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Child Obesity Moderates the Association Between Poverty and Academic Achievement

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Abstract

Childhood overweight and obesity are major public health problems in the United States. Children who experience poverty are 1.5 times more likely to suffer with overweight and 1.6 times more likely to have obesity. The extent to which overweight or obesity exacerbates the negative influence of socioeconomic inequality on child academic outcomes has not yet been examined. We estimated the effect of poverty on math and reading achievement trajectories using the Early Childhood Longitudinal Study (ECLS) Kindergarten class of 1998−1999 survey data and multilevel growth curve modeling techniques. Our findings indicate that the impact of obesity status is more pronounced for children from low socioeconomic backgrounds in both reading and math achievement, as well as for children with overweight in reading achievement scores. Thus, we see evidence that overweight and obesity moderate the pathway through which early-childhood poverty affects school performance. Given that we identified overweight and obesity as putative mechanisms through which socioeconomic deprivation affects academic achievement, focusing on overweight and obesity prevention may alter students' academic trajectories. Taken together, we see evidence that the combined negative effect of increased weight status and poverty, beyond the independent effects of each, has far-reaching consequences for educational outcomes.

Keywords: childhood obesity; socioeconomic inequality; poverty; academic achievement

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Introduction

Linking Child Poverty and Academic Achievement

More than 14 million school-age children in the United States live in poverty (Jiang & Koball, 2018). The percentage of children experiencing poverty varies by age group, with children under age 5 at the greatest risk (Jiang & Koball, 2018). Poverty also varies by race/ethnicity, with African American, Latinx, and American Indian children disproportionally low-income (Jiang & Koball, 2018). Notably, more than 50% of school-age children across the more than 98,000 public schools in the U.S. are raised in families whose incomes fall below the federal poverty threshold (Suitts, 2015). This is significant because socioeconomic inequities in academic achievement are well documented (Reardon, 2013; Sirin, 2005). Specifically, relative to their more affluent counterparts, students from economically disadvantaged backgrounds complete less education, receive lower grades in school, and perform worse on standardized tests (Duncan & Brooks-Gunn, 1997; Haveman & Wolfe, 1995; Sirin, 2005). The consequences of this lower educational attainment often persist into adulthood, ultimately contributing to restricted access to full-time, high-skill, high-return employment opportunities, lower wages, reduced occupational attainment, and lower occupational prestige (Duncan et al., 2012; Restuccia & Urrutia, 2004; Votruba-Drzal, 2009).

To better understand the mechanisms driving this variation in student achievement, empirical studies highlight the costs of poverty-related circumstances, such as chronic psychosocial stress, on children's academic achievement (Hair et al., 2015). Indeed, children growing up in low-income families are more likely to be exposed to long-term stressors including environmental pollution and toxin exposure (e.g., lead; Sargent et al., 1995), under-

resourced communities (Bischoff & Reardon, 2014), high-crime neighborhoods, homelessness, unstable housing, overcrowded households (Evans, 2004), family instability, directive-based parenting styles (Dunifon & Kowaleski-Jones, 2002; Jones et al., 2018; Lareau, 2003), parental psychiatric illness (Cox, 2018; Jensen, 2009; Treat et al., 2019), limited environmental and cognitive stimulation (Cedeño et al., 2016; Hair et al., 2015), and poor nutrition (Giskes et al., 2008; Hair et al., 2015). This is noteworthy because increased exposure to household and community poverty in childhood influences later life brain structure (Johnson et al., 2016; Luby et al., 2013; Taylor et al., 2020) and function (Johnson et al., 2016; Kim et al., 2013; Taylor et al., 2020). Additionally, economic disadvantage is associated with behavioral issues (Dike, 2017), as well as deficits across several cognitive domains such as executive function, attention and concentration, information-processing speed, learning capacity, and working and modality-specific memory (Black et al., 2017; Farah, 2017; Haft & Hoeft, 2017; Lund et al., 2020). Clinical profiles reflect not only behavioral problems and cognitive deficits among children raised in lower socioeconomic households, but also inferior language and math abilities, which in turn may contribute to worse performance on standardized academic achievement tests (Schwab & Lew-Williams, 2016; Sirin, 2005).

