a grocery store has been found to be associated with higher child BMI in cross-sectional studies (Carroll-Scott et al., 2013; Fiechtner et al., 2015); greater proximity to grocery stores was also found to be protective against BMI gains in one longitudinal study (H. Chen & Wang, 2016). Living far away from a full-fledged grocery store may present an additional barrier to providing children with fresh food for financially stressed parents who may not have access to a vehicle (Bader, Purciel, Yousefzadeh, & Neckerman, 2010).

While low-income neighborhoods frequently lack a full-service grocery store, convenience stores and fast food restaurants, which tend not to stock fresh foods and produce, are often more plentiful (Hilmers, Hilmers, & Dave, 2012). Living in both food deserts and "food swamps," defined as four or more corner stores within a quarter mile vicinity of the home, has been found to be associated with adolescent girls' increased consumption of snack and dessert foods (Hager et al., 2017). In addition, some research has found that proximity to fast food restaurants (Carroll-Scott et al., 2013; Galvez et al., 2009) and convenience stores (Leung et al., 2011) is associated with higher BMI for children, perhaps especially for low-income children (Cobb et al., 2015).

In general, high-quality, longitudinal studies testing associations between food store accessibility and child BMI are lacking. The PHRESH study, a "natural experiment" in which researchers evaluated the impact of a full-service grocery store's opening in a low-income Pittsburgh neighborhood, found that the advent of a grocery store did not result in changes in adults' fruit and vegetable intake or adult BMI, but children were not evaluated in the study

(Dubowitz et al., 2015). A study with a similar design that was conducted in New York City (Elbel et al., 2015) found that a new supermarket was not related to children's dietary intake, but effects on children's BMI were not tested.

1.1.2.2 Neighborhood parks and child BMI

There is a small but growing literature to support an association between neighborhood green space and child weight status (Kim, Lee, Olvera, & Ellis, 2014). Studies using large, representative samples have found that more neighborhood greenness is longitudinally associated with children's lower BMI both in the U.S. (J. F. Bell, Wilson, & Liu, 2008) and in the U.K. (Schalkwijk, van der Zwaard, Nijpels, Elders, & Platt, 2017). Disparities in green space availability tend to fall along socioeconomic lines. Research suggests that across the U.S., high-poverty neighborhoods tend to have less green space coverage (Wen, Zhang, Harris, Holt, & Croft, 2013), and children living in low-income neighborhoods often have less access to outdoor recreation in general (R. E. Lee, Booth, Reese-Smith, Regan, & Howard, 2005; McKenzie, Moody, Carlson, Lopez, & Elder, 2013). The association between neighborhood park access and child BMI may be at least partially driven by physical activity, as neighborhood greenness and park area have been concurrently associated with greater outdoor playing time and physical activity for preschoolers and early school-age children (Grigsby-Toussaint, Chi, & Fiese, 2011; Roemmich et al., 2006). Pittsburgh Mayor Bill Peduto and nearly 200 other mayors have recently demonstrated their commitment to improving their cities' access to green spaces, with the goal of all residents living within a 10-minute walk to a park (the "10-minute walk" campaign by The Trust for Public Land). This national movement has gained momentum in part through mounting evidence that park access is important for both physical and mental health (Blanck et al., 2012).

Although some aspects of the neighborhood may not yet be associated with weight when children are very young, some facets of their neighborhoods may still influence the development of their early health behaviors. For example, physical activity is known to be somewhat stable throughout development (Malina, 1996), so when very young children are raised in neighborhoods that are less optimal for physical activity, this could have potential repercussions for weight management later in childhood and adolescence.

1.1.2.3 Neighborhood social context and child BMI

Social factors associated with neighborhood disadvantage may also be critical for understanding low-income children's risk for obesity, as experience of adversity in general has been found to be associated with obesity in early childhood (Suglia, Duarte, Chambers, & Boynton-Jarrett, 2012). Exposure to stress and adversity specific to the neighborhood (e.g., poverty, crime, violence) has been theorized to have repercussions for children's physical health, including obesity (Jutte, Miller, & Erickson, 2015; Morello-Frosch & Shenassa, 2006). There is also some empirical support for an association between neighborhood crime and census-derived neighborhood social disadvantage and child overweight/obesity in cross-sectional studies (Carroll-Scott et al., 2013; Grow et al., 2010; Miranda, Edwards, Anthopolos, Dolinsky, & Kemper, 2012).

Stress exposure may affect children's eating behavior, making children more likely to seek high-calorie foods (Michels et al., 2012; Michels et al., 2013). There is also some research suggesting that stress "turns on" genes associated with obesity risk (e.g., a gene that encodes an enzyme involved with glucose metabolism) (Kaufman et al., 2018). In their recent review paper outlining pathways from stress to early childhood obesity, Miller and Lumeng (2018) propose a theoretical model whereby early life stress exposures influence child self-regulation and child biology (e.g., HPA axis, autonomic nervous system), with both influencing child health behaviors that are subsequently associated with overweight and obesity. Although their model and review do not specifically include stress exposure at the neighborhood level, theoretically the model should apply to this pathway as well.

Although there is some theoretical basis for an association between neighborhood social disadvantage and child weight, findings from empirical studies have been mixed. A recent systematic review found that of five studies testing relationships between objectively measured neighborhood crime and BMI in low-SES black and Hispanic children, two found a significant, positive relationship (K. A. Johnson et al., 2019). Four of the studies were cross-sectional and all operationalized neighborhood crime differently. Further testing of the relationship between neighborhood social disadvantage and child weight using methodologically rigorous study designs is thus an important future direction for this area of research.

1.1.3 Neighborhoods and child self-regulation

1.1.3.1 Self-regulation in context

Before discussing pathways from facets of the neighborhood to children's self-regulation, it is essential to first elaborate on the construct of self-regulation itself. Self-regulation (SR) is crucial to a number of important outcomes, including academic achievement, prosocial behavior, and weight management/health. SR has been defined using a dual process model of "hot," reactive and appetitive processes (e.g., impulsivity) versus a "cool," reasoned cognitive system deployed in emotionally neutral contexts (Isasi & Wills, 2011; Metcalfe & Mischel, 1999).

There is a great deal of literature indicating that stress and adversity experienced in childhood may impair or disrupt the optimal development of children's SR systems (Evans & English, 2002; Lengua, Honorado, & Bush, 2007). Adversity could affect children's SR by stimulating the release of stress hormones (glucocorticoid, norepinephrine) that could compromise neural development in areas important for SR (Blair, 2010; McCoy, 2013). Although the majority of research on pathways from early life adversity to child SR have focused on specific exposures, typically within the family or household (Lengua et al., 2014; Sturge-Apple, Davies, Cicchetti, Hentges, & Coe, 2017), or broad contextual influences such as exposure to poverty (Thompson, Lengua, Zalewski, & Moran, 2013), there is also some evidence that stressors within the neighborhood may be independently associated with child SR (Pratt, Turner, & Piquero, 2004; Roy, McCoy, & Raver, 2014).

1.1.3.2 Neighborhood social context and child self-regulation

The neighborhood social context refers to both the socioeconomic standing of the families who reside in a given neighborhood, and also the social processes, relationships, and interactions among its residents (Suglia et al., 2016). The neighborhood social context is typically measured using indices of residents' socioeconomic status (e.g., median family income, education levels, residential crowding) and sometimes also includes measures of safety, belongingness, and cohesion within a neighborhood (Callahan, Scaramella, Laird, & Sohr-Preston, 2011). Prior research on the importance of children's neighborhood context has focused on such outcomes as children's academic achievement (Milam, Furr-Holden, & Leaf, 2010) and behavior problems (Ingoldsby et al., 2006), as well as changes in areas of the brain linked to executive functioning (Whittle et al., 2017). The relationship between neighborhood social context and poor child outcomes is thought to be mediated in part by children's response to exposure to a variety of stressors (Hackman, Betancourt, Brodsky, Hurt, & Farah, 2012) that are more common in low-income neighborhoods (Harrell, Langton, Berzofsky, Couzens, & Smiley-McDonald, 2014), including violence (Guerra, Rowell Huesmann, & Spindler, 2003), exposure to drug/alcohol use

(Schaefer-McDaniel, 2009), and physical disorder (Gold & Nepomnyaschy, 2018). Another proposed pathway for associations between the neighborhood social context and children's development is through "collective efficacy" (Ichikawa, Fujiwara, & Kawachi, 2017; Leventhal & Brooks-Gunn, 2003). Collective efficacy within a neighborhood refers to a neighborhood's social cohesion and the willingness of its residents to intervene for the common good (Sampson, Raudenbush, & Earls, 1997). Collective efficacy is often measured using questionnaires that assess levels of cohesion and engagement (i.e., the extent to which neighbors can be counted on to intervene or help; feeling like neighbors share similar values), and belongingness (i.e., how well one feels that they fit into the neighborhood) within a community. Theoretically, an absence of neighborhood collective efficacy could influence children's optimal development through parents' sense of a lack of social support and trust in their community (Donnelly et al., 2016; Odgers et al., 2009), thus having downstream effects on their parenting of young children (Simons, Simons, Burt, Brody, & Cutrona, 2005).

Fewer studies have tested associations between neighborhood social environment and child SR, even though SR in early childhood has been a robust predictor of positive outcomes later in childhood, including learning ability (Blair, Ursache, Greenberg, & Vernon-Feagans, 2015) and mental (King, Lengua, & Monahan, 2013) and physical health (Bub, Robinson, & Curtis, 2016). As described above, child SR is a broad construct that is often separated into the two components of "hot" and "cool" SR. Prior research suggests that children's changes in residence from low- to high-poverty neighborhoods and exposure to community violence are associated with lower cool SR at school-age (Roy et al., 2014). There is also some evidence for associations between a neighborhood's social context (census-based measures) and child SR, based on parent (Gibson, Sullivan, Jones, & Piquero, 2010) and adolescent reports of SR (Pratt et al., 2004; Teasdale & Silver, 2009) (questionnaire measures of SR typically include aspects of both hot and cool SR).

One limitation of prior research is that it remains unclear whether neighborhood influences on child SR are unique to the "cool," executive function domain or whether neighborhood context is also associated with increases in "hot" impulsive and emotional processes. In the extant literature on neighborhoods and child SR, an additional issue is that constructs like "self-control" and "impulsivity" are sometimes conceptualized as dispositional traits (Lynam et al., 2000), even though there is considerable research indicating that the development of child SR is influenced by social context (Li-Grining, 2007). Further study of the effects of communities' social contexts on different domains of child SR could be important for understanding disparities in child development and health outcomes across variations in neighborhood quality (Jutte et al., 2015).

1.1.4 Theoretical models and empirical work on self-regulation and child weight outcomes

One such health outcome that has particular relevance to children is obesity. Both theoretical work and empirical research suggest that suboptimal child SR is associated with individual differences in child weight. Theoretically, appetite regulation and adjustment of eating behavior based on hunger and satiety cues is thought to be one of the earliest forms of child SR (Fox, Devaney, Reidy, Razafindrakoto, & Ziegler, 2006). Empirically, SR deficits have consistently been found to predict child overweight and obesity (Francis & Susman, 2009; Seeyave et al., 2009). There also is some theoretical and empirical support for relationships between both hot and cool SR in relation to child weight outcomes (Miller, 2016).

Associations between hot SR and child weight outcomes are theorized to be driven in part by mechanisms including emotional overeating (Pieper & Laugero, 2013) and poor emotion regulation (Miller, 2016). With respect to the specific relationship between emotion regulation and food, children may learn from an early age that eating is an effective strategy for coping with negative emotion (Blissett, Haycraft, & Farrow, 2010). Food stimulates neural reward pathways (Norgren, Hajnal, & Mungarndee, 2006), and high-calorie, palatable foods in particular could be used as a reliable way to experience positive emotion, or handle distress, that is consistently reinforced over time (Brown, Schiraldi, & Wrobleski, 2009). Hot SR in early childhood is typically measured using tasks that require children to wait for an item that is inherently rewarding (e.g., a cookie, a wrapped gift) by controlling their impulse to immediately consume or interact with the item (Carlson, 2005). Observational hot SR tasks have been consistently found to predict child BMI in longitudinal studies (Graziano et al., 2013; Seeyave et al., 2009; Tandon, Thompson, Moran, & Lengua, 2015).

There is also some theoretical rationale to support a relationship between cool SR and child weight outcomes. Executive functioning and the more cognitive domains of SR (e.g., planning, attention, working memory) could influence children's ability to plan to eat healthily and engage in physical activity in the long-term (Miller, 2016). Cool SR could become particularly important beginning in middle childhood, as children start to make choices regarding health behaviors such as physical activity and food intake more independently (Bassett, Chapman, & Beagan, 2008). Specifically, inhibitory control and attention shifting could be important aspects of cool SR for child weight outcomes, as both could influence the ability to make more nutritionally sound food choices when tempted by less healthy options (Nijs, Muris, Euser, & Franken, 2010). Empirically, there also is some support for a relationship between cool SR and child weight. One study found that poor attention shifting, a component of cool SR, predicted higher BMI for school-age children one year later (Groppe & Elsner, 2015), with another study finding that obese school-age children concurrently exhibited decreased performance on an inhibition task compared with normal weight children (Tsai, Chen, Pan, & Tseng, 2016). However, in contrast to the literature on hot SR and child weight, there is less empirical support regarding the contribution of cool SR to child weight. A recent systematic review that included longitudinal studies testing associations between child SR and later weight found that there were more studies that tested hot (n = 7) rather than cool (n = 4) SR, with stronger effect sizes for hot SR (Hails, Zhou, & Shaw, 2019).

1.1.5 Self-regulation as a mediator of the relationship between poverty and child weight

As pathways in the association between children's exposure to poverty and later weight outcomes are still not well understood, there is a critical need to investigate and test potential mechanisms underlying such associations at multiple levels of influence on the child (e.g., how children's own behavioral styles, families, and aspects of their communities affect their maintenance of a healthy weight). If such mediators could be identified, they could serve as targets for future preventive interventions. Child SR could serve as one such mechanism by which poverty-related risk is associated with obesity. Although there is evidence for small to moderate effect sizes in pathways from poverty to SR and SR to weight (Hails et al., 2019), only one study has tested SR as a mediator in the association between poverty-related stress exposure and weight outcomes (Evans et al., 2012). In that longitudinal study, Evans and colleagues found that the association between cumulative risk (an index that included family poverty) at age 9 and weight gain from age 9 to 13 was largely explained by SR at age 9, measured using a food delay of gratification task (i.e., hot SR).

In addition, SR has been found to improve with school-, family-, and individual-based interventions during multiple developmental periods (S. L. Johnson, 2000; Raver et al., 2011;

Riggs, Greenberg, Kusché, & Pentz, 2006; Shelleby et al., 2012). Specifically, the Family Check-Up, a parenting intervention provided annually, is associated with growth in children's SR from toddlerhood to early school-age (Chang, Shaw, Dishion, Gardner, & Wilson, 2014). The Chicago School Readiness Project (CSRP), a school-based intervention for preschool children in Head Start to promote school readiness, has also been found to improve children's self-regulation skills (Raver et al., 2011), Thus, SR represents a viable target for obesity prevention and intervention for low-income children.

1.1.6 Supportive parenting as a moderator of neighborhood social context on child self-regulation and weight

The quality of the caregiving environment in children's homes is another critical piece of a child's ecology (Zaslow et al., 2006). Although the focus thus far has been on more distal correlates of poverty (i.e., neighborhood influences), it would be ecologically invalid to ignore the effects of parenting on influencing the development of child SR in the context of poverty.

Parenting is often conceptualized as a mediator in the association between poverty and child adjustment. As outlined in the family stress model, financial strain and neighborhood violence are thought to influence child outcomes by compromising parental mental health, parenting practices, and parenting efficacy (Conger & Elder, 1994). However, there is also a great deal of research suggesting that parenting is an important protective factor in the context of children's exposure to adversity. Specifically, parenting (e.g., monitoring) has been found to be protective against the development of child externalizing problems in the context of neighborhood deprivation in a sample of low-income preschool-age children (Supplee et al., 2007).

With regard to protective effects on children's SR specifically, supportive parenting is thought to attenuate the relationship between poverty-related risk and SR, while less supportive or unresponsive parenting may exacerbate the negative effects of family or neighborhood poverty on child SR. By providing a predictable, responsive home environment, parents may be able to protect children from the potentially harmful effects of stress in the neighborhood outside the home. Supportive parents may also be better equipped to help young children cope with stressors and trauma (Scheeringa & Zeanah, 2001). Empirically, cumulative risk has been found to be unrelated to teacher-rated child social competence (a scale that included child self-control) when maternal scaffolding was high (Ruberry, Klein, Kiff, Thompson, & Lengua, 2018). In addition, supportive parenting has been found to have a protective effect on social competence for school-age children exposed to violence in the community (Krenichyn, Saegert, & Evans, 2001).

In addition, parenting could also be an important moderator in the association between child SR and weight outcomes. That is, supportive parenting, particularly monitoring, could serve as a protective factor for child weight gain in the context of low SR. Theoretically, more supportive parents would be able to set limits on children's eating and offer increased support to children to help develop greater SR of appetite. There is some empirical work to support such a perspective in which parenting moderates the association between child SR and weight outcomes. Mothers' score on a scale of observed parenting that encompassed both parental sensitivity and expectations for child self-control was found to be protective against BMI gains from age 4 to 15 years for boys with low SR (Connell & Francis, 2014), and supportive parenting has been found to attenuate the association between toddlers' hot SR and weight in early childhood (Moding et al., 2018).

1.2 The Current Study

Although there is a relatively large body of prior work establishing associations between the neighborhoods in which children reside and their health outcomes (Sellström & Bremberg, 2006), including risk for obesity (Carroll-Scott et al., 2013), few studies have tested the specific aspects of the neighborhood that may underlie these effects and how family and child-level factors may mediate or moderate associations between neighborhoods and child weight outcomes. First, the current study aims to assess longitudinal relationships between specific aspects of the neighborhood environment in early childhood (the "built" environment and neighborhood social context) using Geographic Information Systems (GIS), census data, and parent reports of neighborhood quality and child weight among a sample of low-income children from child ages 2 to 10.5. GIS, a tool for mapping and analyzing spatial data, is used to operationalize and test associations between the neighborhood built environment variables and child weight outcomes. Specifically, the built environment variables of interest in the current study reflect density of food outlets (grocery stores, convenience stores, restaurants) and park space within a half-mile radius of children's homes. Neighborhood social context encompasses measures related to neighborhood residents' poverty and social class, as well as perceptions of danger and social cohesion within the community. Second, child SR, using both hot and cool observed measures, is tested as a mediator of associations between both neighborhood factors and child weight. Third, supportive parenting is tested as a moderator of associations between neighborhood context and child SR and between child SR and child weight outcomes.

