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Early childhood obesity and childhood development

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ABSTRACT

Early childhood obesity and childhood development

By Amanda Karyn Brzozowski

In 2011-2012, 14.4% of US children aged two to five years were overweight with an additional 8.4% obese. Because of this high prevalence, a negative effect of early childhood obesity on childhood development – even if small in magnitude – could have a substantial impact on a population level. Studies examining the association between childhood obesity and childhood development have produced inconsistent results, often suffered from small sample sizes and poor control of confounding, and have been conducted primarily in older children. This dissertation explores the association between early childhood obesity and four components of childhood development: cognitive ability; adaptive functioning; behavior; and executive functioning.

The dissertation's first study assessed the extent to which three metrics of early childhood obesity – body mass index (BMI), triceps- and subscapular-skinfold-thickness (TST, SST) – differed in their classification of obesity status. This analysis used data from the Follow-Up Development and Growth Experiences (FUDGE) Study, a population of white and African-American preschool-aged Atlanta children born at either a private, suburban hospital or a downtown, public hospital. Results demonstrated that agreement among obesity metrics was typically poor and the picture of childhood obesity can change dramatically depending on the population. The degree to which differences among metrics exists varies depending on the population.

The second study explored the association of early childhood overweight/obesity and cognitive ability by first using data from 423 FUDGE Study participants to assess the relationship of overweight/obesity with scores on the Differential Ability Scales (DAS). The study then used data from 14,413 participants in the US Collaborative Perinatal Project (CPP) to examine the association between BMI at ages three, four, and seven years and scores on the Stanford-Binet Intelligence Scales (at age four years) and the Wechsler Intelligence Scales for Children (at age seven years). Results from the FUDGE Study found that high BMI, TST, and SST were associated with declines in nonverbal cognitive ability in preschool-aged boys; similar declines were not observed among girls. Analysis of CPP data indicated no meaningful association in either gender between either overweight or obesity and cognitive outcomes at ages four or seven years.

The third study used data from the FUDGE Study to explore the association of early childhood obesity with adaptive functioning, behavior, and executive functioning (assessed using the Vineland Adaptive Behavior Scales (VABS), Child Behavior Checklist, and Developmental NEuroPSYchology Assessment (NEPSY), respectively). Results indicated that overweight/obesity was associated with declines in VABS motor skills scores among boys (with no corresponding association in girls) and in NEPSY statue scores among girls born at the private hospital.

Taken together, these three studies did not find evidence for an association between early childhood overweight/obesity and childhood development, indicating that recent increases in childhood obesity will likely not generate a similar overall rise in children experiencing developmental problems. However, these results indicate possible associations of overweight/obesity with nonverbal cognitive ability and motor skills in boys and NEPSY statue score in girls of higher SES.

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1. INTRODUCTION

Recently, both media and scientific attention have focused on the "public health epidemic" of childhood overweight and obesity. According to data from the 2011 – 2012 National Health and Nutrition Examination Survey (NHANES), 14.9% of children aged two to 19 years were considered overweight and an additional 16.9% were obese.[1] Among preschool-aged children, prevalence of overweight was 14.4% and obesity was 8.4%. Further, obesity was more prevalent among lower-income preschool-aged children, where one child in seven was obese.[2] Risk factors for childhood obesity include:

- prenatal or early-life exposures – large size at birth or in infancy,[3,4] rapid infant weight gain,[3,4,5,6] non-exclusive or short duration of breastfeeding,[7-12] and early introduction of semi-solid foods [9,13,14]
- family-level predictors – genetics, family behaviors, parental obesity[15-18]
- societal factors – socioeconomic status [15,19] and cultural notions of healthy body size.[20]

Adverse health consequences of childhood obesity can occur early, including type-2 diabetes,[21-23] asthma,[21,24,25] or fatty liver disease,[26-28] and long-term, with such risk factors for adult chronic disease as elevated blood pressure or blood lipid levels.[25,29,30] Further, because obese children are more than twice as likely to become obese adults[31] – a likelihood which increases with more severe levels of obesity – obese children are potentially on a trajectory toward additional adverse health consequences later in life. Finally, researchers have reported stigma and socio-emotional pressure related to obesity in children as young as five years, though the physical or behavioral sequelae of this pressure remain controversial.[20,32-37] Because of the high prevalence of childhood obesity, even a small effect that it may have on childhood development could produce a profound societal impact.[38] For this reason, the possible relationship of childhood obesity with childhood cognitive or behavioral development is of particular interest. Studies have found associations between childhood obesity and several aspects of childhood development, including cognitive ability,[39-43] motor skills,[40,44-47] and attentional control.[41,47,48,49] Not all of the evidence, however, has demonstrated clear or consistent associations, and studies were often limited by small sample sizes and improper control of confounding. Additionally, the bulk of studies focused on school-aged children, when an examination of the relationship between obesity and development might be even more critical at younger ages. Younger children's cognitive and behavioral development is typically more tied to physical capabilities compared with older children or adults and evidence shows that certain skills – particularly those related to attentional control – develop rapidly during early childhood.[50] Moreover, if an adverse relationship between early childhood obesity and development does exist, affected children could be entering school already at a disadvantage compared with many of their peers.

An understanding of the potential causal link between early childhood obesity and development could guide interventions targeting obesity, development, or both. For these reasons, this dissertation explores the possible association between obesity among preschool-aged children and childhood development.

Dissertation Aims

This dissertation seeks to address three central questions:

1. To what extent do three noninvasive, easily-obtained metrics of early childhood obesity – body mass index (BMI), triceps-skinfold-thickness (TST), and subscapular-skinfold-thickness (SST) – differ in their classification of obesity status in a population of preschool-aged children?

2. Is there an association between early childhood obesity and cognitive ability?

3. Is there an association between early childhood obesity or adaptive functioning, behavior, and executive functioning?

Chapter 2 of this dissertation is a review of the current literature on childhood obesity and its association with cognitive development. Included in this chapter are: a description of the current prevalence of childhood obesity in the United States, risk factors for and adverse health consequences of childhood obesity; a conceptual framework outlining potential mechanisms through which obesity and development may be linked; and, a summary of the current knowledge base for the association between childhood obesity and development.

Chapters 3-5 are stand-alone manuscripts presenting three studies which seek to address the three primary dissertation aims stated above. **Chapter 3** uses data from the Follow-Up Development and Growth Experiences (FUDGE) Study to compare three noninvasive, easily-obtained metrics of early childhood obesity – BMI, TST, and SST – in a population of African-American and white Atlanta children aged 54 months. This paper demonstrates that the picture of childhood obesity can change, sometimes dramatically, depending on the obesity metric used and that differences among metrics are often non consistent across population groups. The findings from Chapter 3 inform the remainder of the dissertation and provide a useful background when considering and interpreting results from Chapters 4 and 5.

Chapter 4 examines the relationship of early childhood obesity and cognitive ability. Using data from the FUDGE Study, the possible association between BMI/TST/and SST and scores on the Differential Ability Scales (DAS) are evaluated. These results are then validated by exploring the association of BMI and cognitive outcomes in the Collaborative Perinatal Project (CPP). The CPP was a large, multicenter cohort study conducted from 1959 – 74 with the initial goal of prospectively collecting data on neurological defects in children. This dissertation utilizes data from a subsample of the original cohort to assess the possible relationship between BMI at ages three, four, and seven years, and cognitive ability at four years (using the Stanford-Binet Intelligence Scales) and at seven years (using the Wechsler Intelligence Scales for Children).

Chapter 5 further explores the association of early childhood obesity and development by examining the potential relationship between obesity and three additional components of development – adaptive functioning, behavior, and executive functioning. This analysis again uses data from the FUDGE Study and presents results for BMI, TST, and SST.

Finally, **Chapter 6** is a summary and conclusion of this dissertation's overall findings, and includes discussion of the dissertation's strengths and limitations, its contribution to the field of public health, and describes future research needs.

Additional methodologic descriptions, tables, and figures not included in the individual chapters are in Appendices 1-3.

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2. LITERATURE REVIEW

Childhood Obesity

The prevalence of childhood obesity has increased dramatically over the last several decades (Figure 2.1).[1] According to data from the first round of the National Health and Nutrition Examination Survey (NHANES) conducted from 1971 – 1974, the prevalence of overweight among children aged two to 19 years was 10.2%, with an additional 5.1% obese. After remaining relatively constant for the duration of the 1970's , prevalence of childhood overweight and obesity grew to 13.1% and 10.0% , respectively, by the third round of NHANES in 1988-94. By 1999-2000, the prevalence had further increased to 14.0% overweight and 14.4% obese. Since then, childhood obesity prevalence appears to have plateaued, with no statistically significant changes during the period from 2003 – 2012. However, with 14.9% of children overweight and 16.9% obese, the prevalence remains quite high.[2]

The prevalence of childhood overweight and obesity is not distributed uniformly across the population. While NHANES data from 2011 – 2012 indicated no significant differences in overweight and obesity prevalence by gender, differences by race/ethnicity were observed (Figures 2 and 3).[2] Among children of all age groups, Asian children demonstrated the lowest prevalence of overweight and obesity, compared with non-Hispanic white, non-Hispanic African-American, and Hispanic children. For all age groups, Hispanic children had the highest prevalence of both overweight and obesity, followed by non-Hispanic African-American children.

NHANES data indicated that the prevalence of obesity among children aged two to five years was 14.4% overweight and 8.4% obese in 2011 – 12.[2] During the period

2003 – 2012, children aged two to five years experienced a statistically significant decline in the prevalence of obesity; no similar decline was observed among children ages six to 11 or 12 – 19 years. In addition to declines in the prevalence of obesity overall in the preschool-aged population, data from the Centers for Disease Control and Prevention's (CDC) Pediatric Nutrition Surveillance System (PedNSS), showed significant downward trends in obesity prevalence among low-income preschool children (ages two to four years) in a total of 19 states or territories.[3] Across these 19 states/territories, the absolute decrease in obesity prevalence from 2008 – 2011 ranged from 0.3% – 2.6%. Only three states reported a statistically significant upward trend in obesity prevalence. These most recent data indicate encouraging progress in the reduction of early childhood obesity over the past decade, but additional data are needed to determine if this trend continues.

A recent paper by Cunningham *et al.* examined the incidence of childhood obesity, using data from the Early Childhood Longitudinal Study, Kindergarten class of 1998 – 1999, which prospectively followed a population of US kindergarteners.[4] The authors noted that the annual incidence of obesity was highest at the youngest ages and declined through eighth grade. The annual incidence of obesity was 5.4% among kindergarteners, but only 1.9% among boys and 1.4% among girls per year during the period between the fifth and eighth grades. The study further underscored the early development of obesity by reporting that 75% of obese eighth graders had a BMI above the 70th percentile when in kindergarten.

Childhood obesity is strongly correlated with obesity in adulthood. In a systematic review of epidemiologic literature, Serdula *et al*. found that the positive predictive value of obesity among preschool-aged children on adult obesity ranged from 26% – 41%, and among school-aged children from 42% – 63%.[5] For all ages, obese children were at least twice as likely as non-obese children to be overweight as adults. The risk of adult obesity showed a direct relationship with higher levels of obesity in children and obesity at later ages. Finally, the authors noted that the younger a child was at the lowest point of BMI (the “adiposity rebound”), the higher the risk of obesity in adulthood. These results were echoed by Whitiker *et al.*, who, using data on a population of subjects born at a health maintenance organization in Washington State between 1965-1971, also found that the likelihood of adult obesity increased with older age of childhood obesity. After adjusting for parental obesity, the authors reported odds ratios (ORs) for adult obesity associated with obesity in childhood which ranged from 1.3 (95% confidence interval (CI) 0.6 – 3.0) for obesity at one to two years of age to 17.5 (95% CI 7.7 – 39.5) for obesity at 15 – 17 years of age.[6]

Risk factors for childhood obesity

Risk factors for childhood obesity exist on many levels and include prenatal or early life exposures, as well as family-level/societal predictors. A substantial body of literature exists around the association between childhood obesity and infant feeding practices, including breastfeeding and introduction to solid foods. Studies generally indicate a small-to-moderate protective effect of breastfeeding on childhood obesity, though there is great variation among studies in how breastfeeding exposure is measured. For example, longer duration[7-9] and exclusivity[8,10,11] of breastfeeding have both been associated with a reduction in childhood obesity though definitions of exclusive breastfeeding differ (e.g., Li: "high intensity", > 80% milk feedings were breast milk; Hediger: fully breastfed vs. ever breastfed vs. never breastfed) and the durations examined ranged from two months or less to more than nine months.[7,8]

Studies of the possible association between early introduction of solid foods and childhood obesity have produced inconsistent results. In a 2008 study of 430 Chinese families, Jiang *et al.* reported a negative relationship between consumption of solid foods during the first four months of life and obesity at ages one to three years (OR = 1.76, 95% CI 1.15 – 3.64).[12] In contrast, using data on children aged three to five years from NHANES III (1988-94), Hediger *et al.* found a 0.1% decrease in risk of obesity for every month that introduction of solid foods was delayed.[8] (The authors note that this decrease was statistically significant, but carried little clinical meaning.) These results were consistent with those of Mehta *et al.* who reported that early (three to four months) vs. late (six months or later) introduction of solid foods had no effect on infant growth or body composition in the first year of life.[13]

Rapid infant weight gain and large size at birth have both been shown negatively affect childhood obesity. In a prospective cohort study of 559 US children, Taveras *et al.* found that rapid increases in weight-for-length during the first six months of life were directly associated with BMI Z-score, sum of triceps- and subscapular-skinfold-thickness, and obesity status at age three years.[14] Stettler *et al.* reported similar results using data from the US Collaborative Perinatal project, with rapid weight gain during the first four months significantly associated with obesity at age seven years.[15] In a study of German schoolchildren ages five to seven years, Toschke *et al.* found that high early weight gain (> 10,000 grams) was observed in 50% of overweight children, but noted that its positive predictive value was only 25%, indicating that only one in four children who experienced high infant weight gain was overweight at school entry.[16] Two studies examined both the effect of rapid infant weight gain, as well as infant size. Baird and colleagues conducted a systematic review and reported that rapid infant weight gain was associated with ORs or relative risks of later obesity ranging from 1.17 to 5.70. In addition, they reported that infants who were defined as obese (definitions varied) or who were at the highest end of the distribution for weight or BMI were also at increased risk for future obesity (ORs ranging from 1.35 to 9.38).[17] In a prospective cohort study of 1,178 children at increased genetic risk for Type I diabetes mellitus, Lamb *et al.* found statistically significant associations between both rapid infant weight gain and large size for gestational age. This study also reported a potential association of *in utero* diabetes exposure and childhood obesity, but formal mediation analysis suggested that this association may be mediated by LGA status.[18]

Perhaps equally, if not more, important than the early life exposures described above are family-/society-level risk factors for childhood obesity. Many studies have found parental obesity to be predictive of children's obesity status. In a 2006 study of 930 Chinese families with children aged two to six years, Jiang *et al.*, reported a negative association of parental obesity with child obesity (OR = 2.43, 95% CI 0.78 – 6.59), after controlling for sex, age, and family income, though this association was non-significant.[19] In a study of 61 obese children seen in a US nutrition clinic, Unger *et al.* reported that 63% of children had obese mothers and 31% had obese fathers.[20] Further, in the study of German schoolchildren conducted by Toschke and colleagues mentioned above, the authors found that addition of parental obesity status to models attempting to predict obesity status of the children substantially increased the models' positive predictive value.[16] A case-control study of French school children also indicated a positive association of parental and childhood obesity status, reporting a relative risk of 3.1.[21] Finally, in one study of 540 adult Danish adoptees, researchers tried to separate the effects of genetics from those of family environment. The authors found a strong correlation between the weight class of the adopted children and both biological parents, but no relation between the children and their adoptive parents. Moreover, these relationships were not limited to the obese weight class, but were equally true in all weight classes.[22]

Socioeconomic status has also been shown to have an effect on childhood obesity, with parental educational attainment as one measure commonly used to evaluate this association. In a study of 1,420 Italian children aged 10 – 11 years, Gnavi *et al.* reported negative associations with overweight/obesity comparing the lowest to the highest levels of education for both mothers and fathers (maternal and paternal prevalence rate ratios: 1.59, 95% CI 1.19 – 2.13; 1.21, 95% CI 0.90 – 1.63).[23] This study also found significant associations between child's obesity status and parental occupation, another indicator of SES. Similarly, the study conducted by Jiang *et al.* in 2006 mentioned above reported a harmful association between low maternal education level and childhood obesity (OR = 2.22, 95% CI 1.39 – 3.55).[19]

Research indicates that the development of childhood obesity is complex and its causes are multifactorial. The risk factors described above, including infant growth patterns and feeding practices, family genetics and behaviors, and socioeconomic status are all potential contributors to childhood obesity, and the interplay between these factors is likely critical in determining which children become obese and what kinds of interventions will be successful in childhood obesity prevention.

Health consequences of childhood obesity

The adverse health consequences of obesity in adulthood, including diabetes, certain cancers, and cardiovascular disease, have been well-established.[24] However, with the higher prevalence of childhood obesity in general, and the increase in the prevalence of severe obesity among children in particular, negative health effects of obesity are becoming more common in children.

While the negative health effects caused by childhood obesity can occur throughout the life course, many of them begin early. Pulmonary complications such as asthma and sleep disturbances are among the most commonly occurring consequences of childhood obesity. One study conducted in a hospital-based weight control program found that 30% of obese children suffered from asthma,[20] though another study found the association to be much weaker.[25] Additionally, two studies found that one-third of obese children had sleep apnea in obese children to be approximately one-third,[26,27] and another reported a prevalence as high as 94%.[28]

Endocrine problems, including insulin resistance or menstrual abnormalities, have also been observed with increasing frequency among obese children.[29,30] In the Bogalusa Heart Study population, 2.4% of overweight adolescents developed non-insulin dependent diabetes mellitus (NIDDM) before age 30 years, compared with none of their leaner peers.[31] A study conducted in the Cincinnati area reported a ten-fold increase in the prevalence of NIDDM between 1982 – 1994 and noted that over 90% of new patients with NIDDM had a BMI > 90th percentile.[32] Menstrual cycle abnormalities are also common among overweight children and adolescents, with obesity typically associated with earlier age at menarche.[33] Along with other factors (including insulin resistance), obesity is strongly associated with polycystic ovary syndrome (PCOS). Although rates are difficult to assess in adolescents, one study conducted in adult women reported the prevalence of overweight or obesity among women with PCOS was 40 – 60%.[34-36]

Obese children may also suffer from gastroenterological problems. In children, underlying conditions such as congenital heart disease are the primary causes of gallstones, though studies have estimated that obesity accounts for 8 – 33% of the gallstones observed in children.[37,38] Steatohepatitis (fatty liver disease) has also been seen in obese children, with studies reporting 20 – 25% of obese children and 40 – 50% of severely obese children demonstrating evidence of steatohepatitis.[39-41]

Other, more rare consequences potentially associated with obesity in children include neurological problems such as increased intracranial hypertension[42] or orthopedic conditions `including slipped capital epiphyses or Blount's disease.[43-47] Finally, overweight and obesity can be linked with socio-emotional pressure and stigma among children of all ages. One study demonstrated negative perceptions of overweight individuals in children as young as six years,[48] and another reported five-year-old girls expressing fear of gaining weight.[49] Despite evidence of strong social stigma experienced by obese children, whether and how this pressure manifests in behavioral complications like depression remains controversial.[50-54]

Intermediate and longer-term adverse health consequences of childhood obesity largely involve the development of risk factors for chronic disease in adulthood. For example, one study of almost 6,000 children ages five to 11 years found that 20% – 30% of obese children had elevated systolic and/or diastolic blood pressure which are both risk factors for hypertension.[55] Additionally, a study of 61 obese children receiving treatment in a nutrition clinic observed prevalences of elevated blood pressure and blood lipid levels of 25% and 28%, respectively.[20] Finally, results from the Bogalusa Heart Study demonstrated that children with BMI $\geq 95^{th}$ percentile often presented with hyperlipidemia, insulin resistance, or elevated blood pressure and that there was a direct relationship with increasing BMI percentile and the frequency of these risk factors.[56]

The adverse health effects of childhood obesity can begin immediately and persist through adulthood. These negative health consequences range in severity and impact nearly all organ systems. Though clearly many of these conditions (e.g., menstrual cycle abnormalities) are not present in preschool–aged children, early childhood obesity puts children at immediate risk for such characteristics as insulin resistance or asthma and places them on a path for potential additional health consequences as they age.

Measurement of childhood obesity

Despite the public health focus on obesity in children of all ages, no uniform method for defining or measuring obesity currently exists. "Gold standard" methods of assessing adiposity (such as dual-energy X-ray absorptiometry, or DXA) are typically expensive, invasive, or otherwise unsuited to routine studies or office visits. Because of this, body mass index (BMI) has been the mainstay of most clinical and epidemiologic research relating to obesity, in part because it is calculated from measurements – height and weight – which are routinely, easily, and inexpensively obtained. Several studies have demonstrated the validity of BMI to assess obesity in children. In a seminal 1982 paper using data from a longitudinal study of French children, Rolland-Cachera and colleagues evaluated three adiposity indices to determine their validity in children: weight/height; weight/height^2 (BMI, then referred to as the Quetelet index); and, weight/height^3.[57] The authors concluded that BMI, which had a low correlation with height and high correlations with body weight and subscapular skinfold thickness, was the measure most suited to adiposity assessment in children. Pietrobelli *et al.* confirmed these findings in a 1999 study of 198 healthy Italian children and adolescents aged five to 19 years.[58] Using DXA as a reference, this study reported strong correlations between BMI and both total body fat (TBF, correlation coefficients = 0.85 and 0.89 for boys and girls, respectively) and percent body fat (PBF, correlation coefficients = 0.63 and 0.69 for boys and girls), but noted wide variation in both TBF and PBF for individuals of similar BMI. In a 1997 cross-sectional study of 192 healthy children aged seven to 17 years, Daniels *et al.* also found high correlations between BMI and DXA-determined TBF and PBF, but cautioned that the PBF-BMI relationship was dependent on the stage of maturation, gender, and race.[59]

Although the validity of BMI as a measurement tool in children has been demonstrated, notable flaws in the metric exist. One important drawback of assessing childhood obesity using BMI is the lack of generally accepted reference points. Because of this, much discussion in the obesity literature has focused on which BMI cut-points to use when defining overweight and obesity in children. The three most commonly cited cut-points have been those proposed by the CDC, the World Health Organization (WHO), and the International Obesity Task Force (IOTF). The CDC children's BMI-for-age-and-gender growth charts were developed in 2000 and based on data from five cross-sectional, nationally-representative surveys of US children.[60] In contrast, in 2000 the IOTF published age- and sex-specific cut-points for children which used centiles linked to the adult BMI cut-points of 25 and 30 for overweight and obesity, respectively.[61] Finally, the 2006 WHO Child Growth Standards were designed as a standard (rather than a reference), and were derived using an international sample of healthy, breastfed children raised in environments which did not put constraints on growth. [62] Studies conducted in populations of children from around the world, including Bahrain,[63] Ireland,[64] the US,[65] Canada,[66-68] Mexico,[69] and several others[70-72] have compared overweight and obesity prevalence using two or more cut-points for BMI. While the differences among references varied by study, typically the IOTF cut-points were the most conservative, classifying the lowest proportion of children as overweight or obese.

A second disadvantage of BMI is that it does not provide a direct assessment of the amount or distribution of adiposity and is vulnerable to differences in body composition. Research has demonstrated variations in body composition (i.e., relative amounts of muscle vs. fat mass) by race/ethnicity,[59,73,74] gender,[59] and small for gestational age (SGA) status.[75-79] For example, as Flegal *et al.* reported, African-American girls had a higher lean (muscle) to fat mass ratio compared with white girls, resulting in higher body weight for a given height, but a lower percentage of body fat.[73] Similarly, Hediger and colleagues found that children born SGA tended to remain smaller throughout early childhood, but these differences were primarily due to a reduced amount of lean body mass, resulting in a higher percentage of body fat for a given BMI.[75] Because of these differences in body composition, making comparisons of BMI across gender, race, or SGA status could lead to spurious conclusions regarding obesity prevalence among different groups.

Although the bulk of research focuses solely on BMI, there have been studies comparing BMI to other non-invasive methods of obesity assessment, though these often produced conflicting results. In a large, cross-sectional study of children and adolescents, Mei *et al.* compared BMI, triceps-skinfold-thickness (TST), and subscapular-skinfold-thickness (SST) and found they performed equally well when compared to DXA, but that skinfold thickness measurements did not increase sensitivity or specificity when BMI was known and classified the child as obese.[80] In two separate studies of childhood obesity, Malina *et al.* compared BMI and TST and found that the two differed in which children they classified as obese, and noted the relatively high specificity of BMI, but a much lower sensitivity depending on the ethnicity of the population.[81,82] Himes and Bouchard also reported a general pattern of high specificity and lower sensitivity among five anthropometric indicators of obesity – weight, BMI, TST, SST, and sum of four skinfolds, when compared with densitometrically-determined PBF as the criterion of true obesity.[83] They found that TST was the preferred single anthropometric indicator of obesity in boys, but that BMI better assessed obesity status among girls. Roche *et al*. also reported differences by gender, with BMI as the best predictor among girls, but SST among boys.[84] In contrast, studies conducted by Sarría *et al*. (in boys) and Marshall and colleagues (in both boys and girls) found the sum of four and five skinfolds, respectively, to be the best indicators of obesity.[71,85]

BMI is inexpensive, noninvasive, and easily obtained. Further, studies have demonstrated its validity in assessing childhood overweight and obesity. Because of this, BMI remains a commonly-used took in both research and clinical practice. Nonetheless, the limitations of BMI include a lack of universally accepted reference points, that it does not directly measure the amount or distribution of body fat, and that it generally exhibits lower sensitivity that may vary among different populations. Studies suggest that consideration of additional or alternative metrics of obesity status could provide added information in both research and clinical settings.

Childhood obesity and childhood development

The association of childhood obesity and childhood neurocognitive development is an important one. Because of the high prevalence of childhood overweight and obesity, an association between obesity and development – even if small in magnitude – could have a substantial impact on a population level.[86] Further, obesity prevalence is higher among children of lower SES, a population already vulnerable to a myriad of factors which detrimentally affect childhood development and one which often experiences reduced access to educational and social services. Research has been conducted exploring the possible mechanisms and association between childhood obesity and several components of childhood development, including cognitive ability, adaptive functioning, behavior, and executive functioning.

Physiologic pathways have been proposed linking childhood obesity to several components of childhood development. Many, though not all, of these pathways are mediated in some way by mechanisms involving executive functioning. The relationship between obesity and executive functioning has been well studied in older children and adults, though the direction of causality is unclear and compelling arguments have been made for obesity causing deficiencies in executive functioning, as well as for poor executive functioning leading to an increase in obesity.[87] Theories supporting the latter pathway suggested that predisposition to obesity could include a dysregulation of limbic neural circuits connected with the orbito-frontal cortex (which are associated with the inhibitory dimension of executive functioning). Alternatively, other studies have proposed that obesity could induce development of the neural dysfunction associated with deficiencies in executive functioning. If obesity does have a detrimental effect on the brain, psychologists have stressed that prevention of obesity in early childhood could be especially critical given the rapid brain development which occurs in at that time.

Many studies have reported associations between cognitive ability and obesity in children. The specific mechanism underlying these associations is not yet clear, and remains largely unstudied in children. However, research in adults, often from the perspectives of prevention of Alzheimer's disease or the cognitive declines associated with aging, may provide some clues. Neuroimaging studies conducted in obese adults have indicated a number of important structural brain alterations, including global atrophy, regional reduction in gray matter density in the frontal region, disruption of frontal, temporal, and subcortical regions, and metabolic alterations of the prefrontal region.[88] Further, in adults many of these alterations have been well correlated with performance on tests of memory or other aspects of executive functioning. While it is not clear how mechanisms observed in obese adults may relate to those in young children, it is possible executive functioning may serve as a mediator in both relationships.

In contrast to the dearth of research on the potential mechanism linking childhood obesity to cognitive ability, the mechanisms through which childhood obesity may affect adaptive functioning have been better studied. In particular, many studies have focused on the underlying relationship between childhood obesity and deficiencies in fine and gross motor skills. The impact of obesity on motor skills is thought to occur primarily through the negative impact increased body weight (non-contributory mass in particular) has on balance control and postural stability.[89,90] In normal populations, maintaining a stable postural orientation is required for daily activities, especially those involving limb movements. For movements of the upper limbs, studies observed that overweight/obesity contributed to deficiencies in activities such as pointing to a small target or peg placing when in a standing position.[90-92] One study, however, further observed poor fine motor performance among obese children when sitting and suggested that additional underlying perceptual motor coordination issues may be at play in obese children.[90] For lower limb movements, several studies have found differences in gait and postural stability between obese and non-obese children.[93,94,95] Despite the body of literature focusing on obesity and motor skills, the mechanisms between obesity and daily living or socialization skills have been much less studied.

Finally, researchers have explored possible relationships between child behavior and childhood obesity, many of which are linked with executive functioning processes. Both overweight and ADHD children have difficulties with delay of gratification facing food cues, and Holtkamp *et al.* suggest that impulsivity and dysfunctional inhibitory processes could underlie both conditions.[96] Additionally, research has also indicated links between internalizing behavior and obesity in young children. Kirkpatrick *et al.*, demonstrated that children as young as six years exhibit negative perceptions of overweight and obese body types in children,[48] and Feldman and colleagues observed a fear of gaining wait among five year-old girls.[49] Still, as mentioned above, whether increased socio-emotional pressure results in self-esteem issues, depression, or other internalizing behaviors remains controversial.[50-54]

Studies of the association between childhood obesity and cognitive ability have produced mixed results or found that the negative impact of obesity on cognitive ability was limited to certain groups. In a study of children aged eight to 11 years, Campos *et al.* reported that obese children scored significantly lower on the Wechsler Intelligence Scale for Children (WISC) compared with non-obese children matched for age, school level, and SES.[97] Li also found a negative association between obesity and the WISC in children with a mean age of 10 years, but noted this result was only evident among children with severe obesity and no difference was observed in children with milder forms of obesity.[98] In contrast, Cserjési *et al.*, reported no difference in intelligence test scores (using Raven's progressive matrices) between a small sample of obese schoolboys and their non-obese peers,[99] and Datar and colleagues found that differences in reading and math test scores between overweight and non-overweight first graders largely disappeared after adjustment for socioeconomic and behavioral factors.[100] Although the majority of studies examining childhood obesity and development have been conducted in elementary- and high school-aged children, one population-based study of preschool-aged German children found that, among boys, obesity was associated with delayed verbal ability, as well as three other components of cognitive development – motor, social, and daily living skills.[101] Only a moderate association between verbal skills and obesity was observed in girls, which disappeared when International Obesity Task Force cut-points, rather than those typically used for studies of German populations, were used.

Research exploring the effect of obesity on adaptive functioning (which reflects a person's ability to meet the demands of daily life), often focuses on fine and gross motor skills. In a large sample of German schoolchildren (mean age 6.7 years), Graf *et al.* reported significant declines in gross motor skills among obese children,[102] a finding also supported by the research of Okley and colleagues in school-aged Australian children[103] and McGraw *et al*. in a relatively small sample of US obese and non-obese prepubertal boys.[95] Additionally, D'Hondt *et al.* reported a negative association between overweight and obesity on fine motor skills in a large sample of five to 13 year-old children.[90] Two studies conducted in populations of younger German children found that associations between obesity and motor skills differed by gender. In a large, population-based study of children aged 4.4 – 8.6 years, Mond *et al*. found an association between obesity and deficits in gross motor skills among boys, but no corresponding association among girls.[104] Similarly, in a study of 444 children aged two to three years, Cawley and Spiess reported an association with reduced motor skills (as well as verbal, social, and daily living skills) in boys, but not in girls.[101]

Negative associations between obesity and childhood behavior have also been reported. Lam and Yang examined a large population of Chinese adolescents and reported a significant association between obesity and attention deficit/hyperactivity disorder (ADHD) tendency, though they did not find an association between ADHD tendency and overweight status.[105] Braet *et al*. also reported an increase in both attention deficit and hyperactivity behaviors among overweight school-aged boys, but did not find a similar association among girls.[106] Two additional studies reported gender differences in the association of behavior and childhood obesity, with Lawlor *et al.* showing an increase in problematic behavior on the Child Behavior Checklist total behavior scale among overweight 14 year-old girls, but no corresponding association among 14 year-old boys (or among five year-old children of either gender).[107] Datar and Sturm similarly reported an increase in teacher-reported externalizing behavior problems among overweight school-aged girls, but a *reduction* in externalizing problems among boys.[108]

Recent attention has also focused on the possible association between childhood obesity and executive functioning, the umbrella term for a series of cognitive processes responsible for thought and goal-directed behavior. Although the question of directionality in the relationship remains, results have consistently demonstrated detrimental associations between childhood obesity and several components of executive functioning, including inhibitory control,[109-112] reward sensitivity,[113,114] attention focus/shifting,[99,104,106,115] and working memory.[116] Although most studies have found a harmful effect of overweight/obesity on childhood executive functioning, one study in school-aged children found no association among overweight/obese children, but reported a deficit in memory performance among underweight girls.[117]

While recent data suggest a plateau in the prevalence of childhood obesity, the proportion of overweight and obese young children in today's population remains high. Because of this, a possible association of early childhood obesity and components of childhood development could have a considerable impact on a population-level. Underlying mechanisms have been proposed linking obesity to several components of childhood development, including cognitive ability, adaptive behavior, behavior, and executive functioning. While a substantial body of literature exists exploring these possible relationships, results are often inconsistent and typically limited to school-aged children and adolescents. This dissertation will fill a gap in the literature by examining the association between early childhood obesity and childhood cognitive ability, adaptive functioning, behavior, and executive functioning. Further, this dissertation will utilize three obesity metrics and two study populations to gain a deeper understanding of these relationships.

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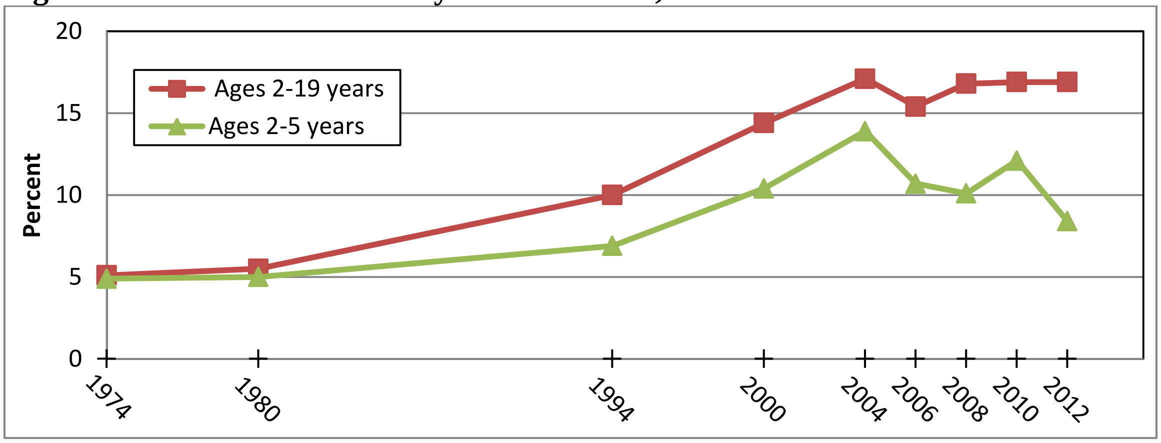
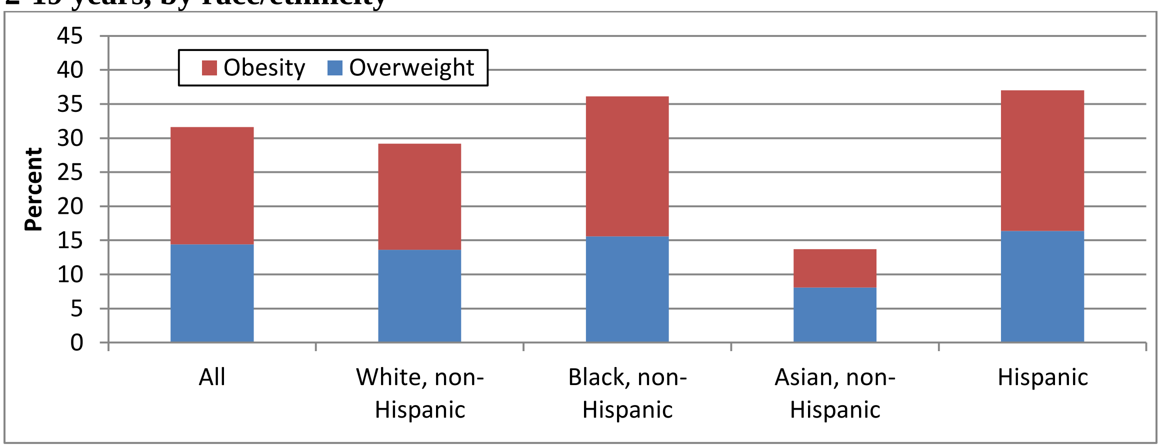
Figures

Figure 2.1: Prevalence of obesity in US children, 1974 - 2012



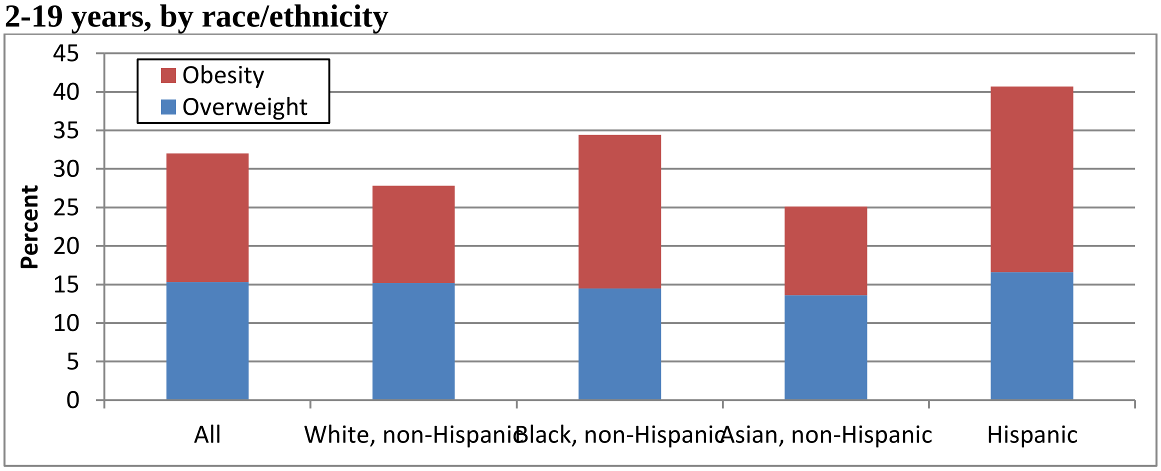
Source: Joliffe, 2004.

Figure 2.2: Prevalence of overweight and obesity in 2011-2012 among US girls aged 2-19 years, by race/ethnicity



Source: Ogden, 2014.

Figure 2.3: Prevalence of overweight and obesity in 2011-2012 among US boys aged 2-19 years, by race/ethnicity



Source: Ogden, 2014.

3. COMPARISON OF THREE OBESITY METRICS IN PRESCHOOL-AGED CHILDREN

Abstract

Background: Despite the public health focus on childhood obesity, no uniform method for accurately defining or measuring obesity exists. Although the validity of body mass index (BMI) in children has been demonstrated, its limitations include that it: lacks generally accepted reference points; does not provide a direct assessment of amount or distribution of adiposity; and, is vulnerable to differences in body composition.

Methods: Using data from the Follow-Up Development and Growth Experiences Study (1997 – 99), this study assessed the extent to which three metrics of early childhood obesity – body mass index (BMI), triceps- and subscapular-skinfold-thickness (TST, SST) – differed in their classification of obesity status. Obesity metrics were measured in 423 children aged 54 months born at one of two Atlanta hospitals. Covariate information was obtained during the study or from previously collected data. Overweight/obesity was defined as being in the top 15th percentile of BMI/TST/SST based on CDC norms.

Results: Overall and for all population subgroups (girls vs. boys, whites vs. African-Americans, small vs. appropriate for gestational age), BMI classified the highest proportion and TST classified the lowest proportion of children as overweight/obese. Within a population group, agreement among metrics was low, with kappa statistics ranging from -0.02 to 0.39. The prevalence of obesity was similar between girls and boys when classified using BMI (15.9% vs. 15.2%, respectively, p = 0.85), though notably higher among girls for both skinfold thickness measures (TST: 7.7% vs. 2.8%, p = 0.02;

SST: 9.6% vs. 6.5%, p = 0.23). Moreover, whites and African-Americans had similar proportions of overweight/obese children when using BMI (15.9% vs 15.3%, p = 0.86), but whites had a higher proportion when using either skinfold thickness measure (TST: 6.9% vs. 3.8%, p = 0.16; SST: 10.6% vs. 5.9%, p = 0.08). Prevalence was higher among AGA children vs. SGA children for all three metrics, but the relative increase in prevalence was lower when using skinfold thickness measures compared with BMI (χ^2 p-values for BMI, TST, and SST comparisons, respectively: 0.01, 0.06, and 0.24). Spearman correlations of BMI Z-score/TST Z-score, BMI Z-score/SST Z-score, and TST Z-score/SST Z-score were 0.47, 0.49, and 0.60.

Conclusions: The picture of childhood obesity can change – sometimes dramatically – depending on the obesity metric used. However, the degree to which differences among metrics exists varies by population subgroup. Within a population subgroup, agreement among obesity metrics was poor, indicating that the metrics are not classifying the same children as overweight/obese.

Introduction

The high prevalence of childhood obesity in the United States is of particular concern. According to data from the 2011-2012 National Health and Nutrition Examination Survey (NHANES), 14.9% of US children between the ages of two and 19 years were considered to be overweight and an additional 16.9% were considered obese.[1] Although slightly lower than for older children, the prevalence of obesity among preschool-aged children was nonetheless high. Among children aged two to five years, 14.4% and 8.4% were considered overweight and obese, respectively. Obesity prevalence among low-income preschool children was even higher, where one child in seven was obese.[2]

Despite the public health focus on obesity in children of all ages, no uniform method for accurately defining or measuring obesity currently exists. "Gold standard" methods of assessing adiposity (such as dual-energy radiograph absorptiometry, or DXA) are typically expensive, invasive, or otherwise unsuited to routine studies or office visits. Because of this, body mass index (BMI) is the mainstay of most clinical and epidemiologic research relating to obesity, in part because it is calculated from measurements – height and weight – which are routinely, easily and inexpensively obtained. Although the validity and reliability of BMI as a measurement tool in children have been demonstrated,[3-5] notable flaws in the metric exist.

One important drawback of assessing childhood obesity using BMI is the lack of generally accepted reference points. Because of this, much discussion in the obesity literature focuses on which BMI cut-points to use when defining overweight and obesity in children, comparing, for example, those proposed by the Centers for Disease Control and Prevention (CDC),[6] the World Health Organization (WHO),[7] and the International Obesity Task Force (IOTF).[8] Studies conducted in populations from Bahrain,[9] Ireland,[10] Mexico,[11] and many others,[12-17] have demonstrated substantial differences in prevalence depending on which cut-point references are used, though typically the IOTF cut-points tend to be the most conservative, classifying the lowest proportion of children as overweight/obese.

A second disadvantage of BMI is that it does not provide a direct assessment of the amount or distribution of adiposity and is vulnerable to differences in body composition. Research has demonstrated variations in body composition (i.e., relative amounts of muscle vs. fat mass) by race/ethnicity,[5,18,19] gender,[5] and small for gestational age (SGA) status.[20-24] For example, as Flegal *et al.* reported, African-American girls had a higher lean (muscle) mass to fat mass ratio compared with white girls, resulting in higher body weight for a given height, but a lower percentage of body fat.[18] Similarly, Hedigar and colleagues found that children born SGA tended to remain smaller throughout early childhood, but these differences were primarily due to a reduced amount of lean body mass, resulting in a higher percentage of body fat for a given BMI.[20] Because of these differences in body composition, making comparisons of BMI across gender, race, or SGA status could lead to spurious conclusions regarding obesity prevalence among different groups.

Although the bulk of research focuses solely on BMI, there have been studies comparing BMI to other non-invasive methods of obesity assessment, though these often produced conflicting results. In a large, cross-sectional study of children and adolescents, Mei *et al.* compared BMI, triceps-skinfold-thickness (TST), and subscapular-skinfold-thickness (SST) and found they performed equally well when compared to DXA, but that skinfold thickness measurements did not increase sensitivity or specificity when BMI was known and classified the child as obese.[25] In two separate studies of childhood obesity, Malina *et al.* compared BMI and TST and found that the two differed in which children they classified as obese, and noted the relatively high specificity of BMI, but a much lower sensitivity depending on the ethnicity of the population.[26,27] Himes and Bouchard also reported a general pattern of high specificity and lower sensitivity among five anthropometric indicators of obesity – weight, BMI, TST, SST, and sum of four skinfolds, when compared with densitometrically-determined percentage body fat as the criterion of true obesity.[28] They found that TST was the preferred single anthropometric indicator of obesity in boys, but that BMI better assessed obesity status among girls. Roche *et al*. also reported differences by gender, with BMI as the best predictor among girls, but SST among boys.[29] In contrast, studies conducted by Sarría *et al*. (in boys) and Marshall and colleagues (in both boys and girls) found the sum of four and five skinfolds, respectively, to be the best indicators of obesity.[30,31]

Although BMI has been shown to be a valid and easily-obtained method for assessing childhood obesity, notable limitations exist. Skinfold thickness measurements, which may be less sensitive to issues of body composition, offer another, non-invasive method for assessing obesity in preschool-aged children. A better understanding of the relationship between BMI and skinfold thickness could help both researchers and clinicians determine the best method to assess obesity in younger children. Using a population of 54 month-old African-American and white children from Atlanta, Georgia, this study sought to add clarity to the current literature base by comparing three noninvasive, easily-obtained childhood obesity metrics: body mass index, triceps-skinfold-thickness, and subscapular skinfold thickness.

Methods

Study Population

This analysis utilized data from the Follow-Up Development and Growth Experiences (FUDGE) Study and its precursor, the Fetal Growth and Development Study (FGDS). The FGDS was a case-control study conducted with the initial goal of developing enhanced surveillance for fetal alcohol syndrome among neonates. All African-American and white singleton infants born at one of two Atlanta-area hospitals between 2/1/93 – 12/31/94 with a gestational age of 32 – 42 weeks were eligible for the study. One of these hospitals was a private, suburban Atlanta hospital serving primarily a white, middle-class population and the other was a public hospital located in downtown Atlanta with a largely African-American, lower socioeconomic status (SES) population. Study staff collected data at hospitals in one week segments and the hospital was randomly selected without replacement from blocks of four weeks. Staff abstracted race, sex, gestational age, and birthweight from labor and delivery or nursery logs. All SGA children (< 10^{th} percentile for gender, race, and gestational age) were selected as case infants. A simple random 3% sample of all other singleton infants was included as appropriate for gestational age (AGA, ≥ 10^{th} percentile for gender, race, and gestational age) controls. The final sample size for the FGDS was 959 children.

These children were then reevaluated for the FUDGE Study when they were as close as possible to 54 months of age to assess psychometric and anthropometric outcomes of preschool-aged children born SGA. Of the original 959 FGDS participants, 760 were identified for follow-up in the FUDGE Study. This group included all participants born AGA, all SGA participants whose mothers reported any alcohol use in pregnancy, and half of the SGA infants whose mothers reported no prenatal alcohol use. Of these, 510 (72.2%) were successfully recruited. Further details of the FGDS and FUDGE study samples can be found in Drews-Botsch *et al*.[32]

The current analysis excluded children with missing values for normalized BMI (N = 41), TST (N = 41), or SST (N = 43) variables, implausible values (≥ 4 standard deviations from the mean) for normalized height (N = 0), weight (N = 2), TST (N = 0), and SST (N = 3) variables, and those born large for gestational age (LGA, ≥ 90th percentile birth weight for gestational age, race, and gender, N = 25). LGA children were excluded because their small sample size prevented analysis of this group separately and it was inappropriate to combine LGA and AGA children into a single group. The final sample size was 425.

Data Collection

Trained study staff conducted in-person interviews with mothers regarding smoking, alcohol use, and socioeconomic factors within 48 hours of delivery. Women were again interviewed in-person at the FUDGE Study follow-up visit where anthropometric measurements were obtained. A single measurement of weight in kilograms (kg) was obtained using a digital scale. Two height measurements in centimeters (cm) were obtained to the nearest millimeter using a portable Schorr stadiometer (Schorr Productions, Olney, MD). If the two measurements differed by more than 0.5 cm, a third measurement was obtained. Two measurements each were also obtained for right-side triceps- and subscapular-skinfold-thickness to the nearest millimeter using Lange skinfold calipers (Beta Technology Incorporated, Santa Cruz, CA). A third measurement was taken if the first two measurements differed by more than 1.0 mm. Two measurements for wrist breadth in cm were obtained using GPM sliding calipers (Seritex, Tinton Falls, NJ). If the measurements differed by more than 0.2 cm, a third was taken. Height, skinfold thickness, and wrist breadth measurements used in this analysis were the average of the two closest measurements. Third measurements were only necessary in 3.0% of children for height, 1.2% of children each for TST and SST, and 1.6% of children for wrist breadth; only one child required more than one third measurement (for SST and wrist breadth). Training of all staff was performed prior to the study and reliability was assessed semi-annually. Internal analyses suggested that the intra-observer reliability of all measures exceeded 95%.

Study Variables/Measures

BMI was calculated using the formula: [weight (kg)] / $[\text{height (m)}]^2$. Age- and gender-specific BMI Z-scores were calculated using CDC formulas and parameters.[33, 34] TST and SST Z-scores were estimated similarly using parameters from Addo and Himes.[35] BMI, TST, and SST percentiles were obtained from Z-scores using the properties of the normal distribution. BMI, TST, and SST were then categorized as overweight/obese ($\geq 85^{th}$ percentile) and not overweight/obese ($< 85^{th}$ percentile). SGA status was determined using birth weight and gestational age from the FGDS. Child's gender, race (self-identified by the mother), total family income, maternal age, educational attainment, pre-pregnancy BMI, prenatal alcohol consumption (any vs. none) and prenatal cigarette use (any vs. none) were also obtained from the FGDS. Current maternal cigarette use (any vs. none) was obtained from the FUDGE Study follow-up interview.

Analysis

Bivariate comparisons were made using t-tests for normally-distributed continuous variables, Wilcoxon rank sum tests for non-normal continuous variables, and chi-square tests for categorical variables. Agreement among measures was assessed using kappa statistics. While no standard guidelines exist for the interpretation of kappa statistics, guidelines from Landis and Koch were used, who advised the following: < 0.0, no agreement; 0.0 – 0.20, slight agreement; 0.21 – 0.40, fair agreement; 0.41 – 0.60, moderate agreement; 0.61 – 0.80, substantial agreement; and, 0.81 – 1, almost perfect agreement.[36] Spearman correlations were used to compare anthropometric measures because Z-scores were not always available (e.g, wrist breadth for which Z-scores were not able to be calculated). Results were considered statistically significant if $p < 0.05$. Analyses were conducted in SAS Version 9.3 (Cary, NC) and plots were generated using R Version 2.15.0.

The FGDS and FUDGE Studies were approved by the Institutional Review Boards of the two hospitals (for the FGDS only), Emory University, and the CDC.

Results

The FUDGE Study population included similar numbers of children from the public and private hospitals (212 and 213 children, respectively) (Table 3.1). Women from the public hospital were younger, had higher average pre-pregnancy BMI, and higher rates of both prenatal and current smoking compared with participants from the private hospital ($p < 0.01$).

The children were assessed at a median age of 54.1 months (interquartile range 53.4 – 55.5 months); median age at follow-up was similar at both hospitals. Approximately half of the children in the study were female (48.9%), although gender distribution differed significantly by hospital (54.9% female private vs. 42.9% public, $p = 0.01$). Sixty-eight percent of the population was born SGA, as would have been expected given the original design of the FUDGE Study, and the prevalence of SGA did not differ by hospital. Almost all of the children (97.2%) of children born at the public hospital were African-American, compared with 14.2% of children at the private hospital ($p < 0.01$). The prevalence of families with total family income < $40,000/year and mothers who completed ≤ 12 years of education were both significantly higher at the public hospital compared with the private hospital ($p < 0.01$).

The overall prevalence of overweight/obesity was 15.5% using BMI, but was considerably lower when using skinfold measurements (5.2% for TST, 8.0% for SST) (Table 3.2). The prevalence of overweight/obesity often differed among obesity metrics and by population group. For all population subgroups, BMI classified the highest proportion and TST classified the lowest proportion of children as overweight/obese. The prevalence of obesity was similar between boys and girls when classified using BMI, though notably higher among girls for both skinfold thickness measures (the difference was only statistically significant for TST, χ^2 p = 0.02). Moreover, whites and African-Americans had similar proportions of overweight/obese children when using BMI, but whites had a higher proportion when using either skinfold thickness measure, though these differences were not statistically significant. Prevalence was higher among AGA children for all three metrics, but the relative increase in prevalence was lower when using skinfold thickness measures compared with BMI (χ^2 p-values for BMI, TST, and SST comparisons respectively: 0.01, 0.06, and 0.24).

When results were stratified by both race and gender, BMI classified a higher proportion of African-American girls as overweight/obese compared with white girls, though the opposite was true for both skinfold thickness measures (Table 3.3). Among boys, the prevalence of overweight/obesity was higher among white boys compared with African-American boys for all three metrics. When stratifying by both SGA status and gender, AGA children had a higher prevalence of overweight/obesity compared with SGA children in all groups except for one. Uniquely, using SST to classify obesity status, SGA boys had a higher prevalence of overweight/obesity (6.8%) compared with AGA boys (5.7%).

Within groups, agreement between the three metrics was generally low, with kappa statistics ranging from 0.33 to 0.39 for all population groups except for boys and AGA children, which were even lower (0.22 and -0.02, respectively). This indicates that, within a population group, the three metrics often differed in which children were classified as overweight/obese. Stratification by gender and race or SGA status (Table 3.3) did not change the conclusions, nor did examining kappa statistics for pairwise comparisons (data not shown).

When considering continuous measures, the correlation of BMI Z-score with TST and SST Z-score were 0.47 and 0.49, respectively. The correlation between skinfold thickness measures was higher, with a coefficient of 0.60 (Table 3.4). Similar correlations were observed within subgroups defined by SGA status, race, and gender, though the highest correlations were found among girls. For all groups except AGA children, the correlation was higher between TST and SST than between BMI and either skinfold thickness measure. Overall and for all subgroups, wrist breadth was more highly correlated with BMI than either skinfold thickness measure and height was only weakly correlated with any of the three obesity metrics (Table 3.5). Height and wrist breadth were moderately correlated, with coefficients varying from 0.55 to 0.61 (data not shown). Scatterplots of the metrics' Z-scores in the overall population (Figures 3.1a – 3.1c) reinforce the moderate correlation among metrics, though the TST Z-score/SST Z-score plots exhibited relatively less spread compared with the plots of BMI Z-score and either skinfold metric. Plots were similar when stratified by race and SGA status, though boys demonstrated more spread compared with girls for all three combinations (plots not shown).

Discussion

These results demonstrate that measurement of early childhood overweight/obesity can be complex in three notable ways: 1) the picture of childhood obesity changed – sometimes dramatically – depending on the obesity metric used; 2) the degree to which differences among metrics existed varies by population subgroup; and 3) within a population subgroup, agreement among the three obesity metrics was poor, indicating that the metrics were not classifying the same children as overweight/obese. Taken together, these points were perhaps best illustrated by the prevalence of overweight/obesity when stratifying by gender. Among girls, the highest prevalence of obesity was observed when using BMI (15.9%), while the prevalence was notably lower when using TST (7.7%) or SST (9.6%). Among boys, the prevalence of overweight/obesity was similar to that in girls when using BMI (15.2%), and was also noticeably lower for both TST and SST. However, the *relative* difference in overweight/obesity prevalence among the three metrics was quite different in boys vs. girls (1.1 for BMI, 2.8 for TST, and 1.5 for SST). Further, as evidenced by low kappa statistic values, agreement among metrics was poor for both girls and boys, indicating that the children classified as overweight/obese by BMI were often not the same ones classified as overweight/obese by TST or SST. It is also important to note that the overall kappa statistic of 0.35 was likely driven by the fact that SGA children were overrepresented in this dataset. Were the dataset not overselected for SGA children, the overall kappa statistic would likely have been even lower, reflecting the very poor agreement among AGA children.