Linking Child Poverty and Child Obesity

Despite intense efforts to curb obesity, the number of children suffering with overweight and obesity in the United States is increasing (Bradwisch et al., 2020), with children raised by families facing economic hardship experiencing the highest susceptibility (Levine, 2011; Lobstein et al., 2015). The rates of childhood overweight and obesity follow a clear socioeconomic gradient, with Americans living in the most poverty-dense areas being the most likely to suffer with overweight or obesity (Wang & Beydoun, 2007). It is also known that the

influence of childhood financial instability on overweight and obesity outcomes varies by demographic characteristics (e.g., girls, African American girls, and Latinx boys are at the highest risk; Ogden et al., 2006), and that racial/ethnic disparities are largely explained by greater socioeconomic disadvantage (Ribeiro et al., 2020; Weden et al., 2012). This is concerning since it is well established that children with obesity are 10 times more likely to suffer with obesity as adults (Lee & Lee, 2011; Reilly & Kelly, 2011). Equally concerning are the published findings indicating that poverty-related long-term psychosocial stress predisposes children to a lifetime of adverse physiological and psychological health effects including asthma, obstructive sleep apnea, cancer, cardiovascular disease, diabetes, metabolic syndrome, stroke, depression, anxiety, and psychosis (Black et al., 2017; Farah, 2017; Ghandour et al., 2019; Rankin et al., 2016).

While the relationship between socioeconomic status (SES) and childhood overweight and obesity has been documented, the putative mechanisms have not been fully elucidated. Still, some modifiable risk factors have been identified (Gunstad et al., 2006; Laitinen et al., 2001; Ziol-Guest et al., 2009). For example, it is increasingly evident that chronic psychosocial stress brought on by having limited economic resources significantly contributes to obesity (Bradwisch et al., 2020). Moreover, poverty associates with decreased physical activity due to safety concerns and a lack of greenspace (Levine, 2011), decreased access to affordable healthy fresh foods (Ghosh-Dastidar et al., 2014; Lane et al., 2020), and increased access to high-caloric foods (i.e., “food swamps”; Cooksey-Stowers et al., 2017) with little-to-no nutritional value (i.e., ‘empty calories’; Casey et al., 2006; Drenowski & Specter, 2004; Lane et al., 2020). Indeed, these nutrition-related patterns begin early on, and fetal “over-nutrition” or “under nutrition” may play a role in the development of childhood obesity (Grun et al., 2009). Other determinants

of child overweight and obesity include the intrauterine environment (Grun et al., 2009; Strauss, 1997), early life sleep hygiene (Bell & Zimmerman, 2010), high-energy intake in early infancy (e.g., consumption of sweetened drinks; Lane et al., 2020; Trandafir & Temneanu, 2016), maternal obesity and gestational weight (Trandafir & Temneanu, 2016), and parenting behaviors (Archer-Banks & Behar-Horenstein, 2008; Luby et al., 2013). Taken together, lowered socioeconomic standing is a potent ingredient in the development of overweight (Bethell et. al., 2010) and obesity (Bradwisch et al., 2020), and children from minority communities are at an increased risk due to the aforementioned socioeconomic and environmental factors (Caprio et al., 2008; Kumanyika & Grier, 2006).

Linking Child Obesity and Academic Achievement

As previously discussed, economic disparities in the United States are linked to inequalities in both educational outcomes (e.g., academic achievement; Schwab & Lew-Williams, 2016; Sirin, 2005) and health outcomes (e.g., obesity; Levine, 2011; Lobstein et al., 2015). At the same time, there is evidence of a negative association between child obesity and academic outcomes (Kranjac, 2015; St.Clair-Thompson & Gathercole, 2006). Similar to the known effects of poverty-related toxic stress on cognition, obesity is also shown to associate with cognitive deficits and lower academic achievement in school-age children (Li et al., 2008; Yau et al., 2012). Data indicate further that poor academic performance in children with overweight or obesity may, in part, be driven by deficits in prefrontal cortex function, the part of the brain involved in executive function and cognitive self-regulation including decision-making, impulsivity, and emotional regulation (Meo et al., 2019; St.Clair-Thompson & Gathercole, 2006).