The following hypotheses are tested:

Hypothesis 1: Based on research suggesting that the neighborhood food environment (Cobb et al., 2015; Schafft, Jensen, & Hinrichs, 2009) and children's access to parks (J. F. Bell et al., 2008; Duncan et al., 2014) are associated with greater risk for child overweight/obesity, it is anticipated that low levels of resources in the neighborhood built environment (i.e., food store access, park space) in early childhood (ages 2 to 4) will be significantly associated with more rapidly increasing BMI from ages 5 to 10.5 and higher BMI at age 10.5.

Hypothesis 2: Based on research suggesting that neighborhood crime and social disadvantage are associated with child overweight/obesity (Carroll-Scott et al., 2013; Grow et al., 2010), it is expected that deprived neighborhood social context (i.e., census-based measures of neighborhood SES, parent report of neighborhood safety) in early childhood will be significantly associated with more rapidly increasing BMI from ages 5 to 10.5 and higher BMI at age 10.5.

Hypothesis 3: Based on research suggesting that high-poverty neighborhoods and exposure to community violence are associated with impaired development of children's SR (Roy et al., 2014), more deprived neighborhood social context in early childhood is expected to be negatively associated with children's observed SR at age 5. An exploratory analysis also tests for differences in the strength of associations between neighborhood social context in predicting hot versus cool SR.

Hypothesis 4: Based on research suggesting that SR deficits are associated with higher child BMI (Graziano et al., 2013; Tsai et al., 2016), it is anticipated that higher levels of children's observed SR at age 5 will be associated with less rapidly increasing BMI from ages 5 to 10.5 and lower BMI at age 10.5. An exploratory analysis also tests for differences in the strength of associations between hot versus cool SR in predicting child BMI.

Hypothesis 5: It is expected that the association between more deprived neighborhood social context in early childhood and more rapid BMI growth from ages 5 to 10.5 and BMI at age 10.5 will be mediated by children's SR at age 5.

Hypothesis 6a: Based on research suggesting that supportive parenting may have a buffering effect on the relationship between early exposure to adversity and child SR (Ruberry et al., 2018), and on the association between child SR and rapid weight gain in early childhood (Moding et al., 2018), supportive parenting assessed at ages 3 and 4 is expected to moderate pathways between neighborhood social context and SR and between SR and BMI growth/BMI during middle childhood. Specifically, higher levels of supportive parenting are expected to attenuate associations between adverse neighborhood social context and SR, and between lower SR and higher child BMI.

Hypothesis 6b: An exploratory analysis also tests the moderated mediation model described above, with neighborhood built environment substituted for neighborhood social context as the independent variable. Although there is some preliminary evidence that neighborhood green space may be associated with fewer emotional problems for low-income toddlers (Flouri, Midouhas, & Joshi, 2014), the relationship between parks and other aspects of the built environment and child SR requires greater investigation. As there is currently insufficient literature supporting a direct association between the neighborhood built environment and child SR, specific predictions regarding the existence of associations between the built environment and child SR and the potential moderating influence of parenting are not hypothesized.

2.0 METHOD

2.1 Participants

Participants in the current study were drawn from the Early Steps Multisite Study, a prospective, longitudinal study of children who were identified as being at risk for behavior problems. The sample consists of 731 children and their primary caregivers who were recruited from Women, Infants, and Children (WIC) Nutritional Supplement Centers when children were two years old. Children were identified as being at risk for behavior problems if, based on screening measures (at or above 1 SD above normative ranges), they met criteria on two out of three domains, including socioeconomic risk (i.e., low education and family income), family problems (e.g., maternal depression, substance use), and child behavior (e.g., conduct problems).

Participants were drawn from three sites: Pittsburgh, PA (37%), Charlottesville, VA (26%), and Eugene, OR (37%). Across the three sites, families lived in a total of 270 census tracts at baseline (age 2). The sample was racially and ethnically diverse, with children from the following racial groups: 50.1% European American, 27.9% African American, 13.0% biracial, and 8.9% other races. Thirteen percent of the sample self-identified as Hispanic. The sample was predominantly low-income, with more than two thirds of families reporting an annual income of less than $20,000 when they were enrolled in the study (2002-2003).

2.2 Procedures

Data were collected at home visits when the target child was 2, 3, 4, 5, 7.5, 8.5, 9.5, and 10.5 years old. Primary caregivers (mostly mothers) were consented for participation in the study by trained research assistants. As this was an intervention study, participants were randomly assigned to the Family Check-Up, a parenting intervention that targets family management practices in early childhood to prevent problem behavior (Dishion et al., 2008). Assessment procedures, which preceded intervention at each assessment wave, were identical for families in the control and intervention groups. Home assessments consisted of both structured and unstructured activities for the target child and primary caregiver (PC) and typically lasted approximately 2.5 hours. During early childhood assessments (i.e., ages 2 to 5), the examiner introduced the child to a variety of age-appropriate toys for the child to play with for 15 minutes while the PC completed a series of questionnaires. After the free play, the child and PC completed a series of interaction tasks (e.g., clean-up, delay of gratification, teaching tasks) that varied slightly depending on the child's age. Children also completed a series of tasks assessing effortful control (referred to as SR in the current study). During middle childhood (i.e., ages 7.5 to 10.5), observational tasks primarily focused on parent-child discussion tasks rather than clean-up, delay of gratification, and teaching tasks. In addition, beginning at age 9.5 children were asked to report on their antisocial behavior (age 9.5 and 10.5) and symptoms of psychiatric disorders (age 10.5). Children were also administered subtests from the Woodcock-Johnson III at ages 7.5 and 8.5. PCs were compensated for their participation in the study at each assessment, receiving $100 for completing the age 2 home assessment, $120 at age 3, $140 at age 4, $160 at age 5, $180 at age 7.5, $90 for a brief assessment at age 8.5, $200 for age 9.5, and $150 for age 10.5. Target children participating in the study received $15 for the assessments at age 7.5 and 8.5, $35 at age 9.5, and $50 at age 10.5.

2.3 Intervention Protocol: The Family Check-Up (FCU)

The FCU is a brief, home-based, family-focused intervention based on motivational interviewing techniques and focused on improving parenting skills for families with children identified as at risk for early behavior problems (Dishion et al., 2008). The FCU operates using a health maintenance model where providers periodically (usually annually) re-engage with the family to assess their current level of need to proactively prevent child maladjustment.

After the baseline assessment at age 2, the PC and target child were randomly assigned to the intervention or treatment as usual condition, with 50% of families in the intervention group. At age 2, all families first completed the assessment before they were randomized. Families in the intervention group were then scheduled to meet with a family coach for two more sessions, with the possibility of follow-up sessions if the family so desired. The two sessions consisted of an initial interview to meet the family, followed by a feedback session. Families also had the option to participate in follow-up treatment sessions with the family coach. Parents were offered the FCU at six assessments after age 2 (at ages 3, 4, 5, 7.5, 8.5, and 9.5). They received a $25 gift card for completing the feedback session at each year. For purposes of the current study, as intervention status is not an issue of interest, intervention status was used as a covariate in all multivariate models.

2.4 Measures

2.4.1 Neighborhood social context

2.4.1.1 Census-derived neighborhood social disadvantage

Census-derived neighborhood social disadvantage at ages 2, 3, and 4 was calculated using U.S. decennial census data at the block group level. A census block group is the smallest geographical unit available from the U.S. census, with a population of between 600 and 3,000 people. Neighborhood social disadvantage was assessed using the address provided at each assessment using data from the 2000 decennial census. A composite variable of neighborhood social disadvantage was created by averaging eight census block group level variables, as recommended by Wikström and Loeber (2000): percent of unemployed adults, percent of households receiving public assistance, percent of households headed by a single mother, percent of households with an annual income of less than $30,000 per year, percent of households below the federal poverty line, percent of families in crowded housing (i.e., more than one person per room), percent of men in management and professional occupations (reverse coded), and percent of adults earning less than a high school education. The composite variable was then converted into z scores. The census-derived neighborhood social disadvantage score was calculated for families' addresses at ages 2, 3, and 4. The z scores for all three ages were then averaged. Social disadvantage was also calculated for families' addresses at age 8.5, again based on data from the 2000 decennial census.

2.4.1.2 Perceived neighborhood danger and cohesion

Primary caregivers completed the 20-item Me and My Neighborhood Questionnaire (MMNQ; Pitt Mother & Child Project, 2001) at assessments when children were 2, 3, and 4 years old. The MMNQ assesses parents' perceptions of their neighborhoods in two major domains: affiliation/cohesion and violence/danger. The dangerousness subscale, which consists of 15 items (e.g., "family member was robbed or mugged in my neighborhood"; "I saw or heard about a shooting gallery near my home"), was used to measure perceived neighborhood danger. The 5-item neighborhood cohesion subscale, which includes items such as "living in this neighborhood gives me a sense of belonging," and "the friendships and connections I have with people in my neighborhood mean a lot to me," was used to measure perceived neighborhood cohesion. PCs rated each item on a 4-point scale, from 1 ("never") to 4 ("often") (α for dangerousness subscale ranged from .86-.88 for ages 2-4; α for cohesion subscale ranged from .85-.86). MMNQ dangerousness and cohesion scores for ages 2, 3, and 4 were standardized and averaged across the three ages. MMNQ dangerousness and cohesion scores collected from primary caregivers when children were 8.5 years old were also included as covariates in sensitivity analyses.

2.4.1.3 Family socioeconomic status

Information about family SES was collected as part of a demographics questionnaire with PCs at each assessment. Family income, PC education, and number of people in the home were included in all models. Annual income was assessed by asking the parent to indicate the range in which their family income fell on a scale from 1 to 13 (e.g., where 1 = $4,999 or less, 2 = $5,000 to $9,999, 3 = 10,000 to $14,999). The income measure for the current study was created by taking the middle value of each range to create a specific value for annual family income. Each SES variable represented the average score across ages 2, 3, and 4.

2.4.2 Neighborhood built environment

2.4.2.1 Food environment

A database of food retailers in the metro area of each site from 2005 was provided by ReferenceUSA, a national commercial database of businesses in the United States. The list of food retailers from 2005 corresponds to the year in which most target children in the study were 3 years old, representing the middle of the 2-4 age range for the early childhood definition used in the current study. ReferenceUSA data are compiled from telephone directories, annual reports, government data, news outlets, and the U.S. Postal Service, and are updated monthly. The use of ReferenceUSA and other commercial databases (e.g., Dun & Bradstreet) is common in the food environment and obesity literature (Bower, Thorpe, Rohde, & Gaskin, 2014; Truong, Fernandes, An, Shier, & Sturm, 2010) and has, in some studies, been validated by ground-truthing (i.e., physical verification of the locations of food outlets in the database) (Gustafson, Lewis, Wilson, & Jilcott-Pitts, 2012). However, there are some important limitations to the use of commercial databases to identify food establishments. A systematic review found that attempts to verify location and establishment type via ground-truthing have not been consistently successful (Fleischhacker, Evenson, Sharkey, Pitts, & Rodriguez, 2013). Nevertheless, the same review found that commercial databases had relatively high sensitivity, with coefficients for the correlation between ground-truth and commercial data sources ranging from .60-.96, with commercial data sources found to be more sensitive than government sources and local directories. Moreover, another systematic review found no evidence for differences in the validity of commercial databases across neighborhoods (Lebel et al., 2017).

ReferenceUSA provides North American Industry Classification System (NAICS) codes, a system used by federal agencies to classify business establishments, for all food retailer listings.

The following NAICS codes were included in the ReferenceUSA dataset: 445110 (supermarkets and other grocery (except convenience) stores), 452311 (warehouse clubs and supercenters), 445120 (convenience stores), 445230 (fruit and vegetable markets), and 722513 (limited service restaurants). Supermarkets, warehouse clubs, and fruit and vegetable markets were coded as "healthy" food retailers and convenience stores and limited service restaurants coded as "less healthy" food retailers based on CDC definitions (CDC, 2011).

The number of "healthy" food retailers and the number of "less healthy" food retailers within an 800-meter network buffer of children's addresses at each age (2, 3, and 4 years) were computed. The number of "healthy" food retailers and "less healthy" food retailers within the buffer were then standardized and averaged across the three ages, with separate counts for each type of food retailer.

The 800m buffer was selected because prior work suggests that 800m (i.e., half mile) is perceived to be an appropriate walking distance for children (Timperio, Crawford, Telford, & Salmon, 2004). Rather than counting the number of food retailers within an administratively defined boundary (e.g., census tract), using an estimate of the density of food retailers within a specified buffer is thought to be more ecologically valid (Charreire et al., 2010), as people do not typically consider census tract borders when deciding where to grocery shop. Although there is no consensus on the buffer size that is most appropriate, a review found that buffers of one mile and .5 miles were the most common in the food environment literature (Gamba, Schuchter, Rutt, & Seto, 2015).

The number of "healthy" food retailers and the number of "less healthy" food retailers within an 800-meter buffer of children's addresses at age 8.5 were also calculated for inclusion as an additional covariate in sensitivity analyses. A list of food retailers from 2010 (when most children in the study were 8.5 years old) was provided by ReferenceUSA.

2.4.2.2 Parks

Parks data are from Environmental Systems Research Institute (ESRI®) Data and Maps 2005 (ESRI, 2005), an annual set of map data from Tele Atlas North America, Inc., that contains geospatial datasets with features of the built environment. The ESRI Data & Maps—Data & Maps and StreetMap USA DVD was used for the current study. The U.S. Parks layer contains parks and forests within the U.S. at national, state, and local levels. Again, the year 2005 was selected as it represents the year in which most children in the study were in the 2-4 age range. Park space (in acres) within an 800m network buffer of children's homes was calculated based on children's addresses at ages 2, 3, and 4 years. The values were then standardized and averaged across the three ages. A 800m buffer has also been found to be appropriate for assessing children's access to parks and green space (Kim et al., 2014). Park space within an 800m buffer was also calculated based on children's addresses when they were 8.5 years old. Park data for this analysis came from the ESRI "USA Parks" layer, created in 2010 (see Table 1 for a summary of measures including the timing of data collection).

Table 1. Summary of measures with timing of data collection

Measure	Child age	Year of assessment	Data source, year (if applicable)
Census-derived neighborhood social disadvantage, early childhood	2, 3, 4 (average)	2003-2007	U.S. decennial census, 2000
Neighborhood food environment, early childhood	2, 3, 4 (average)	2003-2007	ReferenceUSA, 2005
Neighborhood parks, early childhood	2, 3, 4 (average)	2003-2007	ESRI Data and Maps, 2005
Neighborhood danger and cohesion, early childhood	2, 3, 4 (average)	2003-2007	Me and My Neighborhood Questionnaire
Supportive parenting	3, 4 (average)	2005-2007	Observations using HOME, RACS, COIMP
Child self-regulation	5	2006-2008	Effortful control behavioral battery
Census-derived neighborhood social disadvantage, school-age	8.5	2009-2012	U.S. decennial census, 2000
Neighborhood food environment, early childhood	8.5	2009-2012	ReferenceUSA, 2010
Neighborhood parks, early childhood	8.5	2009-2012	ESRI “USA Parks” layer, 2010

2.4.2.3 Child self-regulation

At the age 5 assessment, children were administered several tasks from an established behavioral battery designed to measure effortful control: the Tower task, the Wrapped Gift task, and the Draw-a-Star task (Kochanska, Murray, & Harlan, 2000). The Tower and Wrapped Gift tasks were both videotaped and coded by trained undergraduate research assistances. Inter-rater reliability, established on 16% of the tapes, ranged from .97 to 1.00.

In the Tower task, the child was asked to take turns with the examiner to build a tower with 20 blocks. The examiner was very slow in taking his or her turn, resulting in frustration on the part of the child. The number of blocks that the child placed was divided by the total number of blocks placed (coded from the videotaped interaction) and the mean score across the three trials was calculated ($\alpha = .60$).

In the Wrapped Gift task, the child was instructed to sit with his or her back facing away from the examiner while the examiner noisily wrapped a gift for the child. The child was told not to look while the examiner wrapped the gift for 60 seconds. The examiner then told the child to wait, without peeking at the gift, while the examiner left the room to “find a bow” for the gift (120 seconds). The child’s behaviors, including frequency of peeking, latency to first peek (in seconds), and whether the child touched or opened the gift (coded on a 3-point scale where 0 = child did not touch gift, 1 = child touched but did not open gift, and 2 = child touched and opened gift) were coded. The child’s frequency of peeking and the child’s touching of the gift were reverse-coded. Scores on each of the three variables were standardized and aggregated into a single composite (α = .88).

Finally, in the Draw-a-Star task, the examiner asked the child to draw a star on top of a picture of a star and to be careful to stay between the lines. The task included three trials: baseline, fast, and slow. In the fast trial, the examiner told the child to draw the star as quickly as possible, and in the slow trial, the examiner told the child to draw as slowly as possible. For all three trials, the examiner calculated and recorded the time it took (in seconds) for the child to draw the star and the number of times that the child crossed the lines while drawing it (i.e., number of errors). The examiner calculated the difference (in seconds) between the fast and slow trials. Standardized scores for the time difference were calculated.

Scores for the three SR tasks were used to create a latent factor for child SR at age 5. In addition, exploratory analyses tested for differences in associations between neighborhood social context and hot versus cool SR and for hot versus cool SR in predicting child BMI outcomes. For these analyses, the Wrapped Gift and the Draw-a-Star tasks were used as the measures of hot and cool SR, respectively.

2.4.2.4 Supportive parenting

Supportive parenting was assessed from three different observed measures of parenting when children were 3 and 4 years old. First, the research assistants who conducted the home visit completed an abridged and modified version of the Home Observation for Measurement of the Environment (HOME: Bradley, Corwyn, McAdoo, & García-Coll, 2001). Thirteen items from the HOME, all based on observations rather than gathered through an interview with parents, that reflected proactive parenting/structuring of child's environment (e.g, "parent structures child's play periods") or parental warmth/positive reinforcement (e.g., "parent caresses or kisses child at least once") were summed (α = .76) to create the first supportive parenting subscale. Second, a team of trained research assistants micro-coded videotaped observations of parents' use of positive behavior support using the relationship affect coding system (RACS; Petersen, Winter, Jabson, & Dishion, 2008). The RACS is a micro-social coding system that reflects verbal, physical, and affective dimensions of parent and child behavior. The duration of positive and neutral engagement between the parent and child, coded using the RACS, comprised the second subscale of supportive parenting. Finally, the research assistant who completed the RACS also completed a macro-social rating of parenting using the Coder Impressions Inventory (COIMP; Dishion, Hogansen, Winter, & Jabson, 2004). For the current study, a composite of 11 items that reflected proactive parenting/effective behavior management (e.g., "parent sets limits without using aversive control") or parental warmth (e.g., parent shows affection for TC) was used (α = .84) for the third and final supportive parenting subscale.