The observed variability in the prevalence of childhood obesity among metrics could reflect differences in body composition among population groups or the fact that the different metrics focus on different constructs of obesity. For example, many studies have found that children born SGA, especially those who experienced postnatal catch-up growth, tend to have more visceral fat and an overall higher body fat percentage compared with children born AGA.[20,23,24] This was supported by our results in two ways. First, the percentage of SGA children classified as overweight/obese using SST (which is arguably the best of the three metrics considered in this analysis at assessing central adiposity) was 6.9% compared with 10.2% among AGA children. This relative difference of 1.5 was considerably lower than the corresponding 2.1 for TST and 2.9 for BMI. Further, with a higher percentage body fat (and, thus, a lower percentage of lean muscle mass) in SGA children, one might expect that BMI would have been more likely to represent true obesity (and less likely to incorrectly classify especially muscular children as obese) in SGA children compared with AGA children. This was also supported in our data by the fact that the percentage of children classified as overweight/obese using BMI vs. SST was fairly similar for SGA children (9.7% vs. 6.9%), but substantially different for AGA children (27.7% vs. 10.2%). Conversely, Flegal argued that, in older children (ages eight to 19 years), BMI overestimated obesity among African-American girls relative to white girls, because of their relatively lower percentage of body fat.[18] This was also supported by our findings in which African-American girls had a higher proportion of overweight/obesity compared with whites when using BMI, but the reverse was true for both skinfold thickness measures. Both of the previous examples illustrate the point that, because BMI includes skeletal and muscle mass in addition to fat mass, BMI calculations might be particularly vulnerable to between-group differences in lean body mass compared with measurements which more directly assess adiposity. This was further evidenced in our study by the moderate correlation observed between wrist breadth and BMI, with lower correlations found between wrist breadth and both skinfold thickness measures. Additionally, that height was only weakly correlated with any of the three metrics, provided additional evidence for this supposition.

While our goal was to present evidence that obesity metrics perform *differently* (and making recommendations as to which metrics performed best in specific populations was beyond the scope of this paper), it is interesting to note that these data may suggest that TST could be the best overall measure of obesity based on construct validity. More specifically, convergent validity was demonstrated in the moderate-to-good correlations of TST with the other obesity metrics that we examined, and divergent validity was seen in the very weak correlations with measures of skeletal structure (i.e., height and wrist breadth). In comparison, BMI and SST showed similar correlations with the other measures of obesity and thus similar convergent validity, but both of those metrics were much more highly correlated with both height and wrist breadth, compared with TST.

There were several strengths to our analysis. First, oversampling of SGA children in the FUDGE Study allowed us to assess how different measures of obesity performed in children born SGA relative to children born of average size. Assessment of the impact of SGA status is not commonly examined in research on obesity measurement issues and we feel our study provides an important contribution to the understanding of obesity in this population. Second, our dataset was rich in information on potential confounders, and because much of the information was collected at birth, the possibility of recall bias for prenatal experiences was minimized. Third, while the possibility of measurement error for key variables existed, we believed it to be low, with Cronbach's alpha values comparing the first two height, TST, and SST measurements of 0.99, 0.97, and 0.97 respectively. As mentioned earlier, third measurements for height, TST, SST, and wrist breadth were rare and only one child in the dataset required more than one third measurement. Finally, our focus on younger children was important because recent evidence has highlighted the importance of early-life physical and behavioral patterns in determining the development of obesity and obesity-related health concerns.[37-39] Understanding the picture of obesity earlier in childhood may help direct earlier interventions, minimizing the time children spend at risk for complications arising from overweight/obesity.

Our study methods were subject to several limitations. First, we were only able to consider three obesity metrics. Additional metrics, especially a more direct measure of fat distribution (e.g., dual-energy x-ray absorptiometry), would have added to the depth of this analysis. Second, the relatively small number of overweight and obese children in our study population did not allow us to explore how the obesity metrics performed in overweight and obese children separately. Third, although this dataset contained extensive information on potential confounders, the possibility of residual confounding existed due to improper control of variables in the dataset or from variables not collected in the FUDGE Study. Fourth, no standard guidelines exist for the interpretation of kappa statistics, therefore making our choice to follow the example of Landis and Koch somewhat arbitrary. However, our observed kappa values were perhaps low enough that the interpretation of “poor agreement” was less controversial. (This interpretation, for example, was also in line with guidelines suggested by Fleiss.[40]) Fifth, over one-fourth of FGDS study participants selected to participate in the FUDGE Study were lost to follow-up. However, comparison of FUDGE participants with those lost to follow-up revealed no differences by gender, race, hospital of birth, or maternal educational attainment. Finally, the unique characteristics of our study population – in particular the young age and large proportion of SGA children – limited the generalizability of these findings to a broader population.

To conclude, these findings suggest the observed prevalence of obesity in preschool-aged children may differ substantially depending on the specific obesity metric used. Further, the magnitude and nature of these differences could vary markedly by population subgroup. Although BMI remains a critical tool, it may be important to consider additional non-invasive methods of assessing obesity, including skinfold thickness measures. Researchers and clinicians should evaluate how different obesity metrics relate to the specific aspects of childhood obesity most relevant to their study questions and population of interest. Finally, recent studies have demonstrated the importance of considering childhood obesity not simply as an outcome unto itself, but also focusing on the immediate and long-term adverse health outcomes secondary to childhood obesity. As the clinical and research communities learn more about etiologic mechanisms behind the health effects of childhood obesity, knowing how different obesity metrics perform in specific populations could aid in the development of targeted interventions to improve child health.

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Tables and Figures

Table 3.1: Characteristics of Follow-Up Development and Growth Experiences (FUDGE) Study participants*

	Overall		Private Hospital	Public Hospital	p-value†
			50.1 (213)	49.9 (212)	
Female - %(N)	48.9 (208)		54.9 (117)	42.9 (91)	0.01
SGA - %(N)	67.7 (288)		66.2 (141)	69.3 (147)	0.71
SGA <5th percentile - %(N)	35.5 (151)		33.8 (72)	37.3 (79)	
SGA 5-<10th percentile - %(N)	32.2 (137)		32.4 (69)	32.1 (68)	
AGA - %(N)	32.2 (137)		33.8 (72)	30.7 (65)	
African-American - %(N)	55.5 (236)		14.1 (30)	97.2 (206)	<0.01
Total family income <$40,000/year - %(N)	53.2 (222)		13.5 (28)	92.8 (194)	<0.01
Maternal education ≤ 12 years completed - %(N)	44.8 (190)		11.3 (24)	78.7 (166)	<0.01
Current maternal smoking - %(N)	22.4 (95)		13.2 (28)	31.6 (67)	<0.01
Maternal smoking during pregnancy - %(N)	27.5 (117)		18.8 (40)	36.3 (77)	<0.01
Child's age at testing (months) - Mean (IQR)	54.1 (53.4, 55.5)		54.0 (53.4, 55.2)	54.4 (53.4, 56.0)	0.10
Maternal age when participant born (years) - Mean (SD)	27.4 (6.5)		30.5 (5.0)	24.3 (6.5)	<0.01
Maternal pre-pregnancy BMI - Mean (SD)	23.5 (5.3)		22.8 (4.4)	24.1 (5.9)	<0.01

*SGA – small for gestational age (<10th percentile birthweight for gender, race, and gestational age), AGA – appropriate for gestational age (10th - <90th percentile birthweight for gender, race, and gestational age), IQR – interquartile range, SD – standard deviation, BMI – body mass index

†P-values: T-tests for normally-distributed continuous variables, Wilcoxon rank sum test for child's age (not normally distributed), χ^2 tests for categorical variables

Table 3.2: Percentage overweight/obese classified using body mass index (BMI), triceps-skinfold-thickness (TST), and subscapular-skinfold-thickness (SST): overall and stratified by gender, race, and small for gestational age SGA status*					
	BMI %(N)	TST %(N)	SST %(N)	Kappa Statistic	95% CI for Kappa
Overall† (N=425)	15.5 (66)	5.2 (22)	8.0 (34)	0.35	0.17 – 0.53
Girls (208)	15.9 (33)	7.7 (16)	9.6 (20)	0.39	0.15 – 0.63
Boys (217)	15.2 (33)	2.8 (6)	6.5 (14)	0.22	-0.04 – 0.48
Whites (189)	15.9 (30)	6.9 (13)	10.6 (20)	0.35	0.11 – 0.59
Blacks (236)	15.3 (36)	3.8 (9)	5.9 (14)	0.33	0.07 – 0.60
AGA (137)	27.7 (38)	8.0 (11)	10.2 (14)	-0.02	-0.04 – 0.00
SGA (288)	9.7 (28)	3.8 (11)	6.9 (20)	0.37	0.14 – 0.61

*Overweight/obese: ≥ 85th percentile, SGA – small for gestational age (<10th percentile birthweight for gender, race, and gestational age), AGA – appropriate for gestational age (10th - <90th percentile birthweight for gender, race, and gestational age)

†The overall proportion can be misleading because of the high proportion of SGA children (68%) in the dataset. Assuming that 90% of the population is AGA and 10% is SGA, then the "overall" prevalence of obesity would be: BMI 25.9%, TST 7.6%, and SST 9.9%.

Table 3.3: Percentage overweight/obese classified using body mass index (BMI), triceps-skinfold-thickness (TST), and subscapular-skinfold-thickness (SST): overall and stratified by gender/race and gender/small for gestational age (SGA) status*					
	BMI %(N)	TST %(N)	SST %(N)	Kappa Statistic	95% CI for Kappa
White girls (102)	13.7 (14)	8.8 (9)	10.8 (11)	0.00	-0.20 – 0.19
A-A girls (106)	17.9 (19)	6.6 (7)	8.5 (9)	0.45	0.13 – 0.77
White boys (87)	18.4 (16)	4.6 (4)	10.3 (9)	0.42	-0.01 – 0.84
A-A boys (130)	13.1 (17)	1.5 (2)	3.9 (5)	0.18	-0.14 – 0.51
AGA girls (67)	25.4 (17)	11.9 (8)	14.9 (10)	-0.05	-0.14 – 0.03
SGA girls (141)	11.4 (16)	5.7 (8)	7.1 (10)	-0.02	-0.07 – 0.02
AGA boys (70)	30.0 (21)	4.3 (3)	5.7 (4)	0.47	0.12 – 0.77
SGA boys (147)	8.2 (12)	2.0 (3)	6.8 (10)	0.24	-0.28 – 0.75

*Overweight/obese: ≥ 85th percentile, SGA – small for gestational age (<10th percentile birthweight for gender, race, and gestational age), AGA – appropriate for gestational age (10th - <90th percentile birthweight for gender, race, and gestational age), A-A – African-American

Table 3.4: Spearman correlations of body mass index (BMI), triceps-skinfold-thickness (TST), and subscapular-skinfold-thickness (SST) Z-scores, overall and stratified by gender, race, and small for gestational age (SGA) status*			
	BMI vs. TST	BMI vs. SST	TST vs. SST
Overall	0.45	0.48	0.58
Girls	0.49	0.52	0.62
Boys	0.42	0.44	0.56
Whites	0.50	0.54	0.59
Blacks	0.44	0.44	0.63
AGA	0.44	0.55	0.54
SGA	0.43	0.44	0.60

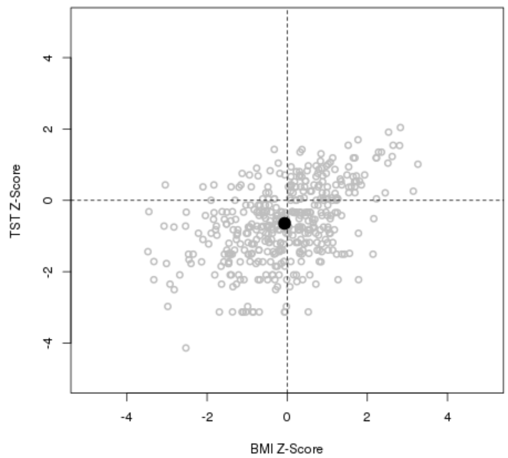
* SGA – small for gestational age (<10^{th} percentile birthweight for gender, race, and gestational age), AGA – appropriate for gestational age (10^{th} - <90^{th} percentile birthweight for gender, race, and gestational age)

Table 3.5: Spearman correlations of body mass index (BMI), triceps-skinfold-thickness (TST), and subscapular-skinfold-thickness (SST) with wrist breadth and height, overall and stratified by gender, race, and small for gestational age (SGA) status*						
	BMI vs.		TST vs.		SST vs.	
	Wrist breadth	Height	Wrist breadth	Height	Wrist breadth	Height
Overall	0.47	0.20	0.03	0.05	0.21	0.17
Girls	0.56	0.33	0.22	0.20	0.31	0.26
Boys	0.39	0.06	0.04	-0.01	0.26	0.11
Whites	0.49	0.25	0.12	0.09	0.21	0.14
Blacks	0.47	0.17	0.06	0.12	0.24	0.21
AGA	0.47	0.18	0.07	0.10	0.20	0.17
SGA	0.40	0.11	-0.04	-0.01	0.19	0.12

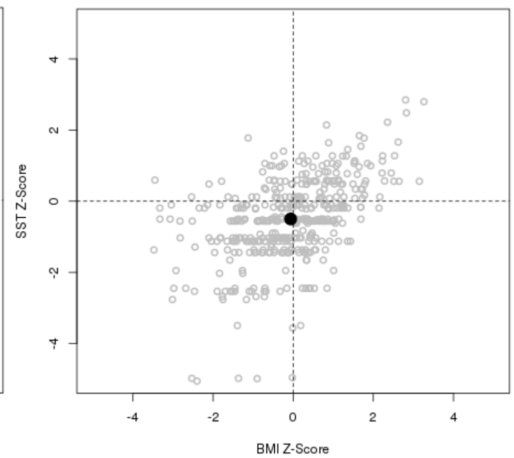
* SGA – small for gestational age (<10^{th} percentile birthweight for gender, race, and gestational age), AGA – appropriate for gestational age (10^{th} - <90^{th} percentile birthweight for gender, race, and gestational age)

Figure 3.1: Scatterplots comparing (a) body mass index (BMI), (b) triceps skinfold tickness (TST), and (c) subscapular skinfold thickness (SST) Z-scores*

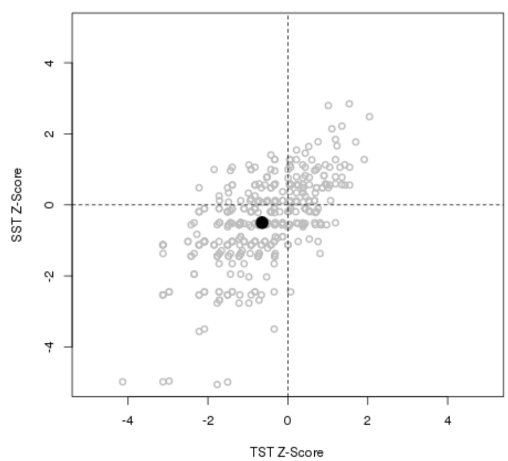
(a) BMI Z-score vs. TST Z-score



(b) BMI Z-score vs. SST Z-score



(c) TST Z-score vs. SST Z-score



* BMI – body mass index, TST – triceps skinfold thickness, SST – subscapular skinfold thickness, the dot represents the centroid of each scatter plot

4. THE ASSOCIATION BETWEEN EARLY CHILDHOOD OVERWEIGHT/OBESITY AND COGNITIVE ABILITY

Abstract

Background: A harmful effect of childhood obesity on cognitive ability could have a substantial impact on a population level. To date, studies of this relationship have produced inconsistent results and have largely been conducted in older children.

Methods: Data from the Follow-Up Development and Growth Experiences (FUDGE) Study (1997-99) were used to assess the relationship between three metrics of early childhood obesity (body mass index (BMI), triceps- and subscapular-skinfold-thickness (TST, SST)) and cognitive ability (assessed using the Differential Ability Scales (DAS), population mean = 100, standard deviation (SD) = 15). Obesity metrics and cognitive ability were measured in 423 children aged 54 months born at one of two Atlanta hospitals. Covariate information was obtained during the study or from previously collected data. Linear regression was used to estimate the change in DAS score associated with being in the top 15^{th} percentile of BMI/TST/SST based on Centers for Disease Control and Prevention norms. Data were also used on 14,431 participants from the US Collaborative Perinatal Project (CPP, 1959-74) to assess the relationship between BMI at ages three, four, and seven years and cognitive ability at ages four years (assessed using the Stanford-Binet Intelligence Scale (SB), mean=100, SD = 16) and seven years (assessed using the Wechsler Intelligence Scales for Children (WISC), mean = 100, SD = 15). Linear regression was used to estimate the change in SB or WISC score associated with being in the 85^{th} – < 95^{th} percentile (overweight) and ≥ 95^{th} percentile (obese).

Results: Analysis of the FUDGE Study data found that overweight/obese BMI, TST, and SST were associated with declines in nonverbal cognitive ability in preschool-aged boys (BMI: -6.1, 95% confidence interval -12.5 – 0.3; TST: -8.2, -21.0 – 4.6; SST: -9.0, -17.5 – -0.5); similar declines were not observed among girls. Results from the CPP indicated no meaningful association between either overweight or obesity and cognitive outcomes at ages four or seven years.

Conclusions: This study did not find evidence of a consistent association between early childhood overweight/obesity and cognitive ability. Results from the FUDGE Study indicated a possible association between early childhood overweight/obesity and nonverbal cognitive ability in boys, though this relationship was not observed in girls. Results from the CPP also failed to find an association between BMI and cognitive outcomes at four or seven years.

Introduction

According to data from the 2011-2012 National Health and Nutrition Examination Survey (NHANES), 31.8% of US children aged two to 19 years were classified as overweight or obese, ranking childhood obesity among the top public health priorities.[1] Although the prevalence of overweight and obesity among preschool-aged children was slightly lower, it was nonetheless high, at 22.8%. Obesity was even more common among low-income preschool children where one child in seven was obese.[2] Because of this high prevalence, possible associations between childhood obesity and childhood cognitive ability, even if small in magnitude, could have a substantial impact on a population level. Moreover, because of the detrimental impact of low socioeconomic status (SES) on childhood cognitive ability,[3] the burden of an obesity/cognitive ability relationship could fall disproportionately on low-income children.

Studies of the association between childhood obesity and cognitive ability have produced mixed results or found that the negative impact of obesity on cognitive ability was limited to certain groups. In a study of children aged eight to 11 years, Campos *et al.*, reported that obese children scored significantly lower on the Wechsler Intelligence Scale for Children (WISC) compared with non-obese children matched for age, school level, and SES.[4] Li also found a negative association between obesity and the WISC in children with a mean age of 10 years, but noted this result was only evident among children with severe obesity and no difference was observed in children with milder forms of obesity.[5] In contrast, Cserjési *et al.*, reported no difference in intelligence test scores (using Raven’s progressive matrices) between a small sample of obese schoolboys and their non-obese peers,[6] and Datar and colleagues found that differences in reading and math test scores between overweight and non-overweight first graders largely disappeared after adjustment for socioeconomic and behavioral factors.[7] Although the majority of studies examining childhood obesity and development have been conducted in elementary- and high school-aged children, one population-based study of preschool-aged German children found that, among boys, obesity was associated with delayed verbal ability, as well as three other components of cognitive development – motor, social, and daily living skills.[8] Only a moderate association between verbal skills and obesity was observed in girls, which disappeared when International Obesity Task Force cut-points, rather than those typically used for studies of German populations, were used.

As the above studies indicate, research evaluating the possible association between childhood obesity and childhood cognitive ability has produced inconsistent findings. Additionally, studies were typically conducted in older children, were often limited to small sample sizes, frequently had incomplete control of confounding, and primarily used a single obesity metric (body mass index, or BMI) with cut-points that varied among studies. This study sought to expand on previous research by examining the early childhood obesity/cognitive ability relationship in three ways. First, data were used from a study of 54 month-old African-American and white Atlanta children to explore the possible association between high BMI and cognitive ability. Then two additional metrics of obesity – triceps- and subscapular-skinfold-thickness (TST, SST) – were used in the same study population to validate our initial results. Finally, this study sought to further validate our findings by examining the relationship between BMI and cognitive ability using data from the U.S. Collaborative Perinatal Project (CPP), a large, multicenter, cohort study conducted from 1959 – 1974 which contained data on BMI at three points in time and cognitive ability at two points in time.

Methods

Study Populations

Two study populations were utilized for this analysis: the Follow-Up Development and Growth Experiences (FUDGE) Study (and its precursor, the Fetal Growth and Development Study, FGDS) and the Collaborative Perinatal Project (CPP). The FGDS was a case-control study conducted with the initial goal of developing enhanced surveillance for fetal alcohol syndrome among neonates. All African-American and white singleton infants born at one of two Atlanta-area hospitals between 2/1/93 – 12/31/94 with a gestational age of 32 – 42 weeks were eligible for the study. One of these hospitals was a private, suburban Atlanta hospital serving primarily a white, middle-class population and the other was a public hospital located in downtown Atlanta with a largely African-American, lower SES population. Study staff collected data at hospitals in one week segments and the hospital was randomly selected without replacement from blocks of four weeks. Staff abstracted race, sex, gestational age, and birthweight from labor and delivery or nursery logs. All small for gestational age children (SGA, $< 10^{th}$ percentile for gender, race, and gestational age) were selected as case infants. A simple, random 3% sample of all other singleton infants was included as appropriate for gestational age (AGA, $\geq 10^{th}$ percentile for gender, race, and gestational age) controls. The final sample size for the FGDS was 959 children.

These children were then reevaluated for the FUDGE Study when they were as close as possible to 54 months of age to assess psychometric and anthropometric outcomes of preschool-aged children born SGA. Of the original 959 FGDS participants, 760 were identified for follow-up in the FUDGE Study. This group included all participants born AGA, all SGA participants whose mothers reported any alcohol use in pregnancy, and half of the SGA infants whose mothers reported no prenatal alcohol use. Of these, 510 (72.2%) were successfully recruited. Further details of the FGDS and FUDGE study samples can be found elsewhere.[9]

The second dataset, the US Collaborative Perinatal Project, was a study conducted by the National Institute of Neurological Diseases and Blindness from 1959 – 74 with the initial goal of obtaining prospectively-collected data on neurological defects in children.[10] Twelve study sites – Baltimore, Boston, Buffalo, Memphis, Minneapolis, New Orleans, Philadelphia, Portland, OR, Providence, Richmond, and 2 in New York City – enrolled 55,908 pregnant women between 1959 – 1965. Nearly all study sites were university hospitals, and participant recruitment methods differed across sites. Pregnant women provided clinical samples and extensive information on medical history, family medical history, and socioeconomic and behavioral factors during prenatal visits with study staff. Women were reevaluated at delivery and their children were followed-up at four-, eight-, and 12-months, and three-, four-, seven-, and eight-years. Of the 53,043 women on whom pregnancy and delivery records were available, follow-up rates were 48% at three years (not all study sites conducted the three-year exam), 75% at four years, and 79% at seven years.[11] The current analysis was conducted on a subsample of the CPP study population. Children were excluded if they met any of the following criteria:

- non-singleton birth (N = 1,327);
- missing values for sex, race, study site, major congenital malformations diagnosed prior to one year of age, and four- and seven- year height, weight, and full-scale IQ score (N = 30,128);
- implausible values (≥ 5 standard deviations (SD) from the internal mean) for three-, four-, and seven-year height and weight (N = 341);
- non-African-American or white race (N = 4,470);
- severe cognitive disability at age four years (full-scale Stanford-Binet IQ score ≤ 50, N = 181);
- non-term birth (< 37 or > 42 weeks, N = 17,879);
- major congenital malformations diagnosed prior to age one year (N = 6,876);
- born large for gestational age (LGA, ≥ 90^{th} percentile birth weight for gestational age, race, and gender, N = 1,550). LGA children were excluded so that the CPP sample more closely resembled the FUDGE Study sample.

If more than one child in the same family was eligible for inclusion, a birth was selected at random. In total, 38,630 were excluded, yielding a final sample size of 14,413 children.

Data Collection

In the FGDS, in-person interviews with mothers regarding smoking, alcohol use, and socioeconomic factors were conducted by trained study staff within 48 hours of delivery. In-person interviews were again conducted at the 54-month follow-up visit, where anthropometric measurements were obtained. A single measurement of weight in kilograms (kg) was obtained using a digital scale. Two height measurements in centimeters (cm) were obtained to the nearest millimeter using a portable Schorr stadiometer (Schorr Productions, Olney, MD). When the two measurements differed by more than 0.5 cm, a third measurement was obtained. Two measurements each were also obtained for right-side triceps and subscapular skinfold thickness to the nearest millimeter using Lange skinfold calipers (Beta Techonology Incorporated, Santa Cruz, CA). A third measurement was taken if the first two measures differed by more than 1.0 mm. Height and skinfold thickness measurements used in this analysis were the average of the two closest measurements. Training of all staff was performed prior to the study and reliability was assessed semi-annually. Internal analyses suggested that the intra-observer reliability of all measures exceeded 95%.

In the CPP, height and weight were collected at the three-, four-, and seven-year exams by study staff. Not all hospitals participated in the three-year follow-up visit, so the sample size for 3-year BMI was substantially smaller than for four- and seven-year BMI. Cognitive ability was assessed at the four- and seven-year follow-up visits. At all visits, study staff followed standardized data-collection protocols. Reliability of the cognitive ability measures was demonstrated by retesting a sample of children three months after their original assessment. Test-retest correlations were 0.83 for the four-year Stanford-Binet full-scale IQ score (N = 140) and 0.85 for the seven-year WISC full-scale IQ score (N = 416).[12]

Study variables

<u>Obesity status</u>

In the FUDGE Study, obesity status was assessed using three metrics – BMI, TST, and SST. BMI was calculated using the formula: [weight (kg)] / [height (m)]^2 and age- and gender-specific BMI Z-scores were calculated using formulas and parameters provided by the CDC.[12,13] TST and SST Z-scores were estimated similarly using parameters from Addo and Himes.[14] BMI, TST, and SST percentiles were obtained from Z-scores using the properties of the normal distribution. BMI, TST, and SST were then categorized as overweight/obese (≥ 85th percentile) and not overweight/obese (< 85th percentile).

In the CPP, BMI was used to assess obesity status. BMI and BMI Z-scores were calculated as described above. For analysis of CPP data, BMI was classified as: underweight, < 5th percentile; normal weight, 5th – < 85th percentile; overweight, 85th – < 95th percentile; and, obese, ≥ 95th percentile. Change in BMI was assessed using BMI at age seven years – BMI at age four years. Change in BMI, rather than BMI Z-score, was used because research has shown that this metric is more appropriate when analyzing growth in children.[15-17]

Cognitive ability

In the FUDGE Study, childhood cognitive development was assessed using the composite scale, verbal cluster, and nonverbal cluster of the Differential Ability Scales (DAS; population mean = 100, SD = 15).

In the CPP, full-scale cognitive ability at age four years was assessed using an abbreviated version of the Stanford-Binet Intelligence Scale (population mean = 100, SD = 16). At age seven years full-, verbal, and performance scale cognitive ability was assessed using seven of the 11 subtests of the Wechsler Intelligence Scale for Children (WISC: information, comprehension, vocabulary, and digit span (verbal scale); picture arrangement, block design, and coding (performance scale), population mean = 100, SD = 15). On all tests, higher scores indicated better cognitive ability.

Covariates

In the FUDGE Study, covariate information was obtained either within 48 hours of delivery (child's sex, hospital of birth, race, small for gestational age status (from birthweight and gestational age), maternal age, maternal education, maternal pre-pregnancy BMI, maternal prenatal smoking status, maternal prenatal alcohol consumption, and family income) or at the 54-month follow-up visit (current maternal smoking). Socioeconomic status was represented by hospital of birth in this population.

In the CPP, covariate information was collected by study staff at registration (study site, maternal pre-pregnancy BMI (obtained from self-reported pre-pregnancy weight and height), maternal smoking status, maternal age, race), or delivery (child's sex, birthweight, gestational age). Small for gestational age status was determined by calculating internal norms by gender, race, and gestational age, and classified into four groups: SGA < 5^{th} percentile; SGA 5 – < 10^{th} percentile; AGA 10 – < 95^{th} percentile; and LGA ≥ 90^{th} percentile (LGA dropped from this analysis). Socioeconomic index (SEI) was determined at enrollment and calculated using total family income, and the education level and occupation of the head of household. The methods for calculating the SEI can be found in Myrianthopoulos and French.[18]

For both studies, potential confounders were determined *a priori* based on factors which were shown in the scientific literature to have consistent associations with both cognitive development and obesity, factors which influenced selection into the study, and use of directed acyclic graphs.[19] In the FUDGE dataset, covariates included were: hospital of birth; gender; SGA status; prenatal alcohol consumption; race; current and prenatal maternal smoking; maternal age; and, maternal pre-pregnancy BMI. For the CPP, covariates were: study site; race; SEI; SGA status; current maternal smoking; maternal age; and, maternal pre-pregnancy BMI.

Analysis

Bivariate comparisons were made using t-tests, Wilcoxon rank sum tests, one-way ANOVA, Kruskal-Wallis tests, and chi-square tests, depending on the variables' type and normality. Linear regression was used to assess the relationship between the cognitive ability scales and the childhood obesity metrics. Collinearity of independent variables was assessed using variance inflation factors (cut-point = 10). Because of the small sample size of the FUDGE Study and the very large sample size of the CPP, an *a priori* decision was made to present both pooled and stratified models, regardless of the presence of statistically significant interaction. The models for the FUDGE dataset were stratified by gender and hospital of birth. Because no established guidelines existed for stratification of the SEI in the CPP dataset which would appropriately parallel the hospital of birth variable in the FUDGE Study, CPP models were stratified by gender and race. Models with three different levels of adjustment for confounding were run: Model 1 – crude model with no adjustment; Model 2 – adjustment for a narrow set of covariates with strong potential for confounding or which influenced selection into the study; and, Model 3 – additional adjustment for a wider set of factors also shown in previous studies to be potential confounders. Results were considered statistically significant if $p < 0.05$ or if 95% confidence intervals (CI's) did not cross the null. All analyses were conducted in SAS Version 9.3 (Cary, NC).

The FGDS and FUDGE Studies were approved by the Institutional Review Boards of the two hospitals (for the FGDS only), Emory University, and the CDC. The CPP is a public use dataset and was obtained from `ftp://sph-ftp.jhsph.edu/cpp/`.[20]

Results

The FUDGE Study population included similar numbers of children from the public and private hospitals (210 and 213 children respectively) (Table 4.1). On average, mothers from the public hospital were younger, had higher average pre-pregnancy BMI, and higher rates of prenatal and current smoking compared with mothers from the private hospital ($p < 0.01$).

Children were assessed at a median age of 54.1 months (interquartile range (IQR) 53.4 – 55.5 months); median age at follow-up was similar at both hospitals. Approximately half of the FUDGE Study children were female (50.8%), although gender distribution differed significantly by hospital of birth (54.9% female private vs. 43.3% public, $p = 0.02$). In accordance with the study's initial design, 68% of the population was born SGA. The prevalence of SGA did not differ by hospital. Almost all (97.2%) of the children born at the public hospital were African-American, compared with 14.1% of children at the private hospital ($p < 0.01$). The prevalence of families with total family income < $40,000/year and mothers who completed ≤ 12 years of education were both significantly higher at the public hospital compared with the private hospital.

In the FUDGE Study dataset, BMI classified the highest proportion of children as overweight/obese, and TST the lowest proportion, regardless of gender, hospital of birth, or SGA status (Table 4.3). Overweight/obesity prevalence was similar between boys and girls when using BMI, but higher among girls when using skinfold thickness measures. Likewise, BMI classified similar proportions of children born at the private and public hospitals as overweight/obese, though more children were classified as overweight/obese from the private hospital for both TST and SST. Overweight/obesity prevalence was higher in AGA children compared with SGA children for all three metrics, though the relative difference in prevalence was greater for BMI than for either skinfold thickness measure. For example, when classifying obesity status using BMI, the prevalence of overweight/obesity among AGA children was 2.9 times higher than among children born SGA (SGA < 5% and 5 – < 10% combined), but only 2.1 and 1.5 times as high when using TST and SST, respectively.

Statistically significant differences in mean DAS composite, verbal, and nonverbal scores by hospital of birth were observed for all three scales. Differences in mean score by gender were also observed, with girls scoring statistically significantly higher on all three scales. Much, though not all, of these differences can be attributed to confounding by hospital of birth (data not shown). Mean scores were not significantly different by SGA status for any DAS scale, though scores on all DAS scales were similar between AGA children and children born SGA 5 – < 10^{th} percentile, and lower in children born SGA < 5^{th} percentile.

The proportion of the total CPP study population varied markedly by study site, with the three largest sites (Boston, Philadelphia, and Baltimore) contributing 46.2% of the total population, while the three smallest sites (New York Columbia-Presbyterian, New York Medical College, and Portland) contributed only 10.4% (Table 4.2). Overall, 50.5% of the total sample was female, and this proportion was similar among study sites. The overall prevalence of African-Americans was 50.2%, and racial makeup of sites differed substantially, with five sites (Baltimore, Memphis, New York Medical College, New Orleans, and Richmond) having > 80% African-American participants, and three sites (Boston, Buffalo, and Minneapolis) having < 20%. Overall, the proportion of children born SGA was 10.2%, which was consistent with the definition of < 10^{th} percentile of birthweight for gender, race, and gestational age. Maternal smoking status (48.6% overall), SEI at registration (mean = 47.7 (SD = 21.9)), maternal age (mean = 24.4 years, (SD = 6.2)) and maternal pre-pregnancy BMI (mean = 22.7 (SD = 4.2)) all differed significantly by both study site and race. Median age at the four-year exam was 48 months (IQR: 48 – 49 months), and median age at the seven-year exam was 84 months (IQR: 83 – 85 months).

In the CPP population, combined prevalence of overweight and obesity was 14.2%, 21.2%, and 13.7% at ages three, four, and seven years, respectively (Table 4.4). Obesity status prevalence did not differ by gender at age three years, but differences between boys and girls were significant at both ages four years ($p < 0.001$) and seven years ($p = 0.02$). Whites had lower proportions of underweight and higher proportions of overweight and obese at all ages compared with African-Americans. Differences in obesity status prevalence by race were statistically significant for all ages ($p < 0.001$). The apparent increase in the overall prevalence of overweight and obesity at age four years compared with ages three and seven years was driven by increases in prevalence among white children. Prevalence of overweight and obesity among African-American children differed little between three-, four-, and seven-years.

Overall, mean full-scale IQ scores were 98.8 (SD = 16.6) at age four years on the Stanford-Binet and 97.0 (SD = 14.0) at age seven years on the WISC. Mean IQ score was higher in girls compared with boys for the Stanford-Binet full-scale test, but boys recorded higher mean scores on the WISC full-scale IQ test. Differences by gender for all IQ tests were statistically significant. Scores were significantly higher among whites compared with African-Americans on all four tests of IQ.

Overall, crude and adjusted models indicated no association between overweight/obese BMI and any DAS cognitive ability scale (Table 4.5). (For all models presented in this paper, little difference in results was observed between controlling for the narrower or wider set of potential confounders described above. Thus, only results from the crude and more fully-adjusted models are presented.) However, the association of high BMI and DAS scores often varied by gender, with nonverbal ability driving these differences. Among girls, overweight/obese BMI was associated with a moderate increase in DAS composite and nonverbal scores (composite: 3.4 points, 95% CI: -1.8 – 8.7; nonverbal: 7.8, 2.0 – 13.6), while the reverse was true among boys (composite: -4.6, -10.0 – 0.8; nonverbal: -6.1, -12.5 – 0.3). No difference was observed in DAS verbal score in either gender. In models stratified by hospital of birth, no association was observed in either hospital between high BMI and scores on any DAS scale.

In skinfold thickness models, no statistically significant association was observed between high TST or SST and any DAS outcome in pooled models, though point estimates were suggestive of a small negative effect of high TST/SST on composite and nonverbal DAS scores (Table 4.5). Similar to models examining the effect of high BMI on DAS score, differences in composite and nonverbal ability were evident after stratification by gender. Unlike for BMI, however, no association was observed among girls between overweight/obese TST or SST on any DAS scale. As with BMI, among boys, high TST and SST were associated with moderate-to-strong declines in scores on DAS composite and nonverbal ability (TST: composite -3.6, -14.4 – 7.2, nonverbal -8.2, -21.0 – 4.6; SST: composite -8.0, -15.1 – -0.8, nonverbal -9.0, -17.5 – -0.5). In models stratified by hospital of birth, no significant relationship was observed in children born at either hospital between overweight/obese TST or SST and any of the DAS scales. However, point estimates consistently demonstrated small declines in DAS composite and nonverbal scores in children with high TST (for the public hospital) or SST (for both hospitals) which could be suggestive of a small negative association.

In the CPP, linear regression models evaluating the association between four-year BMI and both four- and seven-year full-scale IQ tests (Stanford-Binet and WISC, respectively), as well as models examining the association between seven-year BMI and seven-year WISC full-scale IQ produced highly consistent results (Table 4.6). In each of these models: 1) underweight BMI was associated with a very small decline in full-scale IQ score with respect to normal weight BMI; and, 2) both overweight and obese BMI were associated with a similarly small increase in full-scale IQ compared with normal weight BMI. The effects of obesity and overweight (vs. normal weight) were similar in magnitude. Stratifying by gender or race (or both) did not change the conclusion, nor did examination of verbal or performance subscales of the seven-year WISC IQ test. We further observed no difference between models considering cross-sectionally assessed BMI and IQ score (e.g., four-year BMI/four-year IQ or seven-year BMI/seven-year IQ), and models which assessed the association between BMI and IQ score measured at a later time (e.g., four-year BMI/seven-year IQ or three-year BMI/four-year or seven-year IQ). Finally, models evaluating the association between change in four-to-seven-year BMI and seven-year IQ produced similarly small effect estimates (data for additional models not shown).

Discussion

Our results from the FUDGE Study indicated that overweight/obesity in preschool-aged boys was associated with declines in composite and nonverbal cognitive ability. These results were consistent across all three obesity metrics assessed – BMI, TST, and SST. Similar declines were not observed among girls, where, in fact, overweight/obese BMI (though not TST or SST) was associated with a statistically significant *increase* in DAS nonverbal score. Further, in the CPP, we found no meaningful association between either overweight or obesity and cognitive outcomes at ages four or seven years. These conclusions did not change after stratification by race or gender (or both).

This study is not the first to report differences in the association of obesity and cognitive ability by gender. Cawley and Spiess found that obesity was associated with declines in verbal skills among preschool-aged boys, while the association was more modest among girls.[8] Similarly, our results indicated a negative association among preschool-aged boys, though we found this association to be driven by declines in nonverbal, rather than verbal, ability.

To our knowledge, this is the first study to assess the association of obesity status and cognitive ability in preschool-aged children using more than one obesity metric. This enabled us to observe that overweight/obese BMI in the FUDGE Study was associated with an increase in DAS nonverbal ability among girls, but that this association was not apparent when overweight/obesity was classified using TST or SST. One possible explanation for this finding is that high BMI could be reflective of increased muscularity (rather than adiposity), which might suggest that these children are more developed both physically and cognitively. However, if this were true, we might expect to see a similar positive association in girls between high BMI and scores on the Vineland Adaptive Behavior Scales motor skills test, which was administered at the same time as the DAS battery. While scores were slightly elevated in girls on this test, they were non-significant and the association was much smaller in magnitude than the one seen here with BMI.

Although this study found no association between overweight or obesity and cognitive ability in the CPP, it is possible that with more severe levels of obesity an association would emerge. In a population of 10-year-old Chinese schoolchildren, Li found a negative association between obesity and scores on the WISC, but noted that these results were observed only in severely obese children.[5] To evaluate the possibility that use of the 95th percentile as the cut-point for obesity in the CPP was masking an association in more severely obese children, we ran similar analyses classifying obesity at both the 97th and 99th percentiles. We found no change in our conclusions when obesity status was defined using these higher cut-points.

One additional interesting finding in this analysis was the increase in prevalence of overweight and obesity among white children at age four years. Because the CPP was conducted from 1959 – 1974, prior to the beginning of the childhood obesity epidemic, one might assume that the prevalence overweight and obesity would be close to 10% and 5%, respectively, as the classification percentiles define. This was, in fact, true for ages three and seven years, regardless of race, but the bump in the prevalence of overweight to 17.6% and obesity to 10.4% among white children was not in line with this expectation. To verify that this increase in prevalence was not an artifact due to one or more of our exclusions, we confirmed that overweight and obesity prevalence at age four years were consistent in the original, full CPP dataset, as well as after exclusion of each group. (Prevalence understandably rose after exclusion of such groups as non-term births, but this increase was only a fraction of a percent.) While we cannot explain the increase in prevalence, or why it was limited to white children, it is possible that today's children follow a different pattern of growth compared with children from the 1960's and that these differences are especially pronounced for white children at around four years of age.

A question that naturally arises when using datasets such as these is how to handle the issue of statistical significance. In the FUDGE dataset, the present study was a secondary data analysis which utilized previously-collected data and the initial power/sample size calculations did not consider the study questions of interest in this paper. This analysis had 80% power to detect a main effect of 0.4 SD, which translates to a difference in 5.6 points on any of the DAS scales. As expected, power to detect statistically significant interaction was lower. While this power would have been sufficient to detect the type of strong relationship which could have a meaningful clinical impact on individuals (such as the observation of the negative association between overweight/obesity and nonverbal ability among boys), it is possible that the study was underpowered to detect smaller associations which could nonetheless have a substantial impact on a population level. Consequently, when consistent relationships were demonstrated, such as the negative association between DAS composite/nonverbal scores and high TST or SST, these results may be suggestive despite their small magnitude or lack of statistical significance.

In contrast, the very large sample size of the CPP meant that statistical significance was often reached even for effect sizes which had little clinical significance. As an extreme example, among girls, overweight seven-year BMI (compared with normal weight) was associated with a 1.0 point increase in WISC full-scale IQ score. The 95% confidence interval for this association was statistically significant, ranging from 0.04 to 2.0. For these reasons, reliance on p-values in either the FUDGE Study or the CPP for decisions such as the presence of effect modification in models would be unhelpful and we chose to instead make *a priori* decisions based on knowledge of the source populations and relevant epidemiology.

The primary strength of this analysis was its multi-faceted approach to evaluating the possible association between early childhood obesity and cognitive ability. Notably, the use of both BMI and skinfold thickness measurements in the FUDGE dataset overcame the limitation some studies face of relying simply on BMI for obesity assessment. While research has demonstrated BMI to be both valid and reliable in assessing childhood obesity,[21-23] important differences in body composition exist by gender, race, and small for gestational age status,[23-30] which could hinder the ability of BMI to assess true underlying obesity in certain groups. In fact, research on the FUDGE Study population has indicated substantial differences between BMI, TST, and SST in assessing obesity prevalence in different population subgroups. Use of BMI, as well as two skinfold thickness metrics, therefore contributed to the depth of this analysis. In addition to multiple metrics, this study's examination of similar study questions in a second dataset – one that was quite different from the FUDGE Study – provided yet another perspective. The CPP allowed not only similar analyses to those from the FUDGE Study, but also expanded the focus of this paper by including two additional time points for BMI measurements (ages three and seven years), and a second assessment of cognitive ability at seven years.

A second strength of this paper was the use of strong metrics to assess SES in both the FUDGE Study and the CPP. In the FUDGE Study, hospital of birth was used to denote SES and the two hospitals from which patients were recruited represented populations with distinctly different socioeconomic characteristics. Because healthcare-seeking behavior is related to wealth, insurance status, neighborhood of residence, access to transportation, and a host of other factors, use of hospital of birth may have better captured the broad, multi-dimensionality of SES compared with simply relying on proxy measures like income and education. In the CPP, SES was represented by the socioeconomic index. This index, developed by the US Census Bureau, combined three factors – income, education, and occupation – into a single metric used to assess a family's SES. To create an even better fit of the SEI to the CPP population, the metric was re-scaled to represent the underlying source population which gave rise to the CPP participants, rather than the US population as a whole. While no method or factor can completely account for differences in socioeconomic status, we believe that hospital of birth (in FUDGE) and the SEI (in the CPP) performed well in allowing us to assess the impact of SES on our study questions.

A third strength of our study was its focus on preschool-aged children. Although most studies of the possible association between childhood obesity and cognitive development have been conducted in older children, if an adverse, causal relationship does exist, it might be especially important in earlier years. Younger children's cognitive skills develop largely through their ability to explore and engage their world. Thus, cognitive development in young children is more tied to their physical capabilities, compared with older children and adults. Further, because early childhood development occurs prior to the start of formal education, if a problem does exist, children could be entering school already at a disadvantage. If interventions could be targeted at earlier ages, it is possible that they could both minimize exposure time and/or provide additional opportunities to mitigate the adverse effects of childhood obesity.

Despite these strengths, our analysis was also subject to several limitations. First, our relatively small sample size in the FUDGE Study restricted the analyses we could perform and limited our statistical power. In particular, analysis of a four-category obesity status variable (or even simply overweight and obese children in separate strata) would have contributed to the depth of this analysis.

Second, our analysis would have been strengthened had we been able to examine a change-in-IQ measure in the CPP dataset. While full-scale cognitive ability was assessed at both ages four and seven years, important differences in the Stanford-Binet and WISC tests prevented a one-to-one comparison. When referring to the versions of both tests used in the CPP, Sattler noted that the Stanford-Binet and WISC tests do not yield comparable mean IQs, especially for children scoring in the Normal and above ranges on the Stanford Binet.[31] This was confirmed in our dataset where Pearson correlations between Stanford-Binet full-scale IQ and WISC full-scale IQ were 0.48 among children with four-year IQ > 100, but only 0.30 among children with four-year IQ > 130.

Third, although both datasets contained extensive information on potential confounders, the possibility of residual confounding existed. For example, differences in the distribution of gender by hospital of birth in the FUDGE Study occurred because of the performance of the SGA norms that were used in this population and may have contributed to difficulties in examining the effects of gender or hospital due to residual confounding.

Fourth, it is possible that missing data, exclusions, and loss to follow-up contributed to errors in our reported results. In the FUDGE Study, over one-fourth of the FGDS participants selected for inclusion in the FUDGE population were lost to follow-up. However, comparison of FUDGE participants with those lost to follow-up revealed no differences by gender, race, hospital of birth, or maternal educational attainment.

Because of the very large size of the CPP dataset, we chose to be fairly liberal in our exclusion scheme to minimize the potential for confounding or other biases. While many of these exclusions were in line with other studies on similar topics published using CPP data (e.g., multiple births, congenital malformations diagnosed prior to one year of age), this caution limits the degree of generalizability of the findings. Further, because this analysis of CPP data was conducted to parallel the main question from the FUDGE Study, several additional exclusions were made (e.g., children born LGA or those of non-white or African-American race) so that the CPP sample better approximated the one used for analysis of the FUDGE dataset. To assess the potential impact of our exclusions, we performed several sensitivity analyses: 1) including children born LGA; 2) expanding from children born 37 – 42 weeks to children born 32 – 45 weeks; and, 3) including children of "Puerto Rican", "Oriental", or "other" races (the original race categories from the CPP). None of these analyses produced notable changes in our conclusions.

Fifth, while the linear regression models using FUDGE Study data were stratified by gender and hospital of birth, no well-established guidelines existed for the SEI in the CPP dataset to create analogous strata. While not directly parallel, we believed that stratification by race in the CPP (with adjustment for SEI score) was a better parallel for analyses in the FUDGE dataset. We did, however, run additional models in the CPP stratifying the SEI in three ways: 1) above vs. below the median; 2) the top 25% vs. the bottom 75%; and, 3) the top 25% vs. the bottom 25%. No changes in conclusions were observed. Further, we additionally ran models in the FUDGE Study stratified on race, rather than hospital of birth, and the conclusions again did not change.

Sixth, both datasets utilized in this analysis were collected either in the 1990's or from the 1950's to the 70's. It is possible that neither of these datasets accurately represents today's picture of childhood obesity. However, if the underlying relationship between obesity and cognitive ability has remained constant, then any increase in obesity prevalence would result in a greater population impact.

Finally, because of important societal changes occurring during the time period between the two studies, we were unable to make direct comparisons of results between the two study populations. For example, shifts in dietary, exercise, and leisure patterns, urbanization and increased exposure to environmental pollutants, and changing breastfeeding and smoking rates have all played roles in both recent changes in obesity prevalence and childhood neurocognitive development.

The question of a possible association between early childhood obesity and cognitive ability is a relevant one because of the high prevalence of overweight and obesity among today's young children. The fact that the proportion of overweight and obese children is even higher among those with lower SES, a population already vulnerable to a host of factors which can detrimentally impact cognitive development, compounds the importance of examining this issue closely. Our results from the FUDGE Study indicated a possible negative association between overweight/obesity and declines in nonverbal cognitive ability among boys. We did not, however, find evidence of an analogous harmful association among girls in the FUDGE Study, nor did our evaluation of similar questions in the CPP confirm our results. Previous research, as well as our own in this analysis, has failed to consistently establish the presence of a relationship between overweight/obesity and cognitive ability in childhood. While there are important public health consequences of obesity in early childhood, at this time there is no evidence to support an association between early childhood obesity and cognitive ability.