Aside from neurocognitive complications, children's challenges may extend to the social domain (Puhl & Latner, 2007; Strauss & Pollack, 2003). Specifically, due to the stigma associated with increased weight status, children with overweight and obesity are more often victims of social shaming, bullying, social marginalization and/or peer discrimination, and they tend to have fewer friendships and are often more socially isolated, compared to their normal-weight peers (Rankin et al., 2016; Strauss & Pollack, 2003). These negative social experiences are known potent environmental stressors that exert detrimental effects on physiological and psychological health (Tzanoulinou & Sandi, 2017). And in turn, as described above, chronic stress can lead to lowered academic performance (Robinson, 2006). The direction of causality, however, is unclear given that impaired social competence in elementary school-age children is associated with lowered academic performance (Jackson & Cunningham, 2015). Still, the perceived and experienced stigma, as well as self-stigma, are frequently observed in children with obesity (Puhl & Latner, 2007; Strauss & Pollack, 2003).

Present Analysis

To date, studies emphasize the independent effects of poverty (Archer-Banks & Behar-Horenstein, 2008; Schwab & Lew-Williams, 2016; Sirin, 2005) and obesity (St.Clair-Thompson & Gathercole, 2006) on academic outcomes, seemingly neglecting potential *additive* effects of poverty and increased weight status on academic achievement. To the best of the authors' knowledge, the extent to which overweight or obesity exacerbates the negative influence of poverty on academic performance has not been examined. Our aim is to investigate the extent to which overweight and obesity moderates the pathway of poverty to academic achievement. Importantly, and relevant to our study, moderating factors may influence the relationship between SES and academic achievement. For example, a medium-to-strong relationship between

SES and academic achievement has been reported, but this relationship appears to be moderated by the unit, source, and range of socioeconomic variables, as well as the type of socioeconomic-achievement measure used (Sirin, 2005). This relationship is further contingent upon children's school level and location, and race/ethnicity (Sirin, 2005). Thus, increased weight status may explain some of the association between poverty and school performance. Our hypothesis is based on the previously well-described *independent* effects of poverty and overweight and obesity on child academic outcomes. Consequently, this study adds to the existing literature, and helps clarify the impact of overweight and obesity on impoverished children's academic achievement.

Method

Data and Sample

Analyses are based on the Early Childhood Longitudinal Study—Kindergarten class 1998-1999 (ECLS-K), a nationally representative sample of 21,260 U.S. children from kindergarten to 8th grade. Participants were selected using a multi-stage sampling design. A more detailed description of the ECLS-K study design is provided by the U.S. Department of Education (Tourangeau et al., 2009). We estimate academic achievement trajectories using maximum-likelihood methods (MLM) that rely on data from children with one or more years of non-missing values. This approach maximizes the statistical power for differentiating between achievement trajectories of children with missing data on the outcome for any assessment period. We exclude children with missing data on key covariates for any assessment period and for those who changed schools (final sample size = 13,694).

Measures

Academic Achievement

At each assessment period, children were tested on age-appropriate reading and mathematical knowledge and skills. The assessment was developed specifically for the ECLS-K, and children were tested on previously used instruments (Willis et al., 1997). The ECLS-K reading assessment focused on basic skills such as print familiarity, letter recognition, beginning and ending sounds, recognition of common words, decoding multisyllabic words, vocabulary knowledge, and reading comprehension. Emphasis is placed on basic reading skills during the kindergarten and 1st grade assessments and greater emphasis is placed on comprehension in the 3rd, 5th, and 8th grade assessments. The ECLS-K math assessment focused on age-appropriate mathematical knowledge and skills such as knowledge of numbers and shapes, relative size, ordinality and sequence, addition and subtraction, multiplication and division, place value, rate and measurement, fractions, and area and volume (Tourangeau et al., 2009, pp 2-10). The assessments yielded number right scores, standardized scores, and latent trait scores from item response theory (IRT). We used item response theory (IRT) scores because this assessment placed children's ability on a continuous scale based on the items a child would have answered correctly if all the questions were answered for that particular assessment. Reliability of reading and math scores were high at Cronbach Alpha levels, ranging from 0.92 to 0.96 and 0.89 to 0.94, respectively (Tourangeau et al., 2009).

Overweight and Obesity Status

ECLS-K staff assessed children's height and weight during each assessment. The measurements were recorded twice, and the average of the two is used. The overall average unweighted body mass index (BMI) score was 18.36, with a standard deviation of 4.53. Using

the 2000 CDC Growth Charts: United States (Kuczmarski et al., 2002), we generated age- and sex-specific measures based on BMI (weight [kg/height [m]^2), and classified children as underweight (<5th percentile), normal-weight (>5th percentile and <85th percentile), overweight (>85th percentile to <95th percentile), or obese (≥95th percentile), with normal-weight as the reference.