A confirmatory factor analysis indicated that these three subscales, the HOME, the RACS, and the COIMP, form a single latent construct (Waller et al., 2015). Thus, scores on the three indices were standardized and summed into a composite to form the supportive parenting variable used in the current study (α = .63). The composite variables for ages 3 and 4 were standardized and averaged across the two ages.

2.4.2.5 Harsh parenting

Harsh parenting was added to the moderator analysis involving supportive parenting as a sensitivity test. Like supportive parenting, harsh parenting was assessed from videotaped observations of parent-child interactions when children were 3 years old using the following six items from the Coder Impressions Inventory: "parent gives developmentally inappropriate reasons for desired behavior change," "parent displays anger/frustration/annoyance with the child," "parent criticizes/blames child for family problems," "parent uses physical discipline," "parent actively ignores/rejects the child," and "parent makes statements/gestures indicating child is worthless." In addition, the average duration of sequences in which parents expressed negative verbal, directive and physical behavior was coded using RPC scores. Individual items from the COIMP and RPC were standardized and summed to create a composite of harsh parenting (Cronbach's α = .75).

2.4.2.6 Pubertal development

The Pubertal Development Scale (PDS; Petersen, Crockett, Richards, & Boxer, 1988), a self-report measure that was administered to children when they were 10.5 years old, was used to measure pubertal development. In the current study, the pubertal development variable was calculated based on the average of responses to five questions from the PDS, which assess the following: growth in height, pubic hair, and skin change for boys and girls, facial hair growth and changes in voice for boys only, and breast development and menarche for girls only.

2.4.2.7 Child BMI

Examiners measured children's height and weight at home visits when children were 5, 7.5, 8.5, 9.5, and 10.5 using a stadiometer and an electronic scale. Children were asked to remove their shoes and any extra clothing (e.g., large sweatshirts) before measurement. Children's height and weight were each measured twice and the averages were retained. BMI was calculated using the ratio of weight (kg) over height (m) squared. For the outcome of BMI at age 10.5, BMI values were converted into normed z-scores (BMIz) based on the CDC's age- and sex-specific growth charts (Kuczmarski et al., 2000). In addition, gender- and age-based percentiles and categorical weight outcomes at age 10.5 (normal weight, overweight, and obese) were calculated for descriptive purposes. For the growth curve analysis, raw BMI was used, as there is evidence that raw BMI is a better measure of BMI change than standardized BMI values (Cole, Faith, Pietrobelli, & Heo, 2005).

2.4.2.8 Covariates

Parent report of externalizing symptoms at age 2 using the Child Behavior Checklist (CBCL; Achenbach & Rescorla, 2000) was included as a covariate in analyses to account for child effects on parenting behaviors. The family's intervention status was also included as a covariate. Other covariates included the number of times the child's family moved residences from age 2 to age 10.5, child race/ethnicity, child gender, and project site (Charlottesville, Eugene, or Pittsburgh).

2.4.3 Sensitivity analyses

After initial models were conducted, several additional variables were added one at a time as covariates to determine whether their inclusion changed relationships between the primary independent variables of interest and the outcome variables. First, neighborhood variables based on children's addresses at school-age (age 8.5) were added to rule out the possibility that findings were driven by later assessments of neighborhood characteristics. Second, a measure of pubertal development administered at age 10.5 was added. There is some evidence that exposure to poverty is associated with early sexual maturation (Obeidallah, Brennan, Brooks-Gunn, Kindlon, & Earls, 2000), and pubertal timing and rate of weight gain are closely linked (Wang, Dinse, & Rogan, 2012). Additionally, a measure of harsh parenting was added to determine whether such a moderating association is specific to supportive parenting or also accounted for by harsh parenting.

2.5 Data Analytic Strategy

First, participants' addresses and addresses for food retailers were geocoded using ArcMap, version 10.6.1 (Redlands, California, http://esri.com/index.html). Food retailers within the 800m network buffer around children's homes were counted and the acreage of park space within the buffer was calculated. Data on both food retailers and parks were from the year 2005 (i.e., the U.S. parks shapefile and the lists of food retailers), which corresponds to the year in which most of the children in the sample were 3 years old. Study visits at ages 2, 3, and 4 all took place between 2003 and 2007, and 2005 falls in the middle of this range. There is some prior work suggesting that locations of parks and food retailers are relatively stable over periods of several years

(Dadvand et al., 2014; Filomena, Scanlin, & Morland, 2013). Children's addresses were geocoded based on their residences at ages 2, 3, and 4 (i.e., where they lived between the years of 2003 and 2007), and mapped onto built environment data from 2005.

Neighborhood social context variables were included in the model as separate independent variables, as inter-correlations between variables were relatively low (r = .40 for census-derived neighborhood social disadvantage and perceived neighborhood danger; r = -.26 for perceived neighborhood danger and perceived cohesion; r = -.17 for census-derived neighborhood social disadvantage and perceived neighborhood cohesion). The built environment variables (i.e., food and parks data) were also analyzed separately, as these two aspects of the built environment are likely associated with child weight through different mechanisms.

All hypotheses were tested in Mplus 7.4 (Muthén & Muthén, 2012) using structural equation modeling (SEM) with full information maximum likelihood estimation. Model parameters were estimated using the maximum likelihood estimator with robust standard errors (MLR). An intraclass correlation coefficient (ICC) was used to evaluate the extent to which children living in the same neighborhoods (operationalized in the current study as census tracts) have similar BMI at age 10.5. The ICC was calculated to be 5.4%, and an ICC of greater than or equal to 2% is indicative of potential higher order effects (Theall et al., 2011). Therefore, a cluster adjustment was included in the model (McNeish, Stapleton, & Silverman, 2017) based on children's addresses at age 2 (baseline) when the highest level of nesting was present.

First, a latent growth curve was fit to the BMI raw values at age 5, 7.5, 8.5, 9.5, and 10.5 with relevant covariates included (i.e., child race and ethnicity, target child gender, study site, intervention group, number of moves from age 2 to 10.5, and child externalizing symptoms at age 2), as well as family sociodemographic risk. Then, hypothesis testing proceeded from examining univariate associations between independent and mediating and moderating variables and child BMI growth, to conducting mediation and moderated mediation analyses using SEM (Preacher, Zyphur, & Zhang, 2010). The overall fit of all models was assessed using standard fit indices. Chi-square values were examined, with non-statistically significant values indicating that the model is a good fit for the data. Additionally, the Root Mean Square Error of Approximation (RMSEA), Comparative Fit Index (CFI), and the Tucker-Lewis Index (TLI) were also used to assess model fit, with RMSEA values < .06 and CFI/TLI values >.95 supporting good model fit (Hu & Bentler, 1999).

After all initial models were tested, age 10.5 pubertal development, age 3 harsh parenting, and school-age (age 8.5) neighborhood variables were each entered into the model one at a time. For the neighborhood variables at age 8.5, Pearson correlation coefficients were first used to test the strength of correlations between early childhood neighborhood variables and neighborhood variables at age 8.5. As correlations between neighborhood variables in early childhood and school-age were found to be less than r =.80 (range was from r = .10 for park acreage within a half-mile buffer of children's homes to .55 for neighborhood census-derived social disadvantage; see Table 2), school-age neighborhood variables were included as covariates as sensitivity analyses. Lastly, models were computed separately on the control group only to ensure that the results replicate and that there are no interactions between the main independent variables of interest and the treatment group.

Table 2. Correlations between early childhood and school-age neighborhood variables

Variable	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
1. Census-based neighborhood disadvantage (early)	--											
2. Neighborhood danger (early)	.44*	--										
3. Neighborhood cohesion (early)	-.20*	-.32*	--									
4. Healthy food retailers (early)	.22*	.23*	-.14*	--								
5. Less healthy food retailers (early)	.21*	.23*	-.08*	.40*	--							
6. Parks (early)	.01	.06	-.04	.08*	.09*	--						
7. Census-based neighborhood disadvantage (school-age)	.55*	.43*	-.19*	.20*	.22*	.03	--					
8. Neighborhood danger (school-age)	.26*	.54*	-.20*	.18*	.19*	.08	.41*	--				
9. Neighborhood cohesion (school-age)	-.06	-.10*	.46*	-.11*	.10*	-.06	-.17*	-.23*	--			
10. Healthy food retailers (school-age)	.22*	.23*	-.10*	.44*	.07	.02	.29*	.18*	-.14*	--		
11. Less healthy food retailers (school-age)	.25*	.27*	-.11*	.37*	.24*	.05	.36*	.28*	-.10*	.53*	--	
12. Parks (school-age)	-.03	-.02	.02	-.04	-.03	.10*	-.04	-.05	.00	-.04	-.06	--

*Denotes significance at $p < .05$

3.0 RESULTS

3.1 Descriptives and Preliminary Analyses

Descriptive statistics are presented in Table 3. Bivariate correlations indicated that higher early childhood family income was significantly associated with slower pubertal development at age 10.5 (r = -.11, p < .05), and that pubertal development was significantly correlated with concurrent BMIz at age 10.5 (r = .12, p < .05). Girls were more likely to endorse higher levels of pubertal development at age 10.5 than boys (r = .27, p < .01). However, independent samples *t*-tests indicated that there were no statistically significant differences in raw BMI or BMI *z*-scores for boys versus girls at any BMI assessment.

Table 3. Descriptives of study variables

	Total Sample (*N*=731) Mean or % (SD)	Pittsburgh (*N*=272) Mean or % (SD)	Eugene (*N*=271) Mean or % (SD)	Charlottesville (*N*=188) Mean or % (SD)
Child/family sociodemographics				
Primary caregiver education: < HS (age 2)	23.5%	18.4%	22.5%	32.4%
Annual family income <$20,000 (age 2)	66.3%	70.5%	62.4%	66.0%
Number of people in household, early (mean: ages 2, 3, 4)	4.59 (1.5)	4.47 (1.4)	4.69 (1.5)	4.62 (1.5)
Number of moves from age 2 -10.5	3.60 (3.1)	3.36 (2.9)	4.2 (3.5)	3.1 (2.8)
Child gender: male	50.5%	50.4%	50.2%	51.1%
Child race: White	50.1%	38.0%	69.7%	39.4%
Black	27.9%	50.6%	1.5%	33.5%
Biracial	13.0%	10.0%	14.4%	15.4%
Other	8.8%	1.5%	12.2%	11.7%
Child ethnicity: Hispanic	13.4%	1.9%	19.9%	20.7%
Pubertal status-Age 10.5	.36 (.2)	.37 (.2)	.35 (.2)	.35 (.2)
Early neighborhood social context (age 2, 3, 4)				
Census-based neighborhood disadvantage	.32 (.7)	.60 (.9)	.14 (.3)	.14 (.5)
Neighborhood danger (parent report)	7.82 (6.6)	10.88 (7.6)	6.32 (4.9)	5.59 (5.3)
Neighborhood cohesion (parent report)	15.04 (6.5)	14.26 (6.4)	15.41 (6.1)	15.64 (6.9)
Early neighborhood built environment (within 800m)				
Healthy food retailers	1.23 (1.5)	1.46 (2.2)	1.06 (1.0)	1.15 (2.2)
Less healthy food retailers	1.02 (1.2)	1.53 (1.1)	.90 (1.0)	.43 (1.1)
Parks (acres)	19.57 (32.9)	21.40 (35.3)	24.40 (30.2)	10.00 (31.0)
Parenting-observed				
Supportive parenting (age 3, 4)	.00 (.7)	-.34 (.7)	.36 (.5)	-.04 (.7)
Harsh parenting (age 4)	.00 (.7)	.10 (.8)	-.13 (.6)	.04 (.6)
Child self-regulation (age 5)				
Tower task	1.92 (.4)	1.93 (.6)	1.94 (.6)	1.85 (.3)
Gift wrapping task	.00 (.7)	.00 (.7)	.07 (.6)	-.12 (.8)
Draw-A-Star task	15.14 (17.2)	13.8 (14.7)	16.6 (20.4)	15.1 (15.3)
Child Body Mass Index (BMI)				
BMI (raw)-Age 5	16.73 (2.5)	16.52 (2.2)	16.39 (1.9)	17.34 (3.2)
Overweight/Obese-Age 5	36.0%	36.8%	31.6%	39.7%
BMI (raw)-Age 10.5	20.58 (4.9)	20.25 (4.5)	20.43 (4.5)	21.36 (6.0)
Overweight/Obese-Age 10.5	48.0%	47.1%	46.0%	52.5%

Of the original sample of 731 families, 95 children had no BMI data from any of the five assessments during which height and weight were measured. Independent samples *t*-tests were conducted to determine if children with no BMI data differed from those with BMI data on any study variables. Children with missing BMI data from all five assessments were more likely to have primary caregivers with less education ($t = 3.65$, $p < .01$) and to have more people living in the home ($t = -2.81$, $p < .01$). No other statistically significant differences were found.

Consistent with children's healthy growth and development during the school-age period, mean raw BMI values for children increased at every assessment from age 5 to 10.5 (Ogden et al., 2002). Gender and age-based BMI *z*-scores also increased during this period, as well as the number of children categorized as overweight or obese (see Table 3). This increase in overweight/obesity rates during childhood is consistent with research indicating that the prevalence of overweight and obesity increases with age (Skinner, Ravanbakht, Skelton, Perrin, & Armstrong, 2018). Mean BMI *z*-scores were positive at each assessment, indicating that children in the sample had higher BMIs than their peers of the same age and gender (based on BMI norms).

3.1.1 Neighborhood built environment and social context measures across study site

Differences were noted across site for many of the social context and built environment variables (see Table 3 for descriptive variables by site). Families from the Pittsburgh site lived in neighborhoods with significantly more census-based social disadvantage than families from the Eugene and Charlottesville sites ($F = 45.66$, $p < .001$). Primary caregivers from Pittsburgh also reported more neighborhood danger than caregivers from the two other sites ($F = 54.44$, $p < .001$). Families from the Charlottesville site had significantly less park space within 800m of their homes than families from both Pittsburgh and Eugene ($F = 11.71$, $p < .001$). Families from Pittsburgh had significantly more food retailers categorized as "less healthy" within 800m of their homes than families from the two other sites, and families from Charlottesville had significantly fewer food retailers categorized as "less healthy" within 800m of their homes than families from the other two sites ($F = 61.11$, $p < .001$).

3.2 Latent Growth Curve Model

First, an unconditional latent growth curve model was fit to BMI raw values at ages 5, 7.5, 8.5, 9.5 and 10.5 (see Figure 2). The model with the best fit included an intercept term (set at age 5 because of interest in predicting initial levels of BMI), a linear growth term, and a quadratic growth term. The model with the quadratic term provided significantly better fit as compared with the model with the linear term only: χ^2_D ($df = 4$) = 112.05, $p < .01$. A quadratic pattern of change (i.e., a more rapid rate of BMI growth starting at age 7-8) is consistent with CDC growth standards (Ogden et al., 2002). The fit indices for the unconditional model, which also included a cluster adjustment for age 2 census tract, indicated adequate fit for the data: χ^2 (df=6) = 26.78 (p = .00); *CFI* = .99 ; *TLI* = .98; *RMSEA* = .08; *SRMR* = .04.

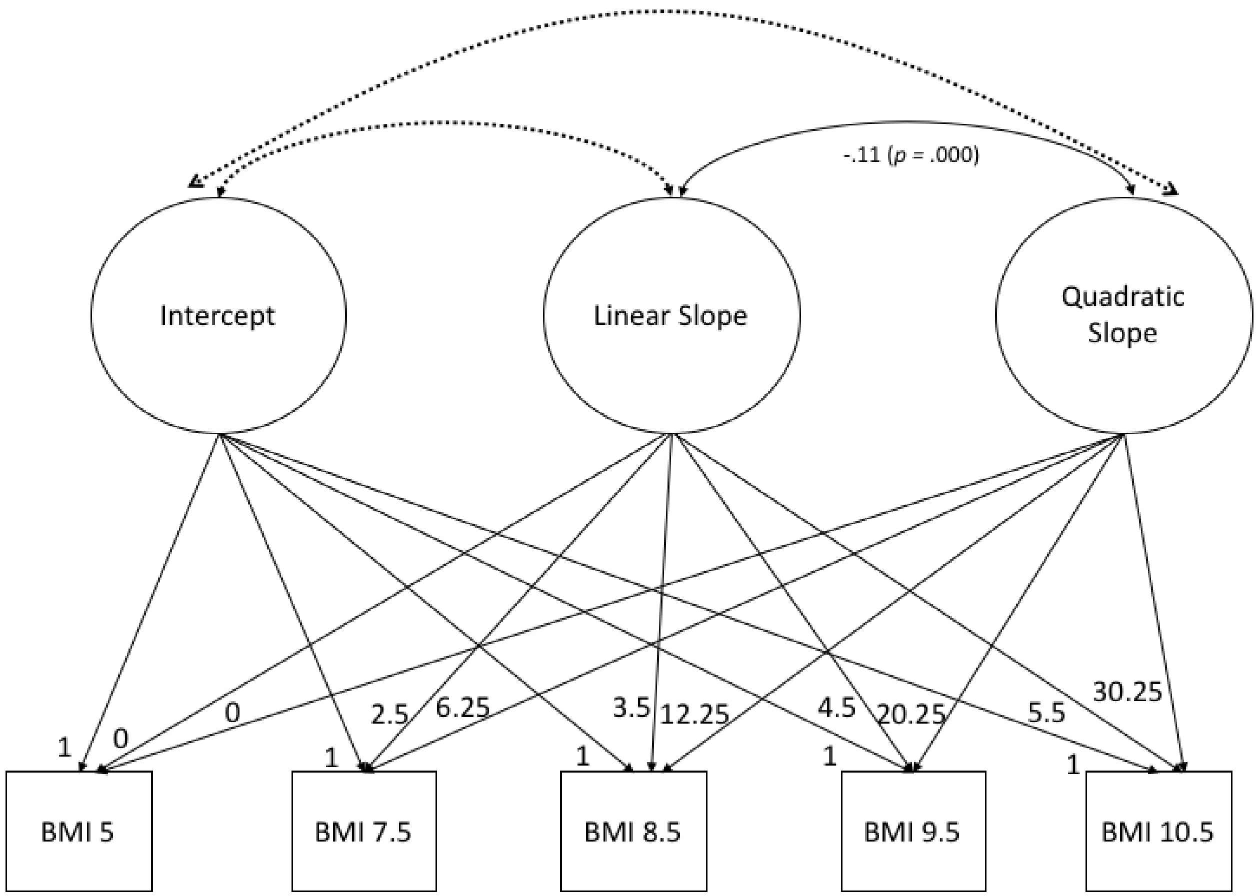

Figure 2. Unconditional latent growth model for child BMI from 5 to 10.5

Significant means and variances for the intercept, linear slope, and quadratic slope were demonstrated for this model. The average BMI at the intercept (age 5) was 16.73 (SE = .11, $p < .001$); the average slope was .22 (SE = .05, $p < .001$); the average quadratic growth factor was .09 (SE = .01, $p < .001$). The statistically significant positive coefficient for the linear slope term reflects an overall increase in BMI from child ages 5 to 10.5, and the positive coefficient for the quadratic term indicates an acceleration in the rate of BMI growth. Based on visual inspection, the rate of growth appears to increase starting at age 8 (see Figure 3).