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Tables

Table 4.1: Characteristics of Follow-Up Development and Growth Experiences (FUDGE) Study participants*					
	Overall		Private Hospital	Public Hospital	p-value†
			50.4 (213)	49.7 (210)	
Female – %(N)	50.8 (215)		54.9 (117)	43.3 (91)	0.02
SGA – %(N)	67.9 (287)		66.2 (141)	69.5 (146)	0.71
SGA <5th percentile – %(N)	35.5 (150)		33.8 (72)	37.1 (78)	
SGA 5-<10th percentile – %(N)	32.4 (137)		32.4 (69)	32.4 (68)	
AGA – %(N)	32.2 (136)		33.8 (72)	30.5 (64)	
African-American – %(N)	55.3 (234)		14.1 (30)	97.1 (204)	<0.01
Total family income <$40,000, %(N)	53.1 (221)		13.5 (28)	92.8 (193)	<0.01
Maternal education ≤ 12 years completed, %(N)	44.6 (188)		11.3 (24)	78.5 (164)	<0.01
Current maternal smoking - %(N)	22.2 (94)		13.2 (28)	31.4 (66)	<0.01
Maternal smoking during pregnancy - %(N)	27.4 (116)		18.8 (40)	36.2 (76)	<0.01
Age at testing (months) – Median (IQR)	54.1 (53.4, 55.5)		54.6 (53.4, 55.2)	55.0 (53.4, 56.0)	0.12
Maternal age when participant born (years) – Mean (SD)	27.4 (6.6)		30.5 (5.0)	24.3 (6.5)	<0.01
Maternal pre-pregnancy BMI – Mean (SD)	23.5 (5.3)		22.8 (4.4)	24.1 (6.0)	<0.01

*SGA – small for gestational age (<10th percentile birthweight for gender, race, and gestational age), AGA – appropriate for gestational age (10th - <90th percentile birthweight for race, gender, and gestational age), IQR – interquartile range, SD – standard deviation, BMI – body mass index
†P-values: T-tests for normally-distributed continuous variables, Wilcoxon rank sum test for child's age (not normally distributed), χ^2tests for categorical variables

Table 4.2: Characteristics of the Collaborative Perinatal Project (CPP) participants*

	Overall	Baltimore	Boston	Buffalo	Mem-phis	Minnea-polis	New Orleans	NYCP	NYMC	Philadel-phia	Portland, OR	Provi-dence	Rich-mond	p-value †
% Total sample - %(N)	100.00 (14413)	9.73 (1402)	21.31 (3072)	7.47 (1076)	7.44 (1072)	6.79 (979)	6.51 (938)	3.05 (439)	1.27 (183)	15.18 (2188)	6.06 (874)	8.60 (1240)	6.59 (950)	
% Female - %(N)	50.51 (7236)	51.79 (724)	50.31 (1539)	49.95 (535)	49.39 (528)	47.43 (462)	50.00 (467)	48.85 (212)	49.44 (89)	53.52 (1164)	47.70 (415)	50.29 (617)	51.76 (484)	0.11
% African-American - %(N)	50.19 (7190)	83.33 (1165)	10.26 (314)	2.05 (22)	99.81 (1067)	0.41 (4)	100.00 (934)	52.30 (227)	89.44 (161)	92.37 (2009)	27.24 (237)	22.17 (272)	83.21 (778)	<0.001
SGA - %(N)	10.16 (1455)	13.59 (190)	10.07 (308)	7.66 (82)	10.76 (115)	9.14 (89)	8.89 (83)	8.76 (38)	10.00 (18)	9.38 (204)	10.46 (91)	11.08 (136)	10.80 (101)	0.01
SGA <5th percentile - %(N)	4.67 (669)	6.94 (97)	4.45 (136)	3.17 (34)	4.77 (51)	4.21 (41)	3.85 (36)	4.38 (19)	5.56 (10)	4.28 (93)	4.14 (36)	5.54 (68)	5.13 (48)	
SGA 5-<10th percentile - %(N)	5.49 (786)	6.65 (93)	5.62 (172)	4.48 (48)	5.99 (64)	4.93 (48)	5.03 (47)	4.38 (19)	4.44 (8)	5.10 (111)	6.32 (55)	5.54 (68)	5.67 (53)	
AGA – %(N)	89.84 (12871)	86.41 (1208)	89.93 (2751)	92.34 (989)	89.24 (954)	90.86 (885)	91.11 (851)	91.24 (396)	90.00 (162)	90.62 (1971)	89.54 (779)	88.92 (1091)	89.20 (834)	
% Maternal smoking - %(N)	48.58 (6959)	41.42 (579)	58.03 (1775)	46.59 (499)	25.54 (273)	50.82 (495)	40.90 (382)	40.78 (177)	47.78 (86)	51.22 (1114)	54.60 (475)	57.62 (707)	42.46 (397)	<0.001
Age at 4-year exam (months) Median (IQR)	48 (48, 49)	48 (47, 48)	48 (47, 49)	48 (48, 49)	46 (46, 48)	48 (48, 48)	48 (47, 48)	48 (47, 49)	48 (48, 49)	48 (48, 48)	48 (48, 49)	48 (48, 49)	48 (48, 49)	<0.001
Age at 7-year exam (months) Median (IQR)	84 (83, 85)	88 (85, 90)	84 (83, 85)	84 (83, 84)	84 (83, 84)	84 (83, 84)	85 (84, 85)	82 (82, 83)	84 (83, 85)	82 (82, 84)	84 (84, 85)	84 (84, 85)	83 (83, 83)	<0.001
Socioeconomic index Mean (SD)	47.71 (21.88)	39.32 (18.39)	59.94 (17.50)	77.34 (16.08)	31.92 (14.82)	60.43 (21.84)	30.51 (14.38)	53.87 (17.34)	42.92 (14.30)	40.20 (16.03)	39.36 (16.28)	45.88 (19.33)	32.85 (16.11)	<0.001
Maternal age (years) Mean (SD)	24.40 (6.18)	23.91 (7.14)	25.76 (6.17)	26.47 (5.12)	21.69 (5.27)	23.36 (5.13)	24.11 (6.05)	26.03 (5.98)	25.04 (6.03)	23.94 (6.22)	23.40 (5.91)	24.27 (6.00)	24.00 (6.47)	<0.001
Maternal pre-pregnancy BMI Mean (SD)	22.65 (4.17)	23.00 (4.63)	22.54 (3.77)	21.79 (3.07)	21.98 (3.55)	21.76 (3.69)	22.78 (4.65)	22.54 (4.32)	23.29 (4.99)	23.40 (4.39)	22.81 (4.52)	22.49 (4.13)	23.21 (4.57)	<0.001

*SGA – small for gestational age (<10th percentile birthweight for gender, race, and gestational age), AGA – appropriate for gestational age (10th - <90th percentile birthweight for gender, race, gestational age), IQR – interquartile range, SD – standard deviation, BMI – body mass index, NYCP – New York (Columbia- Presbyterian), NYMC – New York (Medical College)

†P-values: χ^2 tests for categorical variables, one-way ANOVA for normally-distributed continuous variables, Kruskal-Wallis test for child's age (not normally distributed)

Table 4.3: Percent overweight/obese by body mass index (BMI), triceps-skinfold-thickness (TST), and subscapular-skinfold-thickness (SST), mean values for Differential Ability Scales (DAS) cognitive ability tests in the Follow-Up Development and Growth Experiences (FUDGE) Study population, overall and stratified by gender, hospital of birth, and small for gestational age (SGA) status*

	Overall	Girls	Boys	p-value†	Private Hospital	Public Hospital	p-value	SGA <5%	SGA 5-<10%	AGA	p-value
	% (N)	% (N)	% (N)		% (N)	% (N)		% (N)	% (N)	% (N)	
BMI	15.60 (66)	15.87 (33)	15.35 (33)	0.88	15.02 (32)	16.19 (34)	0.74	6.67 (10)	13.14 (18)	27.94 (38)	<0.01
TST	5.20 (22)	7.69 (16)	2.79 (6)	0.02	6.57 (14)	3.81 (8)	0.20	2.00 (3)	5.84 (8)	8.09 (11)	0.06
SST	8.04 (34)	9.62 (20)	6.51 (14)	0.24	9.39 (20)	6.67 (14)	0.30	6.00 (9)	8.03 (11)	10.29 (14)	0.41
	Mean (SD)	Mean (SD)	Mean (SD)		Mean (SD)	Mean (SD)		Mean (SD)	Mean (SD)	Mean (SD)	
DAS Composite	86.77 (18.26)	90.71 (18.05)	82.87 (17.65)	<0.01	98.29 (15.16)	75.02 (12.87)	<0.01	83.94 (17.58)	88.63 (19.26)	88.03 (17.72)	0.06
DAS Verbal	84.11 (17.82)	87.08 (17.42)	81.20 (17.76)	<0.01	95.38 (15.89)	72.66 (11.12)	<0.01	81.75 (17.53)	86.25 (18.35)	84.59 (17.42)	0.10
DAS Nonverbal	90.27 (18.94)	94.63 (18.31)	85.95 (18.59)	<0.01	100.44 (15.76)	79.91 (16.09)	<0.01	87.92 (18.34)	91.22 (19.49)	91.92 (18.90)	0.16

*Overweight/obese: ≥85th percentile, DAS: population mean = 100; standard deviation = 15, SGA – small for gestational age (<10th percentile birthweight for gender, race, and gestational age), AGA – appropriate for gestational age (10th - <90th percentile birthweight for gender, race, and gestational age), SD – standard deviation,

†P-values: χ^2 for comparisons of overweight/obesity prevalence by gender, hospital of birth, and SGA status; t-test for mean DAS score by gender and hospital of birth; one-way ANOVA for mean DAS score by SGA status

Table 4.4: Obesity status at ages three, four, and seven years; mean values for the Stanford-Binet Intelligence Scales (four years) and Wechsler Intelligence Scales for Children (WISC, seven years) full-scale IQ tests in the Collaborative Perinatal Project: overall and stratified by gender and race
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		Overall		Girls	Boys	p-value†		Whites	A-As	p-value
		%(N)		%(N)	%(N)			%(N)	%(N)	
3 year BMI	Underweight	7.52 (516)		8.00 (273)	7.05 (243)	0.23		6.32 (201)	8.56 (315)	<0.001
	Normal	78.30 (5373)		78.15 (2668)	78.45 (2705)			77.23 (2456)	79.22 (2917)	
	Overweight	9.49 (651)		9.55 (326)	9.43 (325)			11.16 (355)	8.04 (296)	
	Obese	4.69 (322)		4.31 (147)	5.08 (175)			5.28 (168)	4.18 (154)	
4 year BMI	Underweight	5.93 (855)		6.53 (476)	5.32 (379)	<0.001		3.23 (232)	8.61 (623)	<0.001
	Normal	72.89 (10505)		73.41 (5350)	72.35 (5155)			68.79 (4937)	76.95 (5568)	
	Overweight	13.45 (1938)		13.53 (986)	13.36 (952)			17.60 (1263)	9.33 (675)	
	Obese	7.74 (1115)		6.53 (476)	8.97 (639)			10.38 (745)	5.11 (370)	
7 year BMI	Underweight	4.77 (676)		5.31 (381)	4.21 (295)	0.02		2.34 (166)	7.19 (510)	<0.001
	Normal	81.55 (11569)		81.26 (5833)	81.85 (5736)			81.72 (5799)	81.38 (5770)	
	Overweight	9.02 (1279)		8.89 (638)	9.15 (641)			10.57 (750)	7.46 (529)	
	Obese	4.67 (662)		4.54 (326)	4.79 (336)			5.37 (381)	3.96 (281)	
		Mean (SD)		Mean (SD)	Mean (SD)			Mean (SD)	Mean (SD)	
Stanford-Binet Full-scale		98.84 (16.14)		100.03 (16.41)	97.62 (15.76)	<0.001		105.49 (15.95)	92.25 (13.38)	<0.001
WISC full-scale		96.97 (13.99)		96.64 (13.62)	97.31 (14.36)	<0.01		103.30 (13.14)	90.69 (11.82)	<0.001
WISC verbal		95.37 (13.70)		94.60 (13.43)	96.16 (13.93)	<0.001		100.80 (13.47)	89.99 (11.66)	<0.001
WISC performance		99.34 (14.97)		99.59 (14.33)	99.08 (15.59)	0.04		105.50 (14.08)	93.23 (13.21)	<0.001

*BMI – body mass index, BMI classification – underweight: <5th percentile, normal weight: 5 - <85th percentile (reference group), overweight: 85 – <95th percentile, obese: ≥ 95th percentile, SD – standard deviation, Stanford-Binet Intelligence Scale: population mean = 100 standard deviation = 16, Wechsler Intelligence Scales for Children: population mean = 100, standard deviation = 15

†P-values: χ^2 for comparisons of obesity prevalence by gender and race; t-test for comparisons of mean Stanford-Binet and WISC score by gender and race

Table 4.5: Change in composite, verbal, and nonverbal scores of the Differential Ability Scales (DAS) in children classified as overweight/obese using body mass index (BMI), triceps-skinfold-thickness (TST), and subscapular-skinfold-thickness (SST), compared with normal weight children, overall and stratified by gender and hospital of birth in the Follow-Up Development and Growth Experiences (FUDGE) Study*†

				Stratified by gender		Stratified by hospital of birth	
		Crude	Pooled	Girls	Boys	Private	Public
Composite	BMI	-0.54 (-5.40, 4.31)	-0.69 (-4.41, 3.03)	3.43 (-1.81, 8.67)	-4.59 (-10.00, 0.81)	-2.24 (-8.12, 3.64)	0.68 (-4.11, 5.48)
	TST	1.93 (-5.94, 9.80)	-2.58 (-8.46, 3.29)	-2.21 (-9.31, 4.90)	-3.60 (-14.39, 7.19)	-5.30 (-13.41, 2.81)	-0.77 (-9.72, 8.18)
	SST	-1.70 (-8.13, 4.73)	-4.11 (-8.84, 0.61)	-0.09 (-6.53, 6.34)	**-7.95 (-15.10, -0.80)**	-3.12 (-9.96, 3.73)	-5.62 (-12.43, 1.19)
Verbal	BMI	-0.11 (-4.84, 4.63)	-0.21 (-3.89, 3.46)	1.43 (-3.67, 6.52)	-1.32 (-6.81, 4.18)	-0.91 (-7.30, 5.49)	0.02 (-4.12, 4.16)
	TST	4.93 (-2.74, 12.59)	0.52 (-5.28, 6.33)	-1.50 (-8.38, 5.39)	5.13 (-5.77, 16.03)	-0.05 (-8.91, 8.80)	-1.08 (-8.80, 6.64)
	SST	1.13 (-5.14, 7.41)	-1.90 (-6.58, 2.78)	0.05 (-6.18, 6.29)	-3.56 (-10.86, 3.74)	-0.65 (-8.11, 6.81)	-4.52 (-10.39, 1.36)
Nonverb.	BMI	0.55 (-4.48, 5.59)	0.70 (-3.58, 4.99)	**7.75 (1.95, 13.56)**	-6.12 (-12.54, 0.31)	-0.26 (-6.44, 5.93)	1.57 (-4.46, 7.60)
	TST	2.01 (-6.14, 10.18)	-1.73 (-8.50, 5.04)	0.95 (-7.02, 8.93)	-8.18 (-20.98, 4.62)	-5.76 (-14.28, 2.76)	2.04 (-9.21, 13.29)
	SST	-1.80 (-8.47, 4.87)	-3.28 (-8.74, 2.17)	2.20 (-5.01, 9.41)	**-9.00 (-17.52, -0.48)**	-3.32 (-10.52, 3.87)	-3.42 (-12.02, 5.19)

*DAS: population mean = 100, standard deviation = 15, higher scores indicate better cognitive ability, overweight/obese: ≥85th percentile

†Bold font indicates model results are statistically significant at α = 0.05, crude models are unadjusted, other models adjusted for gender (when appropriate) hospital of birth (when appropriate), small for gestational age status, prenatal alcohol consumption, current maternal smoking, maternal prenatal smoking, maternal age, and maternal pre-pregnancy BMI

Table 4.6: Association between body mass index (BMI) and full-scale IQ in the Collaborative Perinatal Project: overall, and stratified by gender and race, mean (95% CI)*†							
				Stratified by gender		Stratified by race	
		Crude	Pooled	Girls	Boys	Whites	African-Americans
Age 4 BMI/ Age 4 IQ	Underweight	**-5.04 (-6.15, -3.92)**	**-2.05 (-3.04, -1.07)**	-1.29 (-2.64, 0.06)	**-2.95 (-4.40, -1.51)**	-1.75 (-3.75, 0.24)	**-2.18 (-3.26, -1.09)**
	Normal	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)
	Overweight	**4.69 (3.92, 5.47)**	**1.80 (1.09, 2.51)**	**1.65 (0.64, 2.67)**	**1.94 (0.94, 2.94)**	**1.58 (0.60, 2.56)**	**1.79 (0.74, 2.84)**
	Obese	**4.44 (3.45, 5.42)**	**1.84 (0.93, 2.76)**	**1.48 (0.07, 2.88)**	**2.13 (0.93, 3.34)**	**1.69 (0.45, 2.93)**	**1.78 (0.38, 3.17)**
Age 7 BMI/ Age 7 IQ	Underweight	**-6.28 (-7.36, -5.20)**	**-2.34 (-3.28, -1.40)**	**-2.61 (-3.86, -1.36)**	**-2.18 (-3.60, -0.75)**	**-2.82 (-4.77, -0.87)**	**-2.10 (-3.16, -1.05)**
	Normal	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)
	Overweight	**2.31 (1.51, 3.11)**	**1.23 (0.52, 1.95)**	**1.03 (0.04, 2.03)**	**1.36 (0.34, 2.38)**	0.69 (-0.29, 1.67)	**1.79 (0.76, 2.83)**
	Obese	**2.75 (1.66, 3.84)**	**1.98 (1.00, 2.95)**	**1.81 (0.44, 3.18)**	**1.99 (0.61, 3.37)**	**1.70 (0.35, 3.04)**	**2.26 (0.85, 3.66)**
Age 4 BMI/ Age 7 IQ	Underweight	**-4.48 (-5.45, -3.52)**	**-1.68 (-2.52, -0.84)**	**-1.70 (-2.82, -0.58)**	**-1.76 (-3.03, -0.50)**	**-1.88 (-3.52, -0.25)**	**-1.69 (-2.65, -0.72)**
	Normal	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)
	Overweight	**3.47 (2.80, 4.14)**	**1.10 (0.49, 1.71)**	0.53 (-0.31, 1.38)	**1.70 (0.83, 2.58)**	**0.91 (0.11, 1.71)**	**0.98 (0.04, 1.92)**
	Obese	**3.44 (2.59, 4.30)**	**1.08 (0.30, 1.86)**	0.89 (-0.28, 2.06)	**1.17 (0.12, 2.22)**	0.72 (-0.30, 1.74)	1.14 (-0.10, 2.3)

*Stanford-Binet Intelligence Scale: population mean = 100, standard deviation = 16; Wechsler Intelligence Scales for Children (WISC): population mean = 100, standard deviation = 15; higher scores indicate better cognitive ability on both, BMI classification – underweight: <5th percentile, normal weight: 5 - <85th percentile (reference group), overweight: 85 – <95th percentile, obese: ≥ 95th percentile; CI – confidence interval

†Bold font indicates model results are statistically significant at α = 0.05, crude models are unadjusted, other models adjusted for gender (when appropriate), race (when appropriate), study site, socioeconomic index, small for gestational age status, current maternal smoking, maternal age, and maternal pre-pregnancy BMI

5. THE ASSOCIATION BETWEEN EARLY CHILDHOOD OVERWEIGHT/OBESITY AND CHILDHOOD ADAPTIVE FUNCTIONING, BEHAVIOR, AND EXECUTIVE FUNCTIONING IN ATLANTA CHILDREN

Abstract

Background: A harmful effect of childhood obesity on cognitive ability could have a substantial impact on a population level. To date, studies of this relationship have produced inconsistent results and have largely been conducted in older children.

Methods: We used data from the Follow-Up Development and Growth Experiences Study (1997 – 99) to assess the relationship between early childhood obesity (body mass index (BMI), triceps- and subscapular-skinfold-thickness (TST, SST)) and three components of childhood development: adaptive functioning (assessed using the Vineland Adaptive Behavior Scale (VABS), population mean = 100, standard deviation (SD) = 15); behavior (assessed using the Child Behavior Checklist (CBCL), mean = 50, SD = 10, higher scores indicate more problematic behavior), and executive functioning (assessed using the Developmental NEuroPSYchology Assessment (NEPSY), mean = 10, SD = 3). Obesity metrics and development scales were measured in 423 children aged 54 months years born at one of two Atlanta hospitals. Covariate information was obtained during the study or from previously collected data. Linear regression was used to estimate the change in VABS/CBCL/NEPSY score associated with being in the top 15th percentile of BMI/TST/SST based on CDC norms.

Results: Overweight/obese TST and SST were associated with declines in VABS motor skills score among boys (TST: -11.69, 95% confidence interval -22.8 – -0.55; SST: -6.09, -13.58 – 1.40). No association was observed in boys for high BMI or in girls for

any obesity metric with VABS motor skills score. Among girls, high TST and SST were associated with lower NEPSY statue scores (TST: -1.02, -2.36 – 0.32; SST: -1.67, -2.87 – -0.48). Among children born at the private hospital, all three metrics were associated with declines in NEPSY statue score (BMI: -0.94, -1.96 – 0.07; TST: -1.17, -2.68 – 0.34; SST: -1.99, -3.17, -0.81). No associations were observed between overweight/obesity and any CBCL scale.

Conclusions: This study did not find evidence that overweight and obesity were consistently associated with measures of childhood adaptive functioning, behavior, or executive functioning. However, high TST and SST were associated with declines in VABS motor skills scores among boys (with no corresponding association in girls) and high BMI/TST/SST were associated with declines in NEPSY statue scores among girls born of higher socioeconomic status.

Introduction

According to 2011 – 2012 National Health and Nutrition Examination Survey (NHANES) data, 14.4% of US children aged two to five years were considered overweight, with an additional 8.4% obese.[1] Obesity was even more common among low-income preschool children where one child in seven was obese.[2] Further, recent evidence has highlighted the importance of early-life physical and behavioral patterns in determining the development of obesity,[3-5] Because of the high prevalence of overweight and obesity among today's children, associations with childhood development, even if small in magnitude, could have a substantial impact on a population level. Moreover, because of the increased prevalence among lower-income children – a population already strained for academic resources and social services, the burden of an obesity/development relationship could be disproportionately borne by children with lower socioeconomic status (SES).

Studies have examined associations between childhood obesity and several components of childhood neurocognitive development, including adaptive functioning, behavior, and executive functioning. Research exploring the effect of obesity on adaptive functioning (which reflects a person's ability to meet the demands of daily life) often focuses on fine and gross motor skills. In a large sample of German schoolchildren (mean age 6.7 years), Graf *et al.* reported significant declines in gross motor skills,[6] a finding also supported by the research of Okley and colleagues in school-aged Australian children[7] and McGraw *et al*. in a relatively small sample of US obese and non-obese prepubertal boys.[8] Additionally, D'Hondt *et al.* reported a negative association between overweight and obesity on fine motor skills in a large sample of five to 13 year-old children.[9] Two studies conducted in populations of younger German children found that associations between obesity and motor skills differed by gender. In a large, population-based study of children aged 4.4 – 8.6 years, Mond *et al*. found an association between obesity and deficits in gross motor skills among boys, but no corresponding association among girls.[10] Similarly, in a study of 444 children aged to two to three years, Cawley and Spiess reported an association with reduced motor skills (as well as verbal, social, and daily living skills) in boys, but not in girls.[11]

Negative associations between obesity and childhood behavior have also been reported. Lam and Yang examined a large population of Chinese adolescents and reported a significant association between obesity and attention deficit/hyperactivity disorder (ADHD) tendency, though they did not find an association between ADHD tendency and overweight status.[12] Braet *et al*. also reported an increase in both attention deficit and hyperactivity behaviors among overweight school-aged boys, but did not find a similar association among girls.[13] Two additional studies reported gender differences in the association of behavior and childhood obesity, with Lawlor *et al.* showing an increase in problematic behavior on the Child Behavior Checklist (CBCL) total behavior scale among overweight 14 year-old girls, but no corresponding association among 14 year-old boys (or among five year old children of either gender).[14] Datar and Sturm similarly reported an increase in teacher-reported externalizing behavior problems among overweight school-aged girls, but a *reduction* in externalizing problems among boys.[15]

Recent attention has also focused on the possible association between childhood obesity and executive functioning, the umbrella term for a series of cognitive processes responsible for thought and goal-directed behavior. Although the question of directionality in the relationship remains, results have consistently demonstrated detrimental associations between childhood obesity and several components of executive functioning, including inhibitory control,[16-19] reward sensitivity,[20,21] attention focus/shifting,[11,14,22,23] and working memory.[24] Although most studies have found a harmful effect of overweight/obesity on childhood executive functioning, one study in school-aged children found no association among overweight/obese children, but reported a deficit in memory performance among underweight girls.[25]

As indicated by the above studies, research on the association between childhood obesity and childhood neurocognitive development has suggested a potential negative effect of obesity on certain components of adaptive functioning, behavior, and executive functioning. The majority of these studies have been conducted in school-aged children and adolescents. Despite this, an examination of the relationship among preschool-aged children may be important from both a developmental and an early-intervention perspective. Further, studies typically used only one obesity metric, BMI, rather than incorporating additional measures of childhood obesity. Using a population of African-American and white, 54 month-old Atlanta children, this study sought to evaluate the potential association between three metrics of early childhood obesity and childhood adaptive functioning, behavior, and executive functioning.

Methods

Study Population

This analysis utilized data from the Follow-Up Development and Growth Experiences (FUDGE) Study and its precursor, the Fetal Growth and Development Study

(FGDS). The FGDS was a case-control study conducted with the initial goal of developing enhanced surveillance for fetal alcohol syndrome among neonates. All African-American and white singleton infants born at one of two Atlanta-area hospitals between 2/1/93 – 12/31/94 with a gestational age of 32 – 42 weeks were eligible for the study. One of these hospitals was a private, suburban Atlanta hospital serving primarily a white, middle-class population and the other was a public hospital located in downtown Atlanta with a largely African-American, lower SES population. Study staff collected data at hospitals in one week segments and the hospital was randomly selected without replacement from blocks of four weeks. Staff abstracted race, sex, gestational age, and birthweight from labor and delivery or nursery logs. All small for gestational age children (SGA, < 10^{th} percentile for gender, race, and gestational age) were selected as case infants. A simple random 3% sample of all other singleton infants was included as appropriate for gestational age (AGA ≥ 10^{th} percentile for gender, race, and gestational age) controls. The final sample size for the FGDS was 959 children.

These children were then reevaluated for the FUDGE Study when they were as close as possible to 54 months of age to assess psychometric and anthropometric outcomes of preschool-aged children born SGA. Of the original 959 FGDS participants, 760 were identified for follow-up in the FUDGE Study. This group included all participants born AGA, all SGA participants whose mothers reported any alcohol use in pregnancy, and half of the SGA infants whose mothers reported no prenatal alcohol use. Of these, 510 (72.2%) were successfully recruited. Further details of the FGDS and FUDGE study samples can be found in Drews-Botsch *et al*.[26]

This analysis excluded children with missing values for normalized BMI (N = 41), TST (N = 41), and/or SST (N = 43) variables, implausible values (≥ 4 standard deviations from the mean) for normalized height (N = 0), weight (N = 2), TST (N = 0), and SST (N = 3) variables, severely developmentally disabled children (Differential Ability Scale (DAS) general cognitive ability composite score < 50, N = 2), and children born large for gestational age (LGA, ≥ 90^{th} percentile birth weight for gestational age, race, and gender, N = 25). LGA children were excluded because their small sample size prevented evaluation of this group separately and it was inappropriate to combine LGA and AGA children into a single group. The final sample size was 423.

Data collection

In the FGDS, trained study staff conducted in-person interviews with mothers regarding smoking, alcohol use, and socioeconomic factors within 48 hours of delivery. Women were again interviewed in-person at the 54-month FUDGE Study follow-up visit and anthropometric measurements were obtained. A single measurement of weight in kilograms (kg) was obtained using a digital scale. Two height measurements in centimeters (cm) were obtained to the nearest millimeter using a portable Schorr stadiometer (Schorr Productions, Olney, MD). If the two measurements differed by more than 0.5 cm, a third measurement was obtained. Two measurements each were also obtained for right side triceps and subscapular skinfold thickness to the nearest millimeter using Lange skinfold calipers (Beta Technology Incorporated, Santa Cruz, CA). A third measurement was taken if the first two measures differed by more than 1.0 mm. Height and skinfold thickness measurements used in this analysis were the average of the two closest measurements. Training of all staff was performed prior to the study and reliability was assessed semi-annually. Internal analyses suggested that the intra-observer reliability of all measures exceeded 95%.

Study variables

<u>Obesity status</u>

BMI was calculated using the formula: [weight (kg)] / [height (m)]^2. Age- and gender-specific BMI Z-scores were calculated using CDC formulas and parameters.[27,28] TST and SST Z-scores were estimated similarly using parameters from Addo and Himes.[29] BMI, TST, and SST percentiles were obtained from Z-scores assuming that the z-scores followed a normal distribution. BMI, TST, and SST were then categorized as overweight/obese (≥ 85th percentile) and not overweight/obese (< 85th percentile).

<u>Childhood development</u>

Children's adaptive functioning was evaluated using the Vineland Adaptive Behavior Scales (VABS; population mean = 100, standard deviation (SD) = 15, lower scores indicate poorer adaptive functioning). The VABS composite scale, as well as the socialization, motor skills, daily living, and communication subscales, were used. The total, internalizing, and externalizing behavior scales of the Child Behavior Checklist (CBCL; mean = 50, SD = 10, higher scores indicate more problematic behavior) were used to assess childhood behavior. Executive functioning was examined using the statue and visual attention scores on the Developmental NEuroPSYchology Assessment (NEPSY; mean = 10, SD = 3, lower scores indicate poorer executive functioning).

Covariates

Covariate information was obtained either within 48 hours of delivery (child's sex, hospital of birth, race, small for gestational age status (from birthweight and gestational age), maternal age, maternal education, maternal pre-pregnancy BMI, maternal prenatal smoking status, maternal prenatal alcohol consumption, and family income) or at the FUDGE follow-up visit (current maternal smoking). SES was represented by hospital of birth in this population, with birth at the public hospital indicative of lower SES and birth at the private hospital indicative of higher SES. Potential confounders were determined *a priori* based on factors which were shown in the scientific literature to have consistent associations with both cognitive development and obesity, factors which influenced selection into the study, and use of directed acyclic graphs.[30] These covariates were: hospital of birth; gender; small for gestational age status; prenatal alcohol consumption; race; current and prenatal maternal smoking; maternal age; and, maternal pre-pregnancy BMI.

Analysis

Bivariate comparisons for descriptive statistics were made using t-tests for normally-distributed continuous variables, Wilcoxon rank sum tests for non-normal continuous variables, and chi-square tests for categorical variables. Means of model variables were compared using t-tests or one-way ANOVA. Linear regression was used to assess the relationship between the childhood development scales and each of the childhood obesity metrics. Collinearity of independent variables was assessed using variance inflation factors (cut-point = 10). Because of the small sample size, we made an *a priori* decision to present pooled models as well as models stratified by gender and hospital of birth, regardless of the presence of statistically significant interaction. Models with three different levels of adjustment for confounding were run: Model 1 – crude model with no adjustment; Model 2 – adjustment for a narrow set of covariates with strong potential for confounding or which influenced selection into the study (hospital of birth, gender, SGA status, and prenatal alcohol consumption); and, Model 3 – additional adjustment for a wider set of factors also shown in previous studies to be potential confounders (Model 2 covariates plus race, current maternal smoking, maternal prenatal smoking, maternal age, and maternal pre-pregnancy BMI). Results were considered statistically significant if $p < 0.05$ or if 95% confidence intervals (CI's) did not cross the null. All analyses were conducted in SAS Version 9.3 (Cary, NC).

The FGDS and FUDGE Studies were approved by the Institutional Review Boards of the two hospitals (for the FGDS only), Emory University, and the CDC.

Results

The FUDGE Study population included similar numbers of children from the public and private hospitals (210 and 213 children respectively) (Table 5.1). Women from the public hospital were younger, had higher average pre-pregnancy BMI, and higher rates of both prenatal and current smoking compared with participants from the private hospital ($p < 0.01$).

The children were assessed at median age of 54.1 months (interquartile range 53.4 – 55.5 months); median age at follow-up was similar at both hospitals. Approximately half of the children in the study were female (50.8%), although gender distribution differed significantly by hospital (54.9% female private vs. 43.3% public, $p = 0.02$). In accordance with the initial study design, 67.9% of the population was born SGA, however, the prevalence of SGA did not differ by hospital. Almost all (97.2%) of the children born at the public hospital were African-American, compared with 14.1% of children at the private hospital ($p < 0.01$). The prevalence of families with total family income < $40,000/year and mothers who completed ≤ 12 years of education were both significantly higher at the public hospital compared with the private hospital ($p < 0.01$).

In the FUDGE Study population, BMI classified the highest proportion of children as overweight/obese, and TST the lowest proportion, regardless of gender, hospital of birth, or SGA status (Table 5.2). Overweight/obesity prevalence was similar between boys and girls when using BMI, but higher among girls when using skinfold thickness measures. BMI classified similar proportions of children born at the private and public hospitals as overweight/obese, though more children were classified as overweight/obese from the private hospital for both TST and SST. Overweight/obesity prevalence was higher in AGA children compared with SGA children for all three metrics, though the relative difference in prevalence was greater for BMI than for either skinfold thickness measure. For example, when classifying obesity status using BMI, the prevalence of overweight/obesity among AGA children was 2.9 times higher than among children born SGA (SGA < 5% and 5 – < 10% combined), but only 2.1 and 1.5 times as high when using TST and SST, respectively.

On average, the children in the FUDGE Study scored 99.1 (SD = 14.5) on the Vineland Adaptive Behavior Scales composite scale, 51.1 (SD = 9.4) on the Child

Behavior Checklist total behavior scale, and 10.3 (SD = 2.5) and 10.3 (SD = 2.3) on the NEPSY statue and visual attention tests, respectively (Table 5.3). Compared with children born at the private hospital, children born at the public hospital had significantly lower scores on all VABS scales except the daily living subscale (on which children from both hospitals scored nearly identically), as well as on both NEPSY tests. In addition, children born at the public hospital scored significantly higher on all CBCL scales (higher scores on the CBCL indicate *more* problematic behavior). Girls scored higher on all VABS scales and the NEPSY visual attention test, compared with boys; these differences were all statistically significant except for the VABS socialization subscale. Statistically significant differences by SGA status were observed for all VABS scales and for the NEPSY visual attention test. In all cases, these differences were driven by lower scores in the SGA < 5^{th} percentile group. No differences by gender or SGA status were observed for any CBCL test or the NEPSY statue standard score.

Overall, in models assessing the possible association between early childhood obesity and adaptive functioning, there was no association between VABS composite score and overweight/obese status according to any of the three obesity metrics (BMI: -0.00, 95% CI -3.8 – 3.7; TST: -1.8, -7.9 – 4.4; SST: -2.5, -7.4 – 2.4) (Table 5.4). (For all models presented in this paper, little difference in results was observed between controlling for the narrower or wider set of potential confounders described above. Thus, only results from the crude and more fully-adjusted models are presented.) Results also indicated no association between scores on the VABS socialization, daily living, motor skills, and communication subscales with any of the three obesity metrics. In models stratified by gender, no association was observed in either boys or girls between high

BMI and scores on any of the VABS scales or among girls between high TST/SST and scores on any VABS scale. In boys, however, a negative association was observed between high TST/SST and scores on all VABS scales except for one (high SST and the VABS socialization subscale). This association was statistically significant for the associations between high TST and VABS composite and motor skills scores, and for the association between high SST and VABS communication score. Stratifying by hospital of birth did not change the observation of no association between high BMI/TST and scores on any VABS scale. While no statistically significant association between high SST and VABS scores was found, among children born at the private hospital, results for all scales were suggestive of a possible negative relationship with overweight/obese SST. No association was observed among children born at the public hospital.

No association was observed between CBCL total behavior score and any of the three obesity metrics (BMI: 0.8, 95% CI -1.8 – 3.4; TST: 1.2, -3.0 – 5.4; SST: -1.5, -4.9 – 1.9), or among the internalizing and externalizing behavior subscales and any obesity metric (Table 5.5). After stratification by gender, no association was observed in girls between scores on any CBCL scale and any obesity metric. Although no associations were statistically significant, results were suggestive of a possible small negative relationship between high BMI/TST (indicated by an *increase* in CBCL score) and all three CBCL scales in boys. In contrast, results in boys were suggestive of a small positive association (indicated by a *decrease* in CBCL score) with high SST and all three CBCL scales, though results were not statistically significant. In models stratified by hospital of birth, no relationship was found among children born at the public hospital between any obesity metric and any CBCL scale. Although not statistically significant, among children born at the private hospital results were suggestive of a possible negative association between high BMI/TST and scores on all CBCL scales, and a possible positive association between high SST and scores on all CBCL scales.

Overall, no association was observed between scores on the NEPSY statue test and high BMI (0.1, 95% CI -0.6 – 0.8) or TST (-0.9, 95% CI -2.1 – 0.2), though a statistically significant negative association was observed for NEPSY statue score and high SST (-1.2, 95% CI -2.1 – -0.3) (Table 5.6). After stratifying by gender, a negative association was observed among girls between NEPSY statue score and both high TST and SST, though the association was only significant in the case of SST. No association was observed in girls between high BMI and NEPSY statue score, or in boys between NEPSY statue score and any obesity metric. In models stratified by hospital of birth, a negative association was observed between NEPSY statue score and all three obesity metrics, though statistical significance was only reached for SST. A statistically significant positive association was observed between high BMI and NEPSY statue score among children born at the public hospital, though no relationship was found for either TST or SST. Stratification by both gender and hospital of birth reinforced the negative association between NEPSY statue score and girls born at the private hospital. In pooled models, as well as models stratified by gender or hospital of birth, no association was observed between NEPSY visual attention score and any obesity metric.

Discussion

Overall, results from this study did not find evidence that early childhood overweight and obesity were consistently associated with measures of childhood adaptive functioning, behavior, or executive functioning. While it is reassuring to note that these results suggest that the recent rise in childhood obesity will likely not lead to a similar dramatic increase in children experiencing developmental problems, two findings in this study bear further discussion. First, the literature has consistently reported a detrimental association between childhood overweight/obesity and deficits in motor skills scores.[7-12] This study's finding that, in boys, high TST and SST were associated with lower motor skills scores is in line with this previous research. However, unlike previous research, these results did not indicate an association between overweight/obese BMI and motor skills in boys. One possible explanation might be that the high BMI group could actually have been comprised of two kinds of children. First, children with excess adiposity who might have been expected to score lower on motor skills tests, and second, children with excess lean (muscle) mass who might have been more physically developed and likely to score higher on motor skills tests. Combining these two groups could have led to a null association overall between high BMI and motor skills score such as the one that was observed. In contrast, when obesity was classified using TST or SST, arguably a more direct measures of adiposity, results indicated a strong, statistically significant negative effect of high TST, and a moderate, though non-significant, effect of high SST. While it was unclear why these associations were limited to boys, this study's findings were similar to those of Mond *et al*. and Cawley and Spiess who reported negative associations of obesity with motor skills in young boys, with no corresponding association among girls.[11,12]

Second, the most consistently-demonstrated associations in this analysis were those between the NEPSY statue score and overweight/obesity among girls and children born at the private hospital. Further, when models were stratified by both gender and hospital of birth, the negative association among girls born at the private hospital was even stronger. This result is especially notable because girls of higher SES are a population group one might generally consider at low risk for executive functioning issues.[31-38] It is possible, though, that the relative low risk of this group is why the negative association of obesity and executive functioning is evident. If, among children of lower SES (such as those from the public hospital in our dataset), SES is the driving force behind the variability in executive functioning capability, it could leave little room for other factors to play a role. In children of higher SES, however, where SES explains less variability, factors such as obesity status could have a stronger impact. Statistically significant differences by hospital of birth in mean score for nearly all developmental outcomes (including differences in mean general cognitive ability on the Differential Ability Scales of 98.3 for the private hospital vs. 75.0 for the public hospital, data not presented here), provide evidence for the strong effect of SES in this population.

If a true, negative relationship between childhood obesity and childhood development does exist, we can think of three possible alternative explanations for the inconsistent or null results of this analysis. First, it is possible that a first-order linear regression model is not the best fit for these data. However, scatterplots of the data (not shown) do not support this hypothesis and exploration of several higher-order models failed to identify a model with better fit. Second, it is possible that null findings could be attributable to a greater variability in overweight/obesity among children with developmental problems. This does not seem to be the case in our data, where variance in overweight/obese children was similar to non-overweight/obese children in all comparisons except three. In only one comparison (BMI and VABS communication subscale) did children with poorer development have a significantly greater variance in obesity metric Z-score. Finally, our study's relatively small sample size could have prevented us from observing additional true effects of obesity in this population. We had 80% power to detect main effect of 0.38 SD (this translates to a difference in 5.6 points for VABS scales, 3.8 points for CBCL scales, and 1.1 points for NEPSY tests). Because of this, we feel we would have been able to detect the strong harmful associations which could potentially have a meaningful clinical impact, such as our observation of the possible negative impact of overweight/obesity on executive functioning in girls of higher SES. This study was a secondary data analysis conducted on previously-collected data. Thus, power and sample size considerations in the initial study design phase did not consider the study questions discussed in this analysis.

This analysis demonstrated several strengths. First, this study evaluated three different child obesity metrics, rather than relying simply on BMI, as is often the case in studies of childhood obesity. Because "gold standard" measures of obesity such as dual-energy radiograph absorptiometry tend to be expensive or invasive, their use in routine clinical visits or research studies is often limited. BMI, derived from easily obtained height and weight measurements, is straightforward to collect, though may not always represent an accurate picture of body composition. While studies have demonstrated the validity of BMI as a tool to evaluate obesity,[38-40] research has described important differences in body composition by race, gender, or small for gestational age status[43-47] which could impact the ability of BMI to assess true obesity status. Indeed, research on the FUDGE Study population has found substantial differences among BMI, TST, and

SST in assessing childhood overweight/obesity in different population subgroups. The results of the regression models in this analysis further illustrated these differences, with the association between overweight/obesity and cognitive development often inconsistent among the three metrics. These results underscore other findings that BMI may not always be the best metric to assess childhood overweight/obesity and that skinfold thickness measurements, also inexpensive and easily obtained, may be attractive additions or alternatives.

A second strength of this analysis was its focus on preschool-aged children. While the majority of research in this area has been conducted in older children, if an adverse, causal relationship does exist between childhood obesity and cognitive development, this relationship might be especially important in earlier years. Compared with older children and adolescents, younger children's cognitive development is more tied to their physical capabilities; young children learn by exploring and engaging their world. Further, research has shown that certain cognitive abilities, notably many involved in executive functioning, undergo a period of rapid development in early childhood.[48] Finally, because early childhood development occurs prior to the start of formal education, if a problem does exist, children would then be entering school already at a disadvantage. If obesity does negatively impact development, interventions targeted at earlier ages could minimize exposure time and/or provide additional opportunities to mitigate adverse effects of obesity.

A third strength of this study was the use of hospital of birth to represent socioeconomic status. The two hospitals selected for participation in this study serve patients who hail from populations with distinctly different socioeconomic characteristics. Because healthcare-seeking behavior is related to wealth, insurance status, neighborhood of residence, access to transportation, and a host of other factors, use of hospital of birth may have better captured the broad, multi-dimensionality of SES compared with simply relying on proxy measures like income and education.

Fourth, while the possibility of measurement error for key variables existed, it was likely minimal. For the obesity metrics, Cronbach's alpha values comparing the first two height, TST, and SST measurements were 0.99, 0.97, and 0.97 respectively. Third measurements (obtained when the difference between the first two measurements for height, TST, or SST exceeded a pre-specified value) were necessary in < 3.0% of children and no child in the dataset required more than one third measurement. Measurement error was also possible for the developmental assessments, though staff were trained according to strict protocols and interviews were conducted either by trained psychologists or interns who were directly supervised by a licensed psychologist. A more likely source of error for both the obesity and development metrics, however, was misclassification arising from the measured quantities not accurately reflecting the true, underlying constructs of obesity or cognitive/behavioral development.

Despite the strengths of our study, our analysis was subject to several limitations. First, as noted above, our small sample size restricted the analyses we could perform and limited our statistical power. In particular, analysis of the overweight and obese children in separate categories would have contributed to the depth of this analysis. Second, although this dataset contained extensive information on potential confounders, the possibility of residual confounding existed due to improper control of variables in the dataset or from variables not collected in the FUDGE Study. For example, differences in the distribution of gender by hospital of birth occurred because of the performance of the SGA norms that were used in this population and may have contributed to difficulties in examining the effects of gender or hospital due to residual confounding. Third, obesity status and developmental outcomes were measured at a single time-point, permitting only a cross-sectional analysis. Additional time points would have enabled us to examine measures of change in obesity status or developmental skill. This could have been especially important for the measures of childhood development which are so rapidly evolving in young children. Fifth, these data, collected in the 1990's, were fairly old at the time of analysis and might not accurately represent current obesity trends. However, if the underlying relationship between obesity and childhood developed has remained constant, then recent increases in obesity prevalence would lead to an even greater impact on a population level. Sixth, over one-fourth of FGDS participants selected for inclusion in the FUDGE Study were lost to follow-up. Comparison of FUDGE participants with those lost to follow-up, though, revealed no differences by gender, race, hospital of birth, or maternal educational attainment. Finally, our unique population (in particular the large number of SGA children in the sample) prevented us from generalizing our findings to a broader population. However, use of this study population allowed us to explore in greater depth the association between early childhood obesity and development in SGA children, a population which was not often evaluated in previous studies on this topic.

With so many of today's young children overweight or obese, the question of a possible effect of obesity on childhood development highlights the foundations of population health which underscore modern public health practice.[49] Even a minor decline in average cognitive or behavioral ability could shift the population distribution and markedly increase the number of children who might then be in need of special education services. Moreover, the prevalence of childhood obesity is even higher among children of lower SES, a population already vulnerable to a myriad of detrimental factors which potentially hinder childhood development or reduce access to social and educational resources. This study did not find evidence of a consistent pattern of association between overweight/obesity across scales for adaptive functioning, behavior, and executive functioning in Atlanta preschool-aged children. Despite these null results, the prevention of early childhood obesity remains a critical focus of public health efforts. Whether or not early childhood obesity detrimentally affects childhood development, interventions targeted at preventing or reducing childhood obesity can dramatically improve the health of children on both the individual and population levels.

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Tables

Table 5.1: Characteristics of Follow-Up Development and Growth Experiences (FUDGE) Study participants*					
	Overall		Private Hospital	Public Hospital	p-value†
			50.4 (213)	49.7 (210)	
Female – %(N)	50.8 (215)		54.9 (117)	43.3 (91)	0.02
SGA – %(N)	67.9 (287)		66.2 (141)	69.5 (146)	0.71
SGA <5th percentile – %(N)	35.5 (150)		33.8 (72)	37.1 (78)	
SGA 5-<10th percentile – %(N)	32.4 (137)		32.4 (69)	32.4 (68)	
AGA – %(N)	32.2 (136)		33.8 (72)	30.5 (64)	
African-American – %(N)	55.3 (234)		14.1 (30)	97.1 (204)	<0.01
Total family income <$40,000, %(N)	53.1 (221)		13.5 (28)	92.8 (193)	<0.01
Maternal education ≤ 12 years completed, %(N)	44.6 (188)		11.3 (24)	78.5 (164)	<0.01
Current maternal smoking - %(N)	22.2 (94)		13.2 (28)	31.4 (66)	<0.01
Maternal smoking during pregnancy - %(N)	27.4 (116)		18.8 (40)	36.2 (76)	<0.01
Age at testing (months) – Median (IQR)	54.1 (53.4, 55.5)		54.6 (53.4, 55.2)	55.0 (53.4, 56.0)	0.12
Maternal age when participant born (years) – Mean (SD)	27.4 (6.6)		30.5 (5.0)	24.3 (6.5)	<0.01
Maternal pre-pregnancy BMI – Mean (SD)	23.5 (5.3)		22.8 (4.4)	24.1 (6.0)	<0.01

*SGA – small for gestational age (<10th percentile birthweight for gender, race, and gestational age), AGA – appropriate for gestational age (10th - <90th percentile birthweight for race, gender, and gestational age), IQR – interquartile range, SD – standard deviation, BMI – body mass index
†P-values: T-tests for normally-distributed continuous variables, Wilcoxon rank sum test for child's age (not normally distributed), χ^2tests for categorical variables

Table 5.2: Percent overweight/obese by body mass index (BMI), triceps-skinfold-thickness (TST), and subscapular-skinfold-thickness (SST), overall and stratified by gender, hospital of birth, and small for gestational age (SGA) status*

	Overall	Girls	Boys	χ^2 p-value	Private Hospital	Public Hospital	χ^2 p-value	SGA <5%	SGA 5-<10%	AGA	χ^2 p-value
	% (N)	% (N)	% (N)		% (N)	% (N)		% (N)	% (N)	% (N)	
BMI	15.60 (66)	15.87 (33)	15.35 (33)	0.88	15.02 (32)	16.19 (34)	0.74	6.67 (10)	13.14 (18)	27.94 (38)	<0.01
TST	5.20 (22)	7.69 (16)	2.79 (6)	0.02	6.57 (14)	3.81 (8)	0.20	2.00 (3)	5.84 (8)	8.09 (11)	0.06
SST	8.04 (34)	9.62 (20)	6.51 (14)	0.24	9.39 (20)	6.67 (14)	0.30	6.00 (9)	8.03 (11)	10.29 (14)	0.41

*SGA – small for gestational age (<10^{th} percentile birthweight for gender, race, and gestational age), AGA – appropriate for gestational age (10^{th} - <90^{th} percentile birthweight for gender, race, and gestational age)

Table 5.3: Mean Values for Vineland Adaptive Behavior Scales (VABS), Child Behavior Checklist (CBCL), and Neuropsychology Developmental Assessment (NEPSY) scales, overall and stratified by gender, hospital of birth, and small for gestational age (SGA) status*†

	Overall Mean (SD)		Girls Mean (SD)	Boys Mean (SD)	p-value ‡		Private Hosp. Mean (SD)	Public Hosp. Mean (SD)	p-value		SGA <5% Mean (SD)	SGA 5-<10% Mean (SD)	AGA Mean (SD)	p-value
VABS Composite	99.09 (14.45)		101.91 (14.32)	96.29 (14.05)	<0.01		103.57 (12.87)	94.52 (14.56)	<0.01		95.42 (14.75)	101.02 (14.12)	101.17 (13.73)	<0.01
VABS Socialization	100.41 (17.10)		101.96 (17.35)	98.89 (16.76)	0.07		105.52 (16.05)	95.27 (16.61)	<0.01		96.82 (16.49)	102.60 (17.56)	102.15 (16.77)	<0.01
VABS Daily Living	101.25 (12.78)		103.12 (12.62)	99.41 (12.71)	<0.01		101.29 (12.24)	101.20 (13.34)	0.95		97.95 (13.43)	102.96 (11.62)	103.15 (12.53)	<0.01
VABS Motor Skills	98.63 (14.06)		101.24 (12.65)	96.07 (14.91)	<0.01		103.05 (11.39)	94.12 (15.08)	<0.01		96.26 (15.81)	99.50 (14.63)	100.36 (10.81)	0.04
VABS Communication	97.41 (11.29)		100.01 (10.80)	94.86 (11.21)	<0.01		101.57 (10.02)	93.21 (10.97)	<0.01		95.05 (11.78)	98.90 (10.63)	98.52 (11.05)	<0.01
CBCL Total Behavior	51.10 (9.43)		50.53 (9.34)	51.66 (9.51)	0.22		49.29 (8.34)	52.93 (10.11)	<0.01		51.80 (8.30)	51.07 (10.58)	50.37 (9.39)	0.44
CBCL Internalizing	47.46 (8.98)		46.84 (8.32)	48.07 (9.55)	0.16		46.33 (7.98)	48.60 (9.77)	<0.01		47.62 (8.91)	47.82 (9.25)	46.93 (8.80)	0.69
CBCL Externalizing	51.33 (9.19)		51.42 (9.24)	51.25 (9.16)	0.84		49.56 (8.06)	53.13 (9.91)	<0.01		51.94 (8.04)	50.84 (10.42)	51.16 (9.09)	0.58
NEPSY Statue	10.31 (2.54)		10.35 (2.52)	10.27 (2.57)	0.75		10.74 (2.41)	9.87 (2.60)	<0.01		9.99 (2.65)	10.53 (2.64)	10.44 (2.29)	0.16
NEPSY Visual Attention	10.30 (2.33)		10.71 (2.29)	9.87 (2.30)	<0.01		11.13 (1.76)	9.42 (2.54)	<0.01		9.77 (2.68)	10.52 (2.23)	10.62 (1.93)	<0.01

*SGA – small for gestational age (<10th percentile birthweight for gender, race, and gestational age), AGA – appropriate for gestational age (10th - <90th percentile birthweight for gender, race, and gestational age), SD – standard deviation,

†Population mean and standard deviations for the cognitive/behavioral tests are as follows:

- VABS: population mean = 100, standard deviation = 15, higher scores indicate better adaptive behavior
- CBCL: population mean = 50, standard deviation = 10, higher scores indicate more problematic behavior
- NEPSY: population mean = 10 standard deviation = 3, higher scores indicate better executive functioning

‡P-values: T-tests for comparisons by gender and hospital of birth, one-way ANOVA for comparisons by SGA status

Table 5.4: Change in composite, socialization, daily living, motor skills, and communication scores on the Vineland Adaptive Behavior Scales (VABS) in overweight/obese children relative to normal weight children, overall and stratified by gender and hospital of birth*†

				Stratified by gender		Stratified by hospital of birth	
		Crude	Pooled	Girls	Boys	Private	Public
Compo-site	BMI	1.77 (-2.04, 5.59)	-0.04 (-3.83, 3.73)	-0.06 (-5.67, 5.55)	-0.36 (-5.73, 5.01)	-1.05 (-6.38, 4.27)	1.00 (-4.51, 6.50)
	TST	1.56 (-4.80, 7.93)	-1.75 (-7.88, 4.39)	2.32 (-5.49, 10.13)	**-10.68 (-21.32, -0.04)**	-3.13 (-10.84, 4.57)	2.10 (-8.18, 12.37)
	SST	-1.02 (-6.12, 4.14)	-2.46 (-7.35, 2.44)	0.08 (-6.92, 7.09)	-5.23 (-12.39, 1.93)	-4.63 (-11.02, 1.75)	1.82 (-6.05, 9.68)
Sociali-zation	BMI	0.51 (-4.01, 5.02)	-1.24 (-5.82, 3.34)	-3.71 (-10.46, 3.04)	1.59 (-4.99, 8.16)	-3.26 (-9.99, 3.45)	1.21 (-5.26, 7.67)
	TST	2.58 (-4.95, 10.11)	0.38 (-7.06, 7.82)	1.77 (-7.66, 11.20)	-4.15 (-17.30, 9.00)	-1.18 (-10.95, 8.59)	5.07 (-6.98, 17.12)
	SST	-0.01 (-6.12, 6.09)	-1.18 (-7.12, 4.76)	-2.92 (-11.36, 5.52)	0.19 (-8.63, 9.01)	-4.16 (-12.27, 3.94)	3.55 (-5.68, 12.77)
Daily living	BMI	2.82 (-0.54, 6.19)	0.68 (-2.82, 4.19)	2.19 (-2.72, 7.10)	-0.44 (-5.62, 4.74)	0.58 (-4.39, 5.55)	1.06 (-4.04, 6.17)
	TST	1.00 (-4.64, 6.63)	-1.60 (-7.29, 4.10)	2.12 (-4.73, 8.97)	-9.10 (-19.39, 1.20)	-2.22 (-6.98, 17.12)	1.50 (-8.03, 11.02)
	SST	-0.23 (-4.80, 4.33)	-1.58 (-6.12, 2.97)	0.06 (-6.09, 6.20)	-2.66 (-9.60, 4.27)	-3.20 (-9.17, 2.77)	2.67 (-4.61, 9.95)
Motor skills	BMI	3.16 (-0.57, 6.89)	2.19 (-1.52, 5.89)	1.70 (-3.36, 6.75)	1.29 (-4.35, 6.92)	1.71 (-3.05, 6.46)	2.42 (-3.26, 8.10)
	TST	0.24 (-5.96, 6.44)	-2.70 (-8.70, 3.29)	1.51 (-5.48, 8.49)	**-11.69 (-22.83, -0.55)**	-2.97 (-9.84, 3.91)	-1.44 (-11.96, 9.08)
	SST	-1.31 (6.33, 3.71)	-2.31 (-7.10, 2.47)	1.25 (-5.02, 7.51)	-6.09 (-13.58, 1.40)	-3.26 (-8.97, 2.45)	-0.28 (-8.33, 7.77)
Commu-nication	BMI	-0.25 (-3.24, 2.73)	-1.10 (-3.97, 1.77)	0.20 (-3.91, 4.31)	-2.95 (-7.10, 1.20)	-1.69 (-5.80, 2.42)	-0.86 (-5.01, 3.29)
	TST	1.52 (-3.45, 6.50)	-1.02 (-5.68, 3.64)	1.53 (-4.18, 7.25)	-5.94 (-14.23, 2.36)	-3.00 (-8.95, 2.95)	1.90 (-5.84, 9.65)
	SST	-0.68 (-4.71, 3.36)	-1.62 (-5.35, 2.09)	2.23 (-2.88, 7.35)	**-6.04 (-11.56, -0.52)**	-2.96 (-7.91, 1.98)	0.16 (-5.77, 6.09)

*Vineland Adaptive Behavior Scales (VABS): population mean = 100, standard deviation = 15, higher scores indicate better adaptive behavior, overweight/obese: ≥85th percentile, BMI – body mass index, TST – triceps skinfold thickness, SST – subscapular skinfold thickness

†Bold font indicates model results are statistically significant at α = 0.05; crude model is unadjusted, other models adjusted for gender (when appropriate) hospital of birth (when appropriate), small for gestational age status, prenatal alcohol consumption, current maternal smoking, maternal prenatal smoking, maternal age, and maternal pre-pregnancy BMI

Table 5.5: Change in total behavior, internalizing behavior, and externalizing behavior scores on the Child Behavior Checklist (CBCL) in overweight/obese children relative to normal weight children, overall and stratified by gender and hospital of birth*†

				Stratified by gender		Stratified by hospital of birth	
		Crude	Pooled	Girls	Boys	Private	Public
Total behavior	BMI	0.66 (-1.84, 3.16)	0.80 (-1.83, 3.43)	-0.89 (-4.59, 2.81)	2.52 (-1.38, 6.42)	1.67 (-1.84, 5.18)	0.17 (-3.85, 4.19)
	TST	0.37 (-3.69, 4.43)	1.19 (-2.97, 5.35)	1.70 (-3.30, 6.69)	1.75 (-6.02, 9.53)	1.84 (-3.03, 6.71)	0.92 (-6.58, 8.42)
	SST	-1.59 (-4.95, 1.77)	-1.52 (-4.92, 1.88)	-0.01 (-4.53, 4.51)	-3.46 (-8.83, 1.92)	-1.59 (-5.76, 2.59)	-2.01 (-7.74, 3.73)
Externalizing behavior	BMI	0.14 (-2.24, 2.53)	-0.14 (-2.68, 2.40)	-1.19 (-4.52, 2.15)	1.03 (-2.90, 4.96)	0.71 (-2.69, 4.11)	-0.94 (-4.76, 2.88)
	TST	-0.10 (-3.97, 3.76)	0.30 (-3.72, 4.32)	0.63 (-3.88, 5.14)	1.67 (-6.15, 9.49)	2.79 (-1.91, 7.49)	-3.68 (-10.80, 3.43)
	SST	-2.31 (-5.50, 0.89)	-2.33 (-5.61, 0.95)	-0.23 (-4.32, 3.85)	-4.18 (-9.57, 1.22)	-1.96 (-6.00, 2.07)	-3.57 (-9.01, 1.87)
Internalizing behavior	BMI	1.11 (-1.32, 3.55)	1.16 (-1.41, 3.73)	-0.37 (-4.03, 3.29)	2.29 (-1.46, 6.03)	3.00 (-0.39, 6.40)	-0.57 (-4.49, 3.36)
	TST	2.23 (-1.72, 6.19)	2.58 (-1.48, 6.64)	3.18 (-1.74, 8.11)	2.99 (-4.48, 10.45)	2.55 (-2.18, 7.28)	3.38 (-3.93, 10.69)
	SST	-0.63 (-3.90, 2.65)	-0.87 (-4.19, 2.45)	0.46 (-4.01, 4.94)	-3.00 (-8.18, 2.17)	-1.29 (-5.35, 2.77)	-0.72 (-6.33, 4.89)

*Child Behavior Checklist (CBCL): population mean = 50, standard deviation = 10, higher scores indicate more problematic behavior, overweight/obese: ≥85^{th} percentile, BMI – body mass index, TST – triceps skinfold thickness, SST – subscapular skinfold thickness

†Bold font indicates model results are statistically significant at α = 0.05; crude model is unadjusted, other models adjusted for gender (when appropriate) hospital of birth (when appropriate), small for gestational age status, prenatal alcohol consumption, current maternal smoking, maternal prenatal smoking, maternal age, and maternal pre-pregnancy BMI

Table 5.6: Change in statue and visual attention scores on the Developmental NEuroPSYchology Assessment (NEPSY) in overweight/obese children relative to normal weight children, overall and stratified by gender and hospital of birth*†

				Stratified by gender		Stratified by hospital of birth	
		Crude	Pooled	Girls	Boys	Private	Public
Statue	BMI	0.17 (-0.51, 0.85)	0.10 (-0.62, 0.82)	0.26 (-0.75, 1.26)	-0.16 (-1.24, 0.93)	-0.94 (-1.96, 0.07)	**1.06 (0.05, 2.07)**
	TST	-0.91 (-2.05, 0.24)	-0.94 (-2.11, 0.24)	-1.02 (-2.36, 0.32)	-0.12 (-2.70, 2.47)	-1.17 (-2.68, 0.34)	-0.41 (-2.30, 1.49)
	SST	**-1.13 (-2.03, -0.23)**	**-1.21 (-2.12, -0.29)**	**-1.67 (-2.87, -0.48)**	-0.58 (-2.05, 0.90)	**-1.99 (-3.17, -0.81)**	-0.32 (-1.77, 1.13)
Visual attention	BMI	0.52 (-0.10, 1.15)	0.39 (-0.22, 1.00)	0.63 (-0.29, 1.49)	0.18 (-0.71, 1.08)	-0.30 (-1.02, 0.42)	0.91 (-0.07, 1.90)
	TST	0.74 (-0.26, 1.75)	0.17 (-0.79, 1.13)	0.61 (-0.55, 1.77)	-0.39 (-2.14, 1.36)	-0.20 (-1.20, 0.80)	0.71 (-1.12, 2.54)
	SST	0.06 (-0.76, 0.88)	-0.24 (-1.01, 0.54)	0.31 (-0.74, 1.36)	-0.54 (-1.71, 0.63)	-0.35 (-1.20, 0.49)	-0.11 (-1.51, 1.30)

*Developmental NEuroPSYchology Assessment (NEPSY): population mean = 10, standard deviation = 3, higher scores indicate better executive functioning, overweight/obese: ≥85th percentile, BMI – body mass index, TST – triceps skinfold thickness, SST – subscapular skinfold thickness

†Bold font indicates model results are statistically significant at α = 0.05; crude model is unadjusted, other models adjusted for gender (when appropriate) hospital of birth (when appropriate), small for gestational age status, prenatal alcohol consumption, current maternal smoking, maternal prenatal smoking, maternal age, and maternal pre-pregnancy BMI

6. DISSERTATION CONCLUSIONS AND SIGNIFICANCE

Dissertation summary

Motivation

The prevalence of early childhood overweight/obesity in the US has increased dramatically over the last several decades, ranking childhood obesity among the top public health problems. Because of this high prevalence, an effect of early childhood overweight/obesity on childhood development could have a significant impact on a population level. There is reason to suggest that a relationship between early childhood obesity and development exists. Young children learn by exploring and engaging their world. Thus, their development is much more closely tied to their physical capabilities compared with adolescents and adults. Further, research has indicated potential mechanisms linking childhood obesity to development, such as a postural imbalance in obese children resulting in motor skills deficits[1,2] or a dysregulation of neural circuits leading to problems with executing functioning.[3] Although studies have previously explored the possible association between childhood obesity and developmental outcomes, these studies: have produced inconsistent results; were often limited by small sample sizes and poor control of confounding; typically relied on a single obesity metric, body mass index (BMI); and, were largely conducted in older children and adolescents. The relative dearth of studies conducted in younger children, as well as those including multiple metrics of childhood obesity, are notable gaps in the childhood obesity literature.