Poverty Status

We used the ECLS-K composite poverty measure as an indicator of childhood poverty. Parents were asked to detail self and spousal education levels, labor force status, occupation, and detailed income ranges at each assessment period. ECLS-K identified children as impoverished or non-impoverished if either the composite measure of poverty or the amount from the detailed income question placed the household in poverty. We use this dichotomized measure to indicate whether or not the household is above or below the federal poverty level threshold, with above the poverty level threshold (i.e., non-impoverished) as the reference.

Covariates

Time-variant and time-invariant measures were included in the final models. Child characteristics include age, race/ethnicity, and sex. Age is centered on the earliest time children usually begin kindergarten (i.e., 5 years of age). Race/ethnicity is an indicator variable representing parent-reported race/ethnicity. Family characteristics include paternal and maternal educational attainment, household income level, and family structure. Educational attainment is an indicator variable representing the highest level of education attained by either parent at any assessment period. Income is a continuous measure and represents the household income at the baseline assessment period. Family structure is a categorical measure representing the child's parent-identified family structure at the first assessment period.

Data Analysis

We estimated the effect of poverty on math and reading achievement trajectories using multilevel growth curve modeling techniques (Singer & Willett, 2003). This approach allowed us to determine whether the changes in developmental trajectories coincide with poverty, and also to determine simultaneously if there is a moderating effect of overweight or obesity. Exploratory analyses indicated that children's achievement is most appropriately captured by a quadratic growth function due to the non-linear relationship between academic achievement and age. Consequently, we only present estimates from these models. All models were estimated in Stata 16 using sampling weights provided by ECLS-K to adjust for the unequal probabilities of selection in the sample.

Results

Descriptive statistics of the study population are shown in Table 1. Spearman correlations of reading and math achievement scores with BMI and independent samples t-tests for achievement scores and poverty were calculated. The resulting rank-order calculations indicate a moderate association between increased weight and reading ($r = .42$, $p < .001$) and increased weight and math ($r = .43$, $p < .001$) achievement scores. Non-impoverished children have significantly higher reading ($t = 32.7$, $p < .001$) and math ($t = 38.8$, $p < .001$) achievement scores, as previously shown (Sirin, 2005).

Table 2 displays results from our multi-level quadratic growth models predicting reading and math achievement scores. Models 1 and 4 capture baseline quadratic growth in reading and math achievement. Models 2 and 5 estimate the effect of weight and poverty status on reading and math scores while controlling for relevant child and family characteristics known to associate with academic achievement. Models 3 and 6 add the interaction effects to test whether

overweight or obesity acts as a moderator on the relationship between poverty and academic achievement.

In Models 1 and 4, the fixed effects (upper portion of Table 2) indicate that children's learning rates increase during early childhood and level off during late middle childhood. At age 5, the estimated mean reading and math scores are 55.6 (*SE* = 0.16) and 40.9 (*SE* = 0.12), respectively. Between the ages of 5 and 9, the average child's achievement scores increase rapidly, evidenced by the large positive values for the linear component of the age slope for reading (53.2) and math (41.2) scores, along with the negative values for the quadratic components of the reading (-1.86) and math (-1.38) slopes. The rate of increase begins to slow around age 9, however, and by age 11 improvements in both reading and math achievement are much more modest, relative to early childhood. The random effects (lower portion of Table 2) indicate that patterns of growth vary significantly among children. Both initial levels of reading and math achievement in the linear (reading: 1.45, $p < .001$; math: 1.66, $p < .001$) and quadratic (reading: 0.11, $p < .001$; math; 0.06, $p < .001$) components vary considerably among children.

In Models 2 and 5 we add the effects of weight and poverty status along with child's gender, race/ ethnicity, parent education and income, and family structure. Impoverished children, on average, score 1.79 points lower in reading ($p < .001$) and 0.75 points lower in math ($p < .001$) achievement at 5 years of age. Given that reading and math achievement rates increase by about 56 and 43 points annually, respectively, over most of the period this reduction is comparable to approximately 1 month of learning. When a child suffers with overweight or obesity, on average, math achievement scores decrease an additional 0.12 ($p>0.05$) and 0.50 ($p<0.05$) points, respectively, from what we would expect if they were normal-weight at 5 years old; this adds to an additional significant deficit in learning over this period. Because seven

waves of data do not provide sufficient statistical power to reliably estimate the time-varying random effects of weight or poverty status, we do not allow the weight or poverty effects in this model or preceding models to randomly vary.