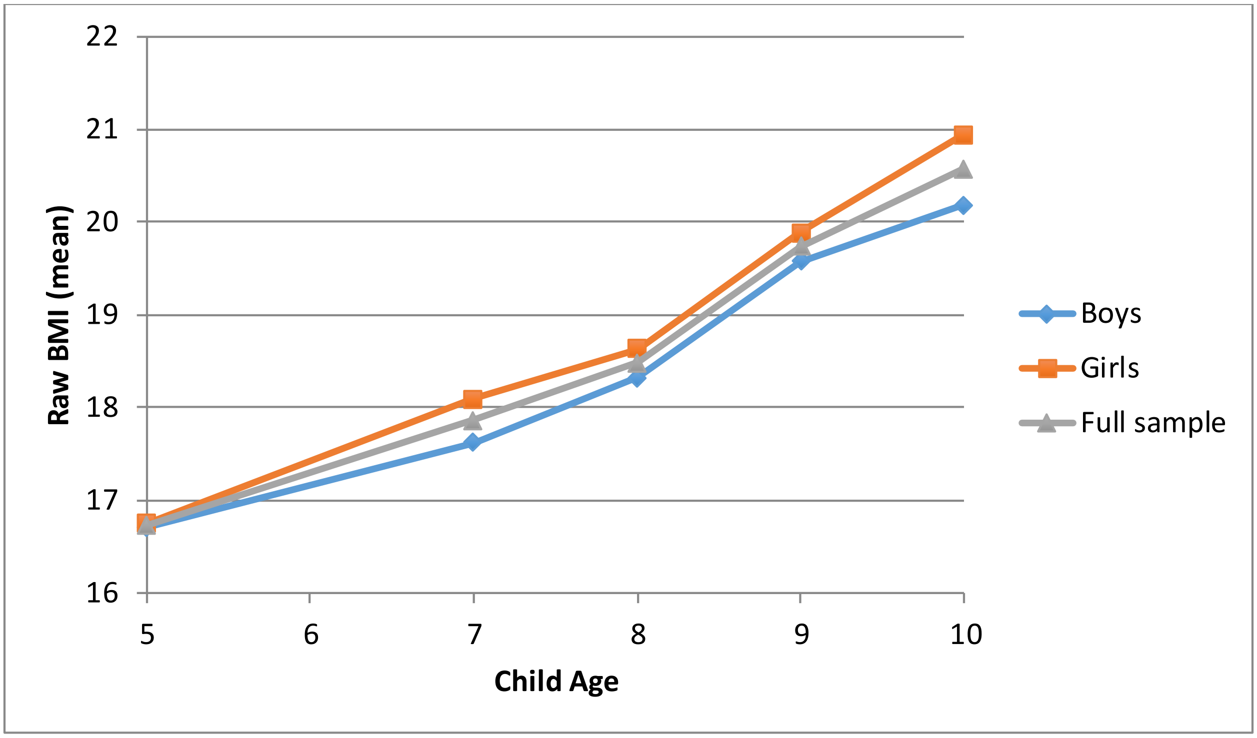

Figure 3. Mean BMI growth from age 5 to 10.5

After fitting an unconditional latent growth curve model to the full sample, latent growth curve models were then tested separately by child gender to determine whether a quadratic model was the best fit for both boys' and girls' BMI data. The quadratic model was found to best fit the data for both boys and girls, as compared to the linear model.

The quadratic model was subsequently computed with the following covariates: child race and ethnicity, target child gender, study site (Eugene, OR served as the reference group), intervention group, child externalizing symptoms at age 2, family income, education, and people in home (the latter three variables represented the mean of values at ages 2, 3, and 4), and number of moves between age 2 and 10.5. This latent growth model also provided adequate fit to the data, χ^2 (*df*=32) = 74.13 (*p* = .00); *CFI* = .99; *TLI* = .97; *RMSEA* = .05; *SRMR* = .02. Of the covariates, Hispanic ethnicity was a statistically significant predictor of the linear term for BMI slope (β= .20, *p* < .05). FCU intervention group was also a statistically significant predictor of the linear slope term (β= .11, $p < .05$) and of the quadratic slope term (β= -.13, $p < .05$), indicating that children in the intervention group had a faster initial rate of BMI increase, which slowed over time. The Charlottesville, VA site was a statistically significant predictor of the BMI intercept term, indicating higher BMI for Charlottesville children at age 5 compared to children at both the Pittsburgh and Eugene sites (β= .15, $p < .01$). Number of people in the home (β= -.09, $p < .05$) was a significant predictor of the intercept term, with more people in the home associated with lower BMI at age 5 (see Table 4).

Table 4. Covariates predicting growth terms in latent growth curve model

	Intercept		Linear Slope		Quadratic Slope	
Variable name	**β (S.E.)**	***p***	**β (S.E.)**	***p***	**β (S.E.)**	***p***
Intervention group	-.08 (.05)	.12	.11 (.05)	.04*	-.13 (.06)	.03*
Child sex-female	.00 (.05)	.93	.07 (.05)	.19	-.04 (.06)	.55
Child race-Black	.05 (.06)	.45	.11 (.07)	.10†	-.07 (.08)	.39
Child race-Biracial	.03 (.05)	.45	-.05 (.06)	.43	.02 (.06)	.70
Child race-Other race	.04 (.06)	.45	-.01 (.08)	.95	.02 (.08)	.78
Child ethnicity-Hispanic	-.03 (.05)	.62	.20 (.10)	.04*	-.14 (.09)	.14
Site-Charlottesville	.15 (.05)	.00*	.01 (.06)	.90	.01 (.07)	.91
Site-Pittsburgh	-.04 (.05)	.49	-.05 (.07)	.52	-.01 (.06)	.88
Family income (early)	-.05 (.04)	.18	-.03 (.06)	.61	-.01 (.06)	.93
Primary caregiver education (early)	.04 (.05)	.46	.06 (.05)	.24	-.08 (.06)	.22
People in home (early)	-.09 (.04)	.05*	-.07 (.05)	.19	.06 (.06)	.30
# of family moves age 2-10	.00 (.06)	.99	-.07 (.07)	.26	.08 (.07)	.22
Externalizing symptoms (age 2)	-.04 (.04)	.40	.06 (.05)	.24	-.07 (.06)	.20
Intercepts (unstandardized)	**B (S.E.)**	***p***	**B (S.E.)**	***p***	**B (S.E.)**	***p***
	17.38 (.83)	.00*	-.19 (.40)	.63	.17 (.07)	.01*
Model fit: χ^2 (*df*=32) = 74.13 (p = .00); *CFI* = .99; *TLI* = .97; *RMSEA* = .05; *SRMR* = .02						

*Denotes significance at $p < .05$
†Denotes marginal significance at $p < .10$

3.3 Covariates Predicting Age 10.5 BMI *Z*-score

A regression analysis testing covariates in relation to age 10.5 BMIz was conducted. Number of people in the home (β = -.07, p = .06) and early family income (β = -.08, p = .07) were found to marginally negatively predict BMIz at age 10.5, with more people in the home and higher family income in early childhood both associated with lower BMIz at age 10.5 (see Table 5). When age 10.5 pubertal status was added as an additional covariate, the association between early family income and BMIz at age 10.5 was no longer marginally significant. Pubertal status significantly predicted age 10.5 BMIz (β = .12, p < .01).

Table 5. Covariates predicting age 10.5 BMIz

	BMIz age 10.5	
Variable name	**β (S.E.)**	***p***
Intervention group	-.06 (.05)	.24
Child sex-female	.01 (.05)	.86
Child race-Black	.06 (.06)	.34
Child race-Biracial	.02 (.05)	.72
Child race-Other race	-.02 (.04)	.72
Child ethnicity-Hispanic	.09 (.05)	.09†
Site-Charlottesville	.06 (.06)	.32
Site-Pittsburgh	-.04 (.06)	.44
Family income (early)	-.07 (.05)	.13
Primary caregiver education (early)	.02 (.05)	.67
People in home (early)	-.07 (.04)	.06†
# of family moves age 2-10	-.01 (.04)	.81
Externalizing symptoms (age 2)	-.01 (.04)	.80
Intercept (unstandardized)	**B (S.E.)**	***p***
	1.42 (.50)	.01*

*Denotes significance at $p < .05$
†Denotes marginal significance at $p < .10$

3.4 Hypothesis 1: Neighborhood Built Environment and BMI Growth and BMIz Age 10.5

First, bivariate correlations between neighborhood built environment variables in early childhood (park acreage within an 800m buffer of families' homes; counts of healthy food retailers and less healthy food retailers, respectively, within an 800m buffer of families' homes) and BMI at age 5 and age 10.5 were tested. The bivariate association between number of healthy retailers in children's early childhood neighborhood environment and age 5 BMI was statistically significant ($r = .13$, $p < .05$), with higher number of healthy retailers within an 800m buffer of children's homes predicting higher age 5 BMI (see Table 6). There were no statistically significant correlations between the other built environment variables and BMI at age 5 or age 10.5, or between the built environment variables measured at school-age and BMI at either age.

Table 6. Correlations between neighborhood social context and built environment, SR, and BMIz at age 5 and 10.5

Variable	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
1. BMIz age 5	--											
2. BMIz age 10.5	.59*	--										
3. SR-Tower task	-.04	-.08†	--									
4. SR-Star task (cool)	-.12*	-.04	.08†	--								
5. SR-Gift task (hot)	.00	.03	.24*	.08†	--							
6. Supportive parenting (age 3 & 4)	-.01	-.04	.00	.17*	.13*	--						
7. Family income (early)	-.09†	-.09†	-.05	.07	-.03	.22*	--					
8. Census-based neighborhood disadvantage (early)	.10*	-.01	.07	-.04	.04	-.28*	-.24*	--				
9. Neighborhood danger (early)	.10†	-.03	.07	-.12*	.00	-.22*	-.21*	.44*	--			
10. Neighborhood cohesion (early)	.06	.05	-.04	.07	0.03	.11*	.12*	-.20*	-.32*	--		
11. Healthy food retailers (early)	.11*	.05	-.01	.00	.01	-.21*	-.14*	.22*	.23*	-.15*	--	
12. Less healthy food retailers (early)	.04	.00	.02	-.05	.05	-.12*	-.04	.21	.23*	-.08*	.40*	--
13. Parks (early)	-.02	-.01	-.01	-.05	.03	.01	.02	.01	.06	-.04	.08	.09*

*Denotes significance at $p < .05$; †Denotes marginal significance at $p < .10$

A) To test hypothesis 1, that early childhood neighborhood built environment factors (less park space, few healthy food retailers, more less healthy food retailers, all within an 800m buffer of children's homes) would be significantly associated with more rapidly increasing BMI from ages 5 to 10.5, the three neighborhood built environment variables were added as predictors in the conditional latent growth curve model described above. Neither type of food retailer nor park space within an 800m radius of children's homes was a significant predictor of the BMI growth terms or intercept (see Table 7).

Table 7. Covariates and early built environment predictors of growth terms in latent growth curve model

	Intercept		Linear Slope		Quadratic Slope	
Variable name	**β (S.E.)**	***p***	**β (S.E.)**	***p***	**β (S.E.)**	***p***
Intervention group	-.07 (.05)	.15	.11 (.05)	.04*	-.14 (.06)	.03*
Child sex-female	-.01 (.05)	.79	.08 (.06)	.18	-.04 (.07)	.52
Child race-Black	.03 (.06)	.66	.11 (.07)	.11	-.05 (.08)	.52
Child race-Biracial	.04 (.05)	.55	-.05 (.07)	.40	.03 (.06)	.66
Child race-Other race	.05 (.06)	.40	-.01 (.08)	.93	.02 (.08)	.76
Child ethnicity-Hispanic	-.03 (.05)	.55	.22 (.10)	.03*	-.16 (.10)	.10
Site-Charlottesville	.18 (.05)	.00*	.01 (.06)	.94	.01 (.07)	.90
Site-Pittsburgh	-.06 (.05)	.23	-.03 (.06)	.71	-.03 (.08)	.70
Family income (early)	-.04 (.04)	.29	-.03 (.06)	.61	-.01 (.06)	.85
Primary caregiver education (early)	.04 (.05)	.40	.07 (.05)	.22	-.09 (.06)	.19
People in home (early)	-.09 (.04)	.04*	-.06 (.05)	.20	.06 (.06)	.32
# of family moves age 2-10	.00 (.06)	.97	-.08 (.07)	.24	.09 (.07)	.20
Externalizing symptoms (age 2)	-.05 (.04)	.27	.06 (.05)	.20	-.07 (.06)	.18
Healthy food retailers (early)	.06 (.06)	.29	.04 (.07)	.53	-.09 (.08)	.24
Less healthy food retailers (early)	.09 (.06)	.13	-.07 (.08)	.38	.08 (.09)	.37
Park space (early)	.03 (.04)	.56	.03 (.05)	.52	-.04 (.06)	.51
Intercepts (unstandardized)	**B (S.E.)**	***p***	**B (S.E.)**	***p***	**B (S.E.)**	***p***
	17.03 (.86)	.00*	-.24 (.40)	.54	.19 (.07)	.01*
Model fit: χ^2 (*df*=38) = 76.25 (*p* = .00); *CFI* = .99; *TLI* = .97; *RMSEA* = .04; *SRMR* = .01						

*Denotes significance at $p < .05$

B) Multivariate linear regression was used to test associations between neighborhood built environment variables and BMIz at age 10.5. Neither type of food retailer count or parks within an 800m radius of children's homes was a significant predictor of BMIz at age 10.5 (see Table 8).

Table 8. Early childhood and school-age built environment predictors of growth terms in latent growth curve model, with covariates

	Intercept		Linear Slope		Quadratic Slope	
Variable name	**β (S.E.)**	***p***	**β (S.E.)**	***p***	**β (S.E.)**	***p***
Intervention group	-0.01 (.06)	0.93	0.04 (.09)	0.65	-0.09 (.11)	0.42
Child sex-female	0.00 (.06)	0.99	0.09 (.09)	0.28	-0.02 (.10)	0.81
Child race-Black	0.05 (.08)	0.57	0.20 (.11)	0.07†	-0.16 (.13)	0.20
Child race-Biracial	-0.04 (.06)	0.47	0.07 (.10)	0.46	-0.13 (.10)	0.20
Child race-Other race	0.02 (.08)	0.83	0.24 (.12)	0.05†	-0.25 (.11)	0.03*
Child ethnicity-Hispanic	0.07 (.06)	0.28	-0.02 (.10)	0.86	0.10 (.11)	0.34
Site-Charlottesville	0.24 (.08)	0.00*	-0.12 (.10)	0.23	0.14 (.11)	0.21
Site-Pittsburgh	-0.05 (.06)	0.50	-0.12 (.12)	0.31	0.06 (.12)	0.61
Family income (early)	-0.14 (.07)	0.06†	0.15 (.11)	0.17	-0.15 (.10)	0.12
Primary caregiver education (early)	0.11 (.11)	0.32	0.21 (.13)	0.12	-0.14 (.15)	0.37
People in home (early)	-0.10 (.06)	0.10	-0.15 (.09)	0.11	0.15 (.12)	0.20
Family income (school-age)	0.03 (.09)	0.72	-0.22 (.13)	0.09†	0.09 (.11)	0.44
Primary caregiver education (school-age)	0.03 (.10)	0.80	-0.23 (.15)	0.12	0.12 (.17)	0.47
People in home (school-age)	0.10 (.07)	0.14	-0.10 (.08)	0.23	0.10 (.08)	0.22
# of family moves age 2-10	0.02 (.08)	0.80	-0.10 (.10)	0.31	0.11 (.09)	0.20
Externalizing symptoms (age 2)	-0.05 (.06)	0.39	0.16 (.08)	0.05†	-0.15 (.09)	0.07†
Healthy food retailers (early)	0.20 (.11)	0.08†	0.12 (.14)	0.40	-0.15 (.16)	0.33
Less healthy food retailers (early)	0.02 (.09)	0.79	-0.15 (.12)	0.20	0.17 (.12)	0.17
Park space (early)	0.03 (.05)	0.49	0.06 (.06)	0.32	-0.03 (.07)	0.70
Healthy food retailers (school-age)	-0.26 (.12)	0.03*	0.07 (.17)	0.67	-0.03 (.18)	0.89
Less healthy food retailers (school-age)	0.12 (.08)	0.13	-0.18 (.14)	0.20	0.13 (.14)	0.36
Park space (school-age)	-0.08 (.04)	0.05†	0.13 (.07)	0.05†	-0.14 (.07)	0.05†
Intercepts (unstandardized)	**B (S.E.)**	***p***	**B (S.E.)**	***p***	**B (S.E.)**	***p***
	15.45 (.88)	.00*	.15 (.44)	.73	.12 (.08)	.14
Model fit: χ^2 (*df*=50) = 75.02 (*p* = .00); *CFI* = .99; *TLI* = .97; *RMSEA* = .04; *SRMR* = .01						

*Denotes significance at $p < .05$
†Denotes marginal significance at $p < .10$

3.4.1 Sensitivity analysis

Three additional latent growth curve models and three additional regression analyses (with BMIz at age 10.5 as the outcome) were tested as sensitivity analyses. The first included school-age built environment variables in the model (see Tables 9 and 10). With school-age built environment variables in the model, healthy food retailers in early childhood became a marginally significant predictor of BMI intercept (β = .20, *p* = .08), with greater number of healthy food retailers associated with higher age 5 BMI. There were no other changes to the magnitude of associations between early childhood built environment variables and BMI growth terms or BMIz at age 10.5.