Aims

This dissertation sought to fill these gaps in the literature by exploring the possible association of three noninvasive, easily-obtained metrics of early childhood obesity – BMI, triceps-skinfold-thickness (TST), and subscapular-skinfold-thickness (SST) – and childhood development. There were three specific study questions which this dissertation sought to address:

1. To what extent do BMI, TST, and SST differ in their classification of obesity status in a population of preschool-aged children?
2. Is there an association between early childhood obesity and cognitive ability?
3. Is there an association between early childhood obesity and adaptive functioning, behavior, or executive functioning?

Conclusions

Overall, this dissertation did not find evidence of a consistent association between early childhood overweight /obesity and childhood development. This is reassuring because it indicates that the recent dramatic increase in childhood obesity prevalence in the US is not likely to be followed by a similar overall rise in the number of children experiencing developmental difficulties. However, certain results, such as the negative associations between overweight/obesity and both nonverbal cognitive ability and motor skills in boys, or NEPSY statue test in girls of higher SES suggest that early childhood overweight/obesity may be associated with certain components of childhood development, and these associations may exist only in specific population groups.

Results addressing the first aim of this dissertation demonstrated that agreement among BMI, TST, and SST was often low, indicating that the three metrics were often not classifying the same children as overweight/obese. Further, due to differences in body composition, the degree to which differences among metrics existed varied substantially depending on the population. Researchers should consider the obesity metric best suited to their study question or population of interest when designing future childhood obesity studies.

Dissertation strengths and limitations

The primary strength of this dissertation is its thorough examination of the possible association between early childhood overweight/obesity and childhood development, which includes three metrics of childhood obesity, four components of childhood development, and two very different study populations.

By using three childhood obesity metrics, rather than relying simply on BMI, this dissertation is able to provide a broader picture of the relationship between early childhood obesity and childhood development. As evidenced by the results from Chapter 3 (which addressed the first aim of this dissertation), the three obesity metrics often performed quite differently depending on the population. Further, in some cases (e.g., DAS score and BMI vs. TST/SST in girls) conclusions regarding the association between obesity and development were dependent on which obesity metric was used. Thus, reliance on BMI alone could potentially have led to spurious conclusions.

Additionally, this dissertation explores four components of childhood development – cognitive ability, adaptive functioning, behavior, and executive functioning. While many studies examine only a single domain of childhood development, such as behavior or cognitive ability, development is not comprised of distinct entities, and many of these developmental processes overlap. Moreover, classification of intellectual disability requires deficits in both intellectual functioning and adaptive behavior.[4] Exploration of the association of overweight/obesity with all four of these components not only provides a fuller picture of the effect of obesity on development, but also allows for cross-validation of results for related developmental measures (e.g., similarly null results for both the CBCL and the VABS socialization subscale).

Examination of this dissertation's study questions in two very different study populations further contributes to its robust analysis of the relationship between early childhood obesity and childhood development. Further, the CPP allows not only similar analyses to those from the FUDGE Study, but also expands the focus of the dissertation by including two additional time points for BMI measurements and a second assessment of cognitive ability at age seven years.

Although null results cannot be considered conclusive, this dissertation's relatively consistent findings which were robust to changes in population, age, obesity metric, and developmental outcome, provide strong evidence to support the claim that early childhood overweight/obesity does not negatively impact childhood development.

A second strength of this dissertation is its focus on a preschool-aged population. While the majority of research on this topic has been conducted in older children, if an adverse, causal relationship does exist between childhood obesity and development, this relationship may be especially important in earlier years. Compared with older children and adolescents, younger children's cognitive and behavioral development is more tied to their physical capabilities. Further, research has shown that certain developmental abilities, notably those involved in executive functioning, undergo a period of rapid development in early childhood.[5] Finally, because early childhood development occurs prior to the start of formal education, if a problem does exist, children would then be entering school already at a disadvantage. Interventions targeted at earlier ages could minimize exposure time and/or provide additional opportunities to mitigate adverse effects of obesity.

A third strength of this dissertation is the use of strong metrics to assess SES in both the FUDGE Study and the CPP. In the FUDGE Study, hospital of birth is used to represent socioeconomic status. Because healthcare-seeking behavior is related to wealth, insurance status, neighborhood of residence, access to transportation, and a host of other factors, use of hospital of birth may better capture the broad, multi-dimensionality of SES, compared with simply using proxy measures like income and education. In the CPP, SES is represented by the socioeconomic index. This index, developed by the US Census Bureau, combines three factors – income, education, and occupation – into a single metric used to assess a family's SES. To create an even better fit of the SEI to the CPP population, the metric was re-scaled to represent the underlying source population which gave rise to the CPP participants, rather than the US population as a whole. While no method or factor can completely account for differences in socioeconomic status, I believe that hospital of birth (in the FUDGE Study) and the SEI (in the CPP) performed well in assessing the impact of SES on this dissertation's study questions.

Despite the strengths of this dissertation, it is also subject to several limitations. First, the relatively small sample size in the FUDGE Study restricted the analyses that could be performed. In particular, analysis of a four-category obesity status variable (or even simply overweight and obese children in separate strata) would have contributed to the depth of this dissertation. The small sample size also limited the statistical power of the analyses. This dissertation is a secondary data analysis which utilized previously collected data and the initial power/sample size calculations did not consider the study questions of interest in this paper. These analyses had 80% power to detect a main effect of 0.4 standard deviations, which translates to 5.6 points on the DAS and VABS scales, 4.0 points on the CBCL, and 1.2 points on both NEPSY tests. As expected, power to detect statistically significant interactions was lower. While this power would have been sufficient to detect the type of strong relationship which could have a meaningful clinical impact on individuals, it is possible that the study was underpowered to detect smaller associations or interactions which could nonetheless have had a substantial impact on a population level.

Second, this dissertation was limited by the presence of only a single obesity metric in the CPP. In particular, had the CPP collected data on skinfold thickness metrics, additional results analogous to those from the FUDGE Study could have been conducted. Further, although the FUDGE Study contained data on three obesity metrics, a more direct measure of adiposity amount and distribution (e.g., dual-energy X-ray absorptiometry) would have added to the depth of the dissertation, especially in Chapter 3.

Third, obesity status and childhood development were measured at a single time point in the FUDGE Study, permitting only a cross-sectional analysis. In contrast, the fact that assessments in the CPP at both 4- and 7-years yielded similar results provides additional credibility to the conclusion that evidence did not support an association between obesity and development in that population. Additional time points in the FUDGE Study would have similarly added to the strength of the conclusions from that study population.

Fourth, while the CPP contained assessments of cognitive ability at two ages, important differences between the Stanford-Binet and WISC tests prevented a one-to-one comparison. Specifically, Sattler found that the Stanford-Binet and WISC tests did not yield comparable mean IQs, especially when scores were in the Normal and above ranges on the Stanford-Binet.[6] This was confirmed in our dataset where Pearson correlations between Stanford-Binet full-scale IQ and WISC full-scale IQ were 0.48 among children with four-year IQ > 100, but only 0.30 among children with four-year IQ > 130.

Fifth, although both datasets contained extensive information on potential confounders, the possibility of residual confounding existed. For example, differences in the distribution of gender by hospital of birth in the FUDGE Study occurred because of the performance of the small for gestational age (SGA) norms that were used in this population and may have contributed to difficulties in examining the effects of gender or hospital due to residual confounding.

Sixth, it is possible that missing data, exclusions, or loss to follow-up contributed to errors in our reported results. In the FUDGE Study, over one-fourth of the FGDS participants selected for inclusion in the FUDGE population were lost to follow-up. However, comparison of FUDGE participants with those lost to follow-up revealed no differences by gender, race, hospital of birth, or maternal educational attainment. Additionally, because of the very large size of the CPP dataset, exclusion criteria were fairly liberal to minimize the potential for confounding or other biases. Many of these exclusions were in line with other studies on similar topics published using CPP data (e.g., multiple births or congenital malformations) and others were made to make the CPP and FUDGE Study datasets more analogous (e.g., exclusion of children born large for gestational age and those of non-African-American or white race). To evaluate the possibility of bias from several of these exclusions, sensitivity analyses were run and none generated results which differed from the study's original findings.

Seventh, both datasets utilized in this analysis were collected either in the 1990's or in the 1950's to 1970's. It is possible that neither of these datasets accurately represents today's picture of early childhood obesity. However, if the underlying relationship between obesity and developmental ability has remained constant, then any increase in obesity prevalence would result in a greater population impact.

Finally, because of important societal changes occurring during the time period between the two studies, we were unable to make direct comparisons of results between the two study populations. For example, shifts in dietary, exercise, and leisure patterns, urbanization and increased exposure to environmental pollutants, and changing breastfeeding and smoking rates have all played roles in both recent changes in obesity prevalence and childhood neurocognitive development.

Contributions of this dissertation and recommendations for the future

This dissertation sought to address gaps in the childhood obesity literature in two notable ways – first, by evaluating obesity measurement issues in preschool-aged children, and second, by providing a robust assessment of the possible relationship between early childhood overweight/obesity and childhood development.

The first contribution of this dissertation is in the analysis of measurement techniques of early childhood obesity. Studies have demonstrated differences in the performance of obesity metrics in older children and adults, as well as differences in body composition by gender, race, and SGA status. Similar research, however, has not been conducted in preschool-aged children. While lower than for older children, overweight and obesity prevalence among young children is nonetheless high. An understanding of how obesity metrics perform in young children and how differences among metrics vary by population group can help inform future research or clinical practice. Further, because SGA children were oversampled in the FUDGE dataset, this dissertation was able to assess how different measures of obesity perform in young children born SGA relative to children born average size. Assessment of the impact of SGA status is not commonly examined in research on obesity measurement issues.

Second, to my knowledge this is the only study which examines the association of childhood development and multiple metrics of obesity in a preschool-aged population. As noted above, if an adverse association exists between childhood obesity and childhood development, it may be of particular importance in early years. Additionally, as this study has demonstrated, substantial differences exist among obesity metrics, and simply relying on BMI to assess the relationship between obesity and development may lead to inaccurate conclusions. The use of multiple obesity metrics to assess the relationship between obesity and development in a critical – and understudied – population, contributes valuable new information to the study of childhood obesity.

The results of this robust analysis did not find evidence of an association between obesity and development in preschool-aged children. Nonetheless, the findings of this dissertation suggest two recommendations for future research. First, researchers developing studies of childhood obesity should take care to include preschool-aged children in their study populations. The literature has revealed a relative lack of research in younger children, though knowledge of how and why obesity develops in this population could lead to key strategies in the prevention of childhood obesity. Second, additional studies are needed to better understand differences in measurement of obesity in a preschool-aged population. Because “gold standard” methods of assessing adiposity are unsuited to most research studies and routine clinical practice, it is important to understand how best to measure obesity using methods such as BMI or skinfold thickness which are noninvasive, inexpensive, and easily-obtained, as well as how your choice of obesity metric may impact your findings. Results from this dissertation demonstrated important differences in the way such metrics perform in young children. Perhaps future studies can shed light on which metrics are best suited to particular populations, research questions, or clinical outcomes.

In an analysis that was robust to changes in study population, obesity metric, and developmental outcome, this study failed to find evidence of an association between obesity and development in a preschool-aged population. While these results are reassuring, the adverse consequences of childhood obesity remain an important concern in the health of young children. Continued study of the development of and complications from childhood obesity can generate crucial strategies to drive prevention and intervention efforts.

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A1. SUPPLEMENTAL MATERIAL TO CHAPTER 3

Appendix 1 contains supplemental material for Chapter 3 of this dissertation (Comparison of three obesity metrics in preschool-aged children). A brief description of this material is below, followed by Tables A1.1 – A1.4, and Figures A1.1 – A1.10.

Abbreviations used in Appendix 1 are: FUDGE Study – Follow-Up Development and Growth Experiences Study; FGDS – Fetal Growth and Development Study; BMI – body mass index; TST – triceps-skinfold-thickness; SST – subscapular skinfold thickness; SGA – small for gestational age (< 10^{th} percentile birthweight for gender, race, and gestational age); AGA – appropriate for gestational age (10 - < 90^{th} percentile birthweight for gestational age).

Figures A1.1, A1.2, and A1.3 contain addition information on the FUDGE Study and its participants, including a more detailed description of participant selection and the calculation of the obesity metrics.

- Figures A1.1 and A1.2: Participation in the FGDS/FUDGE Study
- Figure A1.3: Calculation of BMI Z-scores and BMI centiles

Table A1.1 is an expanded version of Table 3.2, and includes a 4-level obesity status variable. This table demonstrates that the prevalence of underweight was higher for all three metrics in boys (vs. girls) and African-Americans (vs. whites), though this difference was much greater for skinfold thickness metrics. Additionally, this table illustrates that, while the prevalence of overweight/obesity was similar among boys and girls, separation into overweight and obese categories reveals important differences.

- Table A1.1: Prevalence of underweight, normal weight, overweight, and obesity in the FUDGE Study

Tables A1.2 and A1.3 present supplemental information for Table 3.2. Results from Tables A1.2 and A1.3 are discussed in Chapter 3 but the results are not presented.

- Table A1.2: Comparison of overweight/obesity prevalence in the FUDGE Study
- Table A1.3: Relative prevalence of overweight/obesity in the FUDGE Study

Table A1.4 provides supplemental information to Table 3.4 and shows that agreement is still low when pairwise kappa statistics are calculated.

- Table A1.4: Pairwise kappa statistics comparing metrics of overweight/obesity in the FUDGE Study

Figure A1.4 illustrates the tight clustering around 54 months indicating that the majority of participants were observed close to the target age for the follow-up visit.

- Figure A1.4: Histogram of age in the FUDGE Study

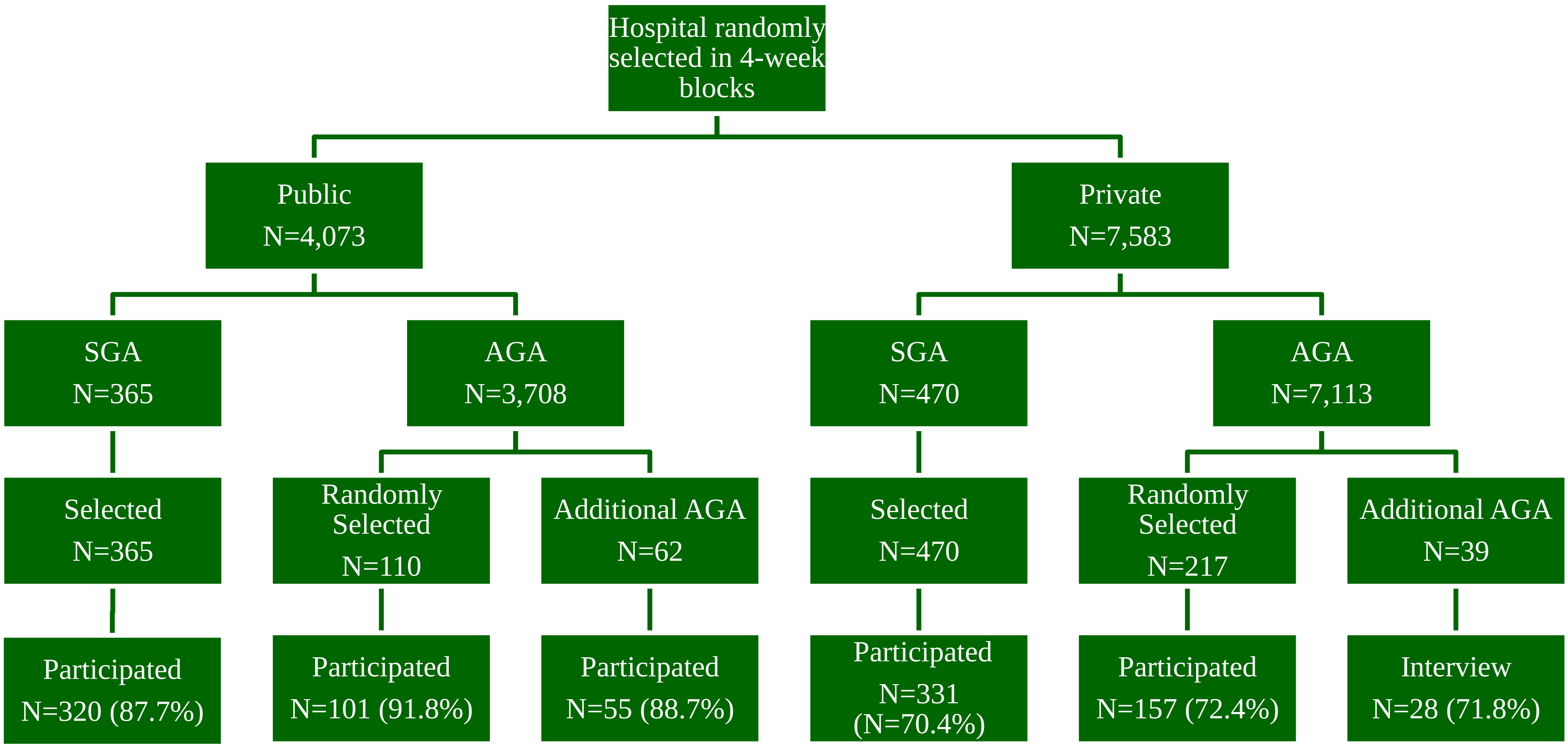
Figures A1.5 – A1.7 present histograms of BMI, TST, and SST Z-scores in the FUDGE Study, overall and stratified by gender, race, and SGA status. Figure A1.5 shows an approximately normal distribution with means that track the population mean well for both gender and race. Examination of the AGA and SGA plots reveal the shift to the right for AGA children and shift to the left for SGA children that would be expected given the results of Table 3.2. Figures A1.6 and A1.7 illustrate a shift to the left compared with the population mean of TST Z-score = 0. This shift is more pronounced for boys (compared with girls), African-Americans (compared with whites), and SGA children (compared with AGA children).

- Figures A1.5: Histograms of BMI Z-score
- Figures A1.6: Histograms of TST Z-score
- Figures A1.7: Histograms of SST Z-score

Figures A1.8 – A1.10 present scatter plots comparing BMI, TST, and SST Z-scores, overall and stratified by gender, race, and SGA status. These three series of scatter plots reveal considerable spread among the data, though spread was less for plots of TST/SST compared with plots of BMI and either skinfold thickness metric. For all three series of plots, spread appears to be somewhat greater for boys (compared with girls) and African-Americans (compared with whites). Spread seems to be similar between AGA and SGA children.

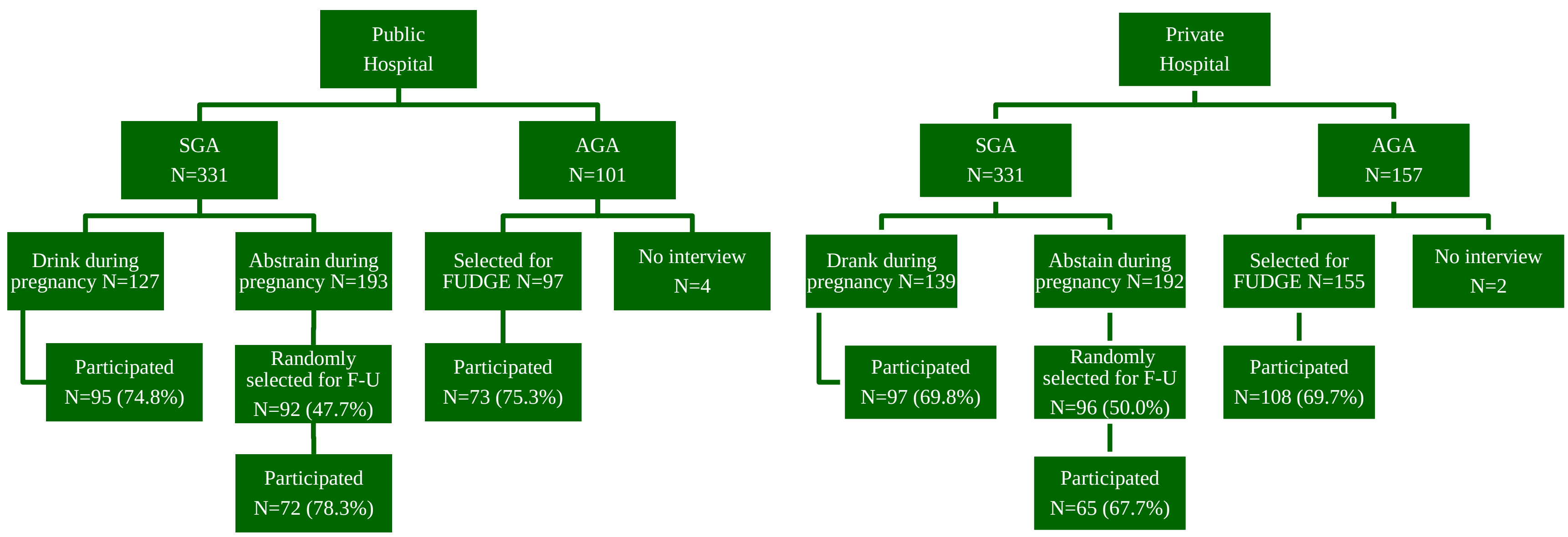
- Figure A1.8: Scatter plot of BMI Z-score versus TST Z-score
- Figure A1.9: Scatter plot of BMI Z-score versus SST Z-score
- Figure A1.10: Scatter plot of TST Z-score versus SST Z-score

Figure A1.1: Participation in the Fetal Growth and Development Study*



* SGA – small for gestational age (<10th percentile birthweight for gender, race, and gestational age), AGA – appropriate for gestational age (10 - <90th percentile birthweight for gender, race, and gestational age)

Figure A1.2: Participation in the Follow-Up Development and Growth Experiences (FUDGE) Study*

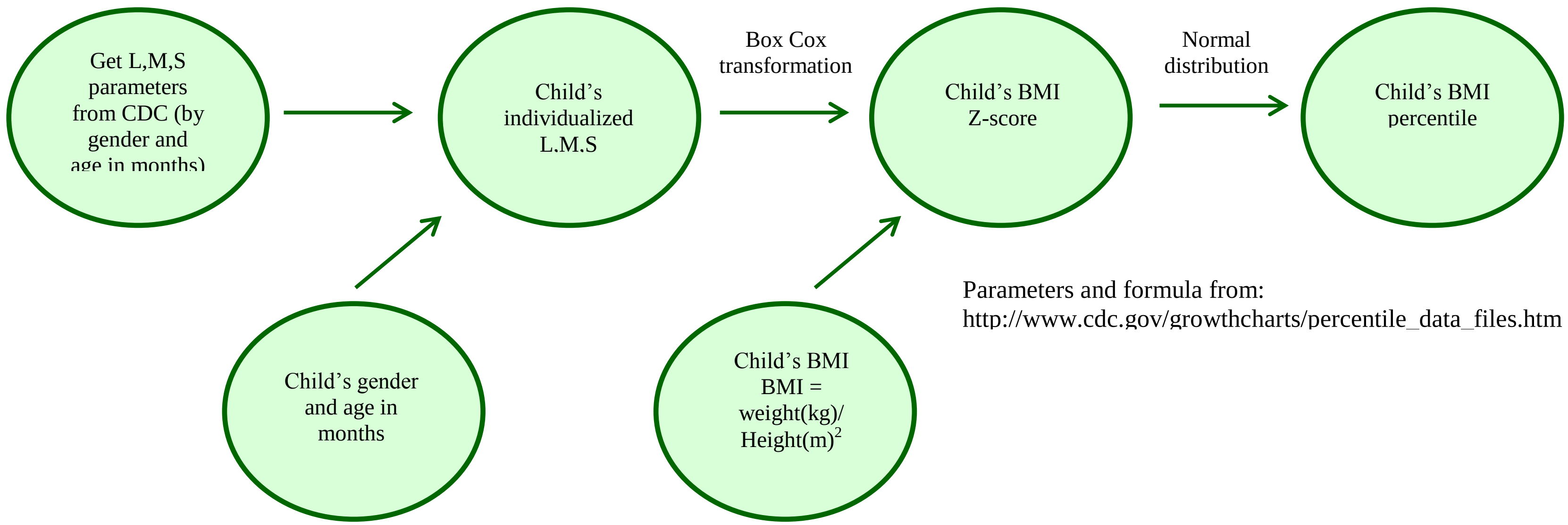


* SGA – small for gestational age (<10th percentile birthweight for gender, race, and gestational age), AGA – appropriate for gestational age (10 - <90th percentile birthweight for gender, race, and gestational age), F-U – follow-up

Figure A1.3: Calculation of BMI Z-scores and BMI centiles

L – Power in the Box-Cox transformation
M – Median
S – Generalized coefficient of variation

$$Z = \frac{((X/M)^{L}) - 1}{LS}, \quad L \neq 0$$



Parameters and formula from:
http://www.cdc.gov/growthcharts/percentile_data_files.htm

Table A1.1: Prevalence of underweight, normal weight, overweight, and obesity in the Follow-Up Development and Growth Experiences Study population: overall and stratified by gender, race, hospital of birth, and small for gestational age status(SGA), % (N) *

			Stratified by gender			Stratified by race			Stratified by SGA status		
		Overall	**Girls**	**Boys**	**P-Value †**	**Whites**	**A-A**	**P-Value**	**AGA**	**SGA**	**P-Value**
BMI	Underweight	8.47 (36)	7.69 (16)	9.22 (20)	0.01	5.82 (11)	10.59 (25)	0.24	4.38 (6)	10.42 (30)	<0.01
	Normal	76.00 (323)	76.44 (159)	75.58 (164)		78.31 (148)	74.15 (175)		67.88 (93)	79.86 (230)	
	Overweight	8.24 (35)	5.29 (11)	11.06 (24)		9.52 (18)	7.20 (17)		14.60 (20)	5.21 (15)	
	Obese	7.29 (31)	10.58 (22)	4.15 (9)		6.35 (12)	8.05 (19)		13.14 (18)	4.51 (13)	
TST	Underweight	17.41 (74)	12.50 (26)	22.12 (48)	0.01	5.29 (10)	27.12 (64)	<0.01	13.14 (18)	19.44 (56)	0.12
	Normal	77.41 (329)	79.81 (166)	75.12 (163)		87.83 (166)	69.07 (163)		78.83 (108)	76.74 (221)	
	Overweight	4.47 (19)	6.25 (13)	2.76 (6)		5.82 (11)	3.39 (8)		6.57 (9)	3.47 (10)	
	Obese	0.71 (3)	1.44 (3)	0.00 (0)		1.06 (2)	0.42 (1)		1.46 (2)	0.35 (1)	
SST	Underweight	11.06 (47)	7.21 (15)	14.75 (32)	0.03	8.47 (16)	13.14 (31)	0.16	10.22 (14)	11.46 (33)	0.69
	Normal	80.94 (344)	83.17 (173)	78.80 (171)		80.95 (153)	80.93 (191)		79.56 (109)	81.60 (235)	
	Overweight	5.88 (25)	6.25 (13)	5.53 (12)		7.41 (14)	4.66 (11)		7.30 (10)	5.21 (15)	
	Obese	2.12 (9)	3.37 (7)	0.92 (2)		3.17 (6)	1.27 (3)		2.92 (4)	1.74 (5)	

*Underweight – <5th percentile, normal weight – 5th - <85th percentile, overweight – 85th - <95th percentile, obese – ≥95th percentile, SGA – small for gestational age (<10th percentile birthweight for gender, race, and gestational age), AGA – appropriate for gestational age (10th – <90th percentile birthweight for gender, race, and gestational age), BMI – body mass index, TST – triceps skinfold thickness, SST – subscapular skinfold thickness, A-A – African-American

†χ^2 p-value

Table A1.2: Comparison of overweight/obesity prevalence by gender, race, and small for gestational age status in the Follow-Up Development and Growth Experiences Study population*

	BMI		TST		SST	
	%(N)	**P-value†**	**%(N)**	**P-value**	**%(N)**	**P-value**
Overall	15.53 (66)		5.18 (22)		8.00 (34)	
Girls	15.87 (33)	0.85	7.69 (16)	0.02	9.62 (20)	0.22
Boys	15.21 (33)		2.76 (6)		6.45 (14)	
Whites	15.87 (30)	0.86	6.88 (13)	0.16	10.58 (20)	0.08
African-Americans	15.25 (36)		3.81 (9)		5.93 (14)	
AGA	27.74 (38)	<0.01	8.03 (11)	0.07	10.22 (14)	0.24
SGA	9.72 (28)		3.82 (11)		6.94 (20)	

*Overweight/obese – ≥85th percentile, SGA – small for gestational age (<10th percentile birthweight for gender, race, and gestational age), AGA – appropriate for gestational age (10th – <90th percentile birthweight for gender, race, and gestational age), BMI – body mass index, TST – triceps skinfold thickness, SST – subscapular skinfold thickness

†χ^2 p-value

Table A1.3: Relative prevalence of overweight/obesity in the Follow-Up Development and Growth Experiences Study, stratified by gender, race, and small for gestational age status*

	BMI	**TST**	**SST**
Girls	1.0	1.0	1.0
Boys	1.1	2.8	1.5
Whites	1.0	1.0	1.0
African-Americans	1.0	1.8	1.8
AGA	1.0	1.0	1.0
SGA	2.9	2.1	1.5

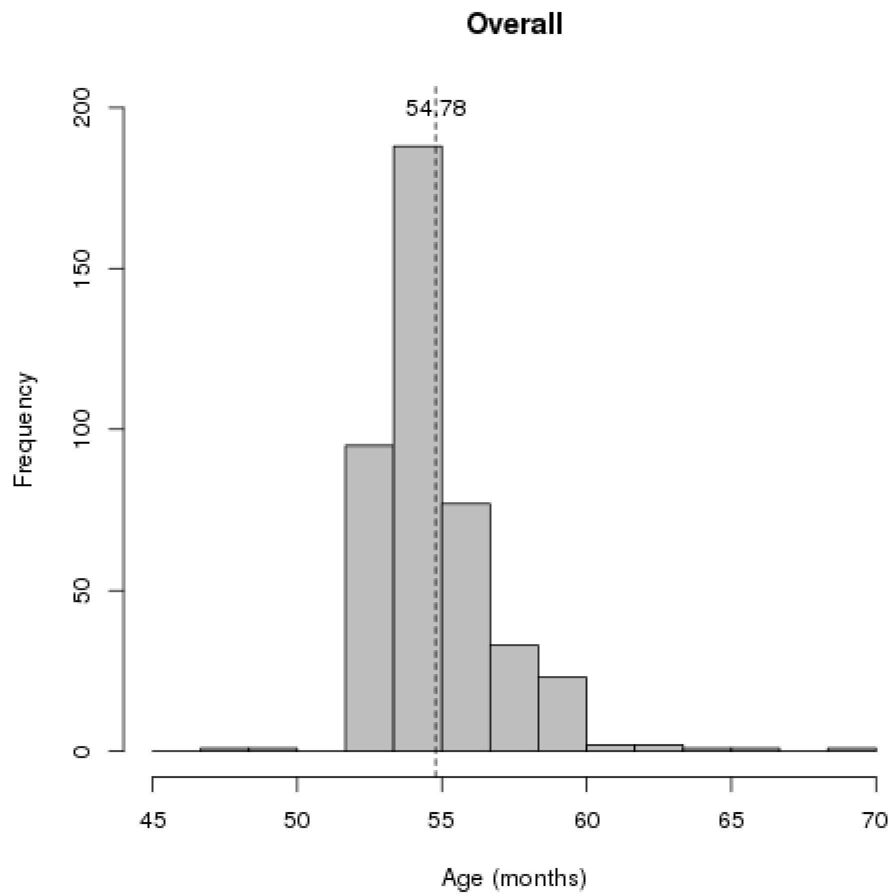
*Overweight/obese – ≥85th percentile, SGA – small for gestational age (<10th percentile birthweight for gender, race, and gestational age), AGA – appropriate for gestational age (10th – <90th percentile birthweight for gender, race, and gestational age), BMI – body mass index, TST – triceps skinfold thickness, SST – subscapular skinfold thickness

Table A1.4: Pairwise kappa statistics comparing metrics of overweight/obesity in the Follow-Up Development and Growth Experiences Study*

	BMI/TST	BMI/SST	TST/SST
Overall	0.31	0.31	0.43
Girls	0.48	0.38	0.51
Boys	0.11	0.28	0.27
Whites	0.31	0.40	0.44
African-Americans	0.31	0.21	0.41
AGA	0.28	0.32	0.43
SGA	0.32	0.27	0.42

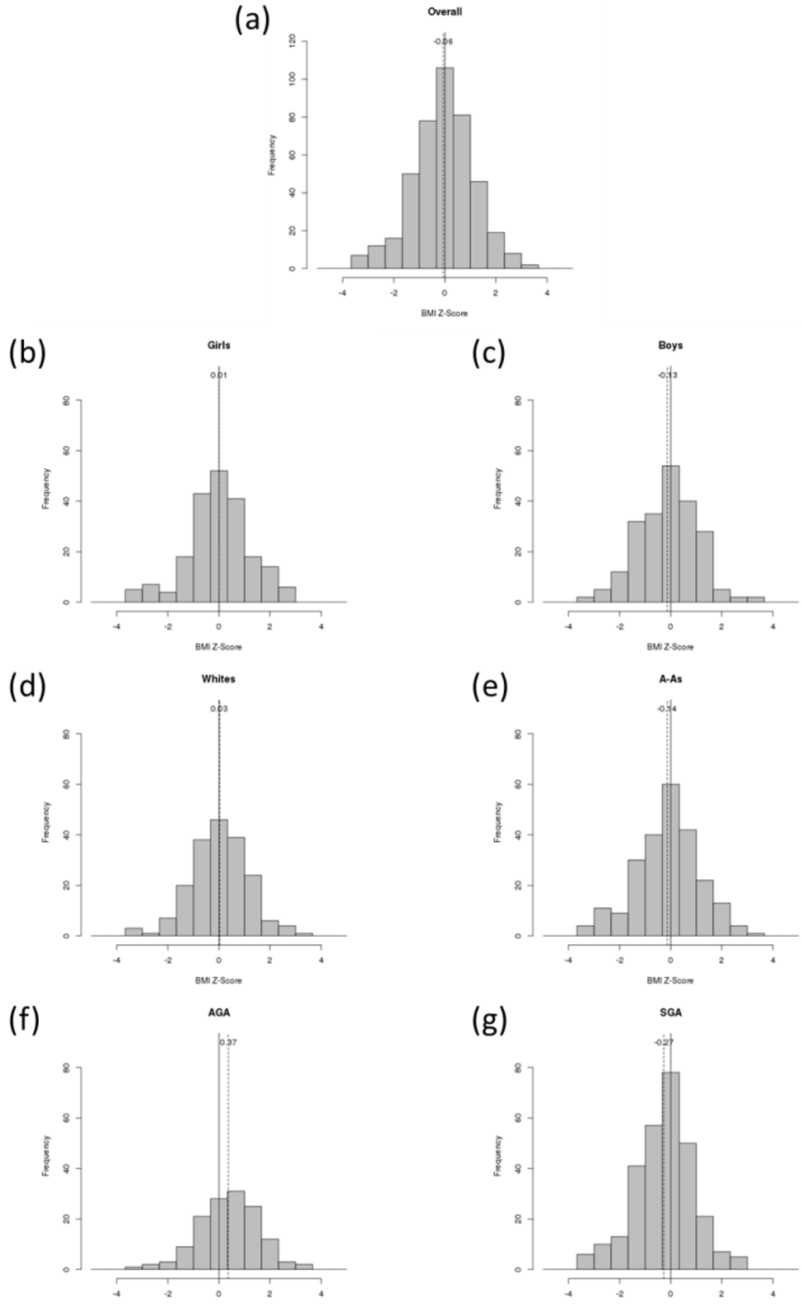
*Overweight/obese – ≥85th percentile, SGA – small for gestational age (<10th percentile birthweight for gender, race, and gestational age), AGA – appropriate for gestational age (10th – <90th percentile birthweight for gender, race, and gestational age), BMI – body mass index, TST – triceps skinfold thickness, SST – subscapular skinfold thickness

Figure A1.4: Histogram of age in the Follow-Up Development and Growth Experiences (FUDGE) Study*



*Dashed line represents sample mean (value provided)

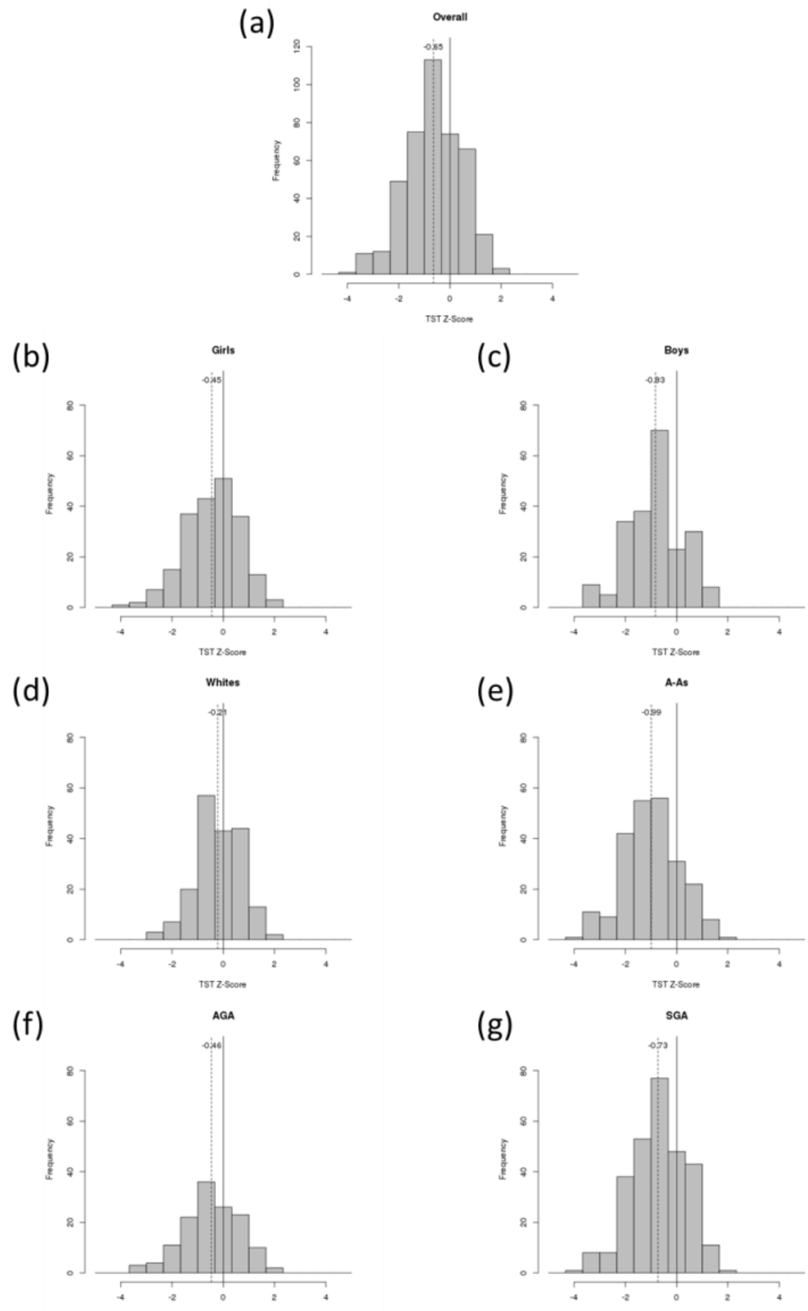
Figure A1.5: Histograms of body mass index (BMI) Z-score in the Follow-Up Development and Growth Experiences (FUDGE) Study – overall (a) and stratified by gender (b-c), race (d-e), and small for gestational age (SGA) status (f-g)*†



*A-A – African-American, SGA – small for gestational age (<10th percentile birthweight for gender, race, and gestational age), AGA – appropriate for gestational age (10 - <90th percentile birthweight for gender, race, and gestational age), overweight/obese: ≥85th percentile

†Solid line represents population mean (μ = 0), dashed line represents group mean (value provided)

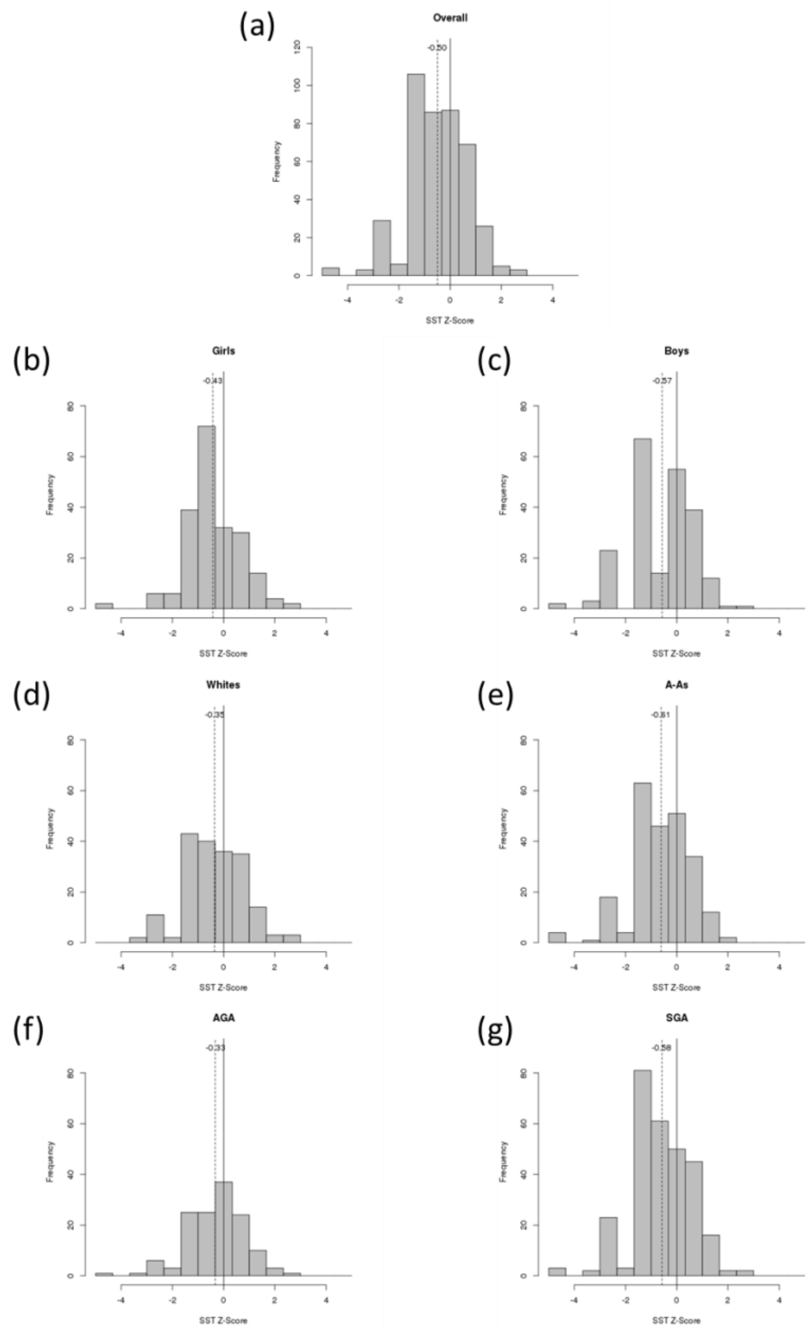
Figure A1.6: Histograms of triceps-skinfold-thickness (TST) Z-score in the Follow-Up Development and Growth Experiences (FUDGE) Study – overall (a) and stratified by gender (b-c), race (d-e), and small for gestational age (SGA) status (f-g)*†



*A-A – African-American, SGA – small for gestational age (<10th percentile birthweight for gender, race, and gestational age), AGA – appropriate for gestational age (10 - <90th percentile birthweight for gender, race, and gestational age), overweight/obese: ≥85th percentile

†Solid line represents population mean (μ = 0), dashed line represents group mean (value provided)

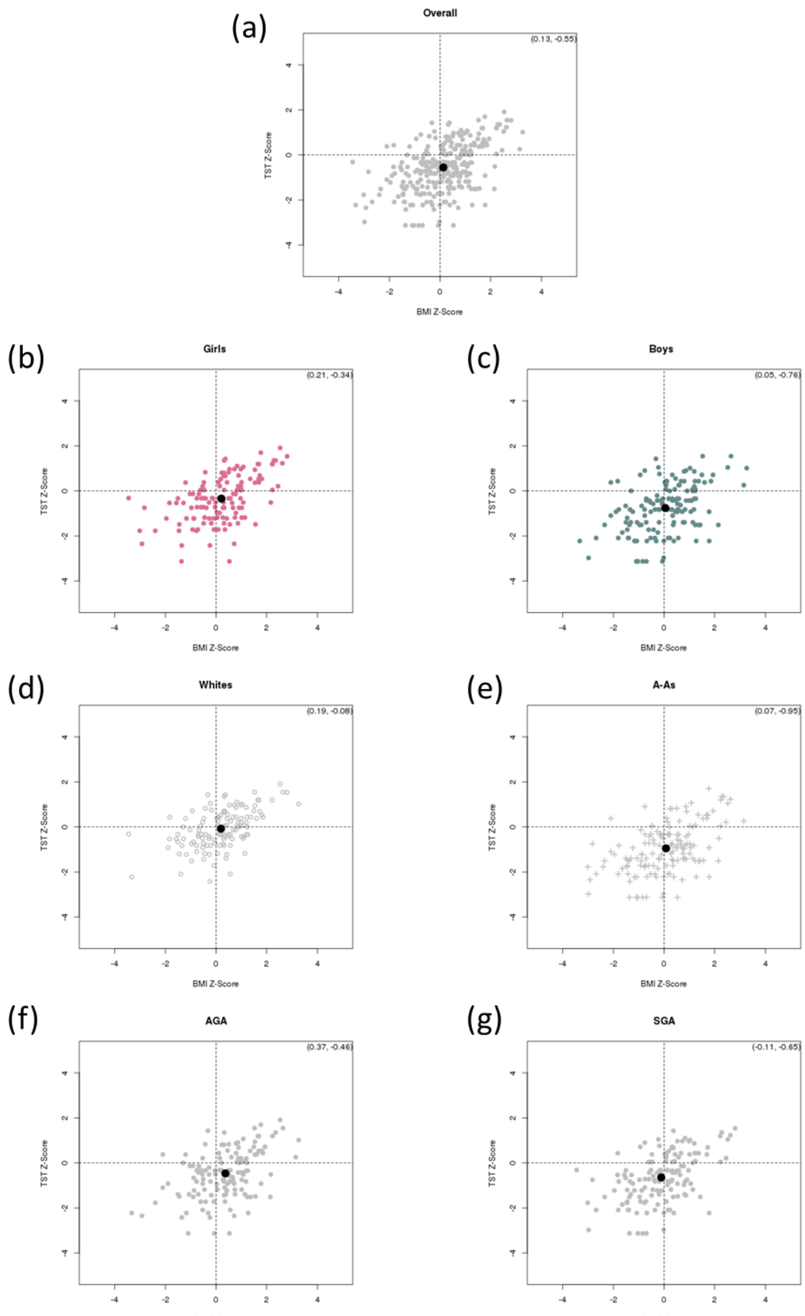
Figure A1.7: Histograms of subscapular-skinfold-thickness (SST) Z-score in the Follow-Up Development and Growth Experiences (FUDGE) Study – overall (a) and stratified by gender (b-c), race (d-e), and small for gestational age (SGA) status (f-g)*†



*A-A – African-American, SGA – small for gestational age (<10th percentile birthweight for gender, race, and gestational age), AGA – appropriate for gestational age (10 - <90th percentile birthweight for gender, race, and gestational age), overweight/obese: ≥85th percentile

†Solid line represents population mean (μ = 0), dashed line represents group mean (value provided)

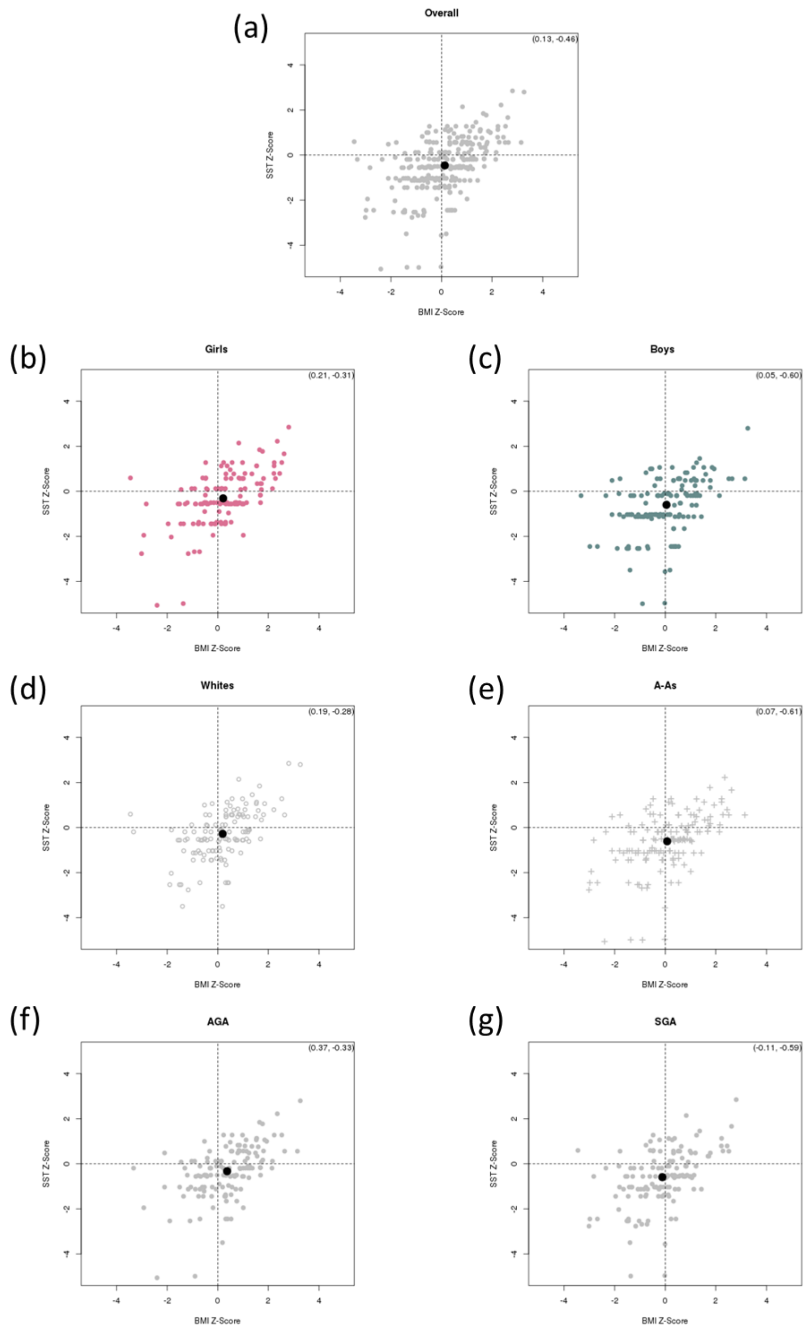
Figure A1.8: Scatter plots of body mass index (BMI) Z-score versus triceps-skinfold-thickness (TST) in the Follow-Up Development and Growth Experiences (FUDGE) Study – overall (a) and stratified by gender (b-c), race (d-e), and small for gestational age (SGA) status (f-g)*†



*A-A – African-American, SGA – small for gestational age (<10th percentile birthweight for gender, race, and gestational age), AGA – appropriate for gestational age (10 - <90th percentile birthweight for gender, race, and gestational age), overweight/obese: ≥85th percentile

†Solid line represents population mean (μ = 0), dashed line represents group mean (value provided)

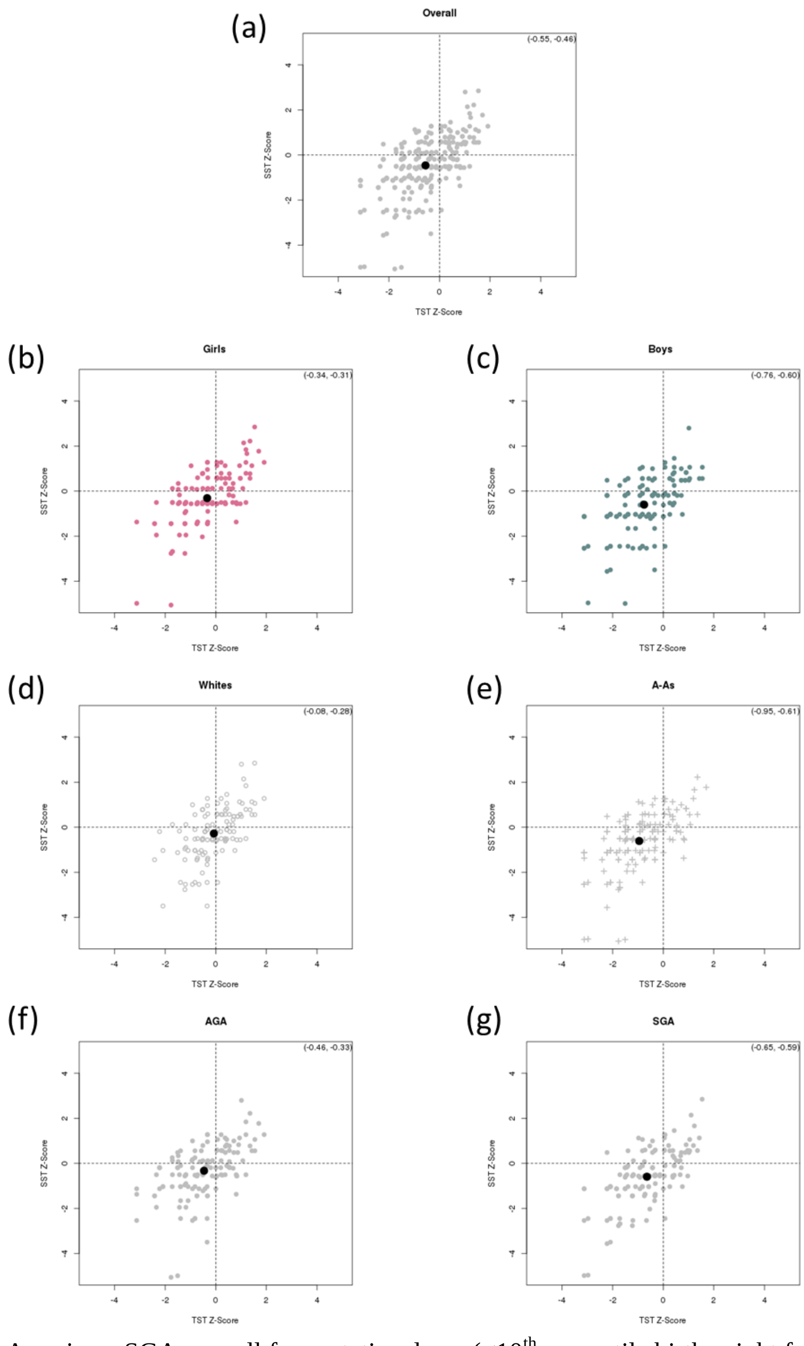
Figure A1.9: Scatter plots of body mass index (BMI) Z-score versus subscapular-skinfold-thickness (SST) in the Follow-Up Development and Growth Experiences (FUDGE) Study – overall (a) and stratified by gender (b-c), race (d-e), and small for gestational age (SGA) status (f-g)*†



*A-A – African-American, SGA – small for gestational age (<10th percentile birthweight for gender, race, and gestational age), AGA – appropriate for gestational age (10 - <90th percentile birthweight for gender, race, and gestational age), overweight/obese: ≥85th percentile

†Solid line represents population mean (μ = 0), dashed line represents group mean (value provided)

Figure A1.10: Scatter plots of triceps-skinfold-thickness (TST) versus subscapular-skinfold-thickness (SST) in the Follow-Up Development and Growth Experiences (FUDGE) Study – overall (a) and stratified by gender (b-c), race (d-e), and small for gestational age (SGA) status (f-g)*†



*A-A – African-American, SGA – small for gestational age (<10th percentile birthweight for gender, race, and gestational age), AGA – appropriate for gestational age (10 - <90th percentile birthweight for gender, race, and gestational age), overweight/obese: ≥85th percentile

†Solid line represents population mean (μ = 0), dashed line represents group mean (value provided)

A2. SUPPLEMENTAL MATERIAL TO CHAPTER 4

Appendix 2 contains supplemental material for Chapter 4 of this dissertation (The association between early childhood overweight/obesity and cognitive ability). A brief description of this material is below, followed by Tables A2.1 – A2.37, and Figures A2.1 – A2.20.