In Models 3 and 6 we add interactions between weight and poverty status. The interaction coefficients are negative and significant for children with overweight (-1.82, $p < .01$) and obesity (-1.74, $p < .01$) in reading achievement, and for children with obesity (-0.99, $p < .05$) in math achievement. Thus, the slope for impoverished children with higher weight status, relative to impoverished children of normal-weight, is less steep. These findings indicate that the impact of obesity status is more pronounced for impoverished children in both reading and math achievement, as well as for overweight children in reading achievement scores.

Discussion

In the present study, we examined the impact of overweight and obesity on children's academic achievement while accounting for child's socioeconomic background. In line with our expectations, we show that childhood overweight and obesity moderate the pathway of child poverty to academic performance. Specifically, our findings indicate that higher body weight exacerbates the negative influence of lower socioeconomic standing on academic achievement. A major implication flowing from our identification of child overweight and obesity as putative mechanisms through which child poverty affects school performance is the need to optimize and implement a range of poverty and obesity intervention strategies (Chai et al., 2019).

Strategies to Combat the Effects of Poverty

It is possible that structural and functional brain development mediate the influence of poverty on children's academic achievement (Farah, 2017; Haft & Hoeft, 2017). Relative to their peers from more advantaged backgrounds, children growing up in impoverished settings are

more likely to exhibit deficits across several cognitive domains, with group differences most pronounced in executive function (Farah, 2017; Haft & Hoeft, 2017; Taylor et al., 2020). It is yet to be determined whether a causal relationship exists between executive function and academic achievement (Jacob & Parkinson, 2015). Still, poor academic performance in children may, in part, be driven by deficits in prefrontal cortex function, the part of the brain involved in executive function (Mamrot & Hanc, 2019; St Clair-Thompson & Gathercole, 2006). Since executive functions are proposed to underlie the initiation of flexible, adaptive and goal-directed behavior, goal-setting may help students develop, execute and maintain the necessary steps to realize a particular goal (Gross & Grossman, 2010; McKenzie, 2019). With that said, it is clear that we need a better understanding of the mechanisms through which early-childhood environmental deprivation embeds biologically to influence brain structure and function (Lund et al., 2020). Only then can we implement evidence-based school- and community-wide initiatives designed to improve executive function that might lead to better academic outcomes (Sun et al., 2020). Nonetheless, school and district leaders can implement evidence-based strategies to support teachers in closing the achievement gap (Gardner & Stephens-Pisecco, 2019; Hair et al., 2015). Solution models might, for example, incorporate general monitoring of a child's physical and emotional well-being, as well as identifying and assisting at-risk low-income students who exhibit behavioral, emotional and social challenges, and/or signs of compromised neurocognitive function (Gardner & Stephens-Pisecco, 2019; Noble et al., 2015). These approaches should be a mainstay of any intervention strategy because socioeconomic disadvantage is associated with inferior language and math abilities, which in turn may contribute to worse performance on standardized academic achievement tests (Sirin, 2005).

Teachers, administrators, coaches, and other practicing educators are aware that child poverty influences academic achievement and is a risk factor for academic failure, school absenteeism, and permanent school dropout (Gubbels et al., 2019; Sirin, 2005). Because poverty awareness training among educators is positively associated with student performance, continued research in this arena is necessary to develop programs that reinforce and enhance the recognition and understanding of the long reach of socioeconomic disadvantage (Steinberg & Krumer-Nevo, 2020). To be successful, school and district leaders must engage and communicate effectively with policymakers to help decrease the academic achievement gap. Policymakers, in turn, must implement evidence-based public policy initiatives such as early-childhood education programs and class-size reductions, and also enable school administrators to invest in professional development, and to hire and retain qualified teachers (Rivkin et al., 2005; Sirin, 2005). The latter two points are especially important because teacher quality and the proportion of novice teachers in a given school explains a portion of the variation in student reading and mathematics achievement scores across schools (Rivkin et al., 2005).