Table 9. Early childhood and school-age built environment predictors of growth terms in latent growth curve model, with covariates

	Intercept		Linear Slope		Quadratic Slope	
Variable name	**β (S.E.)**	***p***	**β (S.E.)**	***p***	**β (S.E.)**	***p***
Intervention group	-0.01 (.06)	0.93	0.04 (.09)	0.65	-0.09 (.11)	0.42
Child sex-female	0.00 (.06)	0.99	0.09 (.09)	0.28	-0.02 (.10)	0.81
Child race-Black	0.05 (.08)	0.57	0.20 (.11)	0.07†	-0.16 (.13)	0.20
Child race-Biracial	-0.04 (.06)	0.47	0.07 (.10)	0.46	-0.13 (.10)	0.20
Child race-Other race	0.02 (.08)	0.83	0.24 (.12)	0.05†	-0.25 (.11)	0.03*
Child ethnicity-Hispanic	0.07 (.06)	0.28	-0.02 (.10)	0.86	0.10 (.11)	0.34
Site-Charlottesville	0.24 (.08)	0.00*	-0.12 (.10)	0.23	0.14 (.11)	0.21
Site-Pittsburgh	-0.05 (.06)	0.50	-0.12 (.12)	0.31	0.06 (.12)	0.61
Family income (early)	-0.14 (.07)	0.06†	0.15 (.11)	0.17	-0.15 (.10)	0.12
Primary caregiver education (early)	0.11 (.11)	0.32	0.21 (.13)	0.12	-0.14 (.15)	0.37
People in home (early)	-0.10 (.06)	0.10	-0.15 (.09)	0.11	0.15 (.12)	0.20
Family income (school-age)	0.03 (.09)	0.72	-0.22 (.13)	0.09†	0.09 (.11)	0.44
Primary caregiver education (school-age)	0.03 (.10)	0.80	-0.23 (.15)	0.12	0.12 (.17)	0.47
People in home (school-age)	0.10 (.07)	0.14	-0.10 (.08)	0.23	0.10 (.08)	0.22
# of family moves age 2-10	0.02 (.08)	0.80	-0.10 (.10)	0.31	0.11 (.09)	0.20
Externalizing symptoms (age 2)	-0.05 (.06)	0.39	0.16 (.08)	0.05†	-0.15 (.09)	0.07†
Healthy food retailers (early)	0.20 (.11)	0.08†	0.12 (.14)	0.40	-0.15 (.16)	0.33
Less healthy food retailers (early)	0.02 (.09)	0.79	-0.15 (.12)	0.20	0.17 (.12)	0.17
Park space (early)	0.03 (.05)	0.49	0.06 (.06)	0.32	-0.03 (.07)	0.70
Healthy food retailers (school-age)	-0.26 (.12)	0.03*	0.07 (.17)	0.67	-0.03 (.18)	0.89
Less healthy food retailers (school-age)	0.12 (.08)	0.13	-0.18 (.14)	0.20	0.13 (.14)	0.36
Park space (school-age)	-0.08 (.04)	0.05†	0.13 (.07)	0.05†	-0.14 (.07)	0.05†

Intercepts (unstandardized)	B (S.E.)	*p*	B (S.E.)	*p*	B (S.E.)	*p*
	15.45 (.88)	.00*	.15 (.44)	.73	.12 (.08)	.14
Model fit: χ^2 (*df*=50) = 75.02 (*p* = .00); *CFI* = .99; *TLI* = .97; *RMSEA* = .04; *SRMR* = .01						

*Denotes significance at $p < .05$; †Denotes marginal significance at $p < .10$

Table 10. Early childhood and school-age built environment predictors of age 10.5 BMIz, with covariates

	BMIz age 10.5	
Variable name	**β (S.E.)**	***p***
Intervention group	-0.08 (.06)	0.13
Child sex-female	0.08 (.05)	0.15
Child race-Black	0.03 (.09)	0.69
Child race-Biracial	-0.03 (.05)	0.57
Child race-Other race	-0.04 (.05)	0.39
Child ethnicity-Hispanic	0.15 (.06)	0.02*
Site-Charlottesville	0.06 (.08)	0.44
Site-Pittsburgh	-0.08 (.08)	0.35
Family income (early)	-0.03 (.07)	0.70
Primary caregiver education (early)	0.10 (.11)	0.33
People in home (early)	-0.05 (.05)	0.31
Family income (school-age)	-0.13 (.07)	0.05†
Primary caregiver education (school-age)	-0.06 (.12)	0.64
People in home (school-age)	-0.01 (.06)	0.88
# of family moves age 2-10	-0.02 (.05)	0.64
Externalizing symptoms (age 2)	0.02 (.05)	0.71
Healthy food retailers (early)	0.06 (.05)	0.23
Less healthy food retailers (early)	0.07 (.07)	0.31
Park space (early)	0.02 (.08)	0.79
Healthy food retailers (school-age)	-0.07 (.08)	0.42
Less healthy food retailers (school-age)	0.06 (.07)	0.40
Park space (school-age)	-0.03 (.04)	0.37
Intercept (unstandardized)	**B (S.E.)**	***p***
	.85 (.62)	.17

*Denotes significance at $p < .05$
†Denotes marginal significance at $p < .10$

Second, pubertal status at age 10 was included in the model. There were no changes in the magnitude of associations between early childhood built environment variables and BMI growth terms or BMIz at age 10.5 with the addition of pubertal status.

Finally, models were tested on the control group alone, with no changes to the findings for the latent growth curve or BMIz at age 10.5.

3.5 Hypothesis 2: Neighborhood Social Context and BMI Growth/BMIz Age 10.5

In a test of bivariate correlations, both early neighborhood social disadvantage derived from census variables (r = .12, p < .05) and parent-reported neighborhood danger (r = .10, p < .05) were positively associated with BMI at age 5 (see Table 6). There were no statistically significant associations between any of the neighborhood social context variables in early childhood or at school-age and BMIz at age 10.

A) To test hypothesis 2, that a less advantaged neighborhood social context would be significantly associated with more rapidly increasing BMI from age 5 to 10.5, the three neighborhood social context variables (census-based social disadvantage; parent-reported neighborhood danger and cohesion) were each added as predictors in the conditional latent growth curve model described above. Parent-reported neighborhood cohesion was found to negatively predict BMI linear slope at a marginally significant level (β= -.13, p = .05) and to positively predict the quadratic term for BMI growth at a statistically significant level (β= .17, p < .05), indicating that greater perceived neighborhood cohesion was associated with less overall growth in BMI, but a later acceleration in BMI growth (see Table 11). A standardized regression coefficient of .17 is approximately equivalent to an r value of .22 (Lenhard & Lenhard, 2016), an effect size small in magnitude (Cohen, 1988). Census-derived neighborhood social disadvantage (β= .12, p < .05) was a significant predictor of the BMI intercept term, indicating that greater social disadvantage was associated with higher BMI at age 5, albeit this effect size is also small in magnitude.

Table 11. Covariates and early social context predictors of growth terms in latent growth curve model

	Intercept		Linear Slope		Quadratic Slope	
Variable name	**β (S.E.)**	***p***	**β (S.E.)**	***p***	**β (S.E.)**	***p***
Intervention group	-0.08 (.05)	0.12	0.11 (.05)	0.04*	-0.13 (.06)	0.02*
Child sex-female	0.00 (.05)	0.97	0.06 (.06)	0.27	-0.03 (.07)	0.69
Child race-Black	0.00 (.07)	0.96	0.11 (.07)	0.14	-0.06 (.09)	0.52
Child race-Biracial	0.04 (.05)	0.36	-0.07 (.06)	0.29	0.05 (.06)	0.47
Child race-Other race	0.05 (.06)	0.39	0.00 (.08)	0.99	0.01 (.08)	0.86
Child ethnicity-Hispanic	-0.03 (.05)	0.62	0.20 (.10)	0.04*	-0.13 (.09)	0.17
Site-Charlottesville	0.17 (.05)	0.00*	0.01 (.06)	0.85	0.00 (.07)	0.99
Site-Pittsburgh	-0.07 (.05)	0.22	-0.04 (.08)	0.65	-0.02 (.08)	0.78
Family income (early)	-0.04 (.04)	0.34	-0.02 (.06)	0.71	-0.02 (.06)	0.77
Primary caregiver education (early)	0.05 (.05)	0.32	0.06 (.05)	0.26	-0.08 (.06)	0.22
People in home (early)	-0.09 (.04)	0.04*	-0.07 (.05)	0.18	0.06 (.06)	0.30
# of family moves age 2-10	0.01 (.06)	0.93	-0.09 (.06)	0.15	0.10 (.06)	0.11
Externalizing symptoms (age 2)	-0.04 (.04)	0.39	0.05 (.05)	0.33	-0.06 (.05)	0.28
Census neighborhood disadvantage (early)	0.12 (.05)	0.03*	-0.03 (.06)	0.63	0.02 (.08)	0.85
Parent-reported neighborhood danger (early)	0.06 (.05)	0.26	-0.02 (.06)	0.76	0.03 (.06)	0.64
Parent-reported neighborhood cohesion (early)	0.09 (.06)	0.15	-0.13 (.07)	0.05†	0.17 (.07)	0.02*
Intercepts (unstandardized)	**B (S.E.)**	***p***	**B (S.E.)**	***p***	**B (S.E.)**	***p***
	16.48 (.95)	.00*	.21 (.38)	.57	.10 (.06)	.11
Model fit: χ^2 (*df*=38) = 84.52 (*p* = .00); *CFI* = .99; *TLI* = .96; *RMSEA* = .05; *SRMR* = .01						

*Denotes significance at $p < .05$
†Denotes marginal significance at $p < .10$

B) Multivariate linear regression was used to test associations between neighborhood social context variables and BMIz at age 10.5. None of the social context variables (census-based social disadvantage; parent-reported neighborhood danger and cohesion) were significantly associated with BMI at age 10.5 (see Table 12).

Table 12. Covariates and early social context predictors of age 10.5 BMIz

	BMIz age 10.5	
Variable name	**β (S.E.)**	***p***
Intervention group	-0.06 (.05)	0.24
Child sex-female	0.01 (.05)	0.80
Child race-Black	0.07 (.07)	0.30
Child race-Biracial	0.03 (.05)	0.62
Child race-Other race	-0.02 (.04)	0.66
Child ethnicity-Hispanic	0.09 (.05)	0.09†
Site-Charlottesville	0.05 (.06)	0.39
Site-Pittsburgh	-0.04 (.06)	0.47
Family income (early)	-0.08 (.05)	0.11
Primary caregiver education (early)	0.02 (.05)	0.69
People in home (early)	-0.07 (.04)	0.06†
# of family moves age 2-10	0.00 (.04)	0.92
Externalizing symptoms (age 2)	-0.01 (.05)	0.89
Census neighborhood disadvantage (early)	-0.01 (.05)	0.85
Parent-reported neighborhood danger (early)	0.00 (.06)	0.96
Parent-reported neighborhood cohesion (early)	0.05 (.05)	0.35
Intercept (unstandardized)	**B (S.E.)**	***p***
	1.24 (.56)	.03*

*Denotes significance at $p < .05$
†Denotes marginal significance at $p < .10$

3.5.1 Sensitivity analysis

When including school-age social context variables in the model, early neighborhood cohesion became a marginally significant predictor of the quadratic term (β= .20, p = .07) for BMI growth, such that higher levels of neighborhood cohesion were related to increased later growth in BMI (see Table 13). All other statistically significant findings remained the same. There were no changes to associations with BMIz at age 10.5 (see Table 14).

Table 13. Early and school-age social context predictors of growth terms in latent growth curve model, with covariates

	Intercept		Linear Slope		Quadratic Slope	
Variable name	**β (S.E.)**	***p***	**β (S.E.)**	***p***	**β (S.E.)**	***p***
Intervention group	0.01 (.06)	0.93	0.03 (.08)	0.71	-0.08 (.10)	0.39
Child sex-female	0.02 (.06)	0.79	0.07 (.08)	0.38	0.00 (.10)	0.97
Child race-Black	0.02 (.09)	0.85	0.19 (.12)	0.12	-0.13 (.14)	0.36
Child race-Biracial	-0.01 (.06)	0.81	0.04 (.09)	0.69	-0.08 (.10)	0.40
Child race-Other race	0.02 (.08)	0.82	0.20 (.11)	0.09†	-0.22 (.12)	0.06†
Child ethnicity-Hispanic	0.03 (.06)	0.59	-0.04 (.09)	0.63	0.13 (.11)	0.24
Site-Charlottesville	0.25 (.08)	0.00*	-0.11 (.09)	0.21	0.13 (.11)	0.25
Site-Pittsburgh	0.04 (.08)	0.64	-0.23 (.13)	0.07†	0.15 (.12)	0.22
Family income (early)	-0.13 (.06)	0.05†	0.11 (.10)	0.28	-0.10 (.09)	0.25
Primary caregiver education (early)	0.12 (.10)	0.22	0.23 (.11)	0.05†	-0.17 (.13)	0.20
People in home (early)	-0.11 (.06)	0.07†	-0.09 (.08)	0.25	0.09 (.09)	0.32
Family income (school-age)	-0.02 (.08)	0.86	-0.13 (.11)	0.25	0.00 (.10)	0.99
Primary caregiver education (school-age)	-0.01 (.10)	0.91	-0.24 (.12)	0.04*	0.16 (.15)	0.28
People in home (school-age)	0.13 (.06)	0.05†	-0.09 (.08)	0.23	0.10 (.08)	0.21
# of family moves age 2-10	0.05 (.08)	0.56	-0.12 (.10)	0.20	0.14 (.09)	0.13
Externalizing symptoms (age 2)	-0.03 (.06)	0.55	0.14 (.07)	0.05†	-0.13 (.08)	0.12
Census neighborhood disadvantage (early)	0.06 (.07)	0.37	0.00 (.09)	0.99	-0.02 (.11)	0.84
Parent-reported neighborhood danger (early)	0.07 (.08)	0.35	-0.07 (.09)	0.45	0.05 (.10)	0.57
Parent-reported neighborhood cohesion (early)	0.08 (.08)	0.30	-0.21 (.11)	0.05†	0.20 (.11)	0.07†
Census neighborhood disadvantage (school-age)	-0.11 (.08)	0.15	0.02 (.10)	0.85	-0.05 (.11)	0.62
Parent-reported neighborhood danger (school-age)	0.02 (.08)	0.76	0.01 (.11)	0.95	0.07 (.12)	0.56
Parent-reported neighborhood cohesion (school-age)	0.11 (.08)	0.15	0.06 (.11)	0.60	0.01 (.11)	0.95
Intercepts (unstandardized)	**B (S.E.)**	***p***	**B (S.E.)**	***p***	**B (S.E.)**	***p***
	14.24 (1.14)	.00*	.43 (.46)	.35	.04 (.08)	.59
Model fit: χ^2 (*df*=50) = 84.31 (*p* = .00); *CFI* = .98; *TLI* = .96; *RMSEA* = .05; *SRMR* = .01						

*Denotes significance at $p < .05$

†Denotes marginal significance at $p < .10$

Table 14. Early childhood and school-age social context predictors predictors of age 10.5 BMIz, with covariates

	BMIz age 10.5	
Variable name	**β (S.E.)**	***p***
Intervention group	-0.08 (.05)	0.13
Child sex-female	0.09 (.06)	0.12
Child race-Black	0.07 (.09)	0.45
Child race-Biracial	0.00 (.06)	1.00
Child race-Other race	-0.05 (.05)	0.29
Child ethnicity-Hispanic	0.12 (.06)	0.05†
Site-Charlottesville	0.04 (.08)	0.61
Site-Pittsburgh	-0.03 (.08)	0.69
Family income (early)	-0.01 (.07)	0.93
Primary caregiver education (early)	0.10 (.11)	0.36
People in home (early)	-0.05 (.05)	0.29
Family income (school-age)	-0.17 (.07)	0.01*
Primary caregiver education (school-age)	-0.05 (.12)	0.65
People in home (school-age)	0.01 (.06)	0.91
# of family moves age 2-10	-0.01 (.05)	0.89
Externalizing symptoms (age 2)	0.04 (.05)	0.41
Census neighborhood disadvantage (early)	0.02 (.08)	0.77
Parent-reported neighborhood danger (early)	-0.05 (.07)	0.52
Parent-reported neighborhood cohesion (early)	0.01 (.07)	0.93
Census neighborhood disadvantage (school-age)	-0.08 (.08)	0.34
Parent-reported neighborhood danger (school-age)	0.06 (.07)	0.43
Parent-reported neighborhood cohesion (school-age)	0.11 (.07)	0.12
Intercept (unstandardized)	**B (S.E.)**	***p***
	1.24 (.56)	.03*

*Denotes significance at $p < .05$
†Denotes marginal significance at $p < .10$

When age 10.5 pubertal development was added to the model, neighborhood cohesion was no longer a marginally significant predictor of the BMI linear slope term (β= -.12, p = .10). Cohesion remained a significant predictor of the quadratic slope term (β= .14, $p < .05$) and early neighborhood social disadvantage was significantly associated with BMI intercept (β= .12, $p < .05$), with greater social disadvantage predicting higher age 5 BMI.

In a model with the control group only, there was no longer any association between neighborhood cohesion and BMI linear or quadratic slope, and no changes to the magnitude of associations between neighborhood social context variables and BMIz at age 10.5.

3.6 Hypothesis 3: Neighborhood Social Context and Child SR

First, bivariate correlations between each neighborhood social context variable and each of the three SR tasks were tested. Parent-reported neighborhood danger in early childhood was found to be significantly associated with reduced cool SR on the Draw-A-Star task ($r = -.12$, $p < .05$).

To test the hypothesis that neighborhood social context would be related to child SR, the first step was to compute a confirmatory factor analysis for the child SR factor at age 5, using the three indicators of the Tower task, the Wrapped Gift task ("hot" SR), and the Draw-A-Star task ("cool" SR). Factor loadings (unstandardized) for each of the tasks were .69, .53, and .24 for the Tower, Wrapped Gift, and Draw-A-Star tasks, respectively.

A multivariate structural equation model with covariates and each of the three neighborhood social context variables in relation to the SR latent factor was then tested. The fit indices for this model, which also included the cluster adjustment for age 2 census tract, were as follows: χ^2 (df=26) = 40.48 (p = .04); *CFI* = .72; *TLI* = .55; *RMSEA* = .03; *SRMR* = .03.

In this model, several covariates were found to predict the child SR factor at a marginally significant level (see Table 15). Hispanic ethnicity was a marginally significant predictor of SR, such that Hispanic children were more likely to demonstrate higher scores relative to non-Hispanic children (β= .12, p = .05). Female gender was also a marginally significant predictor of SR (β= .12, p = .06), with girls performing better on the SR tasks. Finally, biracial (β= -.10, p = .08) and

Black children (β= -.19, p = .08) both demonstrated lower SR compared to White children at levels that approached statistical significance.