Abbreviations used in Appendix 2 are: FUDGE Study – Follow-Up Development and Growth Experiences Study; CPP – Collaborative Perinatal Project; BMI – body mass index; TST – triceps-skinfold-thickness; SST – subscapular skinfold thickness; DAS – Differential Ability Scales; SB – Stanford-Binet Intelligence Scales; WISC – Wechsler Intelligence Scales for children; SGA – small for gestational age (< 10^{th} percentile birthweight for gender, race, and gestational age); AGA – appropriate for gestational age (10 - < 90^{th} percentile birthweight for gestational age); LGA – large for gestational age (≥ 90^{th} percentile birthweight for gender, race, and gestational age); SEI – socioeconomic index.

Figures A2.1 and A2.2 and Tables A2.1 – A2.3 contain additional information on the CPP and its participants. As demonstrated in Figure A2.1, while CPP sites were distributed across the country, they were largely concentrated in the northeast. Tables A2.1 and A2.2 illustrate the wide variation in the number of participants from each of the 12 study sites, as well as significant differences in racial composition. Figure A2.2 and Table A2.3 provide more details on what and when information was collected on CPP participants.

- Figure A2.1: Map of the CPP sites

- Table A2.1: CPP enrollment, by site
- Table A2.2: CPP racial/ethnic composition, by site
- Figure A2.2: Data collection in the CPP
- Table A2.3: Summary of protocols of the CPP

Tables A2.4 – A2.6 present additional models run on the FUDGE Study dataset. These tables reinforce the Chapter 4 results which show no association overall between high BMI/TST/SST and DAS composite, verbal, and nonverbal scores in the FUDGE Study population. The tables also demonstrate no association between high BMI/TST/SST and verbal cognitive ability after stratification by hospital of birth or gender. Among girls, no association is observed between any obesity metric and composite DAS score, or between high TST/SST and DAS nonverbal score, though a positive association is observed between high BMI and DAS nonverbal score. Among boys, a negative association is seen between all three obesity metrics and DAS composite and nonverbal scores. While no association is observed between any obesity metric and cognitive ability among children from the public hospital, a potential association between high TST/SST and composite and nonverbal ability is demonstrated among children born at the private hospital. Finally, these tables illustrate that results are similar after adjustment for the narrower and wider sets of potential confounders.

- Table A2.4: BMI/TST/SST, DAS composite score
- Table A2.5: BMI/TST/SST, DAS verbal score
- Table A2.6: BMI/TST/SST, DAS nonverbal score

Tables A2.7 – A2.20 present additional models run on the CPP dataset. Models A2.7 – A2.17 show the change in the IQ metric specified associated with obesity status at the age specified. Models A2.18 – A2.20 show the change in the IQ metric specified associated with a change in BMI from age four years to age seven years.

These models reinforce the highly consistent results of Table 4.6 in the dissertation and the conclusions to be drawn are the same: 1) underweight BMI is associated with a very small decline in full-scale IQ score with respect to normal weight BMI; 2) both overweight and obese BMI are associated with a similarly small increase in full-scale IQ compared with normal weight BMI; and, 3) the effects of obesity and overweight (vs. normal weight) are similar in magnitude.

- Table A2.7: Four-year BMI, four-year SB full-scale IQ
- Table A2.8: Seven-year BMI, seven-year WISC full-scale IQ
- Table A2.9: Seven-year BMI, seven-year WISC verbal IQ
- Table A2.10: Seven-year BMI, seven-year WISC performance IQ
- Table A2.11: Three-year BMI, four-year SB full-scale IQ
- Table A2.12: Three-year BMI, seven-year WISC full-scale IQ
- Table A2.13: Three-year BMI, seven-year WISC verbal IQ
- Table A2.14: Three-year BMI, seven-year WISC performance IQ
- Table A2.15: Four-year BMI, seven-year WISC full-scale IQ
- Table A2.16: Four-year BMI, seven-year WISC verbal IQ
- Table A2.17: Four-year BMI, seven-year WISC performance IQ
- Table A2.18: Change in BMI from four-to-seven years and seven-year WISC full-scale IQ

- Table A2.19: Change in BMI from four-to-seven years and seven-year WISC verbal IQ
- Table A2.20: Change in BMI from four-to-seven years and seven-year WISC performance IQ

Tables A2.21 – A2.36 represent additional models run on the CPP dataset and Table A2.37 is an additional model run on the FUDGE Study dataset. These models are conducted as sensitivity analyses to determine if changes in the way obesity is classified, exclusions that are made, or stratification by different variables would change the conclusions drawn in Chapter 4. Tables A2.21 – A2.37 do not demonstrate any substantial changes in the results or conclusions drawn in Chapter 4.

- Table A2.21: Four-year BMI, four-year SB full-scale IQ, obesity cut-point 97^{th} percentile
- Table A2.22: Seven-year BMI, seven-year WISC full-scale IQ, obesity cut-point 97^{th} percentile
- Table A2.23: Four-year BMI, four-year SB full-scale IQ, obesity cut-point 99^{th} percentile
- Table A2.24: Seven-year BMI, seven-year WISC full-scale IQ, obesity cut-point 99^{th} percentile
- Table A2.25: Four-year BMI, four-year SB full-scale IQ, LGA children included
- Table A2.26: Seven-year BMI, seven-year WISC full-scale IQ, LGA children included

- Table A2.27: Four-year BMI, four-year SB full-scale IQ, including gestational ages 32-45 weeks
- Table A2.28: Seven-year BMI, seven-year WISC full-scale IQ, including gestational ages 32-45 weeks
- Table A2.29: Four-year BMI, four-year SB full-scale IQ, all races included
- Table A2.30: Seven-year BMI, seven-year WISC full-scale IQ, all races included
- Table A2.31: Four-year BMI, four-year SB full-scale IQ, stratified by gender, SEI (dichotomized at the median), and gender/SEI
- Table A2.32: Seven-year BMI, seven-year WISC full-scale IQ, stratified by gender, SEI (dichotomized at the median), and gender/SEI
- Table A2.33: Four-year BMI, four-year SB full-scale IQ, stratified by gender, SEI (≥75th percentile vs. <75th percentile), and gender/SEI
- Table A2.34: Seven-year BMI, seven-year WISC full-scale IQ, stratified by gender, SEI (≥75th percentile vs. <75th percentile), and gender/SEI
- Table A2.35: Four-year BMI, four-year SB full-scale IQ, stratified by gender, SEI (≥75th percentile vs. <25th percentile), and gender/SEI
- Table A2.36: Seven-year BMI, seven-year WISC full-scale IQ, stratified by gender, SEI (≥75th percentile vs. <25th percentile), and gender/SEI
- Table A2.37: Overweight/obese BMI/TST/SST, DAS composite score in the FUDGE Study, overall and stratified by gender and race

Figures A2.3 – A2.5 present histograms for DAS composite, verbal, and nonverbal scores, overall and stratified by gender, hospital of birth, and SGA status in the FUDGE

Study. Of particular note is dramatic shift to the left in all three DAS scales for children born at the public hospital compared with children born at the private hospital. Boys, compared with girls, also exhibit a shift to the left. This is partly due to an effect of gender, but largely because of confounding from the effect of hospital of birth. In the FUDGE Study population, the performance of the norms used to determine SGA status results in a higher proportion of white SGA girls compared with boys. Because of the high correlation of race with hospital of birth in this study, this results in the histograms of gender being somewhat confounded by hospital of birth.

- Figure A2.3: Histogram of DAS composite score
- Figure A2.4: Histogram of DAS verbal score
- Figure A2.5: Histogram of DAS nonverbal score

Figures A2.6 – A2.8 present histograms of BMI Z-score at ages three, four, and seven years in the CPP, overall and stratified by gender, race, and SGA status. Figures A.2.6 and A2.7, in particular, demonstrate that histograms for African-American and SGA children are shifted to the left and have group means somewhat lower than the population mean ($\mu = 0$). Whites, AGA children, and both genders appear to track the population mean and distribution well. Figure A2.7 graphically demonstrates a shift to the right and increase in group mean for four-year BMI Z-score among whites, which is not present among African-Americans.

- Figure A2.6: Histogram of BMI Z-score at age three years
- Figure A2.7: Histogram of BMI Z-score at age four years
- Figure A2.8: Histogram of BMI Z-score at age seven years

Figures A2.9 – A2.12 present histograms of SB full-scale IQ and WISC full-scale, verbal, and performance IQ, overall and stratified by gender, race, and SGA status in the CPP. The histograms in the overall CPP track the population means of 100 for both the SB and the WISC well. All four histograms demonstrate a shift to the left of IQ scores among African-American children compared with white children, though this shift is not as pronounced as the shift by hospital of birth observed in children in the FUDGE Study (Figures A2.2-A2.5). These histograms also show that girls score slightly higher on the SB and boys on the WISC (composite and verbal scores in particular) and that AGA children consistently score slightly higher than SGA children on all CPP IQ tests.

- Figure A2.9: Histogram of SB full-scale IQ score
- Figure A2.10: Histogram of WISC full-scale IQ score
- Figure A2.11: Histogram of WISC verbal IQ score
- Figure A2.12: Histogram of WISC nonverbal IQ score

Figures A2.13 – A2.15 present scatter plots of BMI/TST/SST and DAS composite score in the FUDGE Study. Plots are presented for overall results, and stratified by gender and hospital of birth and include only data from children born AGA (to minimize confounding). Though these plots present data from a relatively small sample, they demonstrate considerable spread. Additionally, these plots reinforce the strong effect of hospital of birth and moderate effect of gender demonstrated in Figures A2.2-A2.5.

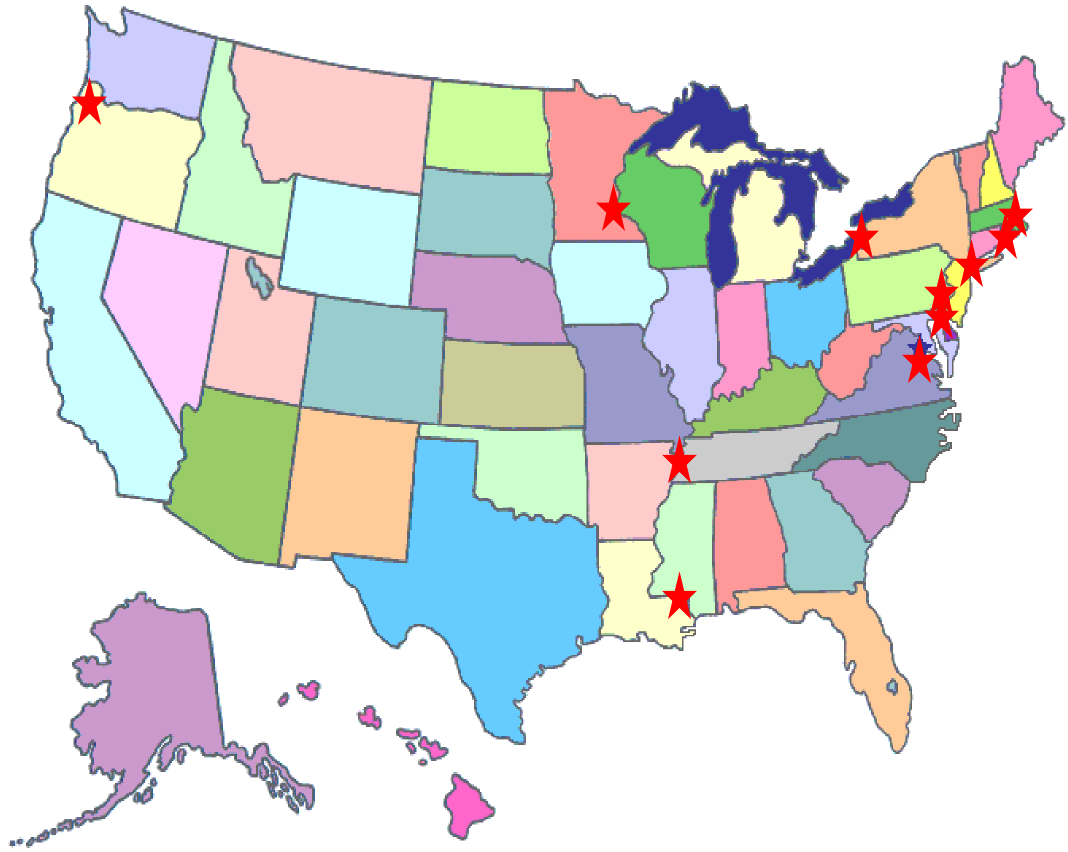
- Figure A2.13: Scatter plot of BMI Z-score and DAS composite score
- Figure A2.14: Scatter plot of TST Z-score and DAS composite score

- Figure A2.15: Scatter plot of SST Z-score and DAS composite score

Figures A2.16 – A2.20 present scatter plots of BMI Z-score at ages three-, four-, and seven-years and full-scale SB and WISC IQ at ages four-years and seven-years, respectively, in the CPP. Plots include data from a random sample of 500 children in the CPP and are presented for overall results, as well as stratified by gender and race. These plots reinforce the result that African-American children scored lower than white children on all tests of IQ, though this shift was not as pronounced as the shift for hospital of birth in the FUDGE Study.

- Figure A2.16: Scatter plot of three-year BMI Z-score and SB full-scale IQ
- Figure A2.17: Scatter plot of four-year BMI Z-score and SB full-scale IQ
- Figure A2.18: Scatter plot of three-year BMI Z-score and WISC full-scale IQ
- Figure A2.19: Scatter plot of four-year BMI Z-score and WISC full-scale IQ
- Figure A2.20: Scatter plot of seven-year BMI Z-score and WISC full-scale IQ

Figure A2.1: Map of the Collaborative Perinatal Project sites



From: http://hua.umf.maine.edu/Chinese/maps/usmap.html

Table A2.1: Collaborative Perinatal Project enrollment, by site			
Location	**Institution**	**Registration Dates**	**# En-rolled ***
Total		1/59 – 12/65	55,908
Baltimore, MD	Johns Hopkins Hospital	1/59 – 12/64	3,774
Boston, MA	Lying-In Hospital/ Children's Medical Center	1/59 – 12/65	13,137
Buffalo, NY	Children's Hospital, SUNY	10/60 – 12/65	2,964
Memphis, TN	University of Tennessee College of Medicine	10/59 12/65	3,553
Minneapolis, MS	University of Minnesota	1/59 – 12/65	3,275
New Orleans, LA	Charity Hospital	3/60 – 12/65	2,590
New York, NY	Columbia-Presbyterian Hospital	1/59 – 4/63	2,235
New York, NY	New York Medical College	2/59 – 12/65	4,709
Philadelphia, PA	Pennsylvania Hospital/Children's Hospital of Philadelphia	1/59 – 12/65	10,315
Portland, OR	University of Oregon Medical School	3/59 – 12/65	3,255
Providence, RI	Providence Lying-In Hospital	3/60 – 12/65	2,851
Richmond, VA	Medical College of Virginia	1/59 – 12/65	3,250

*This represents the number of women enrolled in the core sample. Some of these women were lost to follow-up and/or did not provide labor and delivery records

Table A2.2: Collaborative Perinatal Project racial/ethnic composition, by site*				
Location	White	Black	Puerto Rican	Other
Total	21,919	25,017	3.594	513
Baltimore, MD	798	2,744	1	6
Boston, MA	10,803	1,198	25	167
Buffalo, NY	2,383	59	12	15
Memphis, TN	22	3,501	0	0
Minneapolis, MS	2,986	19	2	140
New Orleans, LA	0	2.582	0	0
New York, NY (CP)	633	876	602	27
New York, NY (NYMC)	269	1,158	2,630	17
Philadelphia, PA	882	8,580	316	14
Portland, OR	2,216	861	1	72
Providence, RI	2,096	672	5	49
Richmond, VA	831	2,367	0	6

*Not including those lost to follow-up, CP – Columbia-Presbyterian Hospital , NYMC – New York Medical College

Figure A2.2: Data collection in the Collaborative Perinatal Project

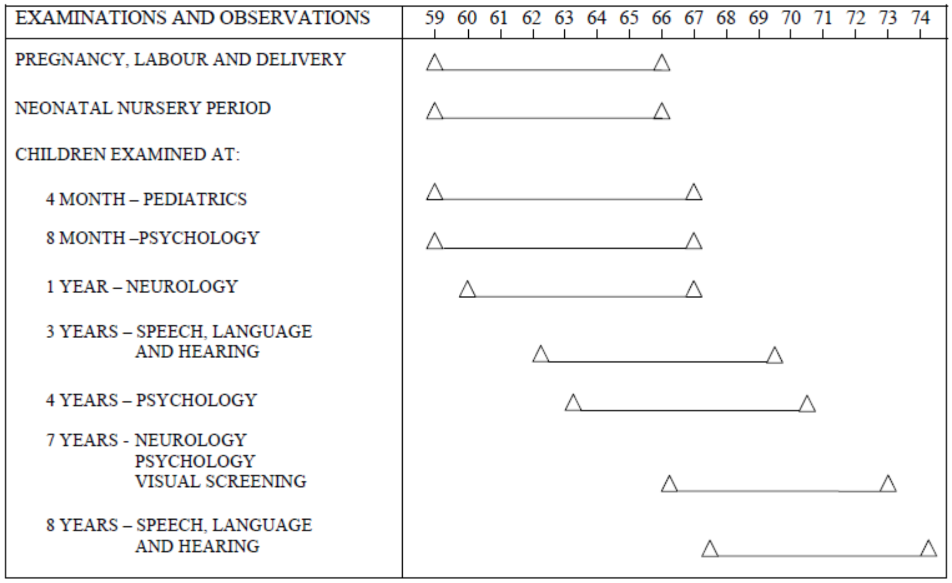


Table A2.3: Summary of Protocols of the Collaborative Perinatal Project

Prenatal

Registration and first prenatal visit

- Obstetric administrative record
- Reproductive and gynecological history and history since last menstrual period
- Recent and past medical history including infectious disease and system review
- Socioeconomic interview
- Family history interview including outcomes of prior pregnancies, family composition, and health history of parents and their relatives

Subsequent prenatal visits

- Repeat prenatal history
- Prenatal observations
- Laboratory record
- Physician's clinic record
- Blood samples for serological studies
- Summary of antepartum hospitalization

Labor and Delivery

- Repeat prenatal history and admission history
- Admission examination
- Laboratory record
- Labor room record
- Delivery room events
- Delivery report
- Obstetric summary
- Anesthetic agents
- Summary of puerperium
- Placental examinations (gross and microscopic)
- Obstetric diagnostic summary

Newborn

- Delivery room observation
- Neonatal examination
- Nursery history
- Results of tests and procedures
- Neonatal neurological examination
- Newborn diagnostic summary

Four months

- Pediatric examination
- Interval medical history

Eight months

- Bayley Scales of Mental and Motor Development
- Infant behavior profile, maternal behavior ratings, and additional observations
- Physical measurements
- Interval medical history

12 months

- Neurological examination
- Interval medical history
- Diagnostic summary of the first year

18 and 24 months

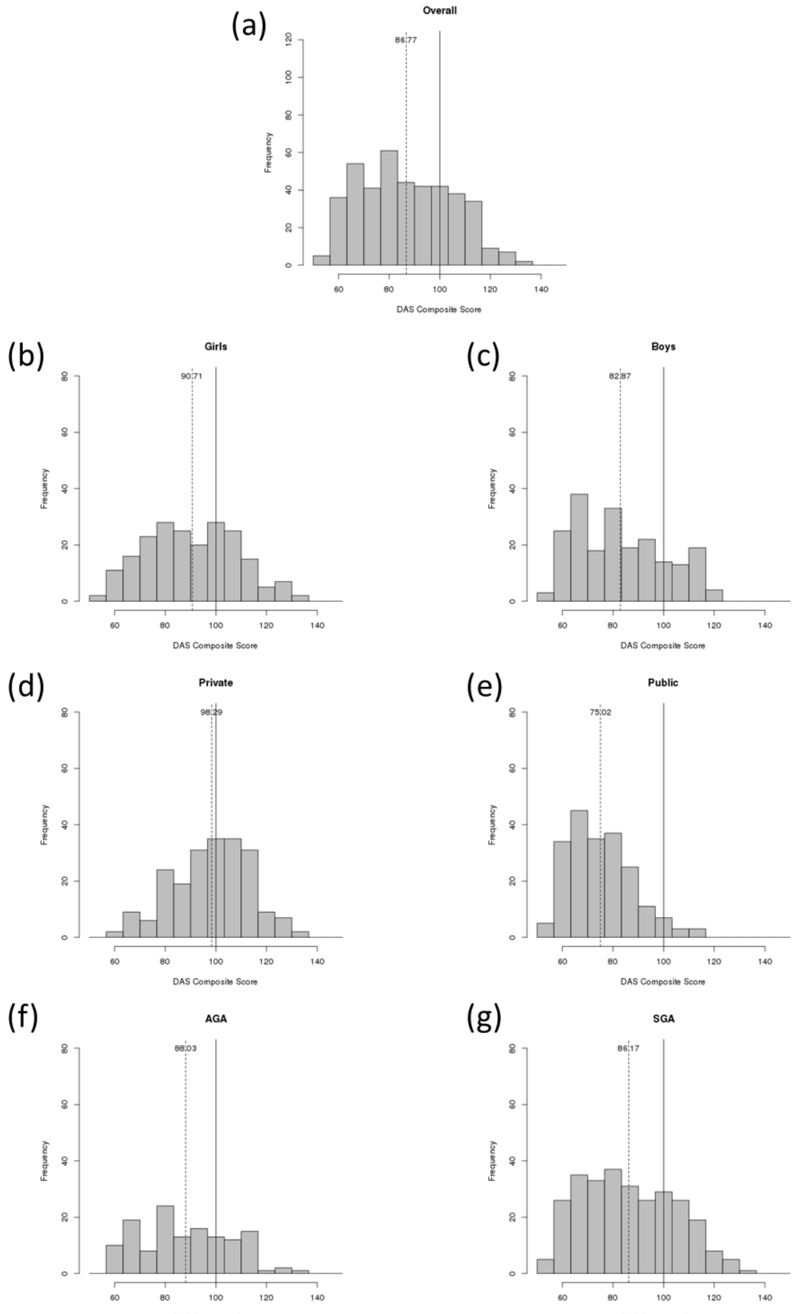
- Interval medical history

Three years (not conducted at all study sites)

- Speech, language, and hearing examination with tests of language reception and expression, auditory memory and discrimination, speech mechanism and production, and additional

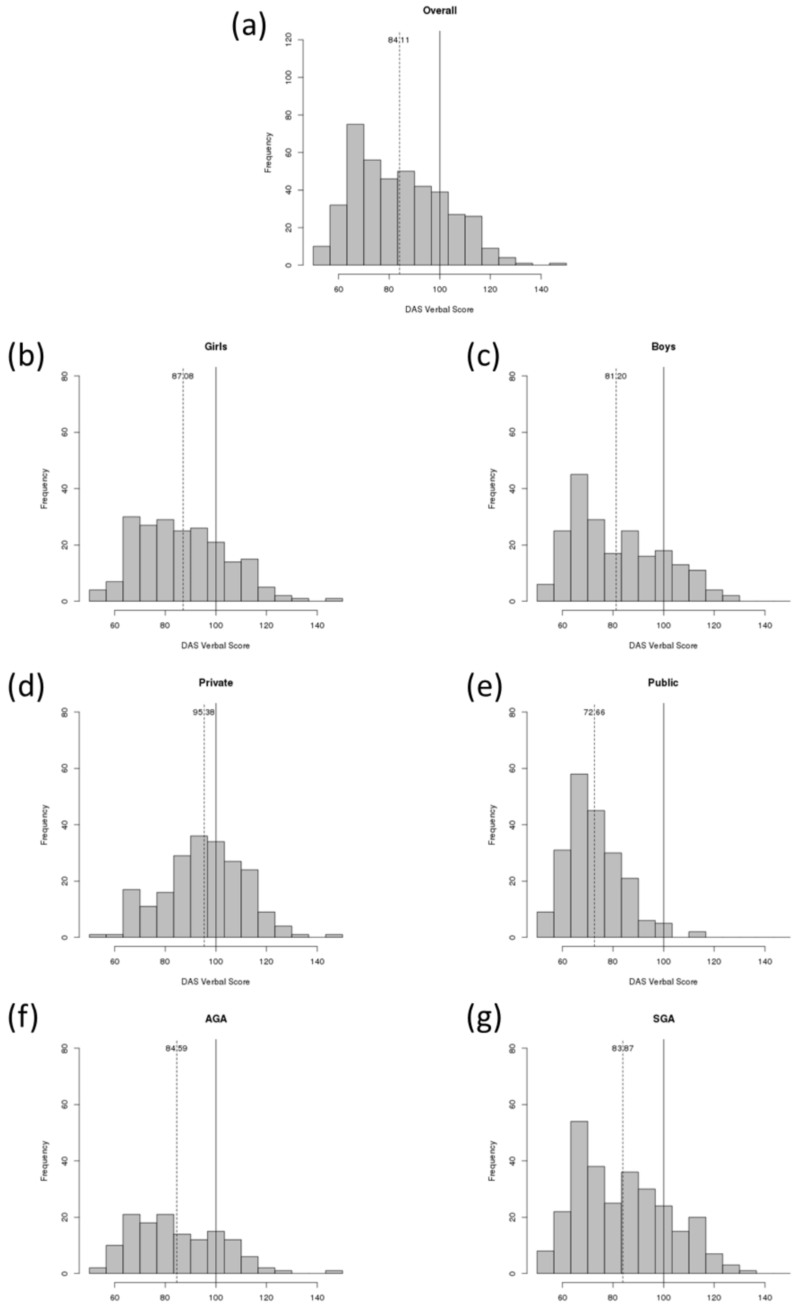
observations • Physical measurements • Interval medical history
Four years • Stanford-Binet Intelligence Scale • Graham-Ernhart Block Sort Test • Gross and fine motor tests • Behavioral profile and additional observations • Science Research Association (SRA) non-verbal intelligence test administered to mother • Physical measurements • Interval medical history
Five and six years • Interval medical history
Seven years • Wechsler Intelligence Scale for Children • Goodenough Harris Draw-a-Person Test • Bender Gestalt Test • Auditory-Vocal Association Test (Illinois Test of Psycho-linguistic Abilities) • Tactile Finger Recognition Test (Halstead-Reitan Battery) • Wide Range Achievement Test • Behavior profile and additional observations • Family health history and socioeconomic interview with mother • Pediatric neurological examination • Visual screening and ophthalmology report • Interval medical history • Diagnostic summary for years one through seven
Eight years (not conducted at all study sites) • Speech, language, and hearing examination with tests of language comprehension and expression, auditory discrimination, speech mechanism and production, and additional observations • Physical measurements • Interval medical history
General forms • Administrative reports for record inventory, patient follow-up, and sample maintenance • Report of fetal, infant, or child death • Autopsy report

Figure A2.3: Histograms of Differential Ability Scales (DAS) composite score in the Follow-Up Development and Growth Experiences (FUDGE) Study – overall (a) and stratified by gender (b-c), hospital of birth (d-e), and small for gestational age (SGA) status (f-g)*†



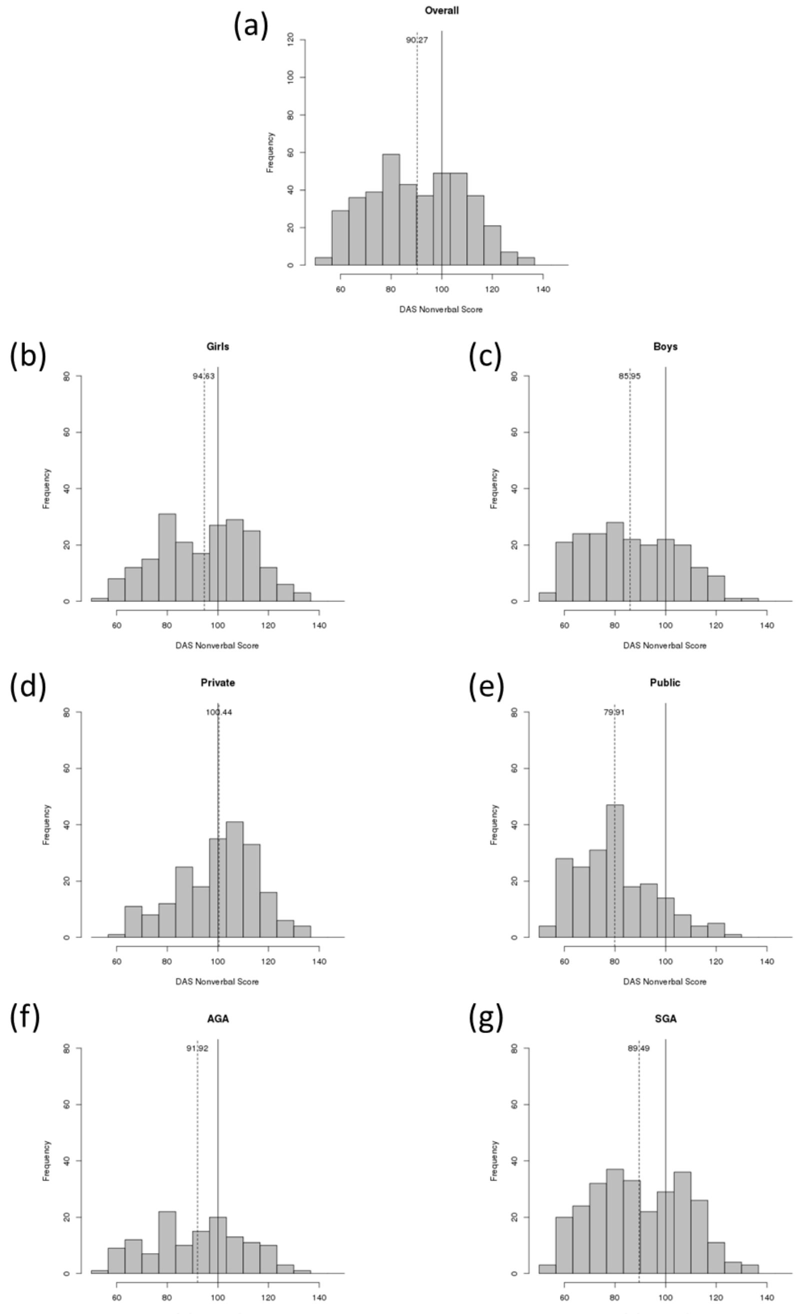
*SGA – small for gestational age (<10th percentile birthweight for gender, race, and gestational age), AGA – appropriate for gestational age (10 - <90th percentile birthweight for gender, race, and gestational age)
†Solid line represents population mean ($\mu = 0$), dashed line represents group mean (value provided)

Figure A2.4: Histograms of Differential Ability Scales (DAS) verbal score in the Follow-Up Development and Growth Experiences (FUDGE) Study – overall (a) and stratified by gender (b-c), hospital of birth (d-e), and small for gestational age (SGA) status (f-g)*†



*SGA – small for gestational age (<10th percentile birthweight for gender, race, and gestational age), AGA – appropriate for gestational age (10 - <90th percentile birthweight for gender, race, and gestational age)
†Solid line represents population mean (μ = 0), dashed line represents group mean (value provided)

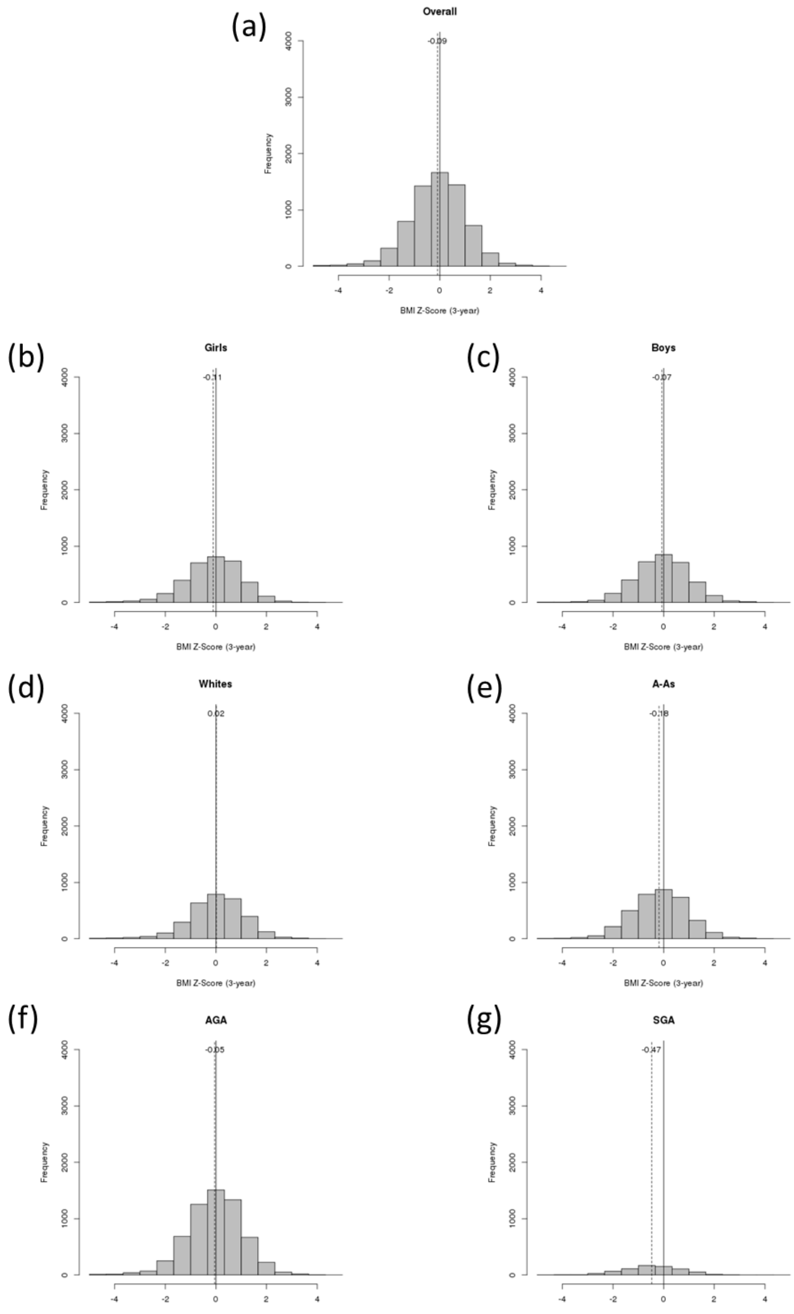
Figure A2.5: Histograms of Differential Ability Scales (DAS) nonverbal score in the Follow-Up Development and Growth Experiences (FUDGE) Study – overall (a) and stratified by gender (b-c), hospital of birth (d-e), and small for gestational age (SGA) status (f-g)*†



*SGA – small for gestational age (<10th percentile birthweight for gender, race, and gestational age), AGA – appropriate for gestational age (10 - <90th percentile birthweight for gender, race, and gestational age)

†Solid line represents population mean ($\mu = 0$), dashed line represents group mean (value provided)

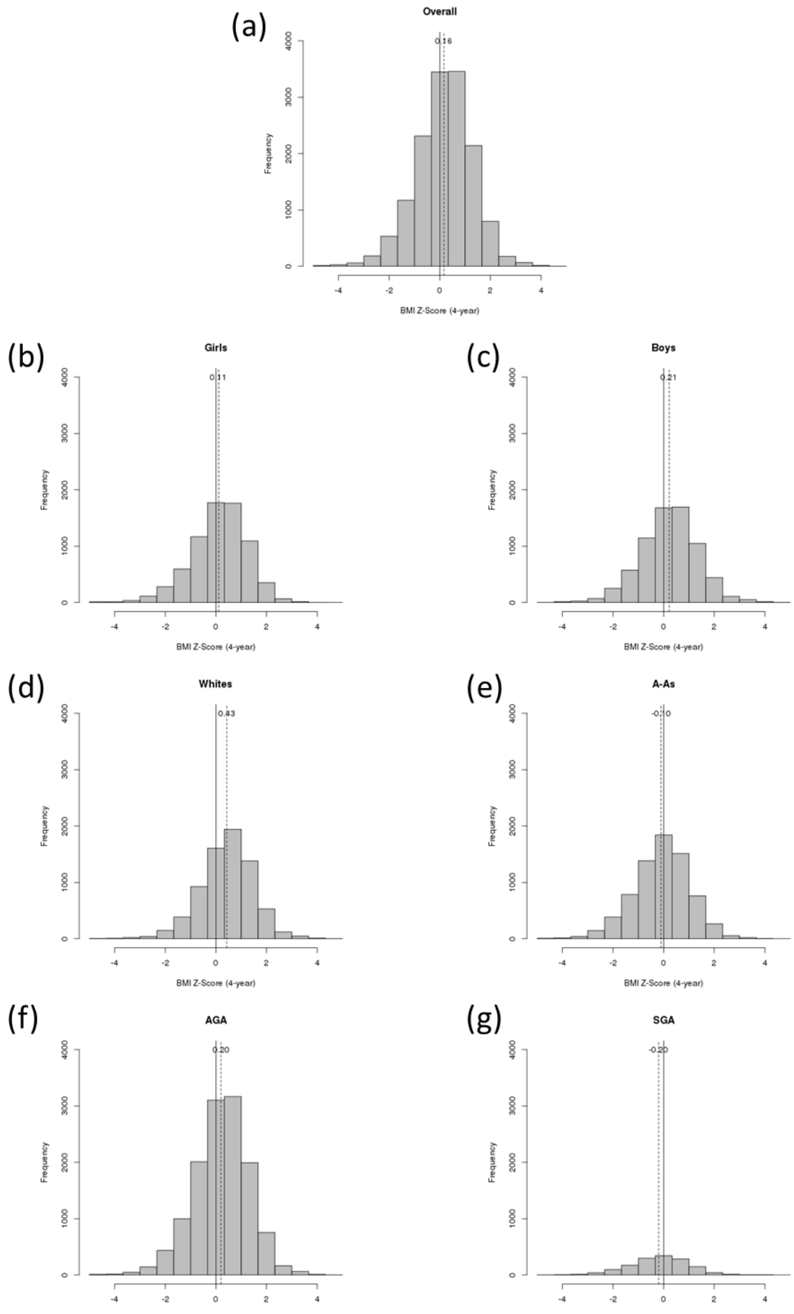
Figure A2.6: Histograms of body mass index (BMI) Z-score at age three years in the Collaborative Perinatal Project (CPP) – overall (a) and stratified by gender (b-c), race (d-e), and small for gestational age (SGA) status (f-g)*†



*A-As – African-Americans, SGA – small for gestational age (<10th percentile birthweight for gender, race, and gestational age), AGA – appropriate for gestational age (10 - <90th percentile birthweight for gender, race, and gestational age)

†Solid line represents population mean ($\mu = 0$), dashed line represents group mean (value provided)

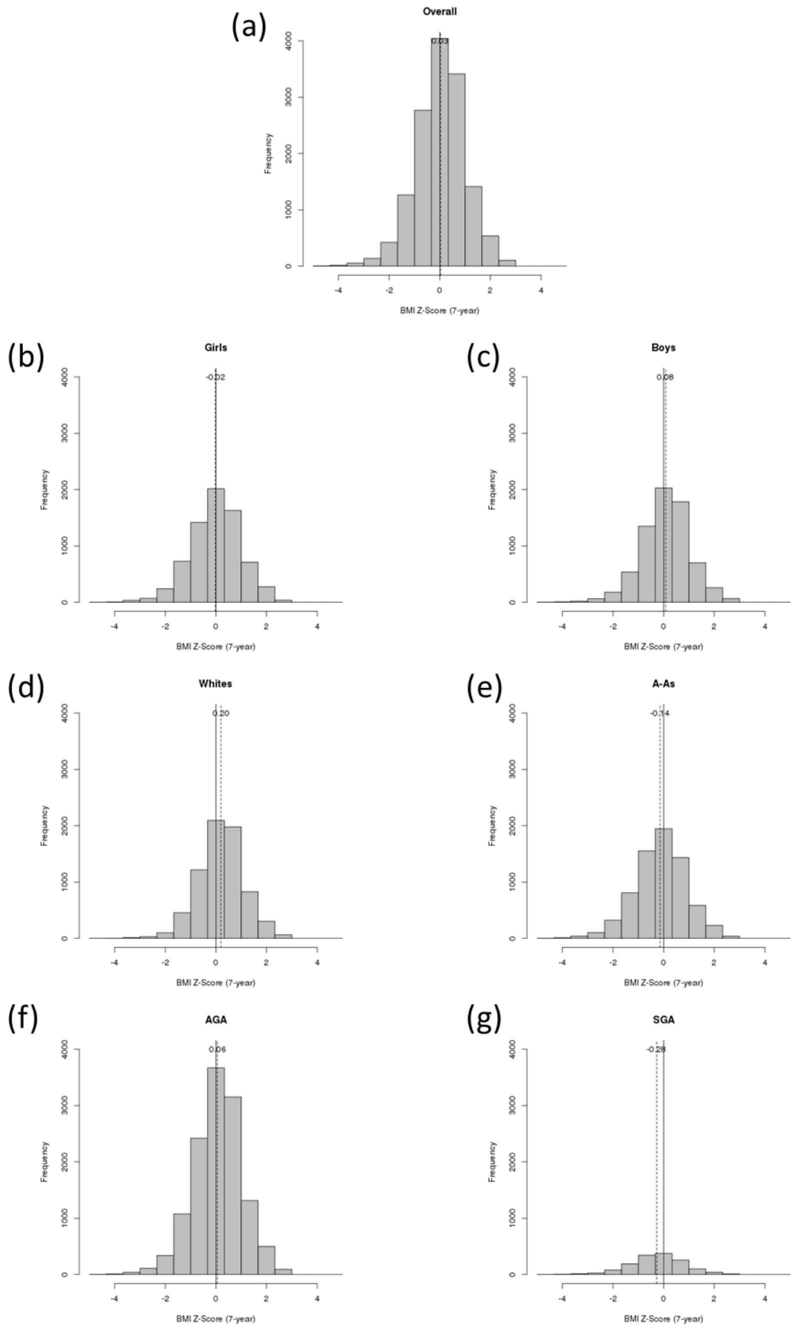
Figure A2.7: Histograms of body mass index (BMI) Z-score at age four years in the Collaborative Perinatal Project (CPP) – overall (a) and stratified by gender (b-c), race (d-e), and small for gestational age (SGA) status (f-g)*†



*A-As – African-Americans, SGA – small for gestational age (<10th percentile birthweight for gender, race, and gestational age), AGA – appropriate for gestational age (10 - <90th percentile birthweight for gender, race, and gestational age)

†Solid line represents population mean ($\mu = 0$), dashed line represents group mean (value provided)

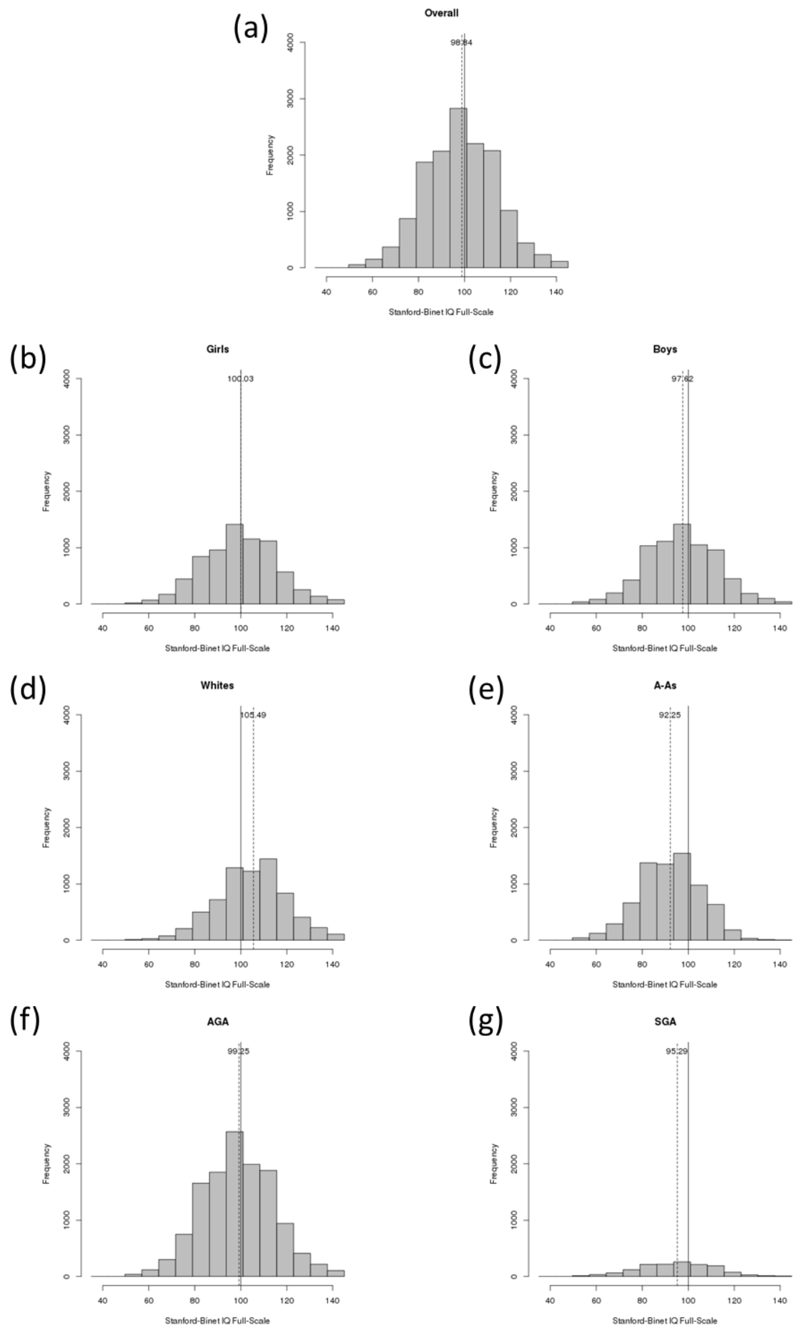
Figure A2.8: Histograms of body mass index (BMI) Z-score at age seven years in the Collaborative Perinatal Project (CPP) – overall (a) and stratified by gender (b-c), race (d-e), and small for gestational age (SGA) status (f-g)*†



*A-As – African-Americans, SGA – small for gestational age (<10th percentile birthweight for gender, race, and gestational age), AGA – appropriate for gestational age (10 - <90th percentile birthweight for gender, race, and gestational age)

†Solid line represents population mean (μ = 0), dashed line represents group mean (value provided)

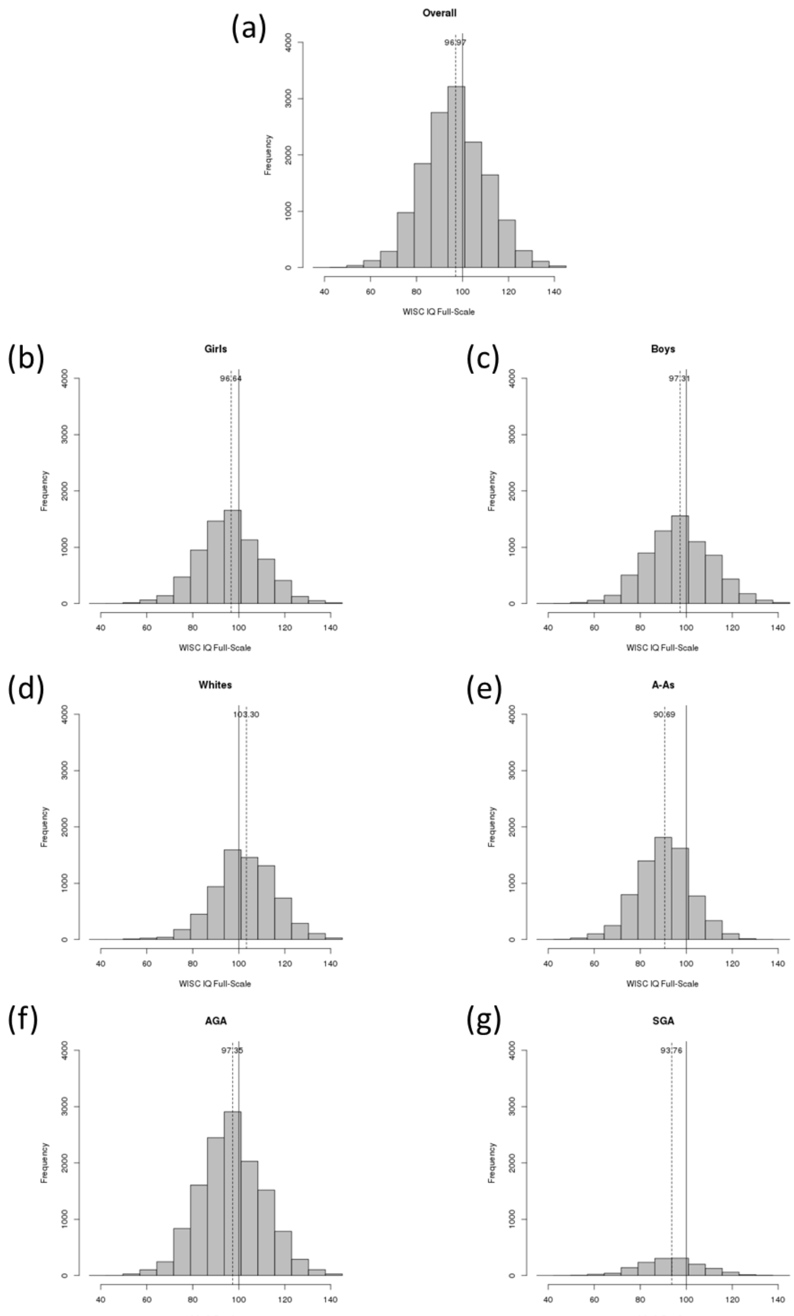
Figure A2.9: Histograms of Stanford-Binet Intelligence Scales composite score at age four years in the Collaborative Perinatal Project (CPP) – overall (a) and stratified by gender (b-c), race (d-e), and small for gestational age (SGA) status (f-g)*†



*A-As – African-Americans, SGA – small for gestational age (<10th percentile birthweight for gender, race, and gestational age), AGA – appropriate for gestational age (10 - <90th percentile birthweight for gender, race, and gestational age)

†Solid line represents population mean (μ = 0), dashed line represents group mean (value provided)

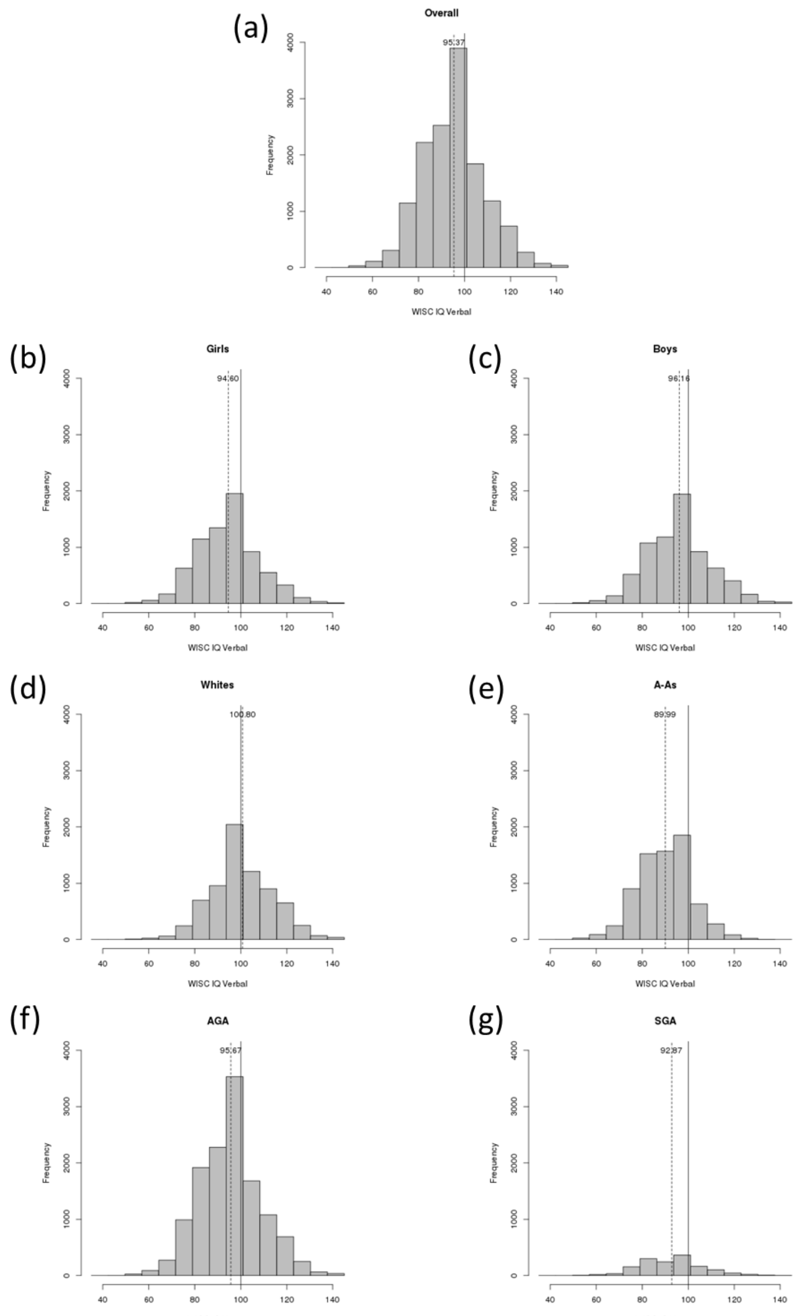
Figure A2.10: Histograms of Wechsler Intelligence Scales for Children (WISC) composite score at age seven years in the Collaborative Perinatal Project (CPP) – overall (a) and stratified by gender (b-c), race (d-e), and small for gestational age (SGA) status (f-g)*†



*A-As – African-Americans, SGA – small for gestational age (<10th percentile birthweight for gender, race, and gestational age), AGA – appropriate for gestational age (10 - <90th percentile birthweight for gender, race, and gestational age)

†Solid line represents population mean (μ = 0), dashed line represents group mean (value provided)