Strategies to Combat the Effects of Obesity

Aside from poverty-based interventions, family-based, long-term intensive intervention programs that focus on the early prevention of obesity are imperative (Barbosa et al., 2020; Chai et al., 2019; Perdew et al., 2020). Indeed, available data indicate that elimination of all sugar-sweetened beverages during infancy is associated with lower rates of obesity at age six (Syeachia et al., 2020). Hence, childhood obesity prevention programs should include nutritional education for parents (Keya et al., 2019; Trandafir & Temneanu, 2016), as well as population-wide initiatives such as tax increases on unhealthy foods (Keya et al., 2019). Moreover, a multicomponent approach that also includes physical activity education for caretakers will

increase the effectiveness of strategies that combat child obesity (Barbosa et al., 2020; Luybli et al., 2019; Wang et al., 2015). Ideally, the ultimate goal of home-based interventions (Pamungkas & Chamroonsawasdi, 2019) and population-wide policies (Keya et al., 2019) should be lifestyle modification, which is likely to have long-term positive effects upon child development and overall public health (Hsiang et al., 2020; Salam et al., 2020). Taken together, because parental behaviors, family patterns, household conditions, and community factors shape child developmental and body weight trajectories, intervention programs and public policies should include nutritional and physical activity education for parents (Chai et al., 2019; Dev et al., 2013; Li et al., 2020), make available healthy food choices at reasonable prices in local stores (Dolati et al., 2020), as well as provide financial investment into the physical and social infrastructures of the disadvantaged communities (e.g., creating neighborhood facilities for recreation; Puga et al., 2020).

It is vital to introduce school-based intervention programs grounded in the most up-to-date scientific evidence if we are to effectively combat childhood overweight and obesity (Davies et al., 2007; Wang et al., 2013, 2015). Notably, some studies on obesity prevention have been conducted using a school-based intervention component (Wang et al., 2013). Evidence indicates that the most effective strategy is a combination of diet and physical activity interventions within school settings concomitant with the home environment (Wang et al., 2013). Even though this combined diet-physical activity program is moderately effective (Wang et al., 2015), childhood overweight and obesity are major health challenges that need to be addressed through early-life, long-term intensive prevention programs that eliminate or reduce the societal and health disparities that continuously create a cycle of inequity (Kuhr et al., 2019). It is clear that we need continued research and development of cost-effective behavioral and systems-level

interventions to curb obesity and promote more successful educational outcomes (Davies et al., 2007). Some nascent approaches appear to be promising, including implementation of nutrition policies in schools (e.g., alternatives to food-based rewards/celebrations; Ickovics et al., 2019), promotion of healthy school food environments (Teo et al., 2019), classroom-based lifestyle interventions (Hsiang et al., 2020; Salam et al., 2020), school-based nutritional education programs (Hawkins et al., 2020), summer and after-school weight management programs (Mabli et al., 2020; Reesor et al., 2018), as well as initiatives aimed at reducing sedentary behavior and screen time (Goldthorpe et al., 2020), with a synchronized focus on increased physical activity through after-school clubs, class physical activity breaks (Jones et al., 2020; Santina et al., 2020; Yuksel et al., 2020), and play-based interventions (Sanchez-Lopez et al., 2020). Moreover, an important component of any intervention strategy is to incentivize decision-makers to advocate for increased funding as a way to implement more large-scale social policy changes in order to educate and train the next generation of school-based health practitioners (e.g., occupational therapists) who will undoubtedly have a significant impact on child body weight management and obesity prevention (Hartley, 2019).

Importantly, child obesity-related difficulties also extend to the social domain (Puhl & Lessard, 2020). Children with obesity are at risk of weight-based victimization, which, in turn, is associated with inferior academic outcomes (Ghandour et al., 2019; Krukowski et al., 2009; Rankin et al., 2016). Related, low confidence may also be associated with worse academic performance in children with overweight or obesity (Tershakovec et al., 1994; Rankin et al., 2016). Thus, school-based policies that mitigate the stigma surrounding increased weight may benefit student performance outcomes among students with overweight or obesity. For example, interventions targeting structural stigma and aiming to reduce stigmatization, as well as to

improve stigma-related knowledge and attitudes, are crucial to minimize discrimination of children with body weight-related social issues (Puhl & Latner, 2007; Strauss & Pollack, 2003). Further prioritization of the development and enactment of school-based anti-bullying programs is needed to prevent negative childhood social experiences due to weight-based teasing and bullying (Rankin et al., 2016). It is of interest that such prevention interventions do not need to be specific to weight-based bullying, as evidence indicates that comprehensive whole-school programs seem to decrease bullying in general (Ttofi & Farrington, 2011).