Table 15. Covariates predicting age 5 self-regulation factor

	Self-regulation factor (age 5)	
Variable name	**β (S.E.)**	***p***
Intervention group	0.06 (.05)	0.22
Child sex-female	0.12 (.07)	0.06†
Child race-Black	-0.19 (.11)	0.08†
Child race-Biracial	-0.10 (.06)	0.08†
Child race-Other race	-0.05 (.07)	0.44
Child ethnicity-Hispanic	0.12 (.06)	0.05†
Site-Charlottesville	-0.10 (.06)	0.11
Site-Pittsburgh	0.07 (.06)	0.28
Family income (early)	-0.10 (.08)	0.24
Primary caregiver education (early)	-0.01 (.05)	0.82
People in home (early)	0.04 (.06)	0.49
# of family moves age 2-10	-0.03 (.05)	0.57
Externalizing symptoms (age 2)	0.05 (.05)	0.35
Intercepts (unstandardized)	**B (S.E.)**	***p***
Tower task	.02 (.12)	.84
Draw-a-Star task	-.01 (.06)	.90
Wrapped gift task	-.07 (.31)	.81
Model fit: χ^2 (df=26) = 40.48 (p = .04); *CFI* = .72; *TLI* = .55; *RMSEA* = .03; *SRMR* = .03		

*Denotes significance at $p < .05$
†Denotes marginal significance at $p < .10$

In the multivariate structural equation model, of the three neighborhood social context variables, census-derived neighborhood disadvantage was found to significantly predict the SR factor such that higher neighborhood disadvantage was associated with *higher* SR (β = .15, p < .05) (see Table 16). The effects of all three of the neighborhood social context variables were then tested on cool (Draw-A-Star task) and hot (Wrapped Gift task) SR separately (see Table 17). None of the social context variables significantly predicted either cool or hot SR. Census-derived neighborhood social disadvantage was associated with hot SR at a level that approached significance (β = .10, p = .06).

Table 16. Covariates and early childhood neighborhood social context predicting age 5 self-regulation factor

	Self-regulation factor (age 5)	
Variable name	**β (S.E.)**	***p***
Intervention group	0.06 (.05)	0.26
Child sex-female	0.12 (.06)	0.05†
Child race-Black	-0.27 (.10)	0.01*
Child race-Biracial	-0.11 (.05)	0.04*
Child race-Other race	-0.05 (.07)	0.49
Child ethnicity-Hispanic	0.11 (.06)	0.07†
Site-Charlottesville	-0.07 (.06)	0.20
Site-Pittsburgh	0.06 (.06)	0.36
Family income (early)	-0.08 (.08)	0.32
Primary caregiver education (early)	0.00 (.06)	0.99
People in home (early)	0.05 (.06)	0.46
# of family moves age 2-5	-0.04 (.06)	0.50
Externalizing symptoms (age 2)	0.04 (.05)	0.40
Census neighborhood disadvantage (early)	0.15 (.07)	0.02*
Parent-reported neighborhood danger (early)	-0.01 (.06)	0.93
Parent-reported neighborhood cohesion (early)	-0.06 (.06)	0.31
Intercepts (unstandardized)	**B (S.E.)**	***p***
Tower task	-.01 (.17)	.97
Draw-a-Star task	-.00 (.07)	.97
Wrapped gift task	-.03 (.36)	.94
Model fit: χ^2 (*df*=32) = 46.39 (*p* = .05); *CFI* = .76; *TLI* = .62; *RMSEA* = .03; *SRMR* = .02		

*Denotes significance at $p < .05$
†Denotes marginal significance at $p < .10$

Table 17. Covariates and early childhood neighborhood social context predicting age 5 hot and cool self-regulation (two separate models)

	Cool self-regulation		Hot self-regulation	
Variable name	**β (S.E.)**	***p***	**β (S.E.)**	***p***
Intervention group	-0.06 (.04)	0.22	.04 (.04	.36
Child sex-female	-0.06 (.04)	0.12	.11 (.04)	.00*
Child race-Black	-0.08 (.05)	0.11	-.21 (.06)	.00*
Child race-Biracial	-0.09 (.05)	0.09	-.08 (.04)	.04*
Child race-Other race	-0.01 (.05)	0.82	-.04 (.06)	.51
Child ethnicity-Hispanic	-0.10 (.05)	0.05	.10 (.05)	.07†
Site-Charlottesville	-0.01 (.06)	0.91	-.06 (.05)	.16
Site-Pittsburgh	-0.06 (.06)	0.32	.04 (.05)	.43
Family income (early)	-0.01 (.06)	0.85	-.06 (.06)	.31
Primary caregiver education (early)	0.11 (.05)	0.02	-.02 (.05)	.74
People in home (early)	0.04 (.06)	0.43	.05 (.05)	.34
# of family moves age 2-5	-0.06 (.05)	0.25	-.05 (.04)	.29
Externalizing symptoms (age 2)	-0.05 (.05)	0.36	.04 (.04)	.29
Census neighborhood disadvantage (early)	0.05 (.04)	0.22	.10 (.05)	.06†
Parent-reported neighborhood danger (early)	-0.08 (.05)	0.11	-.02 (.05)	.72
Parent-reported neighborhood cohesion (early)	0.01 (.05)	0.87	-.04 (.05	.38
Intercept (unstandardized)	**B (S.E.)**	***p***	**B (S.E.)**	***p***
	-.09 (.46)	.85	.00 (.34)	.99

*Denotes significance at $p < .05$
†Denotes marginal significance at $p < .10$

3.6.1 Sensitivity analysis

When models were tested with the control group only, social disadvantage was no longer found to significantly predict the SR factor.

3.7 Hypothesis 4: SR and BMI Growth/BMIz Age 10.5

Bivariate correlations between each of the SR variables and BMI at ages 5 and 10.5 were tested. The association between cool SR and age 5 BMI approached significance (r = -.11, p = .05), with cool SR measured at age 5 predicting lower concurrent BMI.

The SR factor was not found to be associated with any of the BMI growth terms (i.e., intercept, linear slope, quadratic slope) (see Table 18). Neither the cool nor hot SR tasks were found to be associated with any of the BMI growth terms.

Table 18. Covariates and self-regulation factor as predictors of BMI growth terms in latent growth curve model

	Intercept		**Linear Slope**		**Quadratic Slope**	
Variable name	**β (S.E.)**	***p***	**β (S.E.)**	***p***	**β (S.E.)**	***p***
Intervention group	-0.08 (.05)	0.12	0.11 (.05)	0.04*	-0.13 (.06)	0.03*
Child sex-female	0.00 (.05)	0.94	0.07 (.05)	0.19	-0.04 (.06)	0.56
Child race-Black	0.05 (.06)	0.45	0.11 (.07)	0.12	-0.07 (.08)	0.40
Child race-Biracial	0.03 (.05)	0.46	-0.05 (.06)	0.43	0.02 (.06)	0.71
Child race-Other race	0.04 (.06)	0.45	-0.01 (.08)	0.95	0.02 (.08)	0.78
Child ethnicity-Hispanic	-0.03 (.05)	0.62	0.20 (.10)	0.04*	-0.13 (.09)	0.15
Site-Charlottesville	0.15 (.05)	0.00*	0.01 (.06)	0.92	0.01 (.07)	0.91
Site-Pittsburgh	-0.04 (.05)	0.49	-0.05 (.07)	0.54	-0.01 (.07)	0.89
Family income (early)	-0.05 (.04)	0.18	-0.03 (.06)	0.61	-0.01 (.06)	0.91
Primary caregiver education (early)	0.04 (.05)	0.46	0.06 (.05)	0.25	-0.08 (.06)	0.21
People in home (early)	-0.09 (.04)	0.04*	-0.07 (.05)	0.18	0.06 (.06)	0.30
# of family moves age 2-10	0.00 (.06)	1.00	-0.07 (.07)	0.27	0.08 (.07)	0.22
Externalizing symptoms (age 2)	-0.04 (.04)	0.40	0.06 (.05)	0.26	-0.07 (.06)	0.20
Self-regulation factor (age 5)	-0.01 (.08)	0.93	-0.02 (.15)	0.88	-0.02 (.15)	0.91
Growth term intercepts (unstandardized)	**B (S.E.)**	***p***	**B (S.E.)**	***p***	**B (S.E.)**	***p***
	17.38 (.84)	.00*	-.19 (.41)	.65	.17 (.07)	.01*
Self-regulation indicator intercepts (unstandardized)						
Tower task	.02 (.05)					
Draw-a-Star task	.02 (.05)					
Wrapped gift task	.01 (.05)					
Model fit: χ^2 (*df*=83) = 165.66 (*p* = .00); *CFI* = .97; *TLI* = .96; *RMSEA* = .04; *SRMR* = .03						

*Denotes significance at $p < .05$; †Denotes marginal significance at $p < .10$

In a multivariate linear regression, there were no significant associations between the SR factor, hot, or cool SR on BMIz at age 10.5 (see Table 19).

Table 19. Covariates and self-regulation factor as predictors of age 10.5 BMIz

	BMIz age 10.5	
Variable name	**β (S.E.)**	***p***
Intervention group	-0.06 (.05)	0.47
Child sex-female	0.02 (.05)	0.82
Child race-Black	0.05 (.06)	0.35
Child race-Biracial	0.02 (.05)	0.83
Child race-Other race	-0.02 (.04)	0.67
Child ethnicity-Hispanic	0.10 (.06)	0.14
Site-Charlottesville	0.05 (.06)	0.25
Site-Pittsburgh	-0.04 (.06)	0.57
Family income (early)	-0.08 (.05)	0.17
Primary caregiver education (early)	0.02 (.05)	0.71
People in home (early)	-0.07 (.04)	0.17
# of family moves age 2-10	-0.01 (.04)	0.96
Externalizing symptoms (age 2)	-0.02 (.04)	0.97
Extracted self-regulation factor (age 5)	-.10 (.08)	0.21
BMIz intercept (unstandardized)	**B (S.E.)**	***p***
	1.46 (.51)	.00*
Self-regulation indicator intercepts (unstandardized)		
Tower task	.02 (.05)	
Draw-a-Star task	.02 (.05)	
Wrapped gift task	.01 (.05)	
Model fit: χ^2 (*df*=41) = 81.25 (*p* = .00); *CFI* = .30; *TLI* = .01; *RMSEA* = .04; *SRMR* = .03		

*Denotes significance at $p < .05$
†Denotes marginal significance at $p < .10$

3.7.1 Sensitivity analyses

In a model testing SR and BMI growth using only the control group, no significant associations were found. In a model that included age 10.5 pubertal status, there were also no statistically significant associations between SR (factor, hot, or cool) and BMI growth or BMIz at age 10.5.

3.8 Hypothesis 5: SR as a Mediator in the Association between Neighborhood Social Context and BMI Growth/BMIz at Age 10.5

As none of the neighborhood social context variables were directly related to SR or any BMI outcome, it was not possible to test whether SR mediated the association between neighborhood social context and BMI growth.

3.9 Hypothesis 6a: Supportive Parenting as a Moderator of Associations between Neighborhood Social Context and Child SR and SR and BMI Growth/BMIz at Age 10.5

Next, supportive parenting was tested as a moderator of associations between neighborhood social context and child SR, and between SR and BMI growth.

3.9.1 Parenting as a moderator in the association between neighborhood social context and child SR

To test for the potential role of supportive parenting in moderating associations between neighborhood social context and child SR, all neighborhood social context variables (census-based neighborhood social disadvantage, parent-reported neighborhood danger, and parent-reported neighborhood cohesion) were entered into the model as independent variables, along with each variable's interaction with supportive parenting at age 3 and 4. All variables (centered) and the three two-way interaction terms were entered in the same model. In total, three models were tested: one for the broadband SR factor and two for hot and cool SR, respectively, as an exploratory analysis.

3.9.1.1 SR factor

Of the three interactions tested, one significant two-way interaction was found between neighborhood social disadvantage and supportive parenting in relation to the broadband child SR factor. After accounting for the direct effects of supportive parenting (which was not statistically significant; $\beta = .34$, *ns*) and of neighborhood social disadvantage (not statistically significant; $\beta = .05$, *ns*), a significant interaction was evident between neighborhood social disadvantage and supportive parenting in relation to SR ($\beta = -.28$, $p < .05$) (see Table 20).

Table 20. Interactions between early childhood neighborhood social context and supportive parenting in relation to age 5 self-regulation factor

	Self-regulation factor (age 5)	
Variable name	**β (S.E.)**	***p***
Intervention group	0.04 (.05)	0.40
Child sex-female	0.10 (.06)	0.10†
Child race-Black	-0.24(.09)	0.01*
Child race-Biracial	-0.11 (.06)	0.05*
Child race-Other race	-0.05 (.087	0.51
Child ethnicity-Hispanic	0.12 (.07)	0.07†
Site-Charlottesville	-0.03 (.06)	0.59
Site-Pittsburgh	0.13 (.08)	0.11
Family income (early)	-0.09 (.09)	0.28
Primary caregiver education (early)	-0.05 (.07)	0.50
People in home (early)	0.05 (.06)	0.46
# of family moves age 2-5	-0.03 (.06)	0.65
Externalizing symptoms (age 2)	0.05 (.06)	0.40
Census neighborhood disadvantage (early)	0.05 (.06)	0.44
Parent-reported neighborhood danger (early)	.07 (.06)	0.20
Parent-reported neighborhood cohesion (early)	-0.04 (.06)	0.52

Observed supportive parenting (age 3 & 4)	0.34 (.24)	0.16
Parenting x census neighborhood disadvantage	-0.28 (.09)	0.00*
Parenting x parent-reported neighborhood danger	.13 (.13)	0.32
Parenting x parent-reported neighborhood cohesion	-0.14 (.15)	0.35
Intercepts (unstandardized)	**B (S.E.)**	***p***
Tower task	.01 (.18)	.96
Draw-a-Star task	.00 (.08)	.97
Wrapped gift task	.01 (.34)	.99
Model fit: χ^2 (df=40) = 68.68 (p = .00); *CFI* = .63; *TLI* = .42; *RMSEA* = .04; *SRMR* = .02		

*Denotes significance at $p < .05$
†Denotes marginal significance at $p < .10$

Although it was predicted that supportive parenting would provide a buffering effect in which the relationship between high neighborhood social disadvantage and child SR would be attenuated in the context of supportive parenting, it was instead found that the association between supportive parenting and SR became weaker at *higher* levels of neighborhood social disadvantage (see Figure 4). The simple slope of supportive parenting on SR was significant when neighborhood social disadvantage was at or below 0, the centered mean (t = 2.00, $p < .05$). In other words, supportive parenting was significantly associated with greater SR for children who lived in neighborhoods below the mean of social disadvantage during early childhood, and the association between supportive parenting and SR became stronger as neighborhood social disadvantage decreased. The standardized beta coefficient of -.28 is equivalent to an r value of -.33 (Lenhard & Lenhard, 2016), indicative of an moderate effect size (Cohen, 1988).

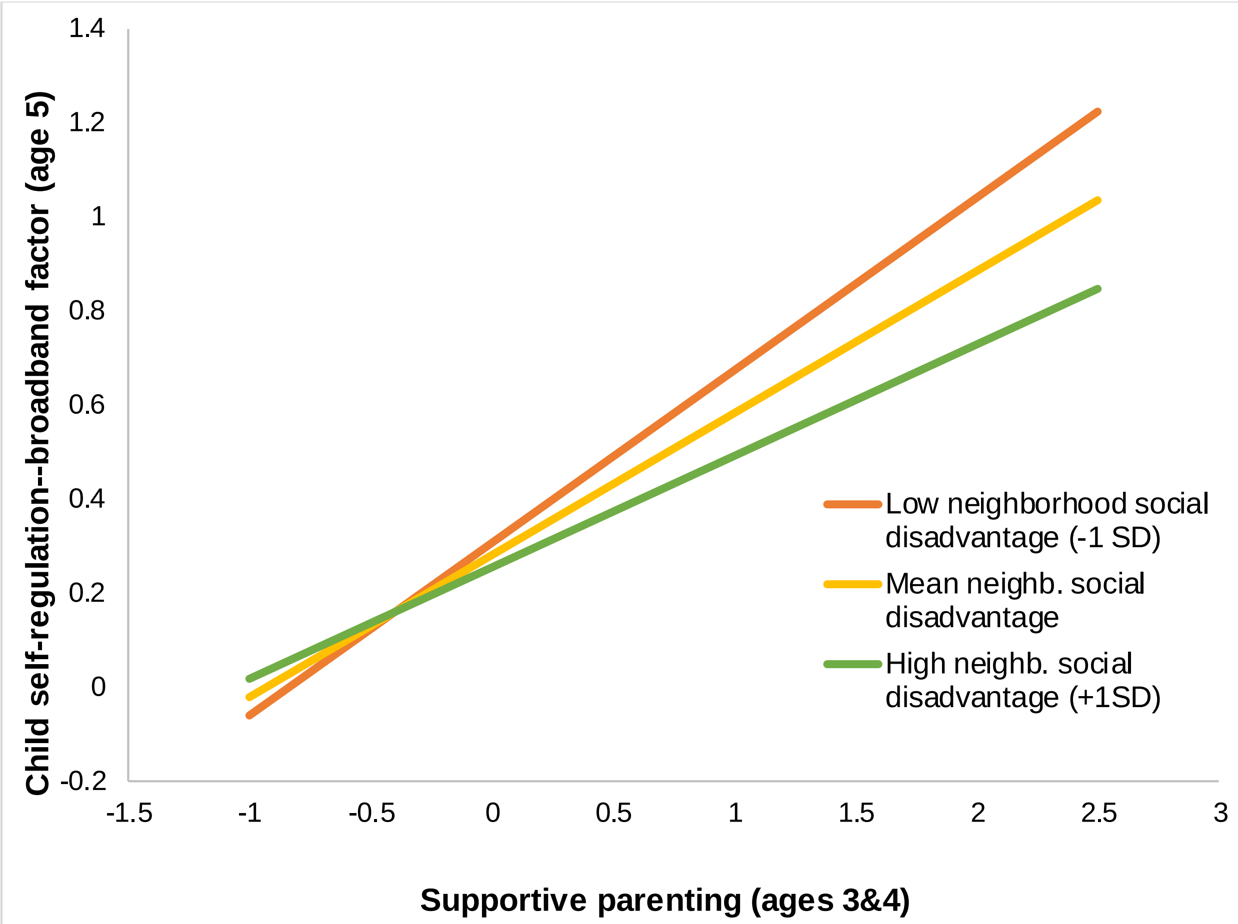

Figure 4. Interaction between supportive parenting and neighborhood social disadvantage in relation to child self-regulation broadband factor

3.9.1.2 Hot/cool SR

Interactions between neighborhood social context variables and supportive parenting in relation to both the cool and hot SR tasks were then tested as an exploratory analysis. After accounting for main effects of supportive parenting (β = .39, p = .05) and neighborhood social disadvantage (β = .04, *ns*), the interaction between supportive parenting and neighborhood social disadvantage in relation to cool SR was not statistically significant (β = -.09, *ns*). For the hot SR task, after accounting for main effects of supportive parenting (β = .22, *ns*) and neighborhood social disadvantage (β = .03, *ns*), there was a significant interaction between supportive parenting and neighborhood social disadvantage in relation to hot SR (β = -.16, $p < .05$) (see Table 21).