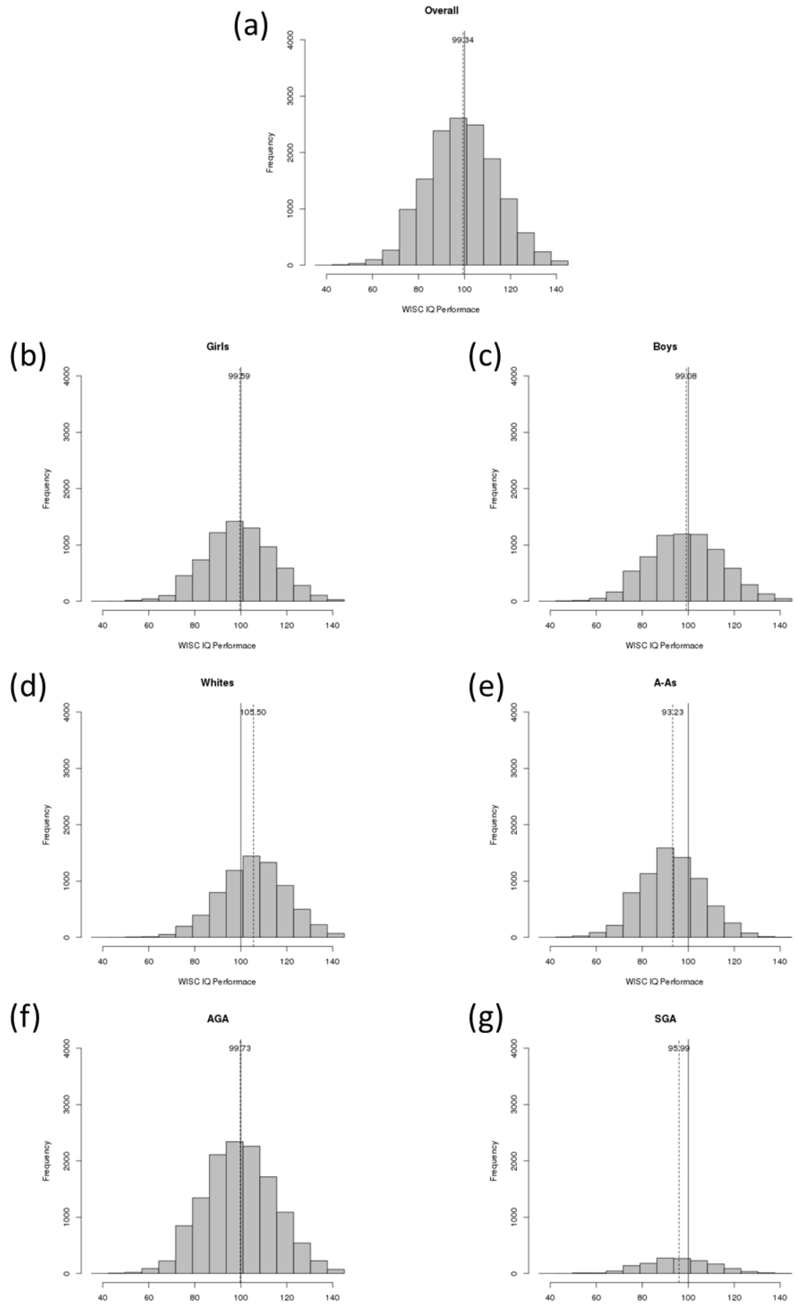
Figure A2.11: Histograms of Wechsler Intelligence Scales for Children (WISC) verbal score at age seven years in the Collaborative Perinatal Project (CPP) – overall (a) and stratified by gender (b-c), race (d-e), and small for gestational age (SGA) status (f-g)*†



*A-As – African-Americans, SGA – small for gestational age (<10th percentile birthweight for gender, race, and gestational age), AGA – appropriate for gestational age (10 - <90th percentile birthweight for gender, race, and gestational age)

†Solid line represents population mean (μ = 0), dashed line represents group mean (value provided)

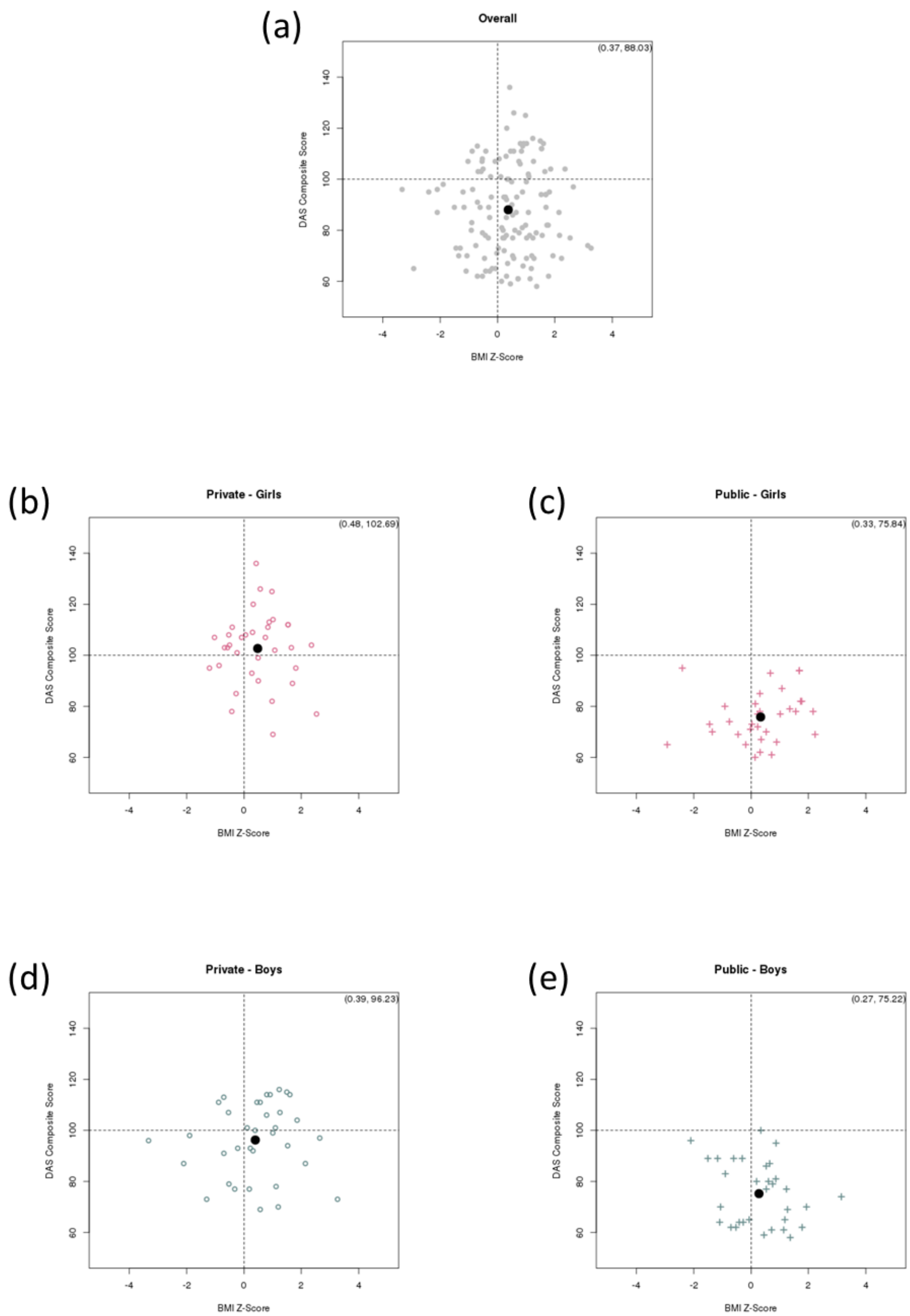
Figure A2.12: Histograms of Wechsler Intelligence Scales for Children (WISC) performance score at age seven years in the Collaborative Perinatal Project (CPP) – overall (a) and stratified by gender (b-c), race (d-e), and small for gestational age (SGA) status (f-g)*†



*A-As – African-Americans, SGA – small for gestational age (<10th percentile birthweight for gender, race, and gestational age), AGA – appropriate for gestational age (10 - <90th percentile birthweight for gender, race, and gestational age)

†Solid line represents population mean (μ = 0), dashed line represents group mean (value provided)

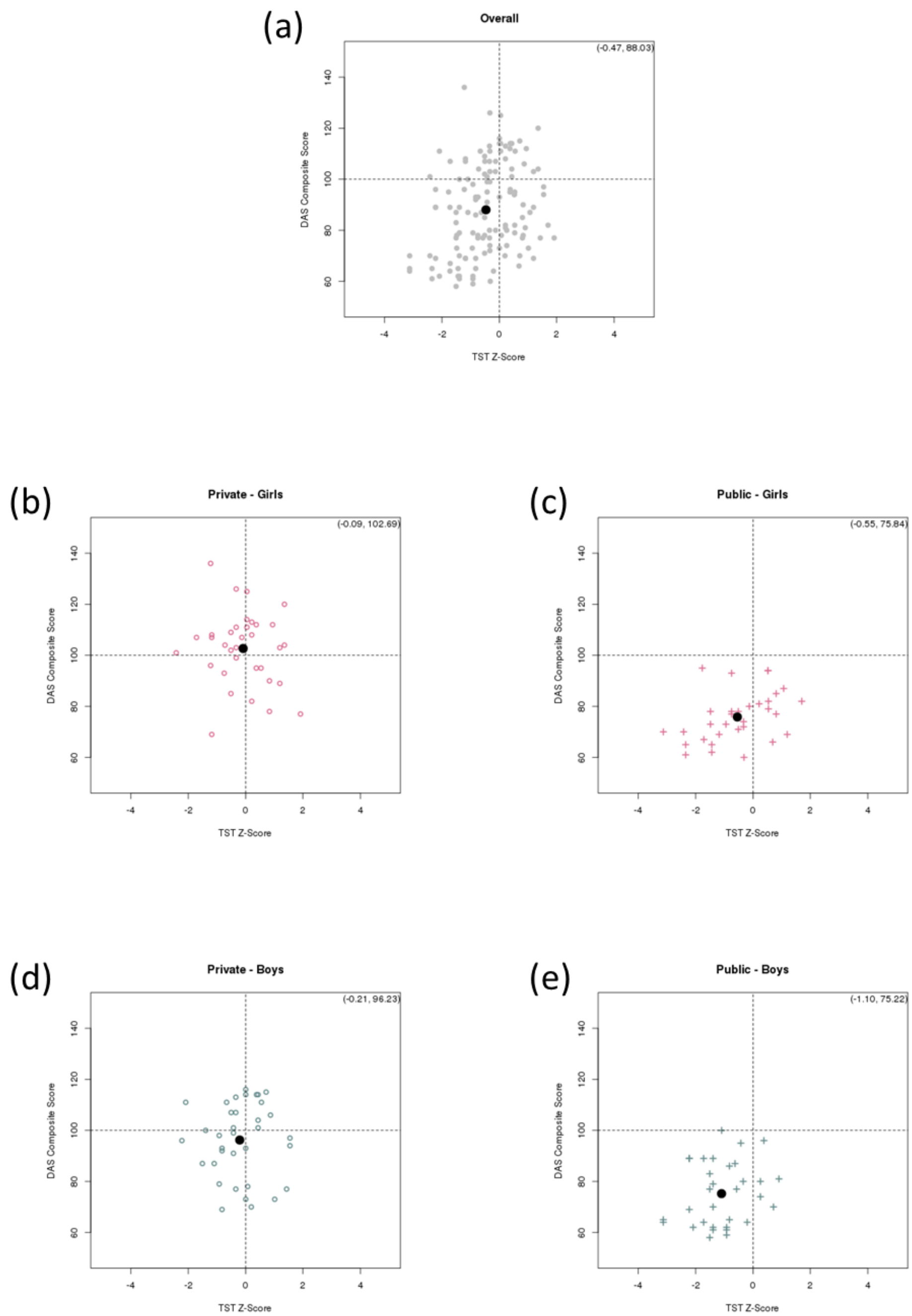
Figure A2.13: Scatter plots of body mass index (BMI) Z-score versus Differential Ability Scales (DAS) composite score in the Follow-Up Development and Growth Experiences (FUDGE) Study among children born appropriate for gestational age (AGA) – overall (a) and stratified by gender and hospital of birth (b-e)*†



* AGA – appropriate for gestational age (10 - <90th percentile birthweight for gender, race, and gestational age)

† The dot represents the centroid of each scatter plot, mean values provided in the upper right-hand corner

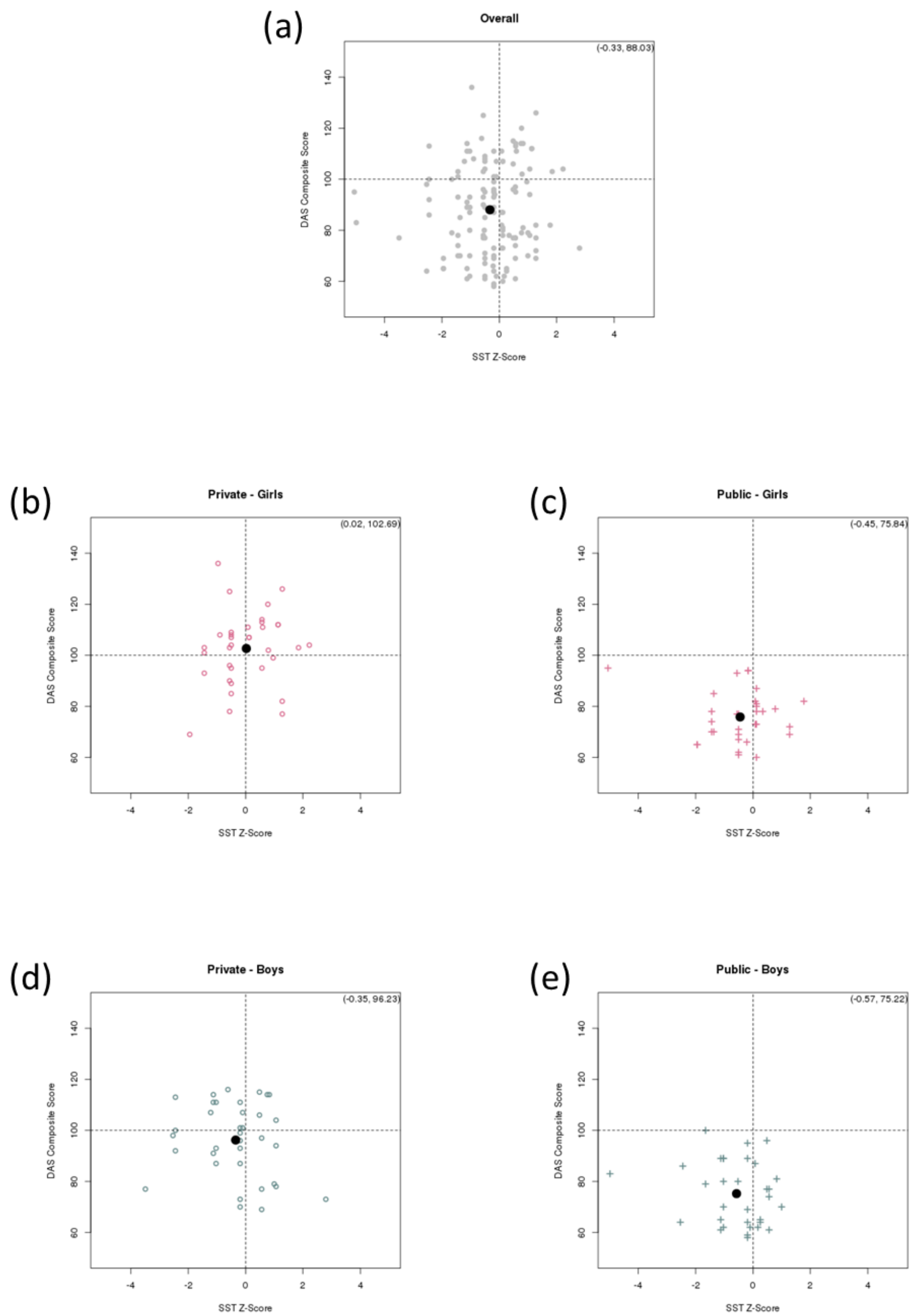
Figure A2.14: Scatter plots of triceps-skinfold-thickness (TST) Z-score versus DAS Composite score in the Follow-Up Development and Growth Experiences (FUDGE) Study among children born appropriate for gestational age (AGA) – overall (a) and stratified by gender and hospital of birth (b-e)*†



* AGA – appropriate for gestational age (10 - <90th percentile birthweight for gender, race, and gestational age)

† The dot represents the centroid of each scatter plot, mean values provided in the upper right-hand corner

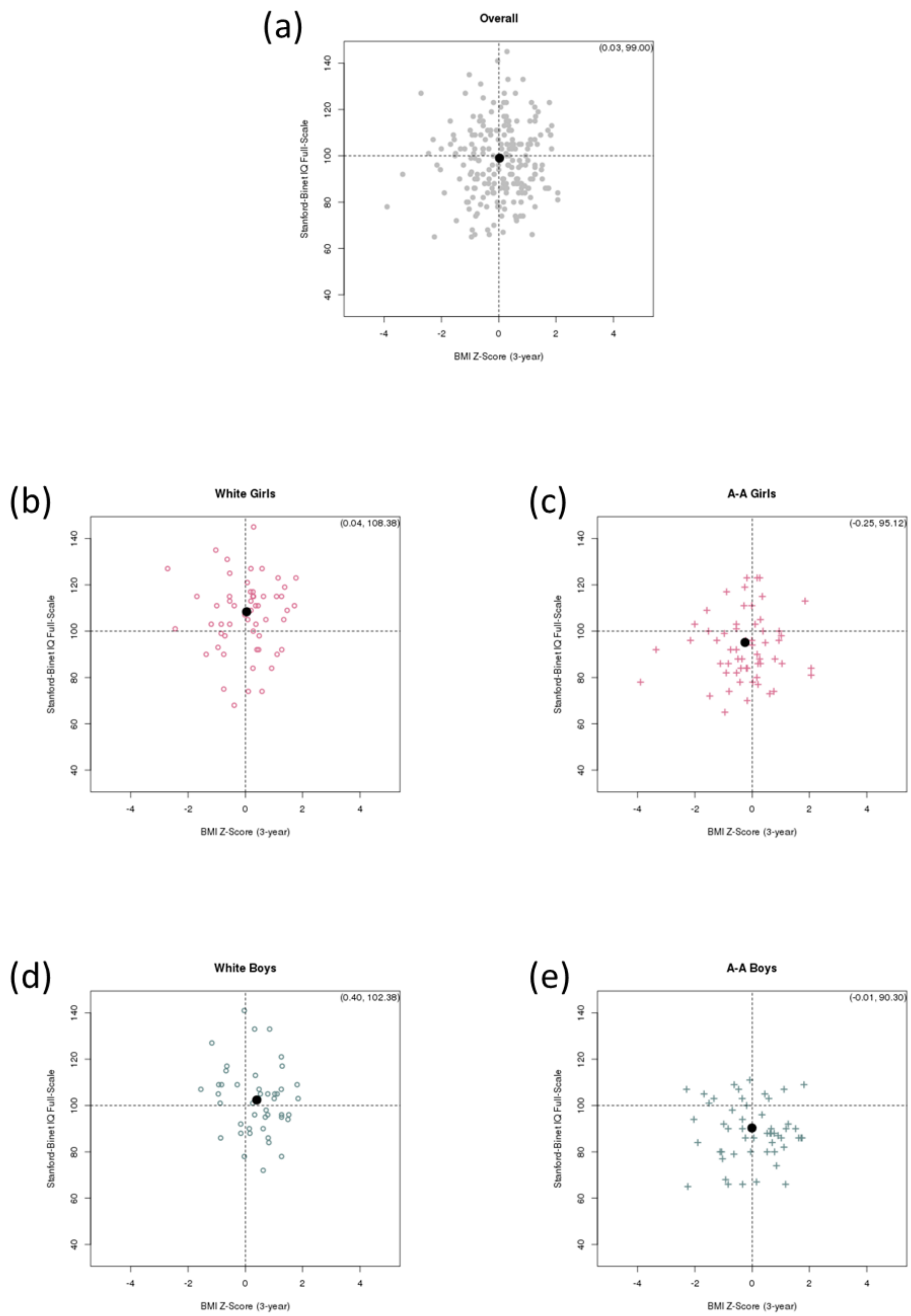
Figure A2.15: Scatter plots of subscapular-skinfold-thickness (SST) Z-score versus DAS Composite score in the Follow-Up Development and Growth Experiences (FUDGE) Study among children born appropriate for gestational age (AGA) – overall (a) and stratified by gender and hospital of birth (b-e)*†



* AGA – appropriate for gestational age (10 - <90th percentile birthweight for gender, race, and gestational age)

† The dot represents the centroid of each scatter plot, mean values provided in the upper right-hand corner

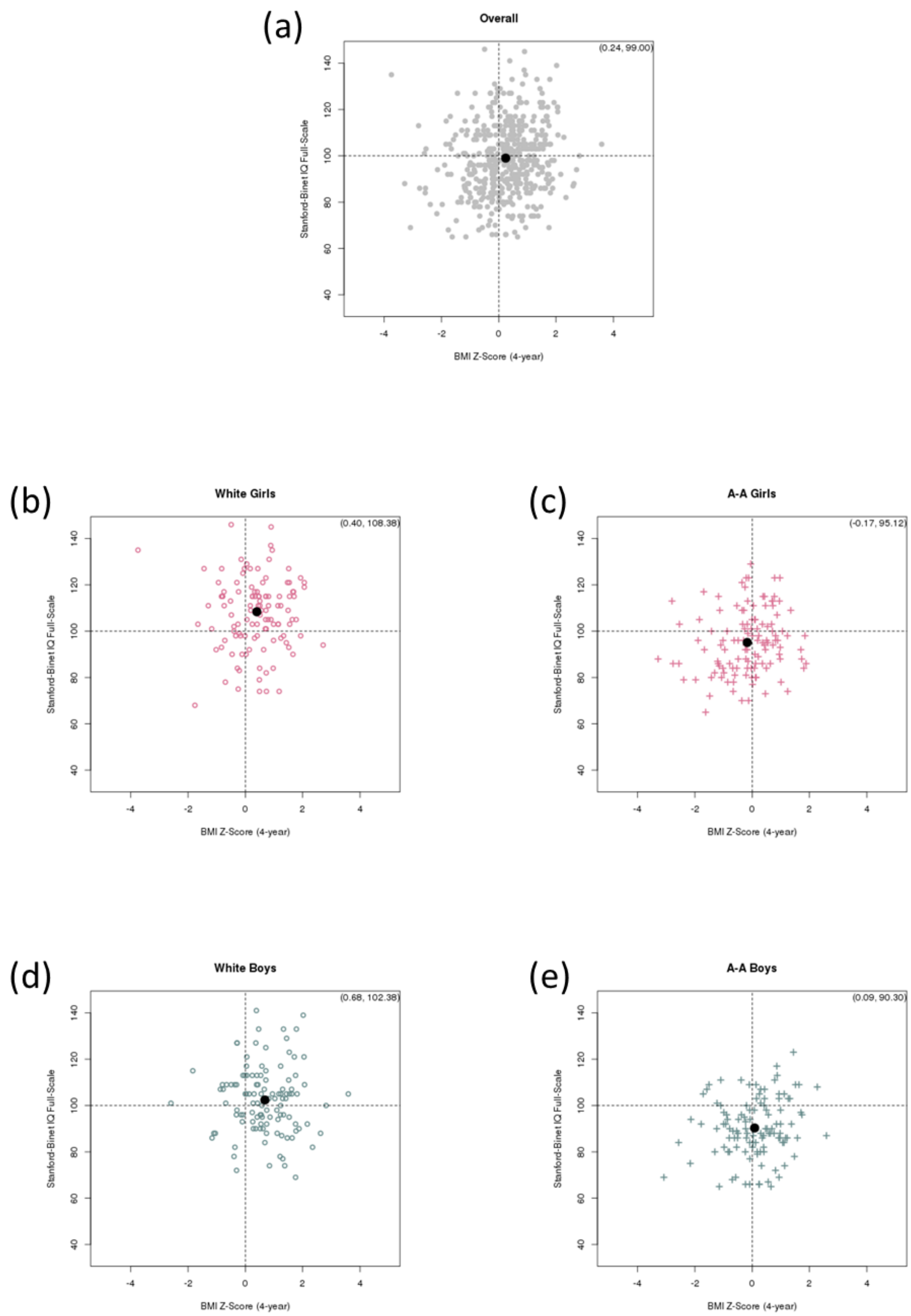
Figure A2.16: Scatter plots of body mass index (BMI) Z-score at age three years versus Stanford-Binet Intelligence Scales composite score at age four years in the Collaborative Perinatal Project (CPP) among children born appropriate for gestational age (AGA) – overall (a) and stratified by gender and race (b-e)*†



* AGA – appropriate for gestational age (10 - <90th percentile birthweight for gender, race, and gestational age)

† The dot represents the centroid of each scatter plot, mean values provided in the upper right-hand corner

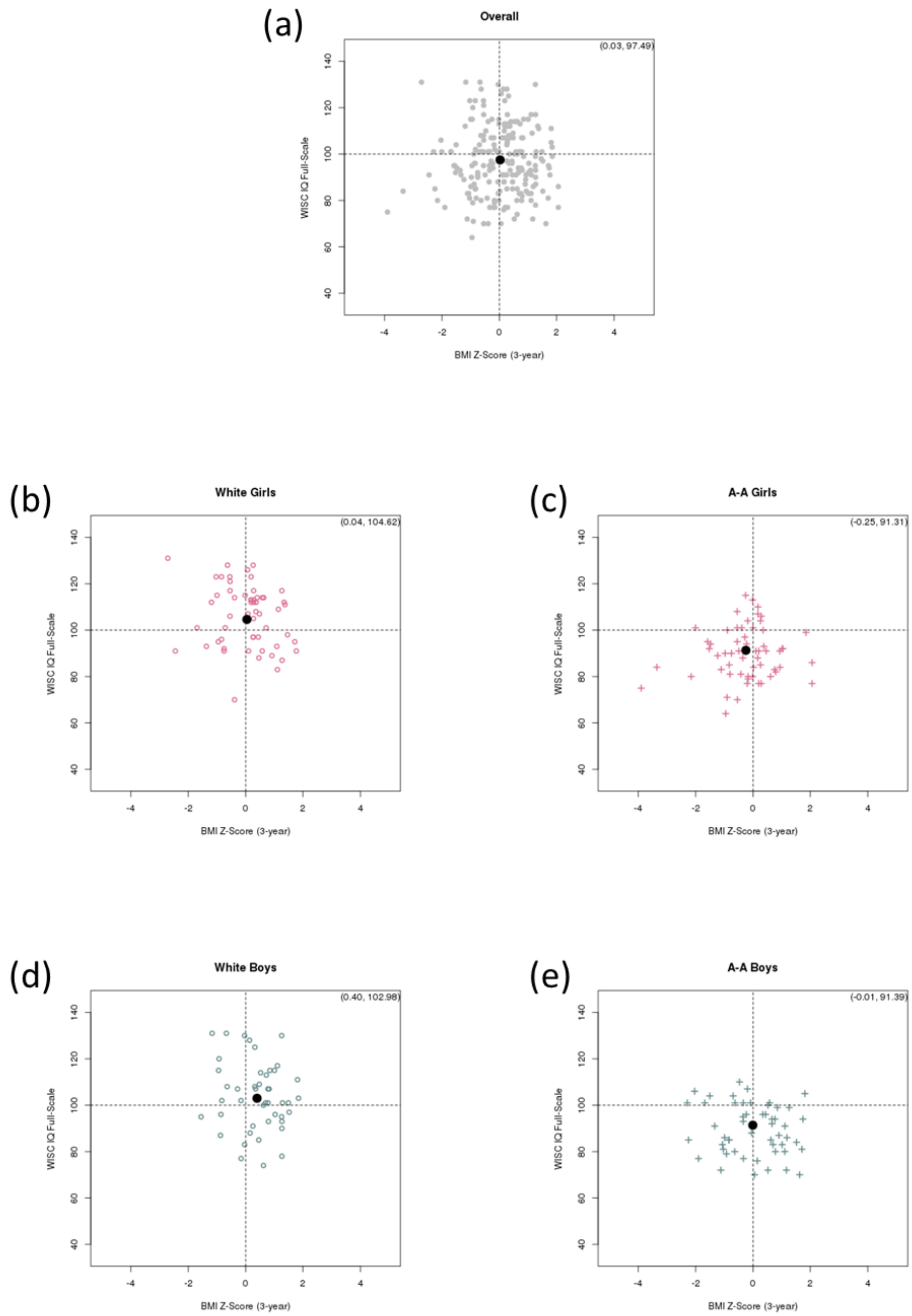
Figure A2.17: Scatter plots of body mass index (BMI) Z-score at age four years versus Stanford-Binet Intelligence Scales composite score at age four years in the Collaborative Perinatal Project (CPP) among children born appropriate for gestational age (AGA) – overall (a) and stratified by gender and race (b-e)*†



* AGA – appropriate for gestational age (10 - <90th percentile birthweight for gender, race, and gestational age)

† The dot represents the centroid of each scatter plot, mean values provided in the upper right-hand corner

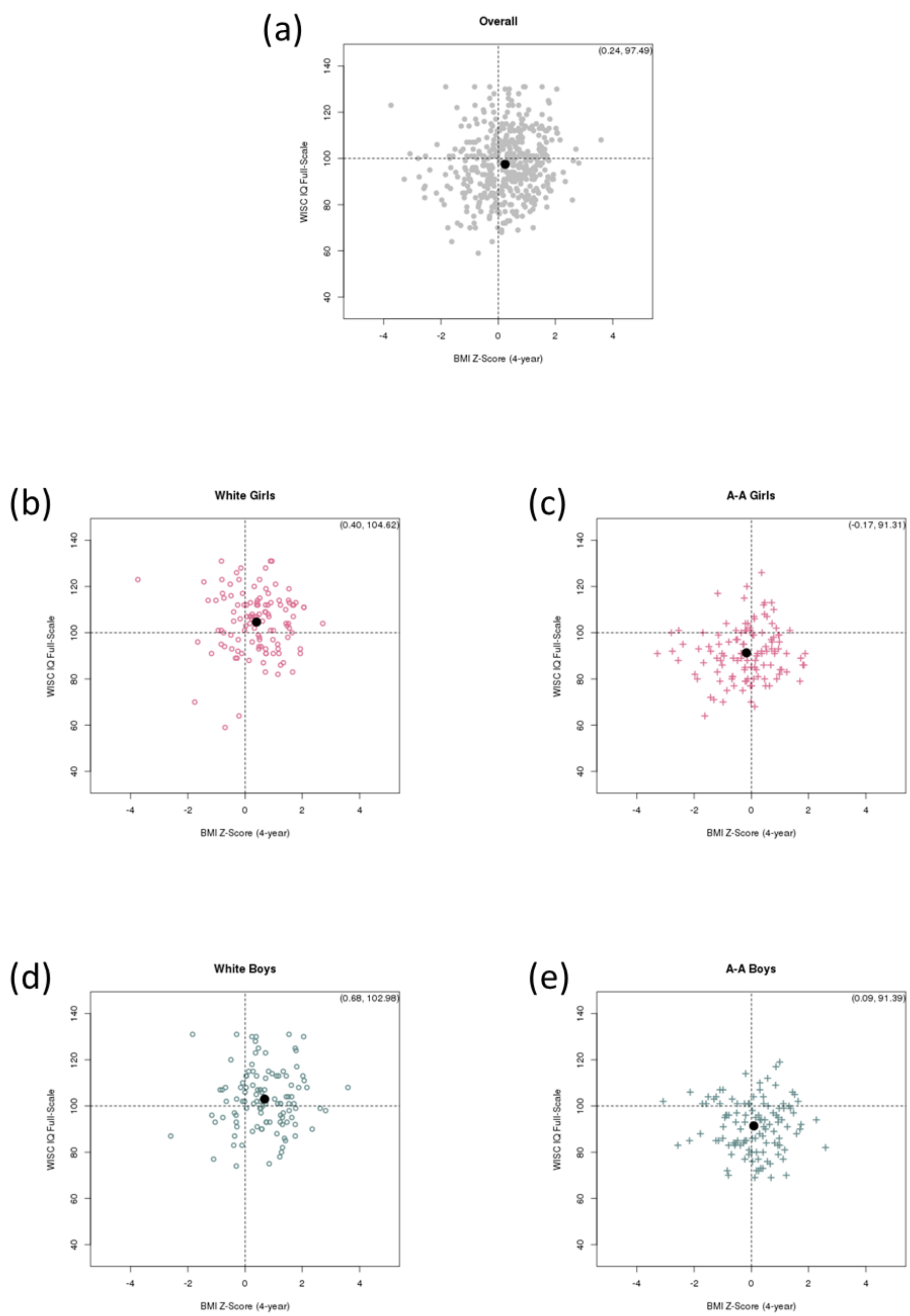
Figure A2.18: Scatter plots of body mass index (BMI) Z-score at age three years versus Wechsler Intelligence Scales for Children (WISC) composite score at age seven years in the Collaborative Perinatal Project (CPP) among children born appropriate for gestational age (AGA) – overall (a) and stratified by gender and race (b-e)*†



* AGA – appropriate for gestational age (10 - <90th percentile birthweight for gender, race, and gestational age)

† The dot represents the centroid of each scatter plot, mean values provided in the upper right-hand corner

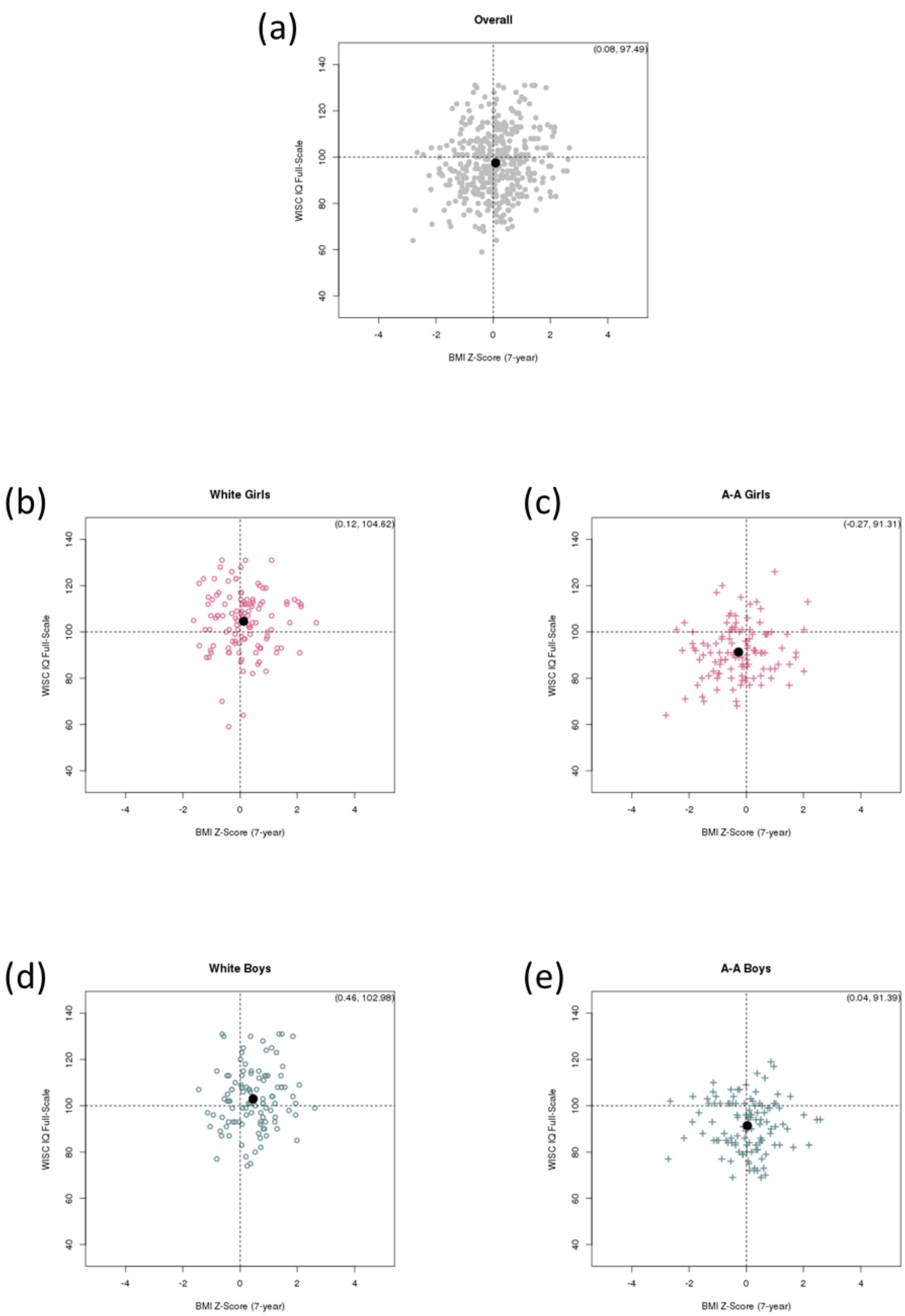
Figure A2.19: Scatter plots of body mass index (BMI) Z-score at age four years versus Wechsler Intelligence Scales for Children (WISC) composite score at age seven years in the Collaborative Perinatal Project (CPP) among children born appropriate for gestational age (AGA) – overall (a) and stratified by gender and race (b-e)*†



* AGA – appropriate for gestational age (10 - <90th percentile birthweight for gender, race, and gestational age)

† The dot represents the centroid of each scatter plot, mean values provided in the upper right-hand corner

Figure A2.20: Scatter plots of body mass index (BMI) Z-score at age seven years versus Wechsler Intelligence Scales for Children (WISC) composite score at age seven years in the Collaborative Perinatal Project (CPP) among children born appropriate for gestational age (AGA) – overall (a) and stratified by gender and race (b-e)
***†**



* AGA – appropriate for gestational age (10 - <90th percentile birthweight for gender, race, and gestational age)
† The dot represents the centroid of each scatter plot, mean values provided in the upper right-hand corner

Table A2.4: Change in Differential Ability Scales composite score in children classified as overweight/obese using body mass index (BMI), triceps-skinfold-thickness (TST), and subscapular-skinfold-thickness (SST), compared with normal weight children, overall and stratified by gender and hospital of birth in the Follow-Up Development and Growth Experiences Study; estimate (95% CI) *†‡

		Crude / Pooled	By gender		By hospital of birth	
			Girls	Boys	Private	Public
Model 1 (Crude)	BMI	-0.54 (-5.39, 4.30)				
	TST	1.92 (-5.94, 9.79)				
	SST	-1.69 (-8.12, 4.72)				
Model 2	BMI	-0.78 (-4.54, 2.96)	3.80 (-1.51, 9.11)	**-5.47 (-10.91, -0.03)**	-2.58 (-8.45, 3.29)	0.68 (-4.14, 5.51)
	TST	-3.35 (-9.32, 2.62)	-2.76 (-9.95, 4.42)	-4.60 (-15.91, 6.71)	-7.55 (-15.62, 0.50)	1.33 (-7.80, 10.47)
	SST	-4.56 (-9.37, 0.25)	-1.74 (-8.23, 4.74)	**-8.01 (-15.47, -0.56)**	-5.21 (-11.99, 1.56)	-3.84 (-10.78, 3.09)
Model 3	BMI	-0.69 (-4.41, 3.02)	3.42 (-1.81, 8.67)	-4.59 (-9.99, 0.81)	-2.23 (-8.11, 3.63)	0.68 (-4.11, 5.48)
	TST	-2.58 (-8.45, 3.28)	-2.20 (-9.30, 4.89)	-3.59 (-14.38, 7.19)	-5.29 (-13.40, 2.81)	-0.77 (-9.72, 8.17)
	SST	-4.11 (-8.83, 0.61)	-0.09 (-6.52, 6.33)	**-7.95 (-15.10, -0.80)**	-3.11 (-9.96, 3.72)	-5.62 (-12.43, 1.18)

*CI – confidence interval

†Overweight/obese: ≥85th percentile

‡Bold font indicates model results are significant at α = 0.05. Model 1 was unadjusted, Model 2 was adjusted for gender (when appropriate), hospital of birth (when appropriate), small for gestational age status, and prenatal alcohol consumption. Model 3 was adjusted for gender (when appropriate), hospital of birth (when appropriate), small for gestational age status, prenatal alcohol consumption, race, prenatal maternal smoking, current maternal smoking, maternal age, and maternal pre-pregnancy BMI.

Table A2.5: Change in Differential Ability Scales verbal score in children classified as overweight/obese using body mass index (BMI), triceps-skinfold-thickness (TST), and subscapular-skinfold-thickness (SST), compared with normal weight children, overall and stratified by gender and hospital of birth in the Follow-Up Development and Growth Experiences Study; estimate (95% CI)
*†‡

		Crude / Pooled	By gender		By hospital of birth	
			Girls	Boys	Private	Public
Model 1 (Crude)	BMI	-0.10 (-4.83, 4.62)				
	TST	4.92 (-2.73, 12.59)				
	SST	1.13 (-5.13, 7.40)				
Model 2	BMI	0.15 (-3.56, 3.87)	2.63 (-2.49, 7.76)	-2.03 (-7.62, 3.55)	-0.36 (-6.69, 5.95)	0.72 (-3.51, 4.97)
	TST	0.55 (-5.37, 6.49)	-0.74 (-7.67, 6.17)	3.52 (-8.01, 15.07)	-1.02 (-9.78, 7.72)	1.43 (-6.60, 9.48)
	SST	-1.42 (-6.21, 3.37)	-0.28 (-6.54, 5.96)	-2.68 (-10.35, 4.98)	-1.03 (-8.37, 6.29)	-2.10 (-8.22, 4.01)
Model 3	BMI	-0.21 (-3.88, 3.45)	1.42 (-3.67, 6.52)	-1.31 (-6.81, 4.17)	-0.90 (-7.29, 5.48)	0.02 (-4.11, 4.16)
	TST	0.52 (-5.28, 6.32)	-1.49 (-8.38, 5.38)	5.13 (-5.76, 16.03)	-0.05 (-8.91, 8.80)	-1.08 (-8.80, 6.63)
	SST	-1.90 (-6.58, 2.77)	0.05 (-6.17, 6.28)	-3.55 (-10.86, 3.74)	-0.64 (-8.10, 6.81)	-4.51 (-10.39, 1.36)

*CI – confidence interval
†Overweight/obese: ≥85th percentile
‡Bold font indicates model results are significant at α = 0.05. Model 1 was unadjusted, Model 2 was adjusted for gender (when appropriate), hospital of birth (when appropriate), small for gestational age status, and prenatal alcohol consumption. Model 3 was adjusted for gender (when appropriate), hospital of birth (when appropriate), small for gestational age status, prenatal alcohol consumption, race, prenatal maternal smoking, current maternal smoking, maternal age, and maternal pre-pregnancy BMI.

Table A2.6: Change in Differential Ability Scales nonverbal score in children classified as overweight/obese using body mass index (BMI), triceps-skinfold-thickness (TST), and subscapular-skinfold-thickness (SST), compared with normal weight children, overall and stratified by gender and hospital of birth in the Follow-Up Development and Growth Experiences Study; estimate (95% CI) *†‡

		Crude / Pooled	By gender		By hospital of birth	
			Girls	Boys	Private	Public
Model 1 (Crude)	BMI	0.55 (-4.47, 5.58)				
	TST	2.01 (-6.14, 10.17)				
	SST	-1.80 (-8.46, 4.86)				
Model 2	BMI	0.15 (-4.10, 4.41)	**7.07 (1.28, 12.86)**	**-6.92 (-13.25, -0.59)**	-1.29 (-7.40, 4.80)	1.07 (-4.92, 7.07)
	TST	-3.09 (-9.87, 3.67)	-0.76 (-8.67, 7.14)	-8.63 (-21.79, 4.51)	**-8.65 (-17.02, -0.29)**	3.89 (-7.45, 15.24)
	SST	-4.49 (-9.96, 0.96)	-0.42 (-7.56, 6.71)	**-9.65 (-18.33, -0.97)**	-6.25 (-13.28, 0.76)	-2.21 (-10.85, 6.42)
Model 3	BMI	0.70 (-3.58, 4.98)	**7.75 (1.94, 13.56)**	-6.11 (-12.53, 0.30)	-0.25 (-6.44, 5.92)	1.57 (-4.45, 7.60)
	TST	-1.73 (-8.49, 5.03)	0.95 (-7.02, 8.93)	-8.18 (-20.98, 4.61)	-5.76 (-14.28, 2.75)	2.03 (-9.21, 13.28)
	SST	-3.28 (-8.73, 2.16)	2.19 (-5.01, 9.41)	**-8.99 (-17.51, -0.47)**	-3.32 (-10.51, 3.86)	-3.41 (-12.02, 5.18)

*CI – confidence interval

†Overweight/obese: ≥85th percentile

‡Bold font indicates model results are significant at α = 0.05. Model 1 was unadjusted, Model 2 was adjusted for gender (when appropriate), hospital of birth (when appropriate), small for gestational age status, and prenatal alcohol consumption. Model 3 was adjusted for gender (when appropriate), hospital of birth (when appropriate), small for gestational age status, prenatal alcohol consumption, race, prenatal maternal smoking, current maternal smoking, maternal age, and maternal pre-pregnancy BMI.

Table A2.7: Association between obesity status classified using body mass index (BMI) and Stanford-Binet Intelligence Scales full-scale IQ score at age four years in the Collaborative Perinatal Project, overall and stratified by gender, race, and gender/race; estimate (95% CI) *†‡

		Crude / Pooled	By gender		By race		By gender and race			
			Girls	Boys	Whites	A-A	White girls	A-A girls	White boys	A-A Boys
Model 1(Crude)	Under-weight	**-5.03 (-6.14, -3.92)**								
	Normal	0.00 (ref)								
	Over-weight	**4.69 (3.91, 5.46)**								
	Obese	**4.43 (3.44, 5.42)**								
Model 2	Under-weight	**-2.21 (-3.19, -1.24)**	**-1.61 (-2.94, -0.28)**	**-2.94 (-4.37, -1.51)**	-1.76 (-3.69, 0.17)	**-2.44 (-3.52, -1.37)**	-1.06 (-3.77, 1.63)	**-1.95 (-3.40, -0.50)**	-2.60 (-5.37, 0.16)	**-3.02 (-4.63, -1.42)**
	Normal	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)
	Over-weight	**1.91 (1.23, 2.59)**	**1.84 (0.87, 2.82)**	**1.97 (1.02, 2.93)**	**1.67 (0.76, 2.59)**	**1.85 (0.81, 2.89)**	**1.65 (0.31, 2.98)**	**1.69 (0.23, 3.15)**	**1.70 (0.44, 2.96)**	**2.04 (0.56, 3.52)**
	Obese	**1.62 (0.75, 2.48)**	**1.45 (0.12, 2.78)**	**1.76 (0.63, 2.89)**	**1.29 (0.14, 2.43)**	**1.84 (0.47, 3.20)**	0.58 (-1.21, 2.39)	**2.68 (0.64, 4.72)**	**1.79 (0.32, 3.26)**	1.13 (-0.70, 2.97)
Model 3	Under-weight	**-2.05 (-3.03, -1.06)**	-1.29 (-2.64, 0.05)	**-2.95 (-4.40, -1.50)**	-1.75 (-3.74, 0.23)	**-2.17 (-3.25, -1.09)**	-0.30 (-3.09, 2.49)	**-1.77 (-3.23, -0.30)**	**-3.32 (-6.16, -0.47)**	**-2.65 (-4.26, -1.04)**
	Normal	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)
	Over-weight	**1.79 (1.08, 2.51)**	**1.65 (0.63, 2.67)**	**1.93 (0.94, 2.93)**	**1.57 (0.59, 2.55)**	**1.79 (0.73, 2.84)**	1.34 (-0.08, 2.76)	**1.71 (0.22, 3.19)**	**1.79 (0.44, 3.14)**	**1.88 (0.38, 3.38)**
	Obese	**1.84 (0.92, 2.76)**	**1.47 (0.06, 2.88)**	**2.13 (0.93, 3.33)**	**1.69 (0.45, 2.93)**	**1.77 (0.38, 3.17)**	0.64 (-1.29, 2.59)	**2.52 (0.43, 4.61)**	**2.37 (0.77, 3.97)**	1.18 (-0.68, 3.06)

*CI – confidence interval, A-A – African-American

†Underweight: <5th percentile, normal weight 5 - <85th percentile, overweight: 85th - <95th percentile, obese: ≥95th percentile

‡Bold font indicates model results are significant at α = 0.05. Model 1 was unadjusted, Model 2 was adjusted for gender (when appropriate), race (when appropriate), study site, and socioeconomic index (SEI), Model 3 was adjusted for gender (when appropriate), race (when appropriate), study site, SEI, small for gestational age status, current maternal smoking, maternal age, and maternal pre-pregnancy BMI.

Table A2.8: Association between obesity status classified using body mass index (BMI) and Wechsler Intelligence Scales for Children full-scale IQ score at age seven years in the Collaborative Perinatal Project, overall and stratified by gender, race, and gender/race; estimate (95% CI)*†‡

Model		Crude / Pooled	By gender		By race		By gender and race			
			Girls	Boys	Whites	A-A	White girls	A-A girls	White boys	A-A Boys
Model 1 (Crude)	Under-weight	**-6.27 (-7.35, -5.20)**								
	Normal	0.00 (ref)								
	Over-weight	**2.31 (1.50, 3.11)**								
	Obese	**2.75 (1.66, 3.83)**								
Model 2	Under-weight	**-2.52 (-3.44, -1.60)**	**-2.99 (-4.21, -1.77)**	**-2.09 (-3.49, -0.68)**	**-3.51 (-5.37, -1.65)**	**-2.13 (-3.17, -1.08)**	**-4.70 (-7.30, -2.11)**	**-2.51 (-3.86, -1.17)**	-2.19 (-4.86, 0.48)	**-1.64 (-3.28, -0.00)**
	Normal	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)
	Over-weight	**0.88 (0.19, 1.56)**	0.63 (-0.32, 1.58)	**1.05 (0.07, 2.02)**	0.16 (-0.75, 1.08)	**1.76 (0.74, 2.78)**	-0.00 (-1.34, 1.33)	1.33 (-0.03, 2.69)	0.32 (-0.93, 1.57)	**2.25 (0.71, 3.78)**
	Obese	**1.59 (0.66, 2.51)**	1.27 (-0.03, 2.58)	**1.71 (0.39, 3.02)**	1.22 (-0.03, 2.47)	**2.03 (0.65, 3.41)**	1.32 (-0.58, 3.24)	1.56 (-0.21, 3.34)	1.11 (-0.53, 2.76)	**2.64 (0.47, 4.81)**
Model 3	Under-weight	**-2.34 (-3.28, -1.39)**	**-2.61 (-3.86, -1.36)**	**-2.17 (-3.60, -0.75)**	**-2.82 (-4.77, -0.86)**	**-2.10 (-3.15, -1.04)**	**-3.33 (-6.08, -0.58)**	**-2.47 (-3.83, -1.10)**	-2.20 (-4.99, 0.57)	**-1.67 (-3.32, -0.03)**
	Normal	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)
	Over-Weight	**1.23 (0.51, 1.94)**	**1.03 (0.03, 2.02)**	**1.35 (0.33, 2.38)**	0.68 (-0.29, 1.66)	**1.79 (0.75, 2.82)**	0.50 (-0.92, 1.93)	**1.50 (0.12, 2.89)**	0.84 (-0.50, 2.19)	**2.12 (0.56, 3.68)**
	Obese	**1.97 (1.00, 2.95)**	**1.80 (0.43, 3.18)**	**1.99 (0.61, 3.37)**	**1.69 (0.35, 3.04)**	**2.25 (0.84, 3.66)**	1.97 (-0.07, 4.03)	1.81 (-0.01, 3.65)	1.46 (-0.31, 3.25)	**2.78 (0.59, 4.97)**

*CI – confidence interval, A-A – African-American

†Underweight: <5th percentile, normal weight 5 - <85th percentile, overweight: 85th - <95th percentile, obese: ≥95th percentile

‡Bold font indicates model results are significant at α = 0.05. Model 1 was unadjusted, Model 2 was adjusted for gender (when appropriate), race (when appropriate), study site, and socioeconomic index (SEI), Model 3 was adjusted for gender (when appropriate), race (when appropriate), study site, SEI, small for gestational age status, current maternal smoking, maternal age, and maternal pre-pregnancy BMI.

Table A2.9: Association between obesity status classified using body mass index (BMI) and Wechsler Intelligence Scales for Children verbal IQ score at age seven years in the Collaborative Perinatal Project, overall and stratified by gender, race, and gender/race; estimate (95% CI) *†‡

		Crude / Pooled	By gender		By race		By gender and race			
			Girls	Boys	Whites	A-A	White girls	A-A girls	White boys	A-A Boys
Model 1 (Crude)	Under-weight	**-5.74 (-6.80, -4.69)**								
	Normal	0.00 (ref)								
	Over-weight	**2.31 (1.52, 3.10)**								
	Obese	**2.91 (1.84, 3.98)**								
Model 2	Under-weight	**-2.45 (-3.38, -1.51)**	**-2.79 (-4.04, -1.53)**	**-2.16 (-3.57, -0.76)**	**-3.49 (-5.41, -1.57)**	**-2.06 (-3.10, -1.03)**	**-4.88 (-7.58, -2.18)**	**-2.20 (-3.56, -0.84)**	-1.99 (-4.73, 0.74)	**-1.92 (-3.51, -0.32)**
	Normal	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)
	Over-weight	**1.03 (0.33, 1.72)**	0.79 (-0.18, 1.77)	**1.18 (0.20, 2.16)**	0.46 (-0.48, 1.41)	**1.75 (0.74, 2.77)**	0.20 (-1.18, 1.59)	**1.46 (0.08, 2.83)**	0.70 (-0.58, 1.99)	**2.08 (0.58, 3.59)**
	Obese	**1.91 (0.97, 2.85)**	**1.60 (0.26, 2.93)**	**2.04 (0.72, 3.36)**	1.21 (-0.07, 2.50)	**2.90 (1.53, 4.27)**	1.17 (-0.80, 3.15)	**2.39 (0.60, 4.19)**	1.23 (-0.45, 2.93)	**3.60 (1.47, 5.73)**
Model 3	Under-weight	**-2.45 (-3.40, -1.49)**	**-2.66 (-3.95, -1.38)**	**-2.33 (-3.76, -0.90)**	**-3.47 (-5.48, -1.45)**	**-2.02 (-3.07, -0.97)**	**-4.52 (-7.36, -1.67)**	**-2.17 (-3.55, -0.78)**	-2.30 (-5.16, 0.55)	**-1.89 (-3.49, -0.28)**
	Normal	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)
	Over-weight	**1.32 (0.59, 2.04)**	**1.21 (0.19, 2.23)**	**1.35 (0.32, 2.37)**	0.91 (-0.09, 1.92)	**1.76 (0.73, 2.79)**	0.73 (-0.75, 2.21)	**1.67 (0.27, 3.07)**	1.08 (-0.30, 2.47)	**1.88 (0.35, 3.41)**
	Obese	**2.19 (1.20, 3.18)**	**1.99 (0.58, 3.39)**	**2.24 (0.85, 3.63)**	**1.52 (0.14, 2.91)**	**3.06 (1.66, 4.46)**	1.60 (-0.52, 3.73)	**2.58 (0.73, 4.43)**	1.47 (-0.35, 3.31)	**3.71 (1.56, 5.85)**

*CI – confidence interval, A-A – African-American

†Underweight: <5th percentile, normal weight 5 - <85th percentile, overweight: 85th - <95th percentile, obese: ≥95th percentile

‡Bold font indicates model results are significant at $\alpha = 0.05$. Model 1 was unadjusted, Model 2 was adjusted for gender (when appropriate), race (when appropriate), study site, and socioeconomic index (SEI), Model 3 was adjusted for gender (when appropriate), race (when appropriate), study site, SEI, small for gestational age status, current maternal smoking, maternal age, and maternal pre-pregnancy BMI.