Strategies Targeting the Concomitant Effects of Poverty and Obesity

Because child overweight and obesity follow a social gradient, for maximum effect, policies must incorporate proven strategies aimed concomitantly at poverty and obesity. For example, initiatives that target children who face exposure to poverty, greater risk of overweight and obesity, and stressful life circumstances may help disadvantaged children overcome obstacles faced within the academic setting (Iguacel et al., 2020; Venturelli et al., 2019). The dual negative impact of economic constraints and overweight or obesity on brain development, cognition, and academic outcomes underscores the importance of early identification of, and assistance to, children suffering with overweight or obesity (Davies et al., 2007; Hair et al., 2015). For example, we need to focus on health-related behaviors in order to alter students' academic trajectory. Indeed, evidence supports the idea that obesity prevention interventions can improve academic performance among low-income elementary school children (Hollar et al., 2010). It is worth noting that such school-based intervention programs are beneficial to school performance regardless of racial/ethnic background (Greening et al., 2012). This finding is of paramount importance because the influence of childhood poverty on obesity outcomes varies by demographic characteristics, with female children, African American girls, and Latinx boys at

the highest risk (Ogden et al., 2006). It is clear that these are urgent matters that need to be addressed through a multifaceted approach because exposure to chronic environmental stress driven by poverty plays a role in the development of obesity (Gunstad et al., 2006; Scott et al., 2012). Thus, given the known negative relationship between chronic stress and academic achievement, in order to limit students' stress, foster resilience, and promote engagement in the classroom, practicing educators may incorporate group-based homework assignments or allow extended time to complete homework assignments, and introduce physical or mental relaxation strategies to mitigate the risk of stressors that negatively impact academic achievement (Gardner & Stephens-Pisecco, 2019; McKenzie, 2019).

Limitations

This is the first study to examine the extent to which obesity exacerbates the negative influence of poverty on academic performance in a nationally representative sample of children. Despite that, this study is not without limitations. The present analysis is constrained by the measures available in the publicly accessible ECLS-K data. For example, poverty is measured by a dichotomized indicator variable representing whether or not the household falls below the federal poverty level threshold, which excludes other relevant measures of poverty such as access to materials and/ or information. Further, children who changed schools were excluded from the analysis in order to generate a sample as homogenous as possible, given that children who transfer schools may differ in important ways related to weight status (e.g., children who experience divorce), compared to children who remain in the same school. This methodological limitation may attenuate the findings and reduce generalizability to a portion of elementary school children in the 1998-1999 school years. Moreover, only seven waves of data are available, and therefore, power to identify complex nonlinear relationships is limited. Related,

estimated reliabilities for the weight coefficients in the individual-level equations are low. Consequently, the ability to detect significant associations between child characteristics and the estimated effects of overweight or obesity on children's developmental trajectories is attenuated. Finally, there is no consensus on the causal effect of child obesity on standardized test scores and academic outcomes (Hollar et al., 2010; Krukowski et al., 2009; Tershakovec et al., 1994), but there is a clear link between obesity and cognitive function (Li et al., 2008). As such, more research is necessary to find mechanisms underlying cognitive decline associated with obesity. This knowledge may help elucidate the relationship between increased weight status and lower academic achievement in children.

Conclusions

Researchers seemingly neglect potential additive effects of poverty and increased weight status on academic achievement. The current study addresses this gap by using nationally representative data to show that childhood overweight and obesity explain some of the negative association between lower socioeconomic standing and school performance. This combined negative effect of increased weight status and poverty, beyond the independent effects of each, has far-reaching consequences for educational outcomes. Our findings clearly underscore the importance of interdisciplinary research to advance the field of early-childhood education.