Table 21. Interactions between early childhood neighborhood social context and supportive parenting in relation to age 5 hot and cool self-regulation (two separate models)

	Cool self-regulation		**Hot self-regulation**	
Variable name	**β (S.E.)**	***p***	**β (S.E.)**	***p***
Intervention group	-0.07 (.04)	0.13	0.03 (.04)	0.44
Child sex-female	-0.07 (.04)	0.10	0.10 (.04)	0.01*
Child race-Black	-0.06 (.05)	0.26	-0.17 (.05)	0.00*
Child race-Biracial	-0.08 (.05)	0.11	-0.08 (.04)	0.05†
Child race-Other race	-0.02 (.05)	0.69	-0.04 (.06)	0.56
Child ethnicity-Hispanic	-0.10 (.06)	0.04*	0.10 (.06)	0.06†
Site-Charlottesville	0.03 (.06)	0.57	-0.03 (.05)	0.55
Site-Pittsburgh	0.00 (.06)	0.94	0.10 (.06)	0.09†
Family income (early)	-0.03 (.05)	0.65	-0.07 (.06)	0.29
Primary caregiver education (early)	0.07 (.06)	0.14	-0.05 (.05)	0.30
People in home (early)	0.05 (.06)	0.39	0.05 (.05)	0.33
# of family moves age 2-5	-0.05 (.06)	0.34	-0.03 (.05)	0.45
Externalizing symptoms (age 2)	-0.04 (.05)	0.48	0.05 (.04)	0.24
Census neighborhood disadvantage (early)	0.04 (.06)	0.48	0.03 (.05)	0.47
Parent-reported neighborhood danger (early)	-0.09 (.06)	0.12	0.05 (.05)	0.30
Parent-reported neighborhood cohesion (early)	0.01 (.05)	0.77	-0.02 (.05)	0.63
Observed supportive parenting (age 3 & 4)	0.39 (.20)	0.05†	0.22 (.17)	0.18
Parenting x census neighborhood disadvantage	-0.09 (.06)	0.14	-0.16 (.07)	0.02*
Parenting x parent-reported neighborhood danger	-0.13 (.09)	0.14	0.16 (.10)	0.11
Parenting x parent-reported neighborhood cohesion	-0.10 (.15)	0.49	-0.13 (.11)	0.22
Intercept (unstandardized)	**B (S.E.)**	***p***	**B (S.E.)**	***p***
	-.04 (.45)	.93	-.02 (.34)	.97

*Denotes significance at $p < .05$
†Denotes marginal significance at $p < .10$

Similar to the interaction found between parenting and neighborhood social disadvantage in relation to the broadband SR factor, supportive parenting was associated with the promotion of hot SR in the context of low levels of neighborhood social disadvantage (see Figure 5). The simple slope of supportive parenting on hot SR was significant when neighborhood social disadvantage was less than -.80, or approximately one standard deviation below the mean (t = 2.02, $p < .05$).

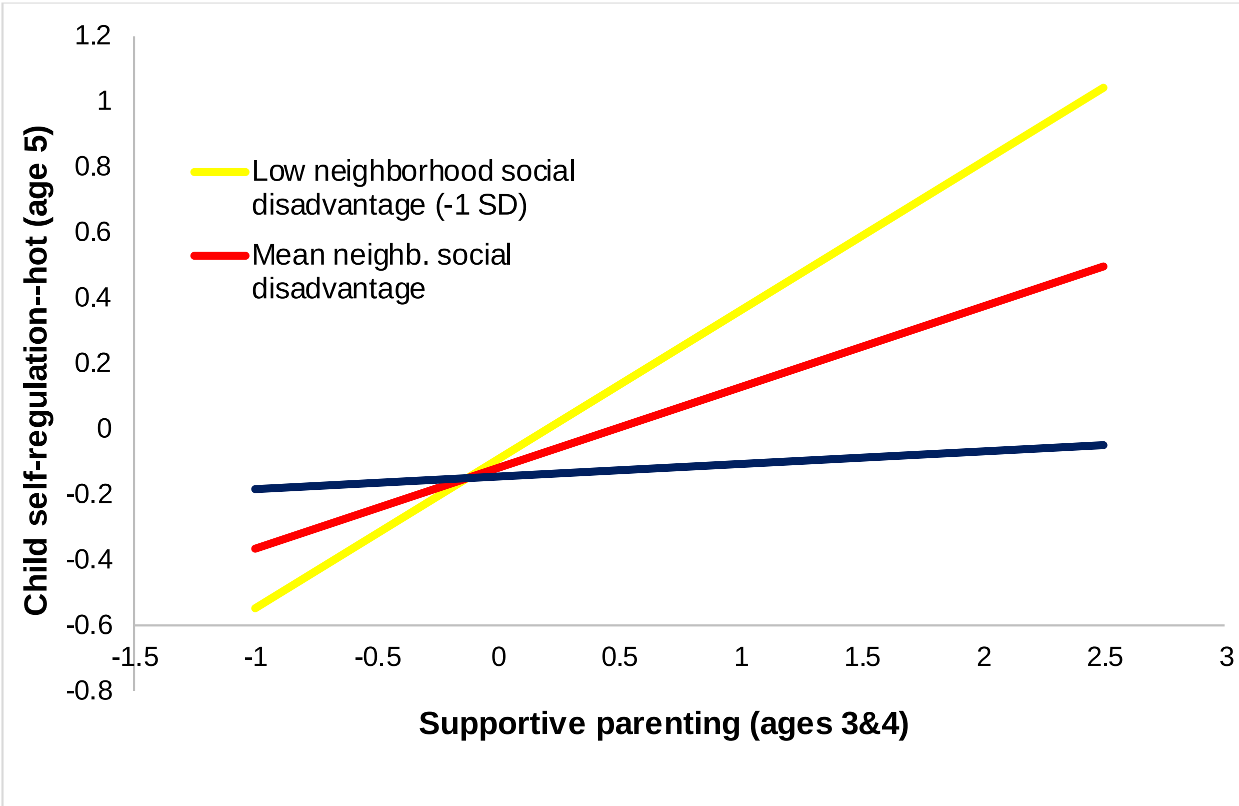

Figure 5. Interaction between supportive parenting and neighborhood social disadvantage in relation to child hot self-regulation (wrapped gift task)

3.9.1.3 Sensitivity analyses

When harsh parenting was added to the model as an additional covariate, the interaction between neighborhood social disadvantage and supportive parenting in relation to the SR factor was still significant ($\beta = -.24$, $p < .05$). With harsh parenting added as a covariate in the model with hot SR as the outcome, the interaction was still significant ($\beta = -.18$, $p < .05$).

In a model testing associations using only the control group, the interaction between early neighborhood social disadvantage and supportive parenting in relation to the broadband SR factor was not significant ($\beta = -.43$, *ns*). The interaction in relation to hot SR was still statistically significant ($\beta = -.32$, $p < .05$).

3.9.2 Parenting as a moderator in the association between child SR and BMI growth/BMIz age 10.5

There were no statistically significant interactions between supportive parenting and SR in relation to any of the BMI growth terms (see Table 22) or BMIz at age 10.5 (see Table 23).

Table 22. Interactions between self-regulation and supportive parenting as predictors of BMI growth terms in latent growth curve model

	Intercept		Linear Slope		Quadratic Slope	
Variable name	**β (S.E.)**	***p***	**β (S.E.)**	***p***	**β (S.E.)**	***p***
Intervention group	-0.05 (.05)	0.30	0.13 (.05)	0.01*	-0.15 (.06)	0.01*
Child sex-female	0.01 (.05)	0.81	0.06 (.06)	0.27	-0.03 (.07)	0.68
Child race-Black	0.02 (.07)	0.82	0.11 (.08)	0.16	-0.07 (.08)	0.40
Child race-Biracial	0.01 (.05)	0.87	-0.07 (.06)	0.22	0.05 (.06)	0.39
Child race-Other race	0.02 (.05)	0.72	-0.05 (.07)	0.47	0.07 (.08)	0.35
Child ethnicity-Hispanic	-0.03 (.05)	0.58	0.23 (.10)	0.02*	-0.15 (.09)	0.10
Site-Charlottesville	0.16 (.05)	0.00*	0.03 (.06)	0.64	-0.02 (.07)	0.74
Site-Pittsburgh	-0.02 (.06)	0.79	0.00 (.08)	0.96	-0.08 (.08)	0.31
Family income (early)	-0.08 (.04)	0.06†	-0.05 (.06)	0.37	0.02 (.06)	0.77
Primary caregiver education (early)	0.01 (.05)	0.88	0.04 (.06)	0.49	-0.05 (.07)	0.46
People in home (early)	-0.06 (.05)	0.16	-0.05 (.05)	0.29	0.05 (.06)	0.42
# of family moves age 2-10	-0.03 (.05)	0.52	-0.06 (.06)	0.32	0.07 (.06)	0.25
Externalizing symptoms (age 2)	-0.03 (.05)	0.51	0.09 (.09)	0.10†	-0.10 (.06)	0.08†
Self-regulation factor-extracted (age 5)	-0.04 (.07)	0.59	-0.04 (.09)	0.63	0.03 (.09)	0.73
Observed supportive parenting (age 3 & 4)	0.03(.06)	0.67	0.04 (.07)	0.54	-0.12 (.08)	0.12
Self-regulation x parenting	0.03 (.08)	0.73	-0.14 (.12)	0.25	0.17 (.13)	0.17
Growth term intercepts (unstandardized)	**B (S.E.)**	***p***	**B (S.E.)**	***p***	**B (S.E.)**	***p***
	17.57 (.85)	.00*	-.21 (.42)	.61	.18 (.07)	.01*
Model fit: χ^2 (*df*=38) = 90.69 (*p* = .00); *CFI* = .98; *TLI* = .96; *RMSEA* = .05; *SRMR* = .01						

*Denotes significance at $p < .05$
†Denotes marginal significance at $p < .10$

Table 23. Interactions between self-regulation and supportive parenting in relation to age 10.5 BMIz

	BMIz age 10.5	
Variable name	**β (S.E.)**	***p***
Intervention group	-0.03 (.05)	0.56
Child sex-female	0.01 (.05)	0.81
Child race-Black	0.04 (.07)	0.51
Child race-Biracial	0.00 (.05)	1.00
Child race-Other race	-0.02 (.05)	0.67
Child ethnicity-Hispanic	0.09 (.06)	0.12
Site-Charlottesville	0.06 (.06)	0.31
Site-Pittsburgh	-0.05 (.06)	0.45
Family income (early)	-0.08 (.05)	0.12
Primary caregiver education (early)	0.04 (.06)	0.51
People in home (early)	-0.06 (.04)	0.17
# of family moves age 2-10	-0.01 (.05)	0.88
Externalizing symptoms (age 2)	0.01 (.05)	0.83
Extracted self-regulation factor (age 5)	-0.04 (.06)	0.46
Observed supportive parenting (age 3 & 4)	-.04 (.06)	0.44
Self-regulation x parenting	-.01 (.06)	0.88
BMIz intercept (unstandardized)	**B (S.E.)**	***p***
	1.16 (.53)	.03*

*Denotes significance at $p < .05$

The interactions between supportive parenting and both hot and cool SR were then tested in relation to BMI growth and age 10.5 BMIz. After accounting for the direct effects of supportive parenting and hot or cold SR, there were no significant interactions between hot/cool SR and supportive parenting in relation to any of the BMI growth terms or BMIz at age 10.5.

3.10 Hypothesis 6b: Supportive Parenting as a Moderator of Associations between Neighborhood Social Context/Built Environment Variables and Child SR

To test for the potential contribution of supportive parenting in moderating associations between neighborhood social context and built environment in relation to child SR, the regression model included the aforementioned covariates, neighborhood early social context variables (neighborhood social disadvantage, cohesion, and danger), and early built environment variables (counts of park acreage, healthy, and less healthy food retailers in an 800m vicinity of children's homes) in relation to child SR. All variables (centered) and each of the six two-way interaction terms with supportive parenting were entered in the same model. A total of three models were tested: one for the broadband SR factor and two for hot and cool SR, respectively, as an exploratory analysis.

Because SR was not found to mediate the association between any of the neighborhood social context or built environment variables, the "full" moderated mediation model was not tested.

3.10.1 SR factor

Of the six interactions tested, one was statistically significant. After accounting for main effects of supportive parenting (*ns*) and neighborhood social disadvantage (*ns*), there was a significant interaction between supportive parenting and neighborhood social disadvantage (β = -.30, $p < .01$), with the relationship between supportive parenting and the broadband SR factor being stronger in the context of low levels of neighborhood social disadvantage (same pattern as described above) (see Table 24)

Table 24. Interactions between supportive parenting and neighborhood social context/built environment variables in relation to child self-regulation

	Self-regulation factor (age 5)	
Variable name	**β (S.E.)**	***p***
Intervention group	0.05 (.05)	0.35
Child sex-female	0.10 (.06)	0.10†
Child race-Black	-0.23 (.10)	0.02*
Child race-Biracial	-0.10 (.06)	0.06†
Child race-Other race	-0.05 (.07)	0.51
Child ethnicity-Hispanic	0.12 (.07)	0.07†
Site-Charlottesville	-0.04 (.06)	0.56
Site-Pittsburgh	0.12 (.08)	0.16
Family income (early)	-0.08 (.09)	0.33
Primary caregiver education (early)	-0.05 (.07)	0.50
People in home (early)	0.06 (.07)	0.37
# of family moves age 2-5	-0.04 (.06)	0.55
Externalizing symptoms (age 2)	0.05 (.05)	0.31
Census neighborhood disadvantage (early)	0.03 (.06)	0.65
Parent-reported neighborhood danger (early)	0.06 (.05)	0.24
Parent-reported neighborhood cohesion (early)	-0.04 (.06)	0.49
Healthy food retailers (early)	0.34 (.26)	0.19
Less healthy food retailers (early)	0.01 (.04)	0.84
Park space (early)	0.03 (.05)	0.52
Observed supportive parenting (age 3 & 4)	0.02 (.05)	0.71
Parenting x census neighborhood disadvantage	-0.30 (.09)	0.00*
Parenting x parent-reported neighborhood danger	0.12 (.13)	0.36
Parenting x parent-reported neighborhood cohesion	-0.15 (.15)	0.31
Parenting x healthy food retailers	0.04 (.09)	0.67
Parenting x less healthy food retailers	0.08 (.06)	0.15
Parenting x park space	-0.02 (.04)	0.61
Intercepts (unstandardized)	**B (S.E.)**	***p***
Tower task	-.02 (.17)	.90
Draw-a-Star task	-.01 (.07)	.86
Wrapped gift task	-.06 (.36)	.87
Model fit: χ^2 (*df*=52) = 79.53 (*p* = .00); *CFI* = .66; *TLI* = .47; *RMSEA* = .03; *SRMR* = .02		

*Denotes significance at $p < .05$
†Denotes marginal significance at $p < .10$

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3.10.2 Hot/cool SR

The interaction between census-based neighborhood social disadvantage and supportive parenting in relation to hot SR, where the association between supportive parenting and hot SR was stronger in the context of low neighborhood social disadvantage, was still significant in the model that included built environment variables and their interactions ($\beta = -.18$, $p < .05$). No other interactions were statistically significant for hot SR, and there were no statistically significant main effects or interactions using cool SR as an outcome.

4.0 DISCUSSION

The overarching aim of the current study was to test a model of child obesity that incorporated multiple levels of influence on child BMI growth, including child, family, and community-level predictors. Specifically, the first aim of the study was to assess longitudinal relationships between aspects of the neighborhood environment in early childhood—the built environment and neighborhood social context—in relation to BMI growth from early to middle childhood. The second aim was to test child SR as a mediator of associations between neighborhood predictors (both built environment and social context) and BMI growth. The final aim was to test supportive parenting as a protective factor in attenuating associations between neighborhood variables and SR and between SR and child weight outcomes. Overall, very little support was found for individual components of the proposed model.

Contrary to the hypothesis that aspects of the early childhood neighborhood built environment would be associated with growth in BMI from early to middle childhood, none of the built environment variables (parks or food retailers) were significantly associated with BMI growth. Of the neighborhood social context variables (parent report of neighborhood danger and cohesion, and census-derived neighborhood social disadvantage) tested, only parent-reported neighborhood cohesion in early childhood was significantly associated with growth in BMI, and only when considering quadratic growth. This finding, which indicated that cohesion was associated with a more rapid increase in growth later in childhood, was contrary to the hypothesis that neighborhood cohesion would be protective for child obesity risk (i.e., contribute to lower BMI growth over time).

In addition, there was no evidence for the hypothesis that a more disadvantaged early childhood neighborhood social context would be associated with lower SR at age 5. Nor was there support for lower age 5 SR predicting more rapid growth in BMI from age 5 to 10.5, so SR could not be tested as a mediator in the association between neighborhood variables and BMI growth.

In general, analyses did not indicate that supportive parenting attenuated the predicted associations between neighborhood social disadvantage and diminished SR, or between low SR and greater BMI growth. However, there was a significant interaction between supportive parenting and census-based neighborhood disadvantage, in which supportive parenting was protective for SR in the context of low levels of neighborhood disadvantage.

Finally, in an exploratory analysis that included both built environment and neighborhood social context predictors, no significant interactions between built environment and supportive parenting were found in relation to child SR.

4.1 Null Findings between Neighborhood Built Environment and Child BMI Growth

The lack of significant associations between the neighborhood built environment—parks and food retailers—and BMI growth from early to middle childhood was surprising, and is contrary to some prior literature. In previous work, including both cross-sectional and longitudinal studies, closer proximity to grocery stores (H. Chen & Wang, 2016) and parks (J. F. Bell et al., 2008) has been found to serve a protective function in preventing child obesity, and proximity to fast food restaurants and convenience stores has been associated with greater child obesity risk (Carroll-Scott et al., 2013; Galvez et al., 2009; Leung et al., 2011).