Table A2.10: Association between obesity status classified using body mass index (BMI) and Wechsler Intelligence Scales for Children performance IQ score at age seven years in the Collaborative Perinatal Project, overall and stratified by gender, race, and gender/race; estimate (95% CI) *†‡

		Crude / Pooled	By gender		By race		By gender and race			
			Girls	Boys	Whites	A-A	White girls	A-A girls	White boys	A-A Boys
Model 1 (Crude)	Under-weight	**-5.55 (-6.71, -4.40)**								
	Normal	0.00 (ref)								
	Over-weight	**1.96 (1.10, 2.82)**								
	Obese	**1.94 (0.78, 3.11)**								
Model 2	Under-weight	**-1.99 (-3.03, -0.95)**	**-2.34 (-3.68, -1.00)**	**-1.68 (-3.30, -0.06)**	**-2.60 (-4.70, -0.51)**	**-1.69 (-2.87, -0.52)**	**-3.08 (-5.90, -0.26)**	**-2.17 (-3.66, -0.68)**	-2.04 (-5.15, 1.06)	-1.10 (-2.98, 0.77)
	Normal	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)
	Over-weight	0.64 (-0.12, 1.41)	0.42 (-0.62, 1.47)	0.79 (-0.33, 1.92)	-0.15 (-1.18, 0.87)	**1.61 (0.46, 2.77)**	-0.05 (-1.50, 1.40)	0.91 (-0.59, 2.42)	-0.24 (-1.70, 1.21)	**2.41 (0.64, 4.18)**
	Obese	0.83 (-0.21, 1.87)	0.65 (-0.77, 2.08)	0.85 (-0.67, 2.37)	0.86 (-0.54, 2.26)	0.65 (-0.90, 2.21)	1.19 (-0.86, 3.26)	0.36 (-1.60, 2.33)	0.54 (-1.37, 2.47)	1.01 (-1.49, 3.51)
Model 3	Under-weight	**-1.76 (-2.82, -0.70)**	**-1.97 (-3.34, -0.59)**	**-1.66 (-3.30, -0.01)**	-1.69 (-3.89, 0.50)	**-1.72 (-2.91, -0.53)**	-1.62 (-4.61, 1.36)	**-2.16 (-3.68, -0.64)**	-1.68 (-4.91, 1.54)	-1.22 (-3.11, 0.66)
	Normal	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)
	Over-weight	**1.02 (0.22, 1.83)**	0.74 (-0.34, 1.84)	**1.24 (0.06, 2.42)**	0.36 (-0.73, 1.47)	**1.69 (0.51, 2.86)**	0.39 (-1.16, 1.95)	1.02 (-0.50, 2.56)	0.33 (-1.23, 1.89)	**2.45 (0.65, 4.25)**
	Obese	**1.28 (0.18, 2.38)**	1.23 (-0.26, 2.74)	1.20 (-0.39, 2.80)	1.42 (-0.08, 2.94)	0.92 (-0.66, 2.51)	1.95 (-0.28, 4.19)	0.62 (-1.40, 2.65)	0.97 (-1.09, 3.04)	1.22 (-1.29, 3.75)

*CI – confidence interval, A-A – African-American

†Underweight: <5th percentile, normal weight 5 - <85th percentile, overweight: 85th - <95th percentile, obese: ≥95th percentile

‡Bold font indicates model results are significant at $\alpha = 0.05$. Model 1 was unadjusted, Model 2 was adjusted for gender (when appropriate), race (when appropriate), study site, and socioeconomic index (SEI), Model 3 was adjusted for gender (when appropriate), race (when appropriate), study site, SEI, small for gestational age status, current maternal smoking, maternal age, and maternal pre-pregnancy BMI.

Table A2.11: Association between obesity status classified using body mass index (BMI) at age three years and Stanford-Binet Intelligence Scales full-scale IQ score at age four years in the Collaborative Perinatal Project, overall and stratified by gender, race, and gender/race; estimate (95% CI) *†‡

		Crude / Pooled	By gender		By race		By gender and race			
			Girls	Boys	Whites	A-A	White girls	A-A girls	White boys	A-A Boys
Model 1 (Crude)	**Under-weight**	**-3.59 (-5.01, -2.18)**								
	Normal	0.00 (ref)								
	Over-weight	-0.83 (-2.10, 0.43)								
	Obese	-0.67 (-2.45, 1.10)								
Model 2	**Under-weight**	**-2.06 (-3.28, -0.83)**	-1.28 (-3.00, 0.42)	**-2.91 (-4.66, -1.16)**	-0.87 (-2.93, 1.17)	**-2.78 (-4.25, -1.30)**	-0.04 (-2.93, 2.84)	**-2.13 (-4.19, -0.07)**	-1.83 (-4.76, 1.09)	**-3.45 (-5.57, -1.33)**
	Normal	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)
	Over-weight	-0.72 (-1.81, 0.37)	-0.43 (-2.00, 1.13)	-1.02 (-2.54, 0.49)	-1.26 (-2.84, 0.30)	0.70 (-0.80, 2.22)	-1.47 (-3.78, 0.84)	1.25 (-0.87, 3.38)	-1.08 (-3.22, 1.06)	0.12 (-2.02, 2.27)
	Obese	0.13 (-1.39, 1.66)	1.82 (-0.48, 4.12)	-1.27 (-3.31, 0.76)	-0.15 (-2.39, 2.08)	1.34 (-0.72, 3.40)	1.43 (-2.12, 4.98)	2.88 (-0.07, 5.84)	-1.28 (-4.15, 1.57)	-0.19 (-3.08, 2.69)
Model 3	**Under-weight**	**-1.87 (-3.10, -0.63)**	-1.04 (-2.77, 0.68)	**-2.74 (-4.51, -0.98)**	-0.66 (-2.76, 1.43)	**-2.54 (-4.02, -1.06)**	0.34 (-2.61, 3.30)	-1.97 (-4.03, 0.09)	-1.62 (-4.61, 1.36)	**-3.17 (-5.29, -1.05)**
	Normal	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)
	Over-weight	-0.82 (-1.92, 0.28)	-0.70 (-2.27, 0.87)	-0.98 (-2.51, 0.55)	-1.27 (-2.87, 0.31)	0.40 (-1.10, 1.92)	-1.75 (-4.08, 0.56)	0.89 (-1.25, 3.03)	-0.94 (-3.13, 1.25)	-0.07 (-2.21, 2.07)
	Obese	-0.07 (-1.61, 1.46)	1.56 (-0.75, 3.89)	-1.48 (-3.54, 0.57)	-0.30 (-2.58, 1.97)	1.04 (-1.02, 3.11)	1.67 (-1.94, 5.30)	2.21 (-0.74, 5.18)	-1.61 (-4.52, 1.30)	-0.15 (-3.04, 2.74)

*CI – confidence interval, A-A – African-American

†Underweight: <5th percentile, normal weight 5 - <85th percentile, overweight: 85th - <95th percentile, obese: ≥95th percentile

‡Bold font indicates model results are significant at $\alpha = 0.05$. Model 1 was unadjusted, Model 2 was adjusted for gender (when appropriate), race (when appropriate), study site, and socioeconomic index (SEI), Model 3 was adjusted for gender (when appropriate), race (when appropriate), study site, SEI, small for gestational age status, current maternal smoking, maternal age, and maternal pre-pregnancy BMI.

Table A2.12: Association between obesity status classified using body mass index (BMI) at age three years and Wechsler Intelligence Scales for Children full-scale IQ score at age seven years in the Collaborative Perinatal Project, overall and stratified by gender, race, and gender/race; estimate (95% CI) *†‡

		Crude / Pooled	By gender		By race		By gender and race			
			Girls	**Boys**	**Whites**	**A-A**	**White girls**	**A-A girls**	**White boys**	**A-A Boys**
Model 1 (Crude)	**Under-weight**	**-3.18 (-4.41, -1.95)**								
	Normal	0.00 (ref)								
	Over-weight	0.69 (-0.40, 1.79)								
	Obese	-0.20 (-1.74, 1.34)								
Model 2	**Under-weight**	**-1.65 (-2.69, -0.60)**	**-2.06 (-3.48, -0.64)**	-1.17 (-2.70, 0.35)	-0.82 (-2.51, 0.85)	**-2.11 (-3.42, -0.81)**	-1.19 (-3.51, 1.12)	**-2.68 (-4.45, -0.91)**	-0.43 (-2.90, 2.03)	-1.50 (-3.44, 0.42)
	Normal	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)
	Over-weight	0.67 (-0.25, 1.60)	**1.46 (0.16, 2.76)**	-0.08 (-1.41, 1.24)	-0.10 (-1.39, 1.18)	**2.24 (0.90, 3.58)**	0.22 (-1.63, 2.07)	**3.26 (1.43, 5.08)**	-0.35 (-2.15, 1.45)	1.16 (-0.80, 3.13)
	Obese	0.28 (-1.02, 1.58)	0.07 (-1.82, 1.98)	0.40 (-1.38, 2.18)	0.31 (-1.52, 2.15)	0.87 (-0.95, 2.70)	-0.81 (-3.66, 2.03)	1.47 (-1.06, 4.00)	1.19 (-1.22, 3.60)	0.29 (-2.35, 2.93)
Model 3	**Under-weight**	**-1.64 (-2.69, -0.58)**	**-2.06 (-3.49, -0.62)**	-1.19 (-2.73, 0.34)	-0.80 (-2.52, 0.92)	**-2.06 (-3.37, -0.75)**	-1.16 (-3.54, 1.21)	**-2.67 (-4.45, -0.89)**	-0.36 (-2.87, 2.15)	-1.45 (-3.38, 0.48)
	Normal	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)
	Over-weight	0.64 (-0.29, 1.57)	**1.34 (0.03, 2.65)**	-0.01 (-1.35, 1.32)	-0.11 (-1.42, 1.19)	**2.21 (0.87, 3.56)**	0.02 (-1.84, 1.89)	**3.23 (1.39, 5.08)**	-0.23 (-2.07, 1.60)	1.18 (-0.77, 3.14)
	Obese	0.15 (-1.15, 1.47)	-0.15 (-2.08, 1.77)	0.33 (-1.46, 2.13)	0.23 (-1.64, 2.10)	0.75 (-1.07, 2.59)	-1.02 (-3.93, 1.88)	1.23 (-1.31, 3.79)	1.22 (-1.22, 3.67)	0.30 (-2.34, 2.94)

*CI – confidence interval, A-A – African-American

†Underweight: <5th percentile, normal weight 5 - <85th percentile, overweight: 85th - <95th percentile, obese: ≥95th percentile

‡Bold font indicates model results are significant at $\alpha = 0.05$. Model 1 was unadjusted, Model 2 was adjusted for gender (when appropriate), race (when appropriate), study site, and socioeconomic index (SEI), Model 3 was adjusted for gender (when appropriate), race (when appropriate), study site, SEI, small for gestational age status, current maternal smoking, maternal age, and maternal pre-pregnancy BMI.

Table A2.13: Association between obesity status classified using body mass index (BMI) at age three years and Wechsler Intelligence Scales for Children verbal IQ score at age seven years in the Collaborative Perinatal Project, overall and stratified by gender, race, and gender/race; estimate (95% CI) *†‡

		Crude / Pooled	By gender		By race		By gender and race			
			Girls	**Boys**	**Whites**	**A-A**	**White girls**	**A-A girls**	**White boys**	**A-A Boys**
Model 1 (Crude)	**Under-weight**	**-2.60 (-3.80, -1.39)**								
	Normal	0.00 (ref)								
	Over-weight	0.99 (-0.08, 2.07)								
	Obese	0.38 (-1.13, 1.89)								
Model 2	**Under-weight**	**-1.28 (-2.33, -0.22)**	**-1.66 (-3.11, -0.21)**	-0.83 (-2.36, 0.69)	-0.80 (-2.54, 0.92)	**-1.62 (-2.92, -0.33)**	-1.21 (-3.60, 1.18)	**-2.07 (-3.86, -0.29)**	-0.35 (-2.88, 2.17)	-1.14 (-3.03, 0.74)
	Normal	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)
	Over-weight	**1.07 (0.13, 2.01)**	**1.71 (0.39, 3.04)**	0.43 (-0.89, 1.76)	0.19 (-1.13, 1.52)	**2.57 (1.24, 3.91)**	0.37 (-1.54, 2.28)	**3.55 (1.71, 5.39)**	0.05 (-1.79, 1.90)	1.54 (-0.38, 3.47)
	Obese	0.90 (-0.41, 2.21)	0.36 (-1.57, 2.31)	1.29 (-0.49, 3.07)	0.69 (-1.20, 2.58)	1.60 (-0.20, 3.42)	-0.17 (-3.11, 2.77)	1.38 (-1.17, 3.93)	1.33 (-1.13, 3.80)	1.83 (-0.75, 4.41)
Model 3	**Under-weight**	**-1.27 (-2.34, -0.20)**	**-1.64 (-3.12, -0.17)**	-0.84 (-2.39, 0.70)	-0.76 (-2.54, 1.01)	**-1.56 (-2.87, -0.26)**	-1.07 (-3.54, 1.38)	**-2.10 (-3.90, -0.30)**	-0.36 (-2.94, 2.21)	-1.01 (-2.90, 0.88)
	Normal	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)
	Over-weight	**1.03 (0.08, 1.98)**	**1.61 (0.27, 2.96)**	0.47 (-0.86, 1.82)	0.21 (-1.13, 1.56)	**2.50 (1.16, 3.84)**	0.30 (-1.62, 2.23)	**3.42 (1.55, 5.28)**	0.10 (-1.78, 1.99)	1.56 (-0.35, 3.48)
	Obese	0.94 (-0.38, 2.27)	0.27 (-1.69, 2.25)	1.41 (-0.38, 3.22)	0.75 (-1.18, 2.68)	1.67 (-0.14, 3.50)	-0.10 (-3.11, 2.91)	1.15 (-1.42, 3.73)	1.42 (-1.08, 3.94)	2.17 (-0.40, 4.76)

*CI – confidence interval, A-A – African-American

†Underweight: <5th percentile, normal weight 5 - <85th percentile, overweight: 85th - <95th percentile, obese: ≥95th percentile

‡Bold font indicates model results are significant at $\alpha = 0.05$. Model 1 was unadjusted, Model 2 was adjusted for gender (when appropriate), race (when appropriate), study site, and socioeconomic index (SEI), Model 3 was adjusted for gender (when appropriate), race (when appropriate), study site, SEI, small for gestational age status, current maternal smoking, maternal age, and maternal pre-pregnancy BMI.

Table A2.14: Association between obesity status classified using body mass index (BMI) at age three years and Wechsler Intelligence Scales for Children performance IQ score at age seven years in the Collaborative Perinatal Project, overall and stratified by gender, race, and gender/race; estimate (95% CI) *†‡

		Crude / Pooled	By gender		By race		By gender and race			
			Girls	Boys	Whites	A-A	White girls	A-A girls	White boys	A-A Boys
Model 1 (Crude)	Under-weight	**-3.29 (-4.61, -1.97)**								
	Normal	0.00 (ref)								
	Over-weight	0.29 (-0.88, 1.46)								
	Obese	-0.84 (-2.50, 0.80)								
Model 2	Under-weight	**-1.81 (-2.98, -0.64)**	**-2.25 (-3.80, -0.70)**	-1.33 (-3.09, 0.43)	-0.75 (-2.64, 1.14)	**-2.34 (-3.81, -0.86)**	-1.11 (-3.61, 1.38)	**-2.97 (-4.93, -1.02)**	-0.36 (-3.23, 2.49)	-1.67 (-3.89, 0.55)
	Normal	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)
	Over-weight	0.13 (-0.90, 1.18)	0.76 (-0.65, 2.18)	-0.45 (-1.98, 1.08)	-0.47 (-1.92, 0.97)	**1.60 (0.09, 3.11)**	-0.10 (-2.09, 1.89)	**2.19 (0.17, 4.21)**	-0.74 (-2.84, 1.35)	0.98 (-1.28, 3.25)
	Obese	-0.47 (-1.94, 0.98)	-0.36 (-2.44, 1.71)	-0.60 (-2.65, 1.45)	-0.19 (-2.25, 1.87)	-0.08 (-2.14, 1.97)	-1.56 (-4.63, 1.50)	1.30 (-1.50, 4.10)	0.88 (-1.91, 3.69)	-1.44 (-4.48, 1.59)
Model 3	Under-weight	**-1.81 (-3.00, -0.63)**	**-2.28 (-3.86, -0.71)**	-1.33 (-3.11, 0.43)	-0.71 (-2.65, 1.22)	**-2.34 (-3.82, -0.86)**	-1.17 (-3.76, 1.40)	**-2.98 (-4.95, -1.01)**	-0.17 (-3.07, 2.73)	-1.72 (-3.94, 0.50)
	Normal	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)
	Over-weight	0.12 (-0.92, 1.18)	0.67 (-0.76, 2.10)	-0.35 (-1.90, 1.19)	-0.51 (-1.98, 0.95)	**1.68 (0.16, 3.20)**	-0.40 (-2.43, 1.62)	**2.33 (0.28, 4.37)**	-0.58 (-2.71, 1.54)	1.03 (-1.22, 3.29)
	Obese	-0.76 (-2.24, 0.71)	-0.70 (-2.82, 1.40)	-0.86 (-2.93, 1.20)	-0.43 (-2.54, 1.66)	-0.36 (-2.43, 1.70)	-2.05 (-5.22, 1.10)	1.12 (-1.69, 3.94)	0.84 (-1.98, 3.67)	-1.79 (-4.83, 1.24)

*CI – confidence interval, A-A – African-American

†Underweight: <5th percentile, normal weight 5 - <85th percentile, overweight: 85th - <95th percentile, obese: ≥95th percentile

‡Bold font indicates model results are significant at α = 0.05. Model 1 was unadjusted, Model 2 was adjusted for gender (when appropriate), race (when appropriate), study site, and socioeconomic index (SEI), Model 3 was adjusted for gender (when appropriate), race (when appropriate), study site, SEI, small for gestational age status, current maternal smoking, maternal age, and maternal pre-pregnancy BMI.

Table A2.15: Association between obesity status classified using body mass index (BMI) at age four years and Wechsler Intelligence Scales for Children full-scale IQ score at age seven years in the Collaborative Perinatal Project, overall and stratified by gender, race, and gender/race; estimate (95% CI) *†‡

		Crude / Pooled	By gender		By race		By gender and race			
			Girls	**Boys**	**Whites**	**A-A**	**White girls**	**A-A girls**	**White boys**	**A-A Boys**
Model 1 (Crude)	**Under-Weight**	**-4.48 (-5.45, -3.51)**								
	Normal	0.00 (ref)								
	Over-Weight	**3.46 (2.79, 4.14)**								
	Obese	**3.44 (2.58, 4.29)**								
Model 2	**Under-Weight**	**-1.76 (-2.58, -0.93)**	**-1.90 (-3.00, -0.79)**	**-1.68 (-2.93, -0.43)**	**-1.92 (-3.51, -0.34)**	**-1.78 (-2.73, -0.83)**	**-2.63 (-4.80, -0.46)**	**-1.80 (-3.05, -0.55)**	-1.10 (-3.44, 1.23)	**-1.79 (-3.26, -0.33)**
	Normal	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)
	Over-Weight	**0.95 (0.37, 1.53)**	0.45 (-0.34, 1.26)	**1.47 (0.64, 2.31)**	0.74 (-0.00, 1.50)	**0.93 (0.01, 1.85)**	0.79 (-0.26, 1.86)	-0.47 (-1.72, 0.78)	0.69 (-0.36, 1.76)	**2.42 (1.07, 3.77)**
	Obese	0.72 (-0.00, 1.46)	0.68 (-0.42, 1.78)	0.69 (-0.29, 1.68)	0.37 (-0.57, 1.31)	0.90 (-0.30, 2.11)	0.31 (-1.13, 1.76)	1.21 (-0.54, 2.96)	0.37 (-0.86, 1.61)	0.67 (-1.00, 2.35)
Model 3	**Under-weight**	**-1.67 (-2.51, -0.83)**	**-1.70 (-2.82, -0.58)**	**-1.76 (-3.02, -0.49)**	**-1.88 (-3.52, -0.24)**	**-1.68 (-2.64, -0.72)**	**-2.25 (-4.49, -0.01)**	**-1.68 (-2.95, -0.42)**	-1.41 (-3.80, 0.98)	**-1.73 (-3.20, -0.26)**
	Normal	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)
	Over-weight	**1.10 (0.49, 1.70)**	0.53 (-0.31, 1.37)	**1.70 (0.83, 2.57)**	**0.90 (0.10, 1.71)**	**0.98 (0.04, 1.91)**	0.77 (-0.36, 1.91)	-0.24 (-1.52, 1.03)	1.04 (-0.08, 2.18)	**2.28 (0.91, 3.65)**
	Obese	**1.07 (0.29, 1.85)**	0.89 (-0.27, 2.06)	**1.17 (0.11, 2.22)**	0.72 (-0.29, 1.74)	1.14 (-0.09, 2.38)	0.49 (-1.06, 2.05)	1.25 (-0.55, 3.06)	0.82 (-0.52, 2.16)	1.06 (-0.64, 2.77)

*CI – confidence interval, A-A – African-American

†Underweight: <5th percentile, normal weight 5 - <85th percentile, overweight: 85th - <95th percentile, obese: ≥95th percentile

‡Bold font indicates model results are significant at α = 0.05. Model 1 was unadjusted, Model 2 was adjusted for gender (when appropriate), race (when appropriate), study site, and socioeconomic index (SEI), Model 3 was adjusted for gender (when appropriate), race (when appropriate), study site, SEI, small for gestational age status, current maternal smoking, maternal age, and maternal pre-pregnancy BMI.

Table A2.16: Association between obesity status classified using body mass index (BMI) at age three years and Wechsler Intelligence Scales for Children verbal IQ score at age seven years in the Collaborative Perinatal Project, overall and stratified by gender, race, and gender/race; estimate (95% CI) *†‡

		Crude / Pooled	By gender		By race		By gender and race			
			Girls	Boys	Whites	A-A	White girls	A-A girls	White boys	A-A Boys
Model 1 (Crude)	Under-weight	**-4.37 (-5.32, -3.43)**								
	Normal	0.00 (ref)								
	Over-weight	**3.32 (2.66, 3.98)**								
	Obese	**3.35 (2.51, 4.19)**								
Model 2	Under-weight	**-1.95 (-2.79, -1.11)**	**-1.72 (-2.85, -0.59)**	**-2.33 (-3.58, -1.08)**	**-2.18 (-3.81, -0.54)**	**-1.97 (-2.91, -1.02)**	**-2.60 (-4.85, -0.35)**	**-1.56 (-2.82, -0.30)**	-1.68 (-4.08, 0.70)	**-2.52 (-3.95, -1.09)**
	Normal	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)
	Over-weight	**1.10 (0.52, 1.69)**	0.51 (-0.30, 1.34)	**1.71 (0.88, 2.55)**	**0.82 (0.05, 1.60)**	**1.33 (0.42, 2.24)**	0.53 (-0.57, 1.63)	0.20 (-1.05, 1.47)	**1.13 (0.04, 2.21)**	**2.53 (1.21, 3.85)**
	Obese	**0.85 (0.11, 1.60)**	1.06 (-0.06, 2.19)	0.63 (-0.35, 1.63)	0.58 (-0.38, 1.55)	1.11 (-0.09, 2.31)	0.87 (-0.61, 2.37)	1.33 (-0.43, 3.10)	0.37 (-0.89, 1.65)	0.93 (-0.71, 2.57)
Model 3	Under-weight	**-1.96 (-2.81, -1.11)**	**-1.62 (-2.76, -0.47)**	**-2.47 (-3.74, -1.21)**	**-2.39 (-4.07, -0.70)**	**-1.87 (-2.83, -0.91)**	**-2.51 (-4.84, -0.19)**	**-1.45 (-2.73, -0.17)**	-2.19 (-4.64, 0.26)	**-2.43 (-3.87, -0.99)**
	Normal	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)
	Over-weight	**1.27 (0.66, 1.89)**	0.68 (-0.17, 1.55)	**1.89 (1.01, 2.76)**	**1.02 (0.19, 1.85)**	**1.40 (0.47, 2.33)**	0.66 (-0.52, 1.84)	0.41 (-0.87, 1.70)	**1.38 (0.21, 2.55)**	**2.47 (1.13, 3.81)**
	Obese	**1.09 (0.30, 1.88)**	1.12 (-0.06, 2.32)	1.02 (-0.03, 2.07)	0.81 (-0.24, 1.86)	**1.30 (0.07, 2.53)**	0.95 (-0.66, 2.57)	1.26 (-0.56, 3.08)	0.68 (-0.70, 2.06)	1.34 (-0.32, 3.02)

*CI – confidence interval, A-A – African-American

†Underweight: <5th percentile, normal weight 5 - <85th percentile, overweight: 85th - <95th percentile, obese: ≥95th percentile

‡Bold font indicates model results are significant at α = 0.05. Model 1 was unadjusted, Model 2 was adjusted for gender (when appropriate), race (when appropriate), study site, and socioeconomic index (SEI), Model 3 was adjusted for gender (when appropriate), race (when appropriate), study site, SEI, small for gestational age status, current maternal smoking, maternal age, and maternal pre-pregnancy BMI.

Table A2.17: Association between obesity status classified using body mass index (BMI) at age three years and Wechsler Intelligence Scales for Children performance IQ score at age seven years in the Collaborative Perinatal Project, overall and stratified by gender, race, and gender/race; estimate (95% CI) *†‡

		Crude / Pooled	By gender		By race		By gender and race			
			Girls	Boys	Whites	A-A	White girls	A-A girls	White boys	A-A Boys
Model 1 (Crude)	Under-weight	**-3.76 (-4.80, -2.72)**								
	Normal	0.00 (ref)								
	Over-weight	**2.96 (2.24, 3.68)**								
	Obese	**2.88 (1.96, 3.80)**								
Model 2	Under-weight	**-1.21 (-2.14, -0.28)**	**-1.68 (-2.88, -0.47)**	-0.72 (-2.17, 0.71)	-1.06 (-2.84, 0.72)	**-1.35 (-2.42, -0.27)**	-1.73 (-4.08, 0.61)	**-1.84 (-3.23, -0.46)**	-0.27 (-2.98, 2.44)	-0.76 (-2.45, 0.91)
	Normal	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)
	Over-weight	0.62 (-0.02, 1.27)	0.34 (-0.53, 1.22)	0.91 (-0.04, 1.88)	0.59 (-0.25, 1.43)	0.21 (-0.82, 1.25)	1.07 (-0.08, 2.22)	-1.25 (-2.63, 0.13)	0.11 (-1.11, 1.35)	**1.78 (0.22, 3.34)**
	Obese	0.44 (-0.38, 1.27)	0.22 (-0.97, 1.43)	0.55 (-0.59, 1.70)	0.09 (-0.96, 1.15)	0.46 (-0.90, 1.83)	-0.23 (-1.79, 1.33)	0.84 (-1.08, 2.78)	0.25 (-1.18, 1.70)	0.17 (-1.76, 2.11)
Model 3	Under-weight	**-1.14 (-2.09, -0.19)**	**-1.59 (-2.82, -0.36)**	-0.70 (-2.16, 0.75)	-1.03 (-2.87, 0.80)	**-1.29 (-2.37, -0.20)**	-1.66 (-4.10, 0.77)	**-1.77 (-3.17, -0.37)**	-0.28 (-3.05, 2.49)	-0.74 (-2.44, 0.95)
	Normal	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)
	Over-weight	**0.70 (0.02, 1.38)**	0.26 (-0.66, 1.19)	**1.17 (0.16, 2.17)**	0.66 (-0.24, 1.56)	0.24 (-0.80, 1.30)	0.82 (-0.41, 2.06)	-1.02 (-2.43, 0.38)	0.51 (-0.80, 1.82)	**1.61 (0.03, 3.19)**
	Obese	0.86 (-0.01, 1.74)	0.58 (-0.69, 1.86)	1.03 (-0.17, 2.24)	0.51 (-0.63, 1.65)	0.72 (-0.67, 2.13)	0.05 (-1.65, 1.75)	1.03 (-0.95, 3.03)	0.75 (-0.80, 2.31)	0.49 (-1.47, 2.47)

*CI – confidence interval, A-A – African-American

†Underweight: <5th percentile, normal weight 5 - <85th percentile, overweight: 85th - <95th percentile, obese: ≥95th percentile

‡Bold font indicates model results are significant at α = 0.05. Model 1 was unadjusted, Model 2 was adjusted for gender (when appropriate), race (when appropriate), study site, and socioeconomic index (SEI), Model 3 was adjusted for gender (when appropriate), race (when appropriate), study site, SEI, small for gestational age status, current maternal smoking, maternal age, and maternal pre-pregnancy BMI.

Table A2.18: Association between change in body mass index (BMI) from age four years to age seven years and Wechsler Intelligence Scales for Children full-scale IQ score at age seven years in the Collaborative Perinatal Project, overall and stratified by gender, race, and gender/race; estimate (95% CI) *†‡

	Crude / Pooled	**By gender**		**By race**		**By gender and race**			
Model 1 (Crude)	-0.16 (-0.32, 0.00)	**Girls**	**Boys**	**Whites**	**A-A**	**White girls**	**A-A girls**	**White boys**	**A-A Boys**
Model 2	**-0.39 (-0.53, -0.25)**	**-0.44 (-0.62, -0.26)**	**-0.30 (-0.51, -0.09)**	**-0.31 (-0.51, -0.11)**	**-0.52 (-0.71, -0.34)**	**-0.32 (-0.60, -0.04)**	**-0.61 (-0.84, -0.37)**	**-0.30 (-0.59, -0.01)**	**-0.40 (-0.70, -0.09)**
Model 3	**-0.42 (-0.56, -0.27)**	**-0.50 (-0.69, -0.31)**	**-0.30 (-0.52, -0.08)**	**-0.33 (-0.55, -0.12)**	**-0.55 (-0.74, -0.36)**	**-0.36 (-0.66, -0.06)**	**-0.65 (-0.90, -0.41)**	**-0.31 (-0.61, -0.00)**	**-0.40 (-0.71, -0.09)**

*CI – confidence interval, A-A – African-American

†Underweight: <5th percentile, normal weight 5 - <85th percentile, overweight: 85th - <95th percentile, obese: ≥95th percentile

‡Bold font indicates model results are significant at $\alpha = 0.05$. Model 1 was unadjusted, Model 2 was adjusted for gender (when appropriate), race (when appropriate), study site, and socioeconomic index (SEI), Model 3 was adjusted for gender (when appropriate), race (when appropriate), study site, SEI, small for gestational age status, current maternal smoking, maternal age, and maternal pre-pregnancy BMI.

Table A2.19: Association between change in body mass index (BMI) from age four years to age seven years and Wechsler Intelligence Scales for Children verbal IQ score at age seven years in the Collaborative Perinatal Project, overall and stratified by gender, race, and gender/race; estimate (95% CI) *†‡

	Crude / Pooled	By gender		By race		By gender and race			
Model 1 (Crude)	**-0.19 (-0.35, -0.03)**	**Girls**	**Boys**	**Whites**	**A-A**	**White girls**	**A-A girls**	**White boys**	**A-A Boys**
Model 2	**-0.43 (-0.57, -0.29)**	**-0.47 (-0.66, -0.29)**	**-0.36 (-0.57, -0.15)**	**-0.33 (-0.54, -0.12)**	**-0.58 (-0.76, -0.39)**	**-0.31 (-0.60, -0.02)**	**-0.67 (-0.91, -0.43)**	**-0.35 (-0.66, -0.05)**	**-0.44 (-0.74, -0.14)**
Model 3	**-0.46 (-0.61, -0.32)**	**-0.54 (-0.74, -0.35)**	**-0.35 (-0.57, -0.13)**	**-0.37 (-0.59, -0.15)**	**-0.59 (-0.78, -0.40)**	**-0.39 (-0.70, -0.08)**	**-0.70 (-0.95, -0.46)**	**-0.36 (-0.67, -0.04)**	**-0.44 (-0.74, -0.13)**

*CI – confidence interval, A-A – African-American

†Underweight: <5th percentile, normal weight 5 - <85th percentile, overweight: 85th - <95th percentile, obese: ≥95th percentile

‡Bold font indicates model results are significant at α = 0.05. Model 1 was unadjusted, Model 2 was adjusted for gender (when appropriate), race (when appropriate), study site, and socioeconomic index (SEI), Model 3 was adjusted for gender (when appropriate), race (when appropriate), study site, SEI, small for gestational age status, current maternal smoking, maternal age, and maternal pre-pregnancy BMI.

Table A2.20: Association between change in body mass index (BMI) from age four years to age seven years and Wechsler Intelligence Scales for Children performance IQ score at age seven years in the Collaborative Perinatal Project, overall and stratified by gender, race, and gender/race; estimate (95% CI) *†‡

	Crude / Pooled	**By gender**		**By race**		**By gender and race**			
Model 1 (Crude)	-0.08 (-0.25, 0.09)	**Girls**	**Boys**	**Whites**	**A-A**	**White girls**	**A-A girls**	**White boys**	**A-A Boys**
Model 2	**-0.25 (-0.40, -0.09)**	**-0.30 (-0.50, -0.10)**	-0.16 (-0.41, 0.07)	-0.22 (-0.44, 0.00)	**-0.34 (-0.55, -0.13)**	-0.27 (-0.58, 0.02)	**-0.40 (-0.66, -0.13)**	-0.16 (-0.50, 0.17)	-0.26 (-0.61, 0.08)
Model 3	**-0.27 (-0.43, -0.11)**	**-0.34 (-0.55, -0.13)**	-0.17 (-0.42, 0.07)	-0.22 (-0.46, 0.01)	**-0.38 (-0.59, -0.16)**	**-0.27 (-0.60, 0.04)**	**-0.45 (-0.72, -0.18)**	-0.17 (-0.53, 0.18)	-0.27 (-0.63, 0.07)

*CI – confidence interval, A-A – African-American

†Underweight: <5^{th} percentile, normal weight 5 - <85^{th} percentile, overweight: 85^{th} - <95^{th} percentile, obese: ≥95^{th} percentile

‡Bold font indicates model results are significant at α = 0.05. Model 1 was unadjusted, Model 2 was adjusted for gender (when appropriate), race (when appropriate), study site, and socioeconomic index (SEI), Model 3 was adjusted for gender (when appropriate), race (when appropriate), study site, SEI, small for gestational age status, current maternal smoking, maternal age, and maternal pre-pregnancy BMI.

Table A2.21: Association between obesity status classified using body mass index (BMI) and Stanford-Binet Intelligence Scales full-scale IQ score at age four years in the Collaborative Perinatal Project using an obesity cut-point of the 97th percentile, overall and stratified by gender, race, and gender/race; estimate (95% CI) *†‡

		Crude / Pooled	By gender		By race		By gender and race			
			Girls	Boys	Whites	A-A	White girls	A-A girls	White boys	A-A Boys
Model 1 (Crude)	Under-weight	**-5.03 (-6.14, -3.92)**								
	Normal	0.00 (ref)								
	Over-weight	**4.52 (3.80, 5.23)**								
	Obese	**4.86 (3.63, 6.09)**								
Model 2	Under-weight	**-2.22 (-3.19, -1.24)**	**-1.61 (-2.94, -0.28)**	**-2.94 (-4.37, -1.51)**	-1.76 (-3.69, 0.16)	**-2.45 (-3.52, -1.37)**	-1.06 (-3.77, 1.63)	**-1.95 (-3.40, -0.50)**	-2.60 (-5.37, 0.16)	**-3.02 (-4.63, -1.42)**
	Normal	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)
	Over-weight	**1.78 (1.15, 2.41)**	**1.76 (0.86, 2.66)**	**1.80 (0.92, 2.68)**	**1.53 (0.68, 2.39)**	**1.75 (0.80, 2.69)**	**1.39 (0.15, 2.63)**	**1.92 (0.60, 3.25)**	**1.68 (0.51, 2.85)**	**1.57 (0.21, 2.93)**
	Obese	**1.88 (0.80, 2.96)**	1.49 (-0.28, 3.28)	**2.14 (0.79, 3.48)**	**1.52 (0.13, 2.92)**	**2.23 (0.46, 4.01)**	0.90 (-1.42, 3.24)	2.48 (-0.38, 5.35)	**1.88 (0.16, 3.60)**	2.05 (-0.19, 4.30)
Model 3	Under-weight	**-2.05 (-3.04, -1.06)**	-1.29 (-2.64, 0.05)	**-2.95 (-4.40, -1.50)**	-1.75 (-3.74, 0.23)	**-2.17 (-3.25, -1.09)**	-0.30 (-3.09, 2.49)	**-1.77 (-3.23, -0.30)**	**-3.32 (-6.16, -0.47)**	**-2.66 (-4.27, -1.04)**
	Normal	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)
	Over-weight	**1.73 (1.07, 2.39)**	**1.62 (0.68, 2.56)**	**1.84 (0.91, 2.76)**	**1.55 (0.64, 2.46)**	**1.66 (0.69, 2.62)**	1.22 (-0.10, 2.54)	**1.84 (0.49, 3.18)**	**1.85 (0.59, 3.11)**	**1.48 (0.10, 2.86)**
	Obese	**2.09 (0.95, 3.23)**	1.47 (-0.40, 3.34)	**2.49 (1.06, 3.92)**	**1.82 (0.32, 3.32)**	**2.28 (0.47, 4.08)**	0.67 (-1.82, 3.17)	2.67 (-0.26, 5.62)	**2.48 (0.61, 4.34)**	2.03 (-0.25, 4.32)

*CI – confidence interval, A-A – African-American

†Underweight: <5th percentile, normal weight 5 - <85th percentile, overweight: 85th - <97th percentile, obese: ≥97th percentile

‡Bold font indicates model results are significant at α = 0.05. Model 1 was unadjusted, Model 2 was adjusted for gender (when appropriate), race (when appropriate), study site, and socioeconomic index (SEI), Model 3 was adjusted for gender (when appropriate), race (when appropriate), study site, SEI, small for gestational age status, current maternal smoking, maternal age, and maternal pre-pregnancy BMI.

Table A2.22: Association between obesity status classified using body mass index (BMI) and Wechsler Intelligence Scales for Children full-scale IQ score at age seven years in the Collaborative Perinatal Project using an obesity cut-point of the 97th percentile, overall and stratified by gender, race, and gender/race; estimate (95% CI) *†‡

		Crude / Pooled	By gender		By race		By gender and race			
			Girls	**Boys**	**Whites**	**A-A**	**White girls**	**A-A girls**	**White Boys**	**A-A Boys**
Model 1 (Crude)	**Under-weight**	**-6.27 (-7.35, -5.20)**								
	Normal	0.00 (ref)								
	Over-weight	**2.31 (1.57, 3.05)**								
	Obese	**3.00 (1.63, 4.37)**								
Model 2	**Under-weight**	**-2.52 (-3.44, -1.60)**	**-2.99 (-4.21, -1.77)**	**-2.09 (-3.49, -0.68)**	**-3.51 (-5.37, -1.64)**	**-2.13 (-3.17, -1.08)**	**-4.70 (-7.30, -2.10)**	**-2.51 (-3.86, -1.17)**	-2.18 (-4.86, 0.48)	**-1.64 (-3.28, -0.01)**
	Normal	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)
	Over-weight	**0.86 (0.23, 1.49)**	0.58 (-0.30, 1.46)	**1.05 (0.15, 1.95)**	0.27 (-0.57, 1.12)	**1.54 (0.60, 2.48)**	0.09 (-1.14, 1.34)	1.11 (-0.12, 2.36)	0.42 (-0.73, 1.59)	**2.03 (0.60, 3.45)**
	Obese	**2.08 (0.91, 3.24)**	**1.88 (0.21, 3.54)**	**2.09 (0.45, 3.73)**	1.44 (-0.12, 3.00)	**3.03 (1.28, 4.77)**	1.74 (-0.68, 4.16)	**2.48 (0.21, 4.75)**	1.20 (-0.85, 3.25)	**3.72 (1.01, 6.43)**
Model 3	**Under-weight**	**-2.34 (-3.28, -1.39)**	**-2.61 (-3.86, -1.36)**	**-2.17 (-3.60, -0.75)**	**-2.81 (-4.77, -0.86)**	**-2.10 (-3.15, -1.05)**	**-3.33 (-6.08, -0.58)**	**-2.47 (-3.84, -1.10)**	-2.20 (-4.99, 0.57)	**-1.68 (-3.32, -0.03)**
	Normal	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)
	Over-Weight	**1.22 (0.56, 1.88)**	**0.96 (0.04, 1.88)**	**1.39 (0.44, 2.33)**	0.80 (-0.10, 1.71)	**1.59 (0.63, 2.54)**	0.57 (-0.75, 1.90)	**1.31 (0.04, 2.58)**	1.00 (-0.24, 2.25)	**1.92 (0.47, 3.36)**
	Obese	**2.46 (1.24, 3.68)**	**2.55 (0.82, 4.29)**	**2.24 (0.53, 3.94)**	**1.82 (0.16, 3.49)**	**3.30 (1.53, 5.08)**	**2.60 (0.02, 5.19)**	**2.74 (0.41, 5.07)**	1.26 (-0.92, 3.44)	**3.99 (1.25, 6.72)**

*CI – confidence interval, A-A – African-American

†Underweight: <5th percentile, normal weight 5 - <85th percentile, overweight: 85th - <97th percentile, obese: ≥97th percentile

‡Bold font indicates model results are significant at $\alpha = 0.05$. Model 1 was unadjusted, Model 2 was adjusted for gender (when appropriate), race (when appropriate), study site, and socioeconomic index (SEI), Model 3 was adjusted for gender (when appropriate), race (when appropriate), study site, SEI, small for gestational age status, current maternal smoking, maternal age, and maternal pre-pregnancy BMI.

Table A2.23: Association between obesity status classified using body mass index (BMI) and Stanford-Binet Intelligence Scales full-scale IQ score at age four years in the Collaborative Perinatal Project using an obesity cut-point of the 99th percentile, overall and stratified by gender, race, and gender/race; estimate (95% CI) *†‡

		Crude / Pooled	By gender		By race		By gender and race			
			Girls	**Boys**	**Whites**	**A-A**	**White girls**	**A-A girls**	**White Boys**	**A-A Boys**
Model 1 (Crude)	**Under-weight**	**-5.03 (-6.14, -3.92)**								
	Normal	0.00 (ref)								
	Over-weight	**4.51 (3.84, 5.17)**								
	Obese	**5.50 (3.55, 7.45)**								
Model 2	**Under-weight**	**-2.22 (-3.19, -1.24)**	**-1.61 (-2.95, -0.28)**	**-2.94 (-4.37, -1.51)**	-1.76 (-3.69, 0.16)	**-2.45 (-3.52, -1.37)**	-1.06 (-3.77, 1.63)	**-1.95 (-3.40, -0.50)**	-2.60 (-5.37, 0.16)	**-3.02 (-4.63, -1.42)**
	Normal	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)
	Over-weight	**1.74 (1.15, 2.33)**	**1.68 (0.83, 2.53)**	**1.80 (0.98, 2.62)**	**1.49 (0.69, 2.29)**	**1.70 (0.82, 2.59)**	**1.26 (0.08, 2.45)**	**1.94 (0.69, 3.20)**	**1.71 (0.62, 2.80)**	**1.46 (0.21, 2.72)**
	Obese	**2.47 (0.78, 4.17)**	2.27 (-0.70, 5.24)	**2.61 (0.57, 4.65)**	1.93 (-0.22, 4.09)	**3.53 (0.68, 6.37)**	1.88 (-1.92, 5.70)	3.22 (-1.78, 8.24)	1.96 (-0.61, 4.54)	**3.66 (0.22, 7.10)**
Model 3	**Under-weight**	**-2.05 (-3.04, -1.06)**	-1.29 (-2.64, 0.05)	**-2.95 (-4.40, -1.50)**	-1.75 (-3.74, 0.23)	**-2.17 (-3.25, -1.09)**	-0.30 (-3.10, 2.48)	**-1.77 (-3.23, -0.30)**	**-3.31 (-6.16, -0.47)**	**-2.66 (-4.27, -1.04)**
	Normal	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)
	Over-weight	**1.77 (1.15, 2.39)**	**1.55 (0.65, 2.44)**	**1.98 (1.12, 2.84)**	**1.62 (0.76, 2.49)**	**1.62 (0.72, 2.53)**	1.08 (-0.18, 2.35)	**1.87 (0.59, 3.15)**	**2.10 (0.93, 3.27)**	**1.39 (0.11, 2.66)**
	Obese	**2.22 (0.44, 3.99)**	2.31 (-0.81, 5.44)	**2.24 (0.10, 4.38)**	1.51 (-0.78, 3.81)	**3.66 (0.77, 6.55)**	1.65 (-2.41, 5.73)	3.81 (-1.33, 8.96)	1.43 (-1.31, 4.19)	**3.64 (0.15, 7.13)**

*CI – confidence interval, A-A – African-American

†Underweight: <5th percentile, normal weight 5 - <85th percentile, overweight: 85th - <99th percentile, obese: ≥99th percentile

‡Bold font indicates model results are significant at α = 0.05. Model 1 was unadjusted, Model 2 was adjusted for gender (when appropriate), race (when appropriate), study site, and socioeconomic index (SEI), Model 3 was adjusted for gender (when appropriate), race (when appropriate), study site, SEI, small for gestational age status, current maternal smoking, maternal age, and maternal pre-pregnancy BMI.

Table A2.24: Association between obesity status classified using body mass index (BMI) and Wechsler Intelligence Scales for Children full-scale IQ score at age seven years in the Collaborative Perinatal Project using an obesity cut-point of the 99th percentile, overall and stratified by gender, race, and gender/race; estimate (95% CI) *†‡

		Crude / Pooled	By gender		By race		By gender and race			
			Girls	Boys	Whites	A-A	White girls	A-A girls	White Boys	A-A Boys
Model 1 (Crude)	Under-weight	**-6.27 (-7.35, -5.20)**								
	Normal	0.00 (ref)								
	Over-weight	**2.35 (1.67, 3.04)**								
	Obese	**4.24 (1.59, 6.88)**								
Model 2	Under-weight	**-2.52 (-3.45, -1.60)**	**-2.99 (-4.21, -1.77)**	**-2.09 (-3.49, -0.68)**	**-3.51 (-5.37, -1.65)**	**-2.13 (-3.17, -1.09)**	**-4.71 (-7.30, -2.11)**	**-2.51 (-3.86, -1.17)**	-2.18 (-4.86, 0.48)	**-1.64 (-3.28, -0.00)**
	Normal	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)
	Over-weight	**1.00 (0.42, 1.59)**	0.69 (-0.12, 1.50)	**1.21 (0.38, 2.05)**	0.38 (-0.40, 1.17)	**1.76 (0.90, 2.63)**	0.27 (-0.88, 1.42)	**1.24 (0.10, 2.38)**	0.47 (-0.60, 1.55)	**2.40 (1.08, 3.72)**
	Obese	**3.10 (0.83, 5.36)**	**4.56 (0.86, 8.25)**	2.05 (-0.81, 4.92)	2.78 (-0.19, 5.77)	3.43 (-0.02, 6.89)	4.22 (-1.32, 9.77)	**5.06 (0.16, 9.96)**	2.20 (-1.33, 5.74)	1.94 (-2.94, 6.84)
Model 3	Under-weight	**-2.34 (-3.28, -1.39)**	**-2.61 (-3.86, -1.36)**	**-2.17 (-3.60, -0.75)**	**-2.81 (-4.77, -0.86)**	**-2.10 (-3.15, -1.04)**	**-3.33 (-6.08, -0.58)**	**-2.47 (-3.83, -1.10)**	-2.20 (-4.99, 0.57)	**-1.67 (-3.32, -0.03)**
	Normal	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)
	Over-Weight	**1.35 (0.74, 1.96)**	**1.12 (0.27, 1.97)**	**1.49 (0.61, 2.36)**	**0.87 (0.02, 1.72)**	**1.83 (0.95, 2.72)**	0.81 (-0.41, 2.05)	**1.43 (0.26, 2.60)**	0.91 (-0.24, 2.07)	**2.32 (0.97, 3.66)**
	Obese	**3.78 (1.42, 6.14)**	**5.26 (1.44, 9.09)**	2.77 (-0.23, 5.78)	**3.63 (0.43, 6.84)**	**3.93 (0.45, 7.41)**	5.11 (-0.75, 10.99)	**5.48 (0.49, 10.46)**	3.08 (-0.72, 6.90)	2.60 (-2.27, 7.48)

*CI – confidence interval, A-A – African-American

†Underweight: <5th percentile, normal weight 5 - <85th percentile, overweight: 85th - <99th percentile, obese: ≥99th percentile

‡Bold font indicates model results are significant at α = 0.05. Model 1 was unadjusted, Model 2 was adjusted for gender (when appropriate), race (when appropriate), study site, and socioeconomic index (SEI), Model 3 was adjusted for gender (when appropriate), race (when appropriate), study site, SEI, small for gestational age status, current maternal smoking, maternal age, and maternal pre-pregnancy BMI.

Table A2.25: Association between obesity status classified using body mass index (BMI) and Stanford-Binet Intelligence Scales full-scale IQ score at age four years in the Collaborative Perinatal Project with large for gestational age children included, overall and stratified by gender, race, and gender/race; estimate (95% CI) *†‡

		Crude / Pooled	By gender		By race		By gender and race			
			Girls	**Boys**	**Whites**	**A-A**	**White girls**	**A-A girls**	**White boys**	**A-A Boys**
Model 1 (Crude)	**Under-weight**	**-4.97 (-6.07, -3.88)**								
	Normal	0.00 (ref)								
	Over-weight	**4.32 (3.60, 5.04)**								
	Obese	**4.28 (3.38, 5.18)**								
Model 2	**Under-weight**	**-2.24 (-3.20, -1.29)**	**-1.61 (-2.90, -0.31)**	**-3.03 (-4.44, -1.62)**	**-1.98 (-3.87, -0.09)**	**-2.39 (-3.44, -1.33)**	-1.24 (-3.85, 1.36)	**-1.84 (-3.25, -0.42)**	**-2.91 (-5.66, -0.17)**	**-3.04 (-4.62, -1.46)**
	Normal	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)
	Over-weight	**1.65 (1.01, 2.28)**	**1.59 (0.68, 2.49)**	**1.71 (0.82, 2.60)**	**1.30 (0.45, 2.16)**	**1.82 (0.86, 2.78)**	**1.27 (0.03, 2.51)**	**1.66 (0.32, 3.01)**	**1.34 (0.15, 2.53)**	**1.99 (0.62, 3.35)**
	Obese	**1.50 (0.71, 2.30)**	**1.36 (0.15, 2.58)**	**1.63 (0.59, 2.67)**	**1.05 (0.00, 2.11)**	**1.98 (0.74, 3.22)**	0.32 (-1.31, 1.96)	**2.87 (1.02, 4.72)**	**1.60 (0.23, 2.96)**	1.24 (-0.41, 2.91)
Model 3	**Under-weight**	**-2.10 (-3.07, -1.14)**	**-1.31 (-2.62, -0.00)**	**-3.08 (-4.51, -1.64)**	**-2.04 (-3.98, -0.09)**	**-2.10 (-3.17, -1.04)**	-0.61 (-3.31, 2.07)	**-1.62 (-3.05, -0.19)**	**-3.68 (-6.50, -0.86)**	**-2.68 (-4.27, -1.08)**
	Normal	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)
	Over-weight	**1.50 (0.84, 2.16)**	**1.42 (0.47, 2.36)**	**1.58 (0.65, 2.52)**	**1.21 (0.29, 2.13)**	**1.62 (0.65, 2.59)**	1.03 (-0.29, 2.36)	**1.61 (0.25, 2.98)**	**1.40 (0.13, 2.68)**	**1.62 (0.24, 3.00)**
	Obese	**1.59 (0.75, 2.43)**	**1.29 (0.00, 2.58)**	**1.84 (0.73, 2.95)**	**1.23 (0.09, 2.38)**	**1.83 (0.56, 3.10)**	0.22 (-1.57, 2.01)	**2.64 (0.73, 4.54)**	**1.93 (0.44, 3.41)**	1.21 (-0.49, 2.92)

*CI – confidence interval, A-A – African-American

†Underweight: <5th percentile, normal weight 5 - <85th percentile, overweight: 85th - <99th percentile, obese: ≥99th percentile, large for gestational age (≥90th percentile birthweight for gender, race, and gestational age)

‡Bold font indicates model results are significant at α = 0.05. Model 1 was unadjusted, Model 2 was adjusted for gender (when appropriate), race (when appropriate), study site, and socioeconomic index (SEI), Model 3 was adjusted for gender (when appropriate), race (when appropriate), study site, SEI, small for gestational age status, current maternal smoking, maternal age, and maternal pre-pregnancy BMI.

Table A2.26: Association between obesity status classified using body mass index (BMI) and Wechsler Intelligence Scales for Children full-scale IQ score at age seven years in the Collaborative Perinatal Project with large for gestational age children included, overall and stratified by gender, race, and gender/race; estimate (95% CI) *†‡

		Crude / Pooled	By gender		By race		By gender and race			
			Girls	Boys	Whites	A-A	White girls	A-A girls	White Boys	A-A Boys
Model 1 (Crude)	**Under-Weight**	**-6.22 (-7.27, -5.16)**								
	Normal	0.00 (ref)								
	Over-weight	**2.31 (1.57, 3.05)**								
	Obese	**2.76 (1.77, 3.75)**								
Model 2	**Under-weight**	**-2.59 (-3.49, -1.69)**	**-2.91 (-4.10, -1.73)**	**-2.35 (-3.72, -0.97)**	**-3.71 (-5.51, -1.90)**	**-2.15 (-3.17, -1.14)**	**-4.84 (-7.36, -2.32)**	**-2.35 (-3.67, -1.04)**	-2.47 (-5.05, 0.10)	**-1.91 (-3.52, -0.30)**
	Normal	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)
	Over-weight	**0.85 (0.22, 1.49)**	0.76 (-0.12, 1.65)	0.88 (-0.01, 1.78)	0.23 (-0.61, 1.08)	**1.60 (0.66, 2.54)**	0.26 (-0.97, 1.50)	**1.30 (0.02, 2.57)**	0.22 (-0.94, 1.39)	**1.92 (0.53, 3.32)**
	Obese	**1.57 (0.73, 2.42)**	**1.24 (0.05, 2.42)**	**1.75 (0.54, 2.96)**	1.00 (-0.12, 2.14)	**2.33 (1.06, 3.61)**	1.19 (-0.50, 2.89)	1.60 (-0.04, 3.25)	0.82 (-0.70, 2.34)	**3.31 (1.31, 5.31)**
Model 3	**Under-weight**	**-2.43 (-3.35, -1.51)**	**-2.52 (-3.74, -1.30)**	**-2.47 (-3.87, -1.07)**	**-3.24 (-5.12, -1.36)**	**-2.07 (-3.11, -1.04)**	**-3.67 (-6.31, -1.03)**	**-2.24 (-3.57, -0.90)**	**-2.72 (-5.39, -0.05)**	**-1.88 (-3.50, -0.26)**
	Normal	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)
	Over-Weight	**1.07 (0.41, 1.74)**	**1.03 (0.10, 1.96)**	**1.05 (0.11, 1.99)**	0.59 (-0.31, 1.50)	**1.51 (0.55, 2.47)**	0.61 (-0.71, 1.95)	**1.37 (0.07, 2.67)**	0.61 (-0.64, 1.86)	**1.68 (0.25, 3.10)**
	Obese	**1.83 (0.94, 2.73)**	**1.65 (0.40, 2.90)**	**1.87 (0.60, 3.15)**	**1.25 (0.02, 2.47)**	**2.52 (1.21, 3.82)**	1.66 (-0.18, 3.51)	**1.79 (0.10, 3.49)**	0.88 (-0.75, 2.53)	**3.45 (1.43, 5.48)**

*CI – confidence interval, A-A – African-American

†Underweight: <5^{th} percentile, normal weight 5 - <85^{th} percentile, overweight: 85^{th} - <99^{th} percentile, obese: ≥99^{th} percentile, large for gestational age (≥90^{th} percentile birthweight for gender, race, and gestational age)

‡Bold font indicates model results are significant at α = 0.05. Model 1 was unadjusted, Model 2 was adjusted for gender (when appropriate), race (when appropriate), study site, and socioeconomic index (SEI), Model 3 was adjusted for gender (when appropriate), race (when appropriate), study site, SEI, small for gestational age status, current maternal smoking, maternal age, and maternal pre-pregnancy BMI.