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Table 1

Weighted Means and Standard Errors for Independent and Dependent Variables for Children Aged 4 to 15 years old; N=13,694

			Mean	Std. Err
Dependent Variables				
	Academic Achievement			
		Reading Achievement	87.48	(0.17)
		Math Achievement	69.15	(0.14)
Independent Variables				
	Child Characteristics			
		Age	8.01	(0.01)
		Gender		
		Boys*	0.52	(0.01)
		Girls	0.48	(0.01)
		Race/ethnicity		
		Non-Hispanic White*	0.58	(0.02)
		Non-Hispanic Black	0.16	(0.01)
		LatinX	0.19	(0.01)
		Asian	0.03	(0.01)
		Other Race	0.05	(0.01)
		Poverty Status		
		Non-impoverished*	0.79	(0.01)
		Impoverished	0.21	(0.01)
		Weight Status		
		Underweight	3.12	(0.01)
		Normal-Weight*	63.91	(0.01)
		Overweight	16.43	(0.01)
		Obese	16.54	(0.01)
	Family Characteristics			
		Parent Education Level	4.97	(0.05)
		Parent Income	50.35	(1.79)
		Family Structure		
		One-Parent Households	21.30	(0.01)
		Two-Parent Households*	78.70	(0.01)

Source: Data are from the ECLS-K Class of 1998-1999

*Note. * Indicates Reference Group*

Table 2

Estimated Coefficients for Quadratic Growth Models Predicting Reading and Math Achievement, ECLS-K 1998-1999; N=13,694

	Model 1 Reading		Model 2 Reading		Model 3 Reading		Model 4 Math		Model 5 Math		Model 6 Math	
	Coeff.	Std.Err.	Coeff.	Std.Err.	Coeff.	Std.Err.	Coeff.	Std.Err.	Coeff.	Std.Err.	Coeff.	Std.Err.
Intercept	55.56***	0.16	44.49***	0.54	44.45***	0.54	40.94***	0.12	34.82***	0.40	34.76***	0.40
Child Characteristics												
Age	53.22***	0.14	55.61***	0.19	55.61***	0.19	41.15***	0.11	43.07***	0.14	43.07***	0.14
Age^2	-1.86***	0.01	-1.99***	0.01	-1.99***	0.01	-1.38***	0.01	-1.48***	0.01	-1.48***	0.01
Gender (boys, ref)												
Girls			4.08***	0.28	4.08***	0.28			0.88***	0.21	0.88***	0.21
Race/ ethnicity (non-Hispanic white, ref)												
Non-Hispanic Black			0.30	0.46	0.25	0.46			-1.80***	0.35	-1.84***	0.35
LatinX			-1.62***	0.42	-1.62***	0.42			-1.64***	0.31	-1.64***	0.31
Asian			6.28***	0.67	6.24***	0.67			2.35***	0.51	2.34***	0.51
Other Race			-0.10	0.61	-0.10	0.61			-1.50**	0.46	-1.50**	0.46
Poverty Status (non-impoverished, ref)												
Impoverished			-1.79***	0.29	-1.18**	0.35			-0.75***	0.21	-0.56*	0.25
Weight Status (normal weight, ref)												
Underweight			0.14	0.44	0.06	0.47			-0.80*	0.32	-0.10**	0.34
Overweight			-0.13	0.23	0.13	0.25			-0.12	0.17	-0.60	0.18
Obese			-0.80	0.30	-0.54	0.31			-0.50*	0.22	-0.34	0.23
Family Characteristics												
Parent Education Level			1.85***	0.91	1.86***	0.09			1.26***	0.07	1.26***	0.07
Parent Income			0.00***	0.00	0.00***	0.00			0.00***	0.00	0.00***	0.00
Family Structure (two-parent, ref)												
One-Parent Household			0.35	0.27	0.35	0.27			0.05	0.20	0.05	0.20
Interaction Effects												
Underweight*Impoverished					0.61	1.24					1.36	0.89
Overweight*Impoverished					-1.82**	0.61					-0.37	0.44
Obese*Impoverished					-1.74**	0.66					-0.99*	0.48
Random Effects												
Level 1												
ε_{it}	13.84	0.04	12.40	0.06	12.40	0.06	10.35	0.03	9.27	0.04	9.27	0.04
Level 2												
Intercept, $\pi 0i$	12.44	0.16	12.28	0.19	12.30	0.19	6.87	0.14	6.88	0.17	6.89	0.17
Age, $\pi 1i$	1.45	0.03	0.73	0.07	0.73	0.07	1.66	0.01	1.28	0.02	1.28	0.02
Age^2, $\pi 2i$	0.11	0.00	0.12	0.00	0.12	0.00	0.06	0.00	0.08	0.00	0.08	0.00

**p <.05, **p <.01, ***p<.001*