One feature of the current study that may explain the null findings is the focus on *early* childhood built environment in relation to weight gain from early to middle childhood. Although some longitudinal studies have established a relationship between the food retail environment and later BMI (H. Chen & Wang, 2016; Leung et al., 2011), few have tested this association in early childhood. It may be that the role of the built environment in predicting children's weight outcomes increases with children's developmental status. For example, of three studies that used the same sample (the Early Childhood Longitudinal Study, Kindergarten cohort) to assess longitudinal relationships between food retail store availability and child weight, the only one to find significant associations tested change in BMI from fifth to eighth grade (H. Chen & Wang, 2016). The other two publications from the same sample that failed to find an association tested BMI change from kindergarten to third grade (Sturm & Datar, 2005) and kindergarten to fifth grade (Lee, 2012). Interestingly, however, there is some evidence from a cross-sectional study for an association between the neighborhood food environment (specifically, fast food restaurant availability) and obesity in 2-4-year-old children living in both high- and low-income towns (Oreskovic, Kuhlthau, Romm, & Perrin, 2009). It could be that the food retail environment is indeed associated with child weight, but that the association does not persist into school-age. For low-income children in particular, who may receive up to two meals per day at school through the School Breakfast and National School Lunch Programs, their diet may undergo a drastic shift upon school entry that may change the effects of the children's food environment prior to school entry. Future studies should assess the food retail environment in relation to child anthropometric data longitudinally across multiple stages of child development.

In contrast, at least two longitudinal studies have found associations between exposure to green spaces in early childhood and later weight outcomes (J. F. Bell et al., 2008; Schalkwijk et al., 2017), a finding that was not supported in the current study. Interestingly, both studies tested neighborhood greenness objectively measured using satellite imagery, rather than parks, whose boundaries are defined by municipalities. Natural areas that children and families use for play may not be categorized as official "parks" and thus would not be included in publicly available databases such as those used in the current study. Moreover, there is some evidence that individuals' behavior in parks may vary depending on geographic context, with more frequent and physically active visits to urban, rather than rural, parks (Shores & West, 2010). In the current study, associations between built environment and child weight were assessed in three sites that varied considerably across the rural to urban continuum. It would therefore be quite useful for future researchers to parse apart how different types of neighborhood green spaces influence child weight (and potentially other health outcomes), and how these associations might vary depending on child age and geographic context.

In addition, the quality of the retrospective data gathered on the food retail environment and park locations could have influenced findings for both types of built environment data. For the food retail environment, business data were generated from the year 2005 for assessments conducted between the years 2003 to 2007 (when children were between 2 and 4 years old). Thus, because it is not clear how stable such data on food establishments would be in the years preceding and proceeding 2005 for age 2 to 10.5 assessments, the accuracy of our data might be less than optimal and could have varied in accuracy by site (e.g., if there was greater/less stability in food establishments in Eugene vs. Pittsburgh vs. Charlottesville). Although there are some known issues with publicly available business datasets (Wong, Peyton, Shields, Curriero, & Gudzune, 2017), there are few viable alternatives when conducting a study across multiple distinct metropolitan areas.

4.2 Null Findings between Neighborhood Social Context and Child BMI Growth

The absence of the hypothesized associations between exposure to neighborhood danger and social disadvantage in early childhood and children's increased BMI growth was somewhat unexpected, as several longitudinal studies (Gable, Chang, & Krull, 2007; Gose et al., 2013; Klebanov, Evans, & Brooks-Gunn, 2014) have found that these aspects of neighborhood social context are associated with BMI in early to middle childhood. However, as previously noted in the introduction, findings from empirical work testing associations between the neighborhood social environment and child weight have been mixed, particularly when assessing neighborhood exposure in early childhood (An, Yang, Hoschke, Xue, & Wang, 2017; Burdette & Whitaker, 2004; Hails & Shaw, 2019; K. Johnson et al., 2019).

Although there is large body of literature focusing on how socioeconomic adversity may influence child weight outcomes, most studies have investigated poverty at the family rather than neighborhood level. Interestingly, in the current study, early family income was not a significant predictor of BMI growth from age 5 to 10.5, although there was a weak and marginally significant correlation between early family income and BMI at age 10.5 (r = -.08, p = .09). In a systematic review, it was found that effect sizes in the association between family income and child BMI were weaker or nonexistent in studies using predominantly low-income samples (Hails et al., 2019). Perhaps within samples comprised predominantly of low-income families residing primarily in disadvantaged neighborhoods, associations between neighborhood and/or family SES and BMI are attenuated. There is some evidence that at very high levels of poverty, children are *less* likely to be overweight or obese than children living in families who are closer to the poverty line (Kimbro et al., 2011; Mahoney, Lord, & Carryl, 2005), although the reason for this is not well understood. It could be that children from families at the lowest end of the income spectrum benefit from government nutritional programs, thereby reducing obesity risk (Chaparro, Crespi, Anderson, Wang, & Whaley, 2019).

The significant association between parent-reported neighborhood cohesion in early childhood and the quadratic term for BMI growth was in the opposite of the expected direction, with greater cohesion associated with an increase in the rate of growth between ages 8.5 and 10.5. Although findings from several studies provide evidence in support of neighborhood cohesion having a protective effect on child risk for obesity (Gose et al., 2013; Schmidt, Sleddens, de Vries, Gubbels, & Thijs, 2015), some researchers suggest that perhaps close social networks that promote less healthy behaviors and lifestyles may increase obesity risk (Christakis & Fowler, 2007; Zhu & Thomas, 2013), or even attenuate the effectiveness of a child obesity prevention program (Shin et al., 2014).

4.3 Null Findings between Neighborhood Social Context and Child SR

In contrast to the null findings in the current study, there is a moderately large body of literature supporting an association between the neighborhood social environment and child SR, although most studies testing relationships between neighborhood conditions and SR focus on school-age children or adolescents (Gibson et al., 2010; McCoy, Roy, & Raver, 2016; Roy et al., 2014). It could be that for the current study, it was simply too early to detect associations between the neighborhood context (measured when children were between 2 and 4 years of age) and SR (measured at age 5). Perhaps such neighborhood influences may not come into play until later in childhood when children start to spend more time outside of the home (e.g., peer influences in neighborhood and at school, exposure to violence). For example, one study found that the association between neighborhood social disadvantage (using the same measure as that used in the current study) and child behavior problems appeared at age 6, but not earlier, and was only apparent for children in the most disadvantaged neighborhoods (Winslow & Shaw, 2007).

On the other hand, some cross-sectional and longitudinal studies *have* found effects of neighborhood conditions on other aspects of early childhood development, including observed effortful control at age 3 (Warren & Barnett, 2020) and externalizing problems at age 5 (Kim, Lee, Jung, Jaime, & Cubbin, 2019). Although direct exposure to the neighborhood environment tends to be limited in early childhood, neighborhood poverty has been found to influence preschool-age children’s verbal skills and behavior indirectly via parenting and the cognitive home environment (Kohen, Leventhal, Dahinten, & McIntosh, 2008). As mediators of associations between neighborhood social context variables and child SR were not assessed in the current study, it remains unknown whether there might be significant indirect effects; this would be a valuable area for future research.

4.4 Null Findings between Child SR and BMI Growth

Poor self-regulation is known to be a risk factor in the development of child obesity. Although many studies assessing this relationship are cross-sectional and use questionnaire measures of SR, there is a smaller body of longitudinal work that has established an association between early observed SR and BMI several years later. In the current study, SR was measured using three observed tasks that assessed facets of SR, including ability to delay (Wrapped Gift task), slowing down motor activity (Draw-A-Star task), and response inhibition (Tower task), with the Wrapped Gift and the Draw-A-Star tasks categorized as measures of hot and cool SR, respectively. None of these observed tasks were found to predict BMI growth.

There are many more observed measures that test other facets of early childhood SR than those assessed in this study. Importantly, an observed measure of SR involving food (e.g., delay of gratification using a palatable snack rather than a wrapped gift) was not used in the current study. Although general measures of SR would be expected to at least moderately correlate with appetite-specific SR measures, theory and empirical evidence suggest that they measure different attributes (Hughes, Power, O'Connor, & Fisher, 2015; Russell & Russell, 2020; Saltzman, Fiese, Bost, & McBride, 2018).

Although general, non-food SR tasks have been found to predict BMI longitudinally (Graziano et al., 2013; Tandon et al., 2015), these studies have not assessed BMI beyond early childhood. It could be that food-specific SR tasks have stronger predictive validity for BMI assessed later in childhood; that is, perhaps reward responsivity to food is more stable than other types of SR in its relationship to later BMI. Indeed, of several studies that tested SR in early childhood in relation to BMI in middle childhood or adolescence, all included a measure of SR that involved food (Bub et al., 2016; Evans et al., 2012; Seeyave et al., 2009).

However, in the current study we would have at least expected to see stronger concurrent associations between the SR tasks and BMI at age 5. The strongest correlation, albeit still modest, was for the Draw-a-Star task and age 5 BMI (r = -.11, p = .05), with greater SR demonstrated in the Draw-a-Star task associated with lower concurrent BMI. Associations between the other two SR tasks and age 5 BMI were not significant (with r's ranging from -.07 to .05). Another possibility is that within a low-income sample, other more powerful obesity-promoting factors, such as diet and physical activity, may dilute the effects of SR, perhaps especially over more time between measurements.

4.5 Interaction between Neighborhood Disadvantage and Supportive Parenting in Relation to Child SR

Although analyses in general did not suggest that supportive parenting moderates associations between neighborhood social context and child SR, one significant interaction was found indicating that the relationship between supportive parenting and child SR was stronger in the context of *low* levels of census-based neighborhood social disadvantage. This finding is consistent with some prior work testing interactions between family functioning and neighborhood context in relation to child outcomes. Findings from a literature review support the theory that in the context of extreme neighborhood deprivation, the influence of family and parenting may be "overwhelmed" by extra-familial contextual risk factors (Schonberg & Shaw, 2007). Specifically, Shaw, Criss, Schonberg, and Beck (2004) found that observations of structured parenting assessed at child age 10 served a protective function for children's antisocial behavior at age 12 for those living in neighborhoods with low to moderate levels of risk, but that the relationship was attenuated at the most severe levels of neighborhood risk.

In the current study, no evidence was found for the hypothesis that supportive parenting would moderate the association between child SR and BMI growth. Relatively few studies have tested interactions between child- and family-level predictors in relation to child weight outcomes or eating behaviors. This area has been identified as an important topic for future investigation (Bohnert, Loren, & Miller, 2020; Saltzman et al., 2018), with studies testing such interactions across multiple stages of child development (i.e., formal school entry, early adolescence, and beyond) being particularly critical. Although a longitudinal study by Moding and colleagues (2018) found support for the theory that supportive parenting attenuates the association between toddlers' poor SR and weight outcomes at preschool-age, their study was limited to early childhood. Thus, there is clearly a need for studies testing associations between early childhood SR and parenting that continue to follow children beyond the early childhood period. In addition, it may be helpful to incorporate multiple observations of parenting across different parent-child interaction contexts, especially observations of mealtime interactions (Saltzman, Bost, McBride, & Fiese, 2019). In sum, there is a great need for more investigators to adopt social-ecological (Harrison et al., 2011) and developmental psychopathology (Bohnert et al., 2020) frameworks into the study of childhood obesity, testing interactions across multiple contexts and levels of influence on children across developmental stages.

4.6 Limitations and Future Directions

There are several important limitations that may have hindered this study's ability to detect predictors of both SR and weight outcomes. One important methodological limitation, already briefly discussed, is the quality of the historical built environment data available in the present study. The datasets containing food retailer and parks locations were based on publicly available datasets from 2005, and unfortunately there is no way to confirm these precise locations due to the 15-year time lag. Perhaps more problematically, there could also be systematic differences in classification of stores and parks across communities. For example, in urban areas, estimates of small food retailers and fast food restaurants are likely low (Wong et al., 2017).

That the study's sample is comprised of families from three very different types of communities (Pittsburgh, PA; Eugene, OR; Charlottesville, VA) is both a unique strength and a significant limitation of this study. These cities vary considerably from one another in ways that may be especially relevant to this study's variables of interest, including but not limited to population density, poverty rates, access to parks and green spaces, and the food retail environment. In the current study, variables were operationalized and analyzed in the same way for all sites. However, the appropriateness of certain methodologies, particularly with respect to some of the measures of built environment, may vary by site. For example, the majority (68%) of families from the more rural Charlottesville site did not have a park within 800m of their home at child age 2, 3, or 4, as compared with 40% in Pittsburgh and 19.2% in Eugene. Families residing in more rural areas generally have greater exposure to green space but less access to neighborhood parks (Wen et al., 2013). As such, the use of a vegetation index, which measures the density of green vegetation cover in a given area, may have been a better measure of children's access to green spaces for families from the more rural Charlottesville site.

It is important to note that child obesity is more prevalent in rural areas (Johnson & Johnson, 2015), and there was some evidence for this trend in the current study. Children from Charlottesville had significantly higher raw BMI at age 5 compared with children from the other two sites, albeit BMI differences across site were not statistically significant at age 10.5. Although children from the Charlottesville site also had the least access to parks in the immediate vicinity of their home, park access was not associated with child weight outcomes in Charlottesville or any study site. It remains unclear whether a different measure of park/green space access would have better discriminated child weight. A more comprehensive understanding of how specific built environment attributes may differentially contribute to child obesity across the rural to urban continuum is critical, as this methodological advance could contribute to our conceptualization of socioeconomic and geographic disparities in child obesity.

A buffer of 800 meters around each child's address was selected for both parks and food retailers because of a desire to capture the walking environment surrounding children's homes (Timperio et al., 2004). Many other researchers have used a buffer of 800m or less to study how neighborhood environments affect different types of child outcomes, including weight, but they have typically focused on children and families residing in metropolitan areas (Oreskovic, Winickoff, Kuhlthau, Romm, & Perrin, 2009; Timperio et al., 2004). An 800m buffer for food retailers may have been too small for rural families, who have fewer food retailers within a small radius of their home. As an example, 37% of Charlottesville families had no food retailers of either type within 800m of their home, as compared with 15.5% and 10.7% in Eugene and Pittsburgh, respectively.

Another important limitation pertains to the measurement of SR used in the current study. As previously noted, none of the tasks were assessed SR in a food- or appetite-specific context, as they were designed to predict broader indices of social and emotional development (Murray & Kochanska, 2002) rather than weight outcomes. Studies that have used food delay tasks to measure child SR have tended to find stronger associations with later weight especially with longer time lags between measures (Evans et al., 2012; Seeyave et al., 2009). Therefore, the absence of a measure of food-specific SR may have resulted in underestimating associations between SR and BMI growth.

Several variables were not measured in the current study that would have been helpful to better elucidate relationships. First, family food insecurity was not assessed. It would have been useful to test whether food insecurity moderates associations between healthy and less healthy food retailers and child weight outcomes, as food insecurity is known to affect the types of foods that parents feed their young children (Cunningham et al., 2012). For example, it could be that greater quantity of fast food restaurants and convenience stores in the neighborhood is associated with faster BMI growth over time, but only for families experiencing food insecurity.

In addition, the first measurements of child height and weight took place when children were 5 years old, but it would have beneficial to have a measurement of child weight even earlier in childhood. It is possible that facets of the built environment and neighborhood social context have already influenced child adiposity prior to age 5. It is recommended that future studies adopt more of a true developmental approach by testing whether effects of neighborhood variables might be seen at different periods of child development, starting in early childhood and continuing through late adolescence. For example, adiposity rebound is a rise in BMI that typically occurs when children are between the ages of 3 and 7 (Cole, 2004), with earlier age at adiposity rebound a known risk factor for later obesity. As increased early caloric intake is associated with earlier adiposity rebound (Ip et al., 2017), it would be useful to understand whether neighborhood built environment and/or social context variables also influence age at adiposity rebound.

In spite of the many limitations, there were also a number of strengths of the current study. These include its longitudinal design, a racially diverse and low-income sample, observational measures of child SR and parenting, and multiple methods of assessing children's early environmental context, including parent report of neighborhood danger and cohesion, census data to measure sociodemographic neighborhood risk, and publicly available datasets of businesses and parks. The strengths of this study should be applied to future work in this area.

Regarding the measurement of neighborhood built environment, a prospective longitudinal study would improve future studies in this area. As retrospectively assessing attributes of neighborhoods based on historical data is difficult to validate, a study in which information on neighborhood built environment factors is collected in the present would be particularly beneficial. A study of this nature would allow for physical locations of food retailers and parks to be selectively "ground-truthed" using physical or electronic verification (e.g., Google Street View; Keralis et al., 2020). In addition, multiple measures of SR should be used, including both eating-specific and general task-based measures, as well as physiological SR measures (Graziano, Calkins, Keane, & O'Brien, 2012). Comparing broader and more specific components of SR relevant to eating could potentially better discriminate how SR influences child weight over time.

4.7 Clinical Implications

Based on mounting evidence that early SR is related to weight outcomes, researchers have started to incorporate general (i.e., not eating-specific) SR improvement strategies into obesity intervention and prevention efforts (Lumeng et al., 2017; Verbeken, Braet, Goossens, & Van der Oord, 2013). Unfortunately, there has thus far been little support for these SR-promoting programs in preventing or improving child obesity even when these interventions have been found to provide benefits for child SR (Lumeng et al., 2017). Rather than conclude that enhancing SR has no effect on child weight outcomes, it is instead essential that researchers further delve into specific types of SR that may be most relevant as targets for child obesity prevention, testing these issues across age periods to determine specific developmental stages most amenable to prevention efforts, and specifying populations of children for whom such interventions might be the most effective (e.g., preschool and/or early adolescent children at high risk of obesity based on family income/food insecurity, children of parents with obesity).

4.8 Summary

In conclusion, the current study provided little evidence for the initially proposed model by which SR mediates the association between neighborhood context and child weight outcomes, and supportive parenting serves as a protective factor in the context of neighborhood and/or child risk. Overall, aspects of the early childhood neighborhood context and SR at preschool-age were both unrelated to growth in child weight over time. Neighborhood social disadvantage was found to interact with supportive parenting in relation to preschool-age SR, such that the relationship between supportive parenting and SR was stronger in the context of lower levels of neighborhood disadvantage.

Although findings from the current study seem to indicate that the early childhood neighborhood context has little influence on weight outcomes at school-age, it would be unwise to conclude that these more distal factors are entirely unrelated to child weight. It could be that neighborhood contextual and built environment influences become more important in adolescence, and that the more immediate family food environment and food-specific parenting practices (Boswell, Byrne, & Davies, 2019; Couch, Glanz, Zhou, Sallis, & Saelens, 2014) in the early childhood home are most important for predicting weight trajectory throughout childhood.

Child obesity is complex and influenced by a multitude of factors both proximal and distal (Harrison et al., 2011). Therefore, continuing to conduct research evaluating interactions and mediating mechanisms among variables at multiple levels of children's ecology will be crucial for the development of effective obesity prevention programs, particularly those for children from low-income families.

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