Table A2.27: Association between obesity status classified using body mass index (BMI) and Stanford-Binet Intelligence Scales full-scale IQ score at age four years in the Collaborative Perinatal Project including children with gestational ages from 32-45 weeks, overall and stratified by gender, race, and gender/race; estimate (95% CI) *†‡

		Crude / Pooled	By gender		By race		By gender and race			
			Girls	Boys	Whites	A-A	White girls	A-A girls	White boys	A-A Boys
Model 1 (Crude)	Under-weight	**-4.62 (-5.63, -3.61)**								
	Normal	0.00 (ref)								
	Over-weight	**4.64 (3.92, 5.35)**								
	Obese	**4.73 (3.81, 5.64)**								
Model 2	Under-weight	**-1.97 (-2.84, -1.09)**	**-1.59 (-2.78, -0.39)**	**-2.42 (-3.73, -1.12)**	-1.14 (-2.95, 0.65)	**-2.22 (-3.18, -1.25)**	-0.47 (-2.95, 1.99)	**-2.03 (-3.33, -0.73)**	-2.01 (-4.67, 0.64)	**-2.43 (-3.87, -0.99)**
	Normal	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)
	Over-weight	**1.64 (1.02, 2.27)**	**1.53 (0.63, 2.43)**	**1.75 (0.88, 2.63)**	**1.28 (0.43, 2.14)**	**1.81 (0.86, 2.75)**	**1.27 (0.03, 2.51)**	**1.44 (0.11, 2.77)**	**1.29 (0.12, 2.47)**	**2.18 (0.84, 3.52)**
	Obese	**1.67 (0.87, 2.48)**	**1.67 (0.42, 2.91)**	**1.71 (0.66, 2.75)**	**1.13 (0.06, 2.20)**	**2.27 (1.01, 3.53)**	0.45 (-1.23, 2.14)	**3.37 (1.47, 5.27)**	**1.63 (0.26, 3.00)**	1.40 (-0.28, 3.08)
Model 3	Under-weight	**-1.85 (-2.74, -0.96)**	**-1.32 (-2.53, -0.10)**	**-2.46 (-3.78, -1.14)**	-1.23 (-3.09, 0.62)	**-2.01 (-2.98, -1.03)**	-0.03 (-2.60, 2.52)	**-1.82 (-3.14, -0.51)**	-2.60 (-5.31, 0.11)	**-2.20 (-3.66, -0.75)**
	Normal	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)
	Over-weight	**1.56 (0.90, 2.21)**	**1.37 (0.43, 2.31)**	**1.72 (0.81, 2.64)**	**1.18 (0.27, 2.09)**	**1.78 (0.83, 2.74)**	0.98 (-0.34, 2.31)	**1.51 (0.16, 2.86)**	**1.33 (0.09, 2.58)**	**2.06 (0.70, 3.41)**
	Obese	**1.94 (1.09, 2.79)**	**1.75 (0.43, 3.07)**	**2.10 (0.98, 3.21)**	**1.64 (0.48, 2.80)**	**2.14 (0.84, 3.43)**	0.66 (-1.15, 2.49)	**3.11 (1.14, 5.07)**	**2.30 (0.81, 3.79)**	1.39 (-0.32, 3.11)

*CI – confidence interval, A-A – African-American

†Underweight: <5th percentile, normal weight 5 - <85th percentile, overweight: 85th - <99th percentile, obese: ≥99th percentile

‡Bold font indicates model results are significant at α = 0.05. Model 1 was unadjusted, Model 2 was adjusted for gender (when appropriate), race (when appropriate), study site, and socioeconomic index (SEI), Model 3 was adjusted for gender (when appropriate), race (when appropriate), study site, SEI, small for gestational age status, current maternal smoking, maternal age, and maternal pre-pregnancy BMI.

Table A2.28: Association between obesity status classified using body mass index (BMI) and Wechsler Intelligence Scales for Children full-scale IQ score at age seven years in the Collaborative Perinatal Project including children with gestational ages from 32-45 weeks, overall and stratified by gender, race, and gender/race; estimate (95% CI) *†‡

		Crude / Pooled	By gender		By race		By gender and race			
			Girls	**Boys**	**Whites**	**A-A**	**White girls**	**A-A girls**	**White boys**	**A-A Boys**
Model 1 (Crude)	**Under-weight**	**-5.91 (-6.88, -4.94)**								
	Normal	0.00 (ref)								
	Over-weight	**2.63 (1.89, 3.36)**								
	Obese	**2.91 (1.90, 3.92)**								
Model 2	**Under-weight**	**-2.32 (-3.16, -1.49)**	**-2.69 (-3.78, -1.61)**	**-1.98 (-3.27, -0.69)**	**-2.86 (-4.59, -1.13)**	**-2.05 (-2.98, -1.12)**	**-3.67 (-6.02, -1.33)**	**-2.34 (-3.53, -1.15)**	-1.89 (-4.45, 0.67)	**-1.65 (-3.14, -0.17)**
	Normal	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)
	Over-weight	**0.85 (0.22, 1.48)**	0.71 (-0.17, 1.60)	**0.93 (0.04, 1.82)**	0.07 (-0.77, 0.92)	**1.83 (0.90, 2.77)**	-0.17 (-1.42, 1.06)	**1.74 (0.47, 3.01)**	0.30 (-0.86, 1.46)	**1.93 (0.55, 3.31)**
	Obese	**1.75 (0.89, 2.61)**	**1.91 (0.72, 3.10)**	**1.40 (0.16, 2.64)**	0.86 (-0.31, 2.04)	**2.78 (1.53, 4.03)**	1.16 (-0.61, 2.93)	**2.87 (1.28, 4.47)**	0.60 (-0.97, 2.19)	**2.64 (0.64, 4.64)**
Model 3	**Under-weight**	**-2.14 (-3.00, -1.29)**	**-2.41 (-3.53, -1.30)**	**-1.97 (-3.28, -0.65)**	**-2.42 (-4.24, -0.61)**	**-1.94 (-2.89, -0.99)**	**-2.89 (-5.40, -0.38)**	**-2.23 (-3.45, -1.02)**	-1.87 (-4.51, 0.77)	**-1.57 (-3.07, -0.08)**
	Normal	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)
	Over-Weight	**1.14 (0.48, 1.80)**	**0.99 (0.07, 1.92)**	**1.21 (0.28, 2.15)**	0.53 (-0.37, 1.44)	**1.81 (0.86, 2.77)**	0.25 (-1.07, 1.58)	**1.76 (0.47, 3.06)**	0.76 (-0.48, 2.01)	**1.87 (0.46, 3.28)**
	Obese	**2.13 (1.23, 3.04)**	**2.45 (1.20, 3.70)**	**1.65 (0.35, 2.96)**	**1.35 (0.08, 2.62)**	**3.00 (1.71, 4.29)**	1.75 (-0.14, 3.66)	**3.18 (1.53, 4.84)**	1.00 (-0.70, 2.70)	**2.71 (0.67, 4.76)**

*CI – confidence interval, A-A – African-American

†Underweight: <5th percentile, normal weight 5 - <85th percentile, overweight: 85th - <99th percentile, obese: ≥99th percentile

‡Bold font indicates model results are significant at $\alpha = 0.05$. Model 1 was unadjusted, Model 2 was adjusted for gender (when appropriate), race (when appropriate), study site, and socioeconomic index (SEI), Model 3 was adjusted for gender (when appropriate), race (when appropriate), study site, SEI, small for gestational age status, current maternal smoking, maternal age, and maternal pre-pregnancy BMI.

Table A2.29: Association between obesity status classified using body mass index (BMI) and Stanford-Binet Intelligence Scales full-scale IQ score at age four years in the Collaborative Perinatal Project including children of all races, overall and stratified by gender, race, and gender/race; estimate (95% CI) *†‡

		Crude / Pooled	By gender: Girls	By gender: Boys	By race: Whites	By race: A-A	By race: Other
Model 1 (Crude)	Under-weight	-4.85 (-5.94, -3.75)					
	Normal	0.00 (ref)					
	Over-weight	4.56 (3.80, 5.32)					
	Obese	4.07 (3.11, 5.03)					
Model 2	Under-weight	-2.33 (-3.29, -1.37)	-1.75 (-3.07, -0.44)	-3.01 (-4.42, -1.60)	-1.76 (-3.69, 0.17)	-2.44 (-3.52, -1.37)	0.38 (-4.96, 5.73)
	Normal	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)
	Over-weight	1.98 (1.31, 2.65)	1.94 (0.98, 2.89)	2.02 (1.08, 2.96)	1.67 (0.76, 2.59)	1.86 (0.82, 2.90)	0.19 (-3.21, 3.60)
	Obese	1.79 (0.95, 2.63)	1.77 (0.48, 3.07)	1.82 (0.71, 2.92)	1.28 (0.14, 2.43)	1.84 (0.47, 3.20)	0.59 (-2.89, 4.07)
Model 3	Under-weight	-2.16 (-3.14, -1.19)	-1.47 (-2.80, -0.13)	-2.98 (-4.41, -1.56)	-1.75 (-3.74, 0.23)	-2.17 (-3.25, -1.09)	2.08 (-3.67, 7.83)
	Normal	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)
	Over-weight	1.86 (1.16, 2.56)	1.74 (0.74, 2.73)	1.99 (1.01, 2.97)	1.57 (0.59, 2.55)	1.79 (0.74, 2.85)	-0.58 (-4.07, 2.89)
	Obese	2.02 (1.14, 2.91)	1.95 (0.59, 3.31)	2.09 (0.92, 3.26)	1.68 (0.44, 2.93)	1.77 (0.38, 3.17)	-0.01 (-3.59, 3.57)

		By gender and race: White girls	A-A girls	Other girls	White boys	A-A boys	Other boys
Model 2	Under-weight	-1.06 (-3.76, 1.64)	-1.95 (-3.40, -0.50)	0.19 (-7.42, 7.81)	-2.60 (-5.37, 0.16)	-3.02 (-4.63, -1.42)	0.68 (-6.92, 8.29)
	Normal	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)
	Over-weight	1.65 (0.32, 2.98)	1.69 (0.23, 3.15)	-0.07 (-4.77, 4.61)	1.70 (0.44, 2.96)	2.05 (0.57, 3.53)	0.52 (-4.54, 5.58)
	Obese	0.59 (-1.21, 2.39)	2.68 (0.64, 4.72)	2.22 (-2.97, 7.42)	1.78 (0.31, 3.26)	1.13 (-0.70, 2.98)	-0.74 (-5.49, 4.00)
Model 3	Under-weight	-0.29 (-3.09, 2.49)	-1.77 (-3.23, -0.30)	1.97 (-6.37, 10.32)	-3.32 (-6.16, -0.47)	-2.65 (-4.26, -1.04)	2.71 (-5.37, 10.80)
	Normal	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)
	Over-Weight	1.34 (-0.07, 2.76)	1.71 (0.22, 3.19)	-1.31 (-5.95, 3.32)	1.79 (0.44, 3.14)	1.90 (0.40, 3.40)	0.30 (-4.99, 5.60)
	Obese	0.65 (-1.29, 2.60)	2.52 (0.43, 4.61)	2.86 (-2.18, 7.92)	2.37 (0.77, 3.97)	1.18 (-0.68, 3.06)	-2.60 (-7.74, 2.53)

*CI – confidence interval, A-A – African-American

†Underweight: <5th percentile, normal weight 5 - <85th percentile, overweight: 85th - <99th percentile, obese: ≥99th percentile; "Other" race includes original Collaborative Perinatal Project categories "Puerto Rican," "Oriental," and "Other"

‡Bold font indicates model results are significant at $\alpha = 0.05$. Model 1 was unadjusted, Model 2 was adjusted for gender (when appropriate), race (when appropriate), study site, and socioeconomic index (SEI), Model 3 was adjusted for gender (when appropriate), race (when appropriate), study site, SEI, small for gestational age status, current maternal smoking, maternal age, and maternal pre-pregnancy BMI.

Table A2.30: Association between obesity status classified using body mass index (BMI) and Wechsler Intelligence Scales for Children full-scale IQ score at age seven years in the Collaborative Perinatal Project including children of all races, overall and stratified by gender, race, and gender/race; estimate (95% CI) *†‡

		Crude / Pooled	By gender: Girls	By gender: Boys	By race: Whites	By race: A-A	By race: Other
Model 1 (Crude)	Underweight	-6.13 (-7.19, -5.08)					
	Normal	0.00 (ref)					
	Overweight	2.24 (1.45, 3.02)					
	Obese	2.37 (1.33, 3.42)					
Model 2	Underweight	-2.76 (-3.67, -1.85)	-3.14 (-4.34, -1.94)	-2.44 (-3.84, -1.04)	-3.51 (-5.37, -1.64)	-2.13 (-3.17, -1.08)	-2.77 (-7.25, 1.71)
	Normal	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)
	Overweight	0.98 (0.30, 1.65)	0.67 (-0.27, 1.61)	1.23 (0.26, 2.19)	0.16 (-0.75, 1.08)	1.77 (0.75, 2.79)	0.31 (-3.08, 3.70)
	Obese	1.84 (0.95, 2.74)	1.34 (0.08, 2.61)	2.20 (0.93, 3.47)	1.22 (-0.02, 2.47)	2.03 (0.65, 3.41)	0.25 (-2.94, 3.44)
Model 3	Underweight	-2.63 (-3.56, -1.70)	-2.78 (-4.00, -1.55)	-2.61 (-4.03, -1.19)	-2.81 (-4.77, -0.86)	-2.10 (-3.15, -1.04)	-2.86 (-7.53, 1.81)
	Normal	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)
	Overweight	1.36 (0.66, 2.07)	1.08 (0.10, 2.06)	1.60 (0.59, 2.61)	0.68 (-0.29, 1.66)	1.80 (0.76, 2.84)	-0.10 (-3.60, 3.39)
	Obese	2.20 (1.26, 3.14)	1.89 (0.57, 3.22)	2.39 (1.06, 3.72)	1.69 (0.35, 3.04)	2.25 (0.84, 3.66)	-0.92 (-4.22, 2.37)

		By gender and race: White girls	A-A girls	Other girls	White boys	A-A boys	Other boys
Model 2	Underweight	-4.70 (-7.30, -2.10)	-2.51 (-3.86, -1.17)	-2.67 (-8.00, 2.65)	-2.19 (-4.86, 0.48)	-1.64 (-3.28, -0.00)	-3.40 (-11.61, 4.81)
	Normal	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)
	Overweight	-0.00 (-1.34, 1.33)	1.33 (-0.03, 2.69)	0.08 (-4.65, 4.82)	0.32 (-0.93, 1.57)	2.27 (0.73, 3.81)	0.45 (-4.46, 5.37)
	Obese	1.33 (-0.58, 3.24)	1.56 (-0.21, 3.34)	-0.41 (-5.08, 4.25)	1.11 (-0.53, 2.76)	2.64 (0.47, 4.81)	0.78 (-3.65, 5.23)
Model 3	Underweight	-3.33 (-6.08, -0.58)	-2.47 (-3.83, -1.10)	-1.54 (-7.34, 4.24)	-2.20 (-4.99, 0.57)	-1.67 (-3.32, -0.03)	-4.29 (-12.40, 3.81)
	Normal	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)
	Over-Weight	0.50 (-0.91, 1.93)	1.50 (0.12, 2.89)	-0.42 (-5.37, 4.52)	0.84 (-0.50, 2.19)	2.15 (0.59, 3.71)	0.56 (-4.49, 5.62)
	Obese	1.98 (-0.07, 4.03)	1.81 (-0.01, 3.65)	-1.57 (-6.30, 3.16)	1.46 (-0.31, 3.25)	2.78 (0.59, 4.97)	-0.62 (-5.26, 4.02)

*CI – confidence interval, A-A – African-American

†Underweight: <5th percentile, normal weight 5 - <85th percentile, overweight: 85th - <99th percentile, obese: ≥99th percentile; "Other" race includes original Collaborative Perinatal Project categories "Puerto Rican," "Oriental," and "Other"

‡Bold font indicates model results are significant at $\alpha = 0.05$. Model 1 was unadjusted, Model 2 was adjusted for gender (when appropriate), race (when appropriate), study site, and socioeconomic index (SEI), Model 3 was adjusted for gender (when appropriate), race (when appropriate), study site, SEI, small for gestational age status, current maternal smoking, maternal age, and maternal pre-pregnancy BMI.

Table A2.31: Association between obesity status classified using body mass index (BMI) and Stanford-Binet Intelligence Scales full-scale IQ score at age four years in the Collaborative Perinatal Project including, overall and stratified by gender, socioeconomic index (SEI, dichotomized at the median), and gender/SEI; estimate (95% CI) *†‡

		Crude / Pooled	By gender		By SEI		By gender and SEI			
			Girls	Boys	High	Low	High-SEI girls	Low-SEI girls	High-SEI Boys	Low-SEI Boys
Model 1 (Crude)	Under-weight	-5.13 (-6.25, -4.00)								
	Normal	0.00 (ref)								
	Over-weight	4.70 (3.91, 5.48)								
	Obese	4.41 (3.42, 5.40)								
Model 2	Under-weight	-2.34 (-3.34, -1.34)	-1.71 (-3.07, -0.34)	-3.09 (-4.55, -1.62)	-2.69 (-4.35, -1.04)	-2.10 (-3.31, -0.89)	-2.53 (-4.85, -0.21)	-1.33 (-2.97, 0.29)	-2.89 (-5.24, -0.54)	-3.10 (-4.92, -1.29)
	Normal	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)
	Over-weight	1.67 (0.97, 2.37)	1.61 (0.61, 2.61)	1.74 (0.76, 2.72)	1.11 (0.15, 2.07)	2.27 (1.25, 3.30)	0.42 (-0.94, 1.79)	3.11 (1.65, 4.57)	1.80 (0.46, 3.13)	1.38 (-0.04, 2.81)
	Obese	1.25 (0.37, 2.14)	1.08 (-0.28, 2.44)	1.41 (0.25, 2.57)	0.90 (-0.29, 2.10)	1.74 (0.42, 3.05)	1.34 (-0.51, 3.20)	0.50 (-1.52, 2.52)	0.60 (-0.97, 2.18)	2.72 (0.99, 4.44)
Model 3	Under-weight	-2.17 (-3.18, -1.16)	-1.35 (-2.73, 0.02)	-3.12 (-4.60, -1.63)	-2.86 (-4.53, -1.18)	-1.74 (-2.96, -0.52)	-2.32 (-4.68, 0.04)	-0.85 (-2.50, 0.79)	-3.43 (-5.81, -1.06)	-2.86 (-4.69, -1.03)
	Normal	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)
	Over-weight	1.59 (0.86, 2.32)	1.44 (0.40, 2.48)	1.73 (0.71, 2.75)	1.13 (0.12, 2.14)	2.14 (1.09, 3.19)	0.34 (-1.10, 1.78)	2.86 (1.36, 4.35)	1.93 (0.53, 3.34)	1.35 (-0.11, 2.82)
	Obese	1.56 (0.62, 2.50)	1.19 (-0.24, 2.63)	1.86 (0.62, 3.09)	1.46 (0.18, 2.74)	1.80 (0.42, 3.17)	1.79 (-0.19, 3.78)	0.41 (-1.66, 2.50)	1.33 (-0.33, 3.00)	2.89 (1.07, 4.71)

*CI – confidence interval

†Underweight: <5th percentile, normal weight 5 - <85th percentile, overweight: 85th - <99th percentile, obese: ≥99th percentile

‡Bold font indicates model results are significant at α = 0.05. Model 1 was unadjusted, Model 2 was adjusted for gender (when appropriate), SEI (when appropriate), study site, and race, Model 3 was adjusted for gender (when appropriate), SEI (when appropriate), study site, race, small for gestational age status, current maternal smoking, maternal age, and maternal pre-pregnancy BMI.

Table A2.32: Association between obesity status classified using body mass index (BMI) and Wechsler Intelligence Scales for Children full-scale IQ score at age seven years in the Collaborative Perinatal Project including, overall and stratified by gender, socioeconomic index (SEI, dichotomized at the median), and gender/SEI; estimate (95% CI) *†‡

		Crude / Pooled	By gender		By SEI		By gender and SEI			
			Girls	**Boys**	**High**	**Low**	**High-SEI girls**	**Low-SEI girls**	**High-SEI Boys**	**Low-SEI Boys**
Model 1 (Crude)	**Under-weight**	-6.19 (-7.28, -5.11)								
	Normal	0.00 (ref)								
	Over-weight	2.26 (1.45, 3.07)								
	Obese	2.72 (1.62, 3.82)								
Model 2	**Under-weight**	-2.78 (-3.73, -1.83)	-3.24 (-4.49, -1.98)	-2.36 (-3.80, -0.92)	-2.19 (-3.74, -0.64)	-2.94 (-4.12, -1.76)	-3.68 (-5.71, -1.64)	-2.90 (-4.48, -1.32)	-0.36 (-2.74, 2.01)	-3.16 (-4.94, -1.39)
	Normal	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)
	Over-weight	0.85 (0.15, 1.55)	0.62 (-0.36, 1.60)	1.01 (0.01, 2.01)	-0.10 (-1.05, 0.83)	2.15 (1.10, 3.19)	-0.27 (-1.59, 1.04)	1.78 (0.31, 3.25)	-0.00 (-1.35, 1.33)	2.46 (0.97, 3.94)
	Obese	1.34 (0.38, 2.29)	0.96 (-0.37, 2.31)	1.52 (0.17, 2.87)	0.68 (-0.58, 1.95)	2.17 (0.73, 3.60)	0.62 (-1.28, 2.53)	1.51 (-0.37, 3.39)	0.61 (-1.08, 2.32)	3.03 (0.82, 5.24)
Model 3	**Under-weight**	-2.61 (-3.58, -1.65)	-2.83 (-4.11, -1.55)	-2.50 (-3.96, -1.04)	-1.85 (-3.45, -0.25)	-2.77 (-3.96, -1.57)	-2.78 (-4.89, -0.66)	-2.67 (-4.27, -1.07)	-0.75 (-3.18, 1.67)	-3.04 (-4.83, -1.25)
	Normal	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)
	Over-Weight	1.28 (0.55, 2.01)	1.11 (0.09, 2.13)	1.38 (0.34, 2.43)	0.55 (-0.43, 1.54)	2.21 (1.14, 3.28)	0.46 (-0.92, 1.85)	1.88 (0.39, 3.37)	0.59 (-0.81, 2.00)	2.55 (1.01, 4.08)
	Obese	1.86 (0.86, 2.85)	1.64 (0.23, 3.05)	1.93 (0.51, 3.34)	1.23 (-0.09, 2.56)	2.50 (1.00, 4.01)	1.07 (-0.92, 3.08)	2.21 (0.25, 4.18)	1.40 (-0.37, 3.18)	2.94 (0.61, 5.28)

*CI – confidence interval

†Underweight: <5th percentile, normal weight 5 - <85th percentile, overweight: 85th - <99th percentile, obese: ≥99th percentile

‡Bold font indicates model results are significant at $\alpha = 0.05$. Model 1 was unadjusted, Model 2 was adjusted for gender (when appropriate), SEI (when appropriate), study site, and race, Model 3 was adjusted for gender (when appropriate), SEI (when appropriate), study site, race, small for gestational age status, current maternal smoking, maternal age, and maternal pre-pregnancy BMI.

Table A2.33: Association between obesity status classified using body mass index (BMI) and Stanford-Binet Intelligence Scales full-scale IQ score at age four years in the Collaborative Perinatal Project including, overall and stratified by gender, socioeconomic index (SEI, ≥75th percentile vs. <75th percentile), and gender/SEI; estimate (95% CI) *†‡

		Crude / Pooled	By gender		By SEI		By gender and SEI			
			Girls	**Boys**	**High**	**Low**	**High-SEI girls**	**Low-SEI girls**	**High-SEI boys**	**Low-SEI Boys**
Model 1 (Crude)	**Under-weight**	-5.13 (-6.25, -4.00)								
	Normal	0.00 (ref)								
	Over-weight	4.70 (3.91, 5.48)								
	Obese	4.41 (3.42, 5.40)								
Model 2	**Under-weight**	-2.46 (-3.45, -1.47)	-1.83 (-3.19, -0.47)	-3.21 (-4.67, -1.76)	-3.73 (-6.16, -1.29)	-2.15 (-3.22, -1.08)	-3.06 (-6.52, 0.38)	-1.56 (-3.01, -0.11)	-4.33 (-7.76, -0.91)	-2.86 (-4.45, -1.28)
	Normal	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)
	Over-weight	2.01 (1.31, 2.70)	1.96 (0.97, 2.96)	2.06 (1.08, 3.03)	0.82 (-0.49, 2.14)	2.56 (1.75, 3.38)	-0.64 (-2.51, 1.22)	3.19 (2.02, 4.36)	2.31 (0.45, 4.17)	1.91 (0.77, 3.05)
	Obese	1.68 (0.79, 2.56)	1.48 (0.12, 2.84)	1.85 (0.69, 3.00)	0.82 (-0.84, 2.49)	2.14 (1.10, 3.18)	1.86 (-0.67, 4.41)	1.33 (-0.27, 2.94)	0.06 (-2.14, 2.27)	2.78 (1.43, 4.14)
Model 3	**Under-weight**	-2.26 (-3.26, -1.26)	-1.47 (-2.84, -0.10)	-3.19 (-4.66, -1.72)	-4.02 (-6.50, -1.54)	-1.84 (-2.92, -0.76)	-2.59 (-6.11, 0.92)	-1.22 (-2.69, 0.24)	-5.23 (-8.72, -1.74)	-2.59 (-4.19, -1.00)
	Normal	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)
	Over-weight	1.92 (1.19, 2.64)	1.84 (0.81, 2.88)	1.98 (0.97, 2.99)	0.86 (-0.54, 2.27)	2.43 (1.59, 3.27)	-0.75 (-2.76, 1.25)	3.00 (1.80, 4.21)	2.46 (0.49, 4.44)	1.80 (0.62, 2.97)
	Obese	1.93 (1.00, 2.86)	1.47 (0.04, 2.90)	2.28 (1.06, 3.50)	1.34 (-0.44, 3.14)	2.36 (1.27, 3.45)	2.38 (-0.34, 5.11)	1.19 (-0.49, 2.87)	0.75 (-1.62, 3.13)	3.25 (1.83, 4.67)

*CI – confidence interval

†Underweight: <5th percentile, normal weight 5 - <85th percentile, overweight: 85th - <99th percentile, obese: ≥99th percentile

‡Bold font indicates model results are significant at α = 0.05. Model 1 was unadjusted, Model 2 was adjusted for gender (when appropriate), SEI (when appropriate), study site, and race, Model 3 was adjusted for gender (when appropriate), SEI (when appropriate), study site, race, small for gestational age status, current maternal smoking, maternal age, and maternal pre-pregnancy BMI.

Table A2.34: Association between obesity status classified using body mass index (BMI) and Wechsler Intelligence Scales for Children full-scale IQ score at age seven years in the Collaborative Perinatal Project including, overall and stratified by gender, socioeconomic index (SEI, ≥75th percentile vs. <75th percentile), and gender/SEI; estimate (95% CI) *†‡

		Crude / Pooled								
Model 1 (Crude)	Under-weight	-6.19 (-7.28, -5.11)								
	Normal	0.00 (ref)								
	Over-weight	2.26 (1.45, 3.07)	**By gender**		**By SEI**		**By gender and SEI**			
	Obese	2.72 (1.62, 3.82)	**Girls**	**Boys**	**High**	**Low**	**High-SEI girls**	**Low-SEI girls**	**High-SEI boys**	**Low-SEI Boys**
Model 2	Under-weight	-2.80 (-3.74, -1.86)	-3.20 (-4.44, -1.96)	-2.46 (-3.89, -1.03)	-3.40 (-5.73, -1.08)	-2.66 (-3.69, -1.64)	-4.32 (-7.43, -1.20)	-2.99 (-4.35, -1.64)	-2.25 (-5.73, 1.22)	-2.39 (-3.96, -0.83)
	Normal	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)
	Over-weight	0.98 (0.28, 1.68)	0.67 (-0.29, 1.65)	1.21 (0.22, 2.20)	-0.44 (-1.70, 0.80)	1.67 (0.83, 2.51)	-0.62 (-2.36, 1.12)	1.30 (0.12, 2.48)	-0.24 (-2.04, 1.55)	1.93 (0.74, 3.11)
	Obese	1.80 (0.86, 2.75)	1.42 (0.08, 2.75)	1.99 (0.65, 3.33)	-1.35 (-3.15, 0.45)	3.06 (1.95, 4.17)	-0.86 (-3.72, 1.99)	2.17 (0.66, 3.68)	-1.67 (-4.00, 0.65)	3.93 (2.30, 5.57)
Model 3	Under-weight	-2.56 (-3.51, -1.60)	-2.76 (-4.03, -1.49)	-2.47 (-3.92, -1.02)	-3.09 (-5.55, -0.64)	-2.39 (-3.43, -1.35)	-3.12 (-6.45, 0.20)	-2.66 (-4.03, -1.28)	-2.94 (-6.60, 0.70)	-2.23 (-3.80, -0.65)
	Normal	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)
	Over-Weight	1.29 (0.56, 2.01)	1.03 (0.02, 2.04)	1.47 (0.44, 2.51)	0.28 (-1.03, 1.60)	1.77 (0.90, 2.64)	-0.06 (-1.91, 1.77)	1.53 (0.31, 2.74)	0.71 (-1.17, 2.59)	1.91 (0.67, 3.15)
	Obese	2.23 (1.24, 3.22)	2.03 (0.63, 3.42)	2.30 (0.89, 3.70)	-0.73 (-2.62, 1.15)	3.43 (2.27, 4.60)	-0.30 (-3.32, 2.71)	2.75 (1.18, 4.32)	-0.71 (-3.14, 1.70)	4.11 (2.39, 5.83)

*CI – confidence interval

†Underweight: <5th percentile, normal weight 5 - <85th percentile, overweight: 85th - <99th percentile, obese: ≥99th percentile

‡Bold font indicates model results are significant at α = 0.05. Model 1 was unadjusted, Model 2 was adjusted for gender (when appropriate), SEI (when appropriate), study site, and race, Model 3 was adjusted for gender (when appropriate), SEI (when appropriate), study site, race, small for gestational age status, current maternal smoking, maternal age, and maternal pre-pregnancy BMI.

Table A2.35: Association between obesity status classified using body mass index (BMI) and Stanford-Binet Intelligence Scales full-scale IQ score at age four years in the Collaborative Perinatal Project including, overall and stratified by gender, socioeconomic index (SEI, ≥75th percentile vs. <25th percentile), and gender/SEI; estimate (95% CI) *†‡

Model		Crude / Pooled	By gender: Girls	By gender: Boys	By SEI: High	By SEI: Low	By gender and SEI: High-SEI girls	By gender and SEI: Low-SEI girls	By gender and SEI: High-SEI boys	By gender and SEI: Low-SEI Boys
Model 1 (Crude)	**Under-weight**	-6.16 (-7.93, -4.40)								
	Normal	0.00 (ref)								
	Over-weight	4.77 (3.55, 5.99)								
	Obese	4.51 (2.95, 6.08)								
Model 2	**Under-weight**	-2.05 (-3.51, -0.59)	-1.33 (-3.35, 0.68)	-2.86 (-4.97, -0.75)	-3.73 (-6.16, -1.29)	-0.96 (-2.68, 0.76)	-3.06 (-6.52, 0.38)	-0.47 (-2.84, 1.90)	-4.33 (-7.76, -0.91)	-1.60 (-4.11, 0.91)
	Normal	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)
	Over-weight	1.36 (0.35, 2.37)	0.73 (-0.69, 2.17)	1.99 (0.57, 3.40)	0.82 (-0.49, 2.14)	1.88 (0.31, 3.46)	-0.64 (-2.51, 1.22)	2.93 (0.67, 5.20)	2.31 (0.45, 4.17)	0.78 (-1.40, 2.97)
	Obese	0.92 (-0.37, 2.22)	1.28 (-0.69, 3.25)	0.63 (-1.07, 2.35)	0.82 (-0.84, 2.49)	0.88 (-1.21, 2.97)	1.86 (-0.67, 4.41)	-0.44 (-3.64, 2.76)	0.06 (-2.14, 2.27)	1.86 (-0.88, 4.61)
Model 3	**Under-weight**	-1.79 (-3.26, -0.31)	-0.60 (-2.65, 1.44)	-3.07 (-5.20, -0.93)	-4.02 (-6.50, -1.54)	-0.32 (-2.07, 1.41)	-2.59 (-6.11, 0.92)	0.43 (-1.96, 2.84)	-5.23 (-8.72, -1.74)	-1.28 (-3.83, 1.25)
	Normal	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)
	Over-weight	1.31 (0.25, 2.37)	0.55 (-0.96, 2.07)	2.05 (0.56, 3.53)	0.86 (-0.54, 2.27)	1.82 (0.20, 3.43)	-0.75 (-2.76, 1.25)	2.62 (0.29, 4.94)	2.46 (0.49, 4.44)	1.00 (-1.22, 3.24)
	Obese	1.13 (-0.24, 2.50)	1.23 (-0.85, 3.33)	1.03 (-0.78, 2.86)	1.34 (-0.44, 3.14)	0.58 (-1.58, 2.75)	2.38 (-0.34, 5.11)	-1.35 (-4.67, 1.95)	0.75 (-1.62, 3.13)	1.96 (-0.89, 4.83)

*CI – confidence interval

†Underweight: <5th percentile, normal weight 5 - <85th percentile, overweight: 85th - <99th percentile, obese: ≥99th percentile

‡Bold font indicates model results are significant at α = 0.05. Model 1 was unadjusted, Model 2 was adjusted for gender (when appropriate), SEI (when appropriate), study site, and race, Model 3 was adjusted for gender (when appropriate), SEI (when appropriate), study site, race, small for gestational age status, current maternal smoking, maternal age, and maternal pre-pregnancy BMI.

Table A2.36: Association between obesity status classified using body mass index (BMI) and Wechsler Intelligence Scales for Children full-scale IQ score at age seven years in the Collaborative Perinatal Project including, overall and stratified by gender, socioeconomic index (SEI, ≥75th percentile vs. <25th percentile), and gender/SEI; estimate (95% CI) *†‡

		Crude / Pooled	By gender		By SEI		By gender and SEI			
			Girls	**Boys**	**High**	**Low**	**High-SEI girls**	**Low-SEI girls**	**High-SEI boys**	**Low-SEI Boys**
Model 1 (Crude)	**Under-weight**	-7.29 (-9.02, -5.56)								
	Normal	0.00 (ref)								
	Over-weight	2.31 (1.06, 3.57)								
	Obese	1.18 (-0.58, 2.96)								
Model 2	**Under-weight**	-2.20 (-3.59, -0.82)	-2.70 (-4.55, -0.85)	-1.81 (-3.88, 0.26)	-3.40 (-5.73, -1.08)	-1.29 (-2.99, 0.40)	-4.32 (-7.43, -1.20)	-1.91 (-4.19, 0.37)	-2.25 (-5.73, 1.22)	-0.91 (-3.45, 1.63)
	Normal	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)
	Over-weight	0.60 (-0.39, 1.60)	-0.33 (-1.72, 1.05)	1.55 (0.11, 2.98)	-0.44 (-1.70, 0.80)	2.45 (0.81, 4.08)	-0.62 (-2.36, 1.12)	0.02 (-2.24, 2.29)	-0.24 (-2.04, 1.55)	4.93 (2.58, 7.29)
	Obese	-0.33 (-1.74, 1.07)	-0.44 (-2.47, 1.59)	-0.38 (-2.33, 1.56)	-1.35 (-3.15, 0.45)	1.24 (-1.00, 3.49)	-0.86 (-3.72, 1.99)	0.39 (-2.47, 3.27)	-1.67 (-4.00, 0.65)	2.64 (-0.96, 6.24)
Model 3	**Under-weight**	-1.95 (-3.37, -0.53)	-2.08 (-4.00, -0.17)	-1.99 (-4.12, 0.12)	-3.09 (-5.55, -0.64)	-0.95 (-2.67, 0.76)	-3.12 (-6.45, 0.20)	-1.43 (-3.75, 0.87)	-2.94 (-6.60, 0.70)	-0.74 (-3.31, 1.83)
	Normal	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)	0.00 (ref)
	Over-Weight	1.10 (0.07, 2.14)	0.15 (-1.28, 1.58)	2.12 (0.63, 3.61)	0.28 (-1.03, 1.60)	2.36 (0.72, 4.01)	-0.06 (-1.91, 1.77)	0.06 (-2.20, 2.32)	0.71 (-1.17, 2.59)	4.76 (2.36, 7.17)
	Obese	0.33 (-1.13, 1.80)	0.41 (-1.71, 2.53)	0.18 (-1.85, 2.21)	-0.73 (-2.62, 1.15)	1.86 (-0.47, 4.20)	-0.30 (-3.32, 2.71)	1.13 (-1.82, 4.10)	-0.71 (-3.14, 1.70)	3.11 (-0.66, 6.90)

*CI – confidence interval

†Underweight: <5th percentile, normal weight 5 - <85th percentile, overweight: 85th - <99th percentile, obese: ≥99th percentile

‡Bold font indicates model results are significant at α = 0.05. Model 1 was unadjusted, Model 2 was adjusted for gender (when appropriate), SEI (when appropriate), study site, and race, Model 3 was adjusted for gender (when appropriate), SEI (when appropriate), study site, race, small for gestational age status, current maternal smoking, maternal age, and maternal pre-pregnancy BMI.

Table A2.37: Change in Differential Ability Scales composite score in children classified as overweight/obese using body mass index (BMI), triceps-skinfold-thickness (TST), and subscapular-skinfold-thickness (SST), compared with normal weight children, overall and stratified by gender and race in the Follow-Up Development and Growth Experiences Study; estimate (95% CI)*†‡

		Crude / Pooled	By gender		By race	
			Girls	**Boys**	**Whites**	**African-Americans**
Model 1 (Crude)	**BMI**	-0.54 (-5.39, 4.30)				
	TST	1.92 (-5.94, 9.79)				
	SST	-1.69 (-8.12, 4.72)				
Model 2	**BMI**	-1.85 (-5.63, 1.91)	1.16 (-4.27, 6.61)	-5.16 (-10.57, 0.23)	-4.31 (-10.24, 1.61)	-0.09 (-4.96, 4.77)
	TST	-4.08 (-10.09, 1.93)	-4.85 (-12.21, 2.50)	-2.13 (-13.33, 9.05)	-9.93 (-18.16, -1.70)	3.31 (-5.53, 12.17)
	SST	-6.03 (-10.88, -1.19)	-3.76 (-10.41, 2.88)	-9.09 (-16.48, -1.70)	-8.12 (-14.77, -1.47)	-2.81 (-9.96, 4.33)
Model 3	**BMI**	-0.69 (-4.41, 3.02)	3.42 (-1.81, 8.67)	-4.59 (-9.99, 0.81)	-3.10 (-9.19, 2.98)	1.26 (-3.39, 5.92)
	TST	-2.58 (-8.45, 3.28)	-2.20 (-9.30, 4.89)	-3.59 (-14.38, 7.19)	-6.58 (-15.08, 1.90)	2.32 (-5.98, 10.63)
	SST	-4.11 (-8.83, 0.61)	-0.09 (-6.52, 6.33)	-7.95 (-15.10, -0.80)	-4.42 (-11.35, 2.49)	-2.54 (-9.23, 4.15)

*CI – confidence interval
†Overweight/obese: ≥85th percentile
‡Bold font indicates model results are significant at α = 0.05. Model 1 was unadjusted, Model 2 was adjusted for gender (when appropriate), race (when appropriate), small for gestational age status, and prenatal alcohol consumption. Model 3 was adjusted for gender (when appropriate), race (when appropriate), small for gestational age status, prenatal alcohol consumption, hospital of birth, prenatal maternal smoking, current maternal smoking, maternal age, and maternal pre-pregnancy BMI.

A3. SUPPLEMENTAL MATERIAL TO CHAPTER 5

Appendix 3 contains supplemental material for Chapter 5 of this dissertation (The association between early childhood overweight/obesity and childhood adaptive functioning, behavior, and executive functioning in Atlanta children). A brief description of this material is below, followed by Figures A3.1 – A3.22 and Tables A3.1 – A3.10.

Abbreviations used in Appendix 3 are: FUDGE Study – Follow-Up Development and Growth Experiences Study; BMI – body mass index; TST – triceps-skinfold-thickness; SST – subscapular skinfold thickness; VABS – Vineland Adaptive Behavior Scales; CBCL – Child Behavior Checklist; NEPSY – a Developmental NEuroPSYchology Assessment; SGA – small for gestational age (< 10^{th} percentile birthweight for gender, race, and gestational age); AGA – appropriate for gestational age (10 - < 90^{th} percentile birthweight for gestational age).

Figures A3.1 – A3.5 present histograms of the VABS composite scale score, as well as the socialization, daily living, motor skills, and communications subscale scores, overall and stratified by gender, hospital of birth, and SGA status in the FUDGE Study population. In general, these plots demonstrate a slight-to-moderate shift to the left among boys and children born at the public hospital, though histograms for the VABS daily living subscale show little variation among groups regardless of stratification by gender or hospital of birth. For the VABS composite and all subscales, these histograms reveal little effect of SGA status on adaptive functioning skills.

- Figure A3.1: Histogram of VABS composite score
- Figure A3.2: Histogram of VABS socialization score

- Figure A3.3: Histogram of VABS daily living score
- Figure A3.4: Histogram of VABS motor skills score
- Figure A3.5: Histogram of VABS communication score

Figures A3.6 – A3.8 present histograms of CBCL total, internalizing, and externalizing behavior scores, overall and stratified by gender, hospital of birth, and SGA status in the FUDGE Study population. Histograms showing the distribution of CBCL total and externalizing behavior indicate a slight shift to the right for children born at the public hospital (indicating *more problematic behavior*), though little effect of gender or SGA status. Histograms for the distribution of CBCL internalizing behavior score track the population distribution well.

- Figure A3.6: Histogram of CBCL total behavior score
- Figure A3.7: Histogram of CBCL internalizing behavior score
- Figure A3.8: Histogram of CBCL externalizing behavior score

Figures A3.9 – A3.10 present histograms of scores on the NEPSY statue and visual attention tests, overall and stratified by gender, hospital of birth, and SGA status in the FUDGE Study population. In both overall and stratified plots, these plots are consistently left-skewed. Most plots track the population mean well, though children from the private hospital scored slightly higher on both tests and girls scored slightly higher on the visual attention test.

- Figure A3.9: Histogram of NEPSY statue score
- Figure A3.10: Histogram of NEPSY visual attention score

Figures A3.11 – A3.22 present scatter plots of BMI/TST/SST and: VABS composite score (A3.11 – A3.13); CBCL total behavior score (A3.14 – A3.16); NEPSY statue score (A3.17 – A3.19); and NEPSY visual attention score (A3.20 – A3.22). Plots are presented for overall results, and stratified by gender and hospital of birth. Plots include only data from children born AGA (to minimize confounding).

In general, these plots reveal little relationship between obesity metrics and scores on developmental assessments. Further, in both overall and stratified plots, the position of the centroid is consistent with the univariate results presented in Chapter 5. These plots also indicate that the NEPSY plots are highly discretized because of the small range of the NEPSY scoring.

- Figure A3.11: Scatter plot of BMI Z-score and VABS composite score
- Figure A3.12: Scatter plot of TST Z-score and VABS composite score
- Figure A3.13: Scatter plot of SST Z-score and VABS composite score
- Figure A3.14: Scatter plot of BMI Z-score and CBCL total behavior score
- Figure A3.15: Scatter plot of TST Z-score and CBCL total behavior score
- Figure A3.16: Scatter plot of SST Z-score and CBCL total behavior score
- Figure A3.17: Scatter plot of BMI Z-score and NEPSY statue score
- Figure A3.18: Scatter plot of TST Z-score and NEPSY statue score
- Figure A3.19: Scatter plot of SST Z-score and NEPSY statue score
- Figure A3.20: Scatter plot of BMI Z-score and NEPSY visual attention score
- Figure A3.21: Scatter plot of TST Z-score and NEPSY visual attention score
- Figure A3.22: Scatter plot of SST Z-score and NEPSY visual attention score

Tables A3.1 – A3.5 present the complete model results (i.e., for all three levels of adjustment) for the information presented in Table 5.4 of the dissertation. These models examine the association between overweight/obese BMI/TST/SST and VABS composite, socialization, daily living, motor skills, and communication scores, overall and stratified by gender and hospital of birth in the FUDGE Study. Tables A3.1 – A3.5 provide additional support for the results from Chapter 5 which demonstrate a potential negative relationship among several components of adaptive functioning and skinfold thickness measurements (TST, especially) among boys. No relationship is observed among overall, among girls, or after stratification by hospital of birth. Results from Models 2 and 3 reveal that adjustment for confounding produced little change in results.

- Table A3.1: BMI/TST/SST and VABS composite score
- Table A3.2: BMI/TST/SST and VABS socialization score
- Table A3.3: BMI/TST/SST and VABS daily living score
- Table A3.4: BMI/TST/SST and VABS motor skills score
- Table A3.5: BMI/TST/SST and VABS communication score

Tables A3.6 – A3.8 present the complete model results (i.e., for all three levels of adjustment) for the information presented in Table 5.5 of the dissertation. These models examine the association between overweight/obese BMI/TST/SST and CBCL total, internalizing, and externalizing behavior scores, overall and stratified by gender and hospital of birth in the FUDGE Study. As with the abbreviated versions of these tables presented in Chapter 5, no association is observed in overall or stratified models between

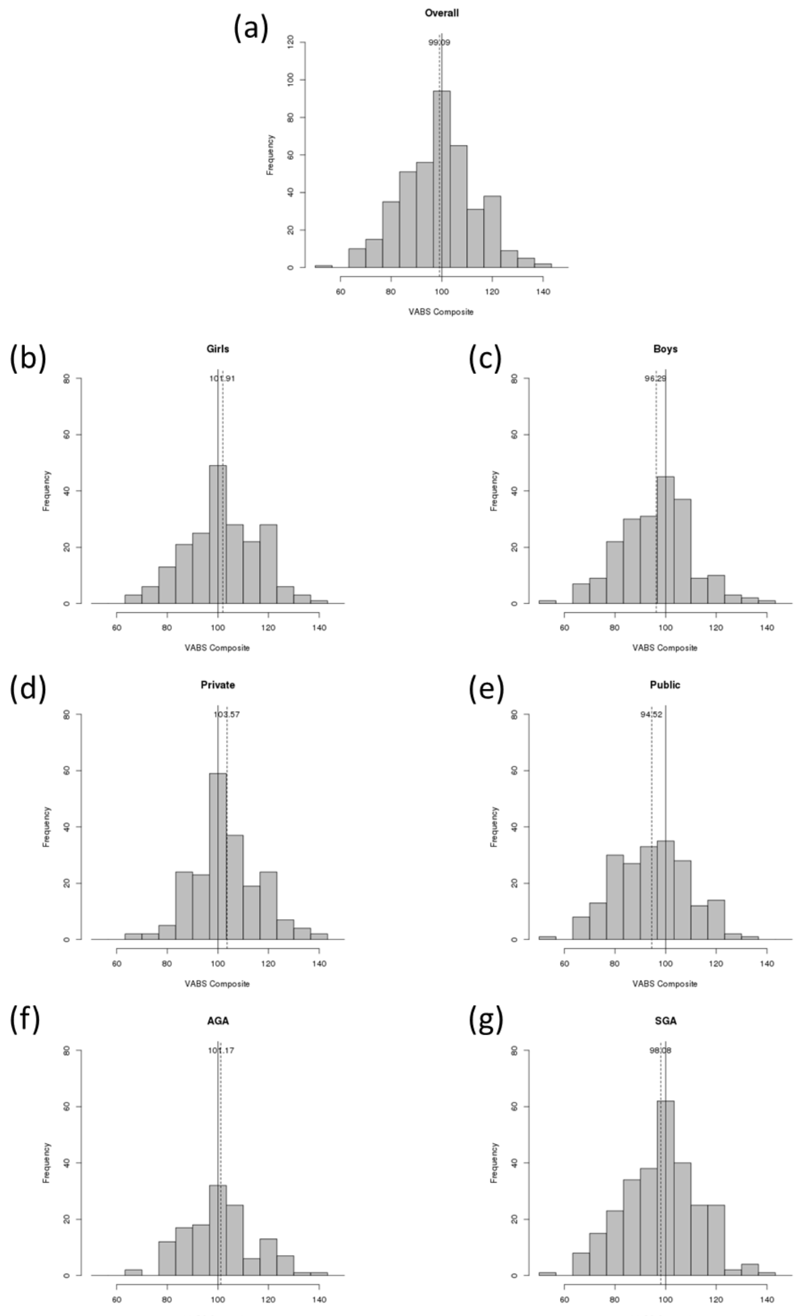
CBCL total, internalizing, or externalizing scores and any obesity metric. Further, adjustment for confounding has little impact on results.

- Table A3.6: BMI/TST/SST and CBCL total behavior score
- Table A3.7: BMI/TST/SST and CBCL internalizing behavior score
- Table A3.8: BMI/TST/SST and CBCL externalizing behavior score

Tables A3.9 – A3.10 present the complete model results (i.e., for all three levels of adjustment) for the information presented in Table 5.6 of the dissertation. These models examine the association between overweight/obese BMI/TST/SST and NEPSY statue and visual attention scores, overall and stratified by gender and hospital of birth in the FUDGE Study. These models suggest that a negative relationship exists between NEPSY statue score and girls and children born at the private hospital. No relationship between NEPSY statue score and boys or children born at the public hospital is observed. Neither overall nor stratified models provide evidence for a relationship between NEPSY visual attention scores and any obesity metric. In both Table A3.9 and A3.10, adjustment for confounding produces little change in results.

- Table A3.9: BMI/TST/SST and NEPSY statue score
- Table A3.10: BMI/TST/SST and NEPSY visual attention score

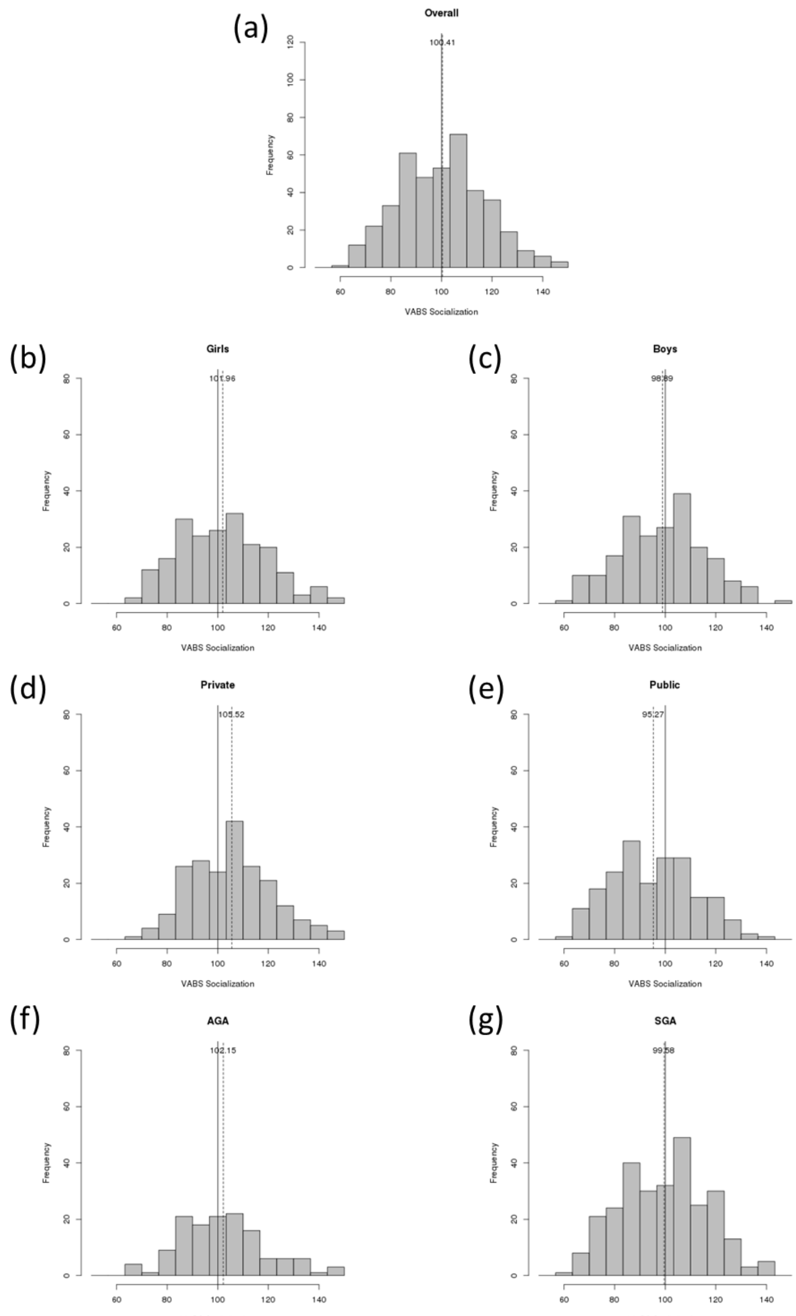
Figure A3.1: Histograms of Vineland Adaptive Behavior Scales (VABS) composite score in the Follow-Up Development and Growth Experiences (FUDGE) Study – overall (a) and stratified by gender (b-c), hospital of birth (d-e), and small for gestational age (SGA) status (f-g)*†



*SGA – small for gestational age (<10th percentile birthweight for gender, race, and gestational age), AGA – appropriate for gestational age (10 - <90th percentile birthweight for gender, race, and gestational age), overweight/obese: ≥85th percentile

†Solid line represents population mean (μ = 0), dashed line represents group mean (value provided)

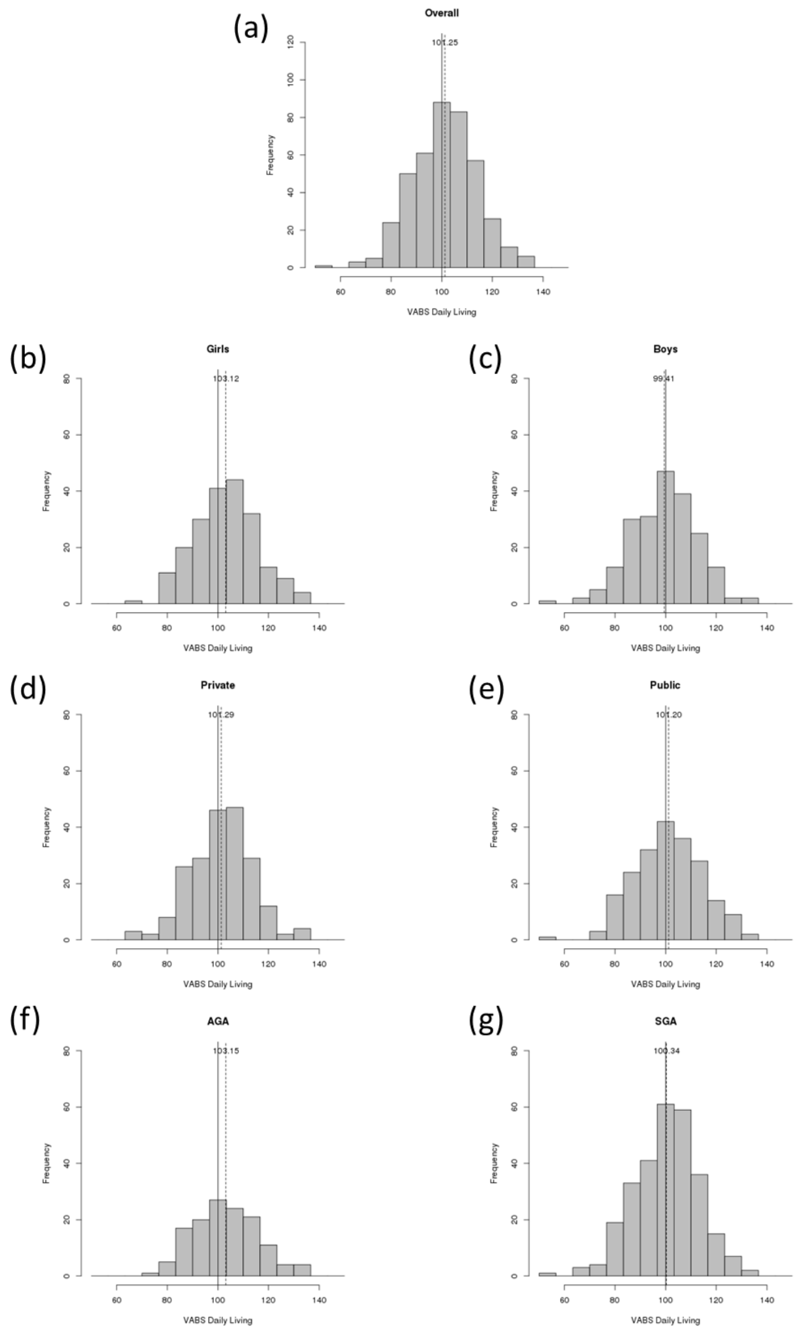
Figure A3.2: Histograms of Vineland Adaptive Behavior Scales (VABS) socialization score in the Follow-Up Development and Growth Experiences (FUDGE) Study – overall (a) and stratified by gender (b-c), hospital of birth (d-e), and small for gestational age (SGA) status (f-g)*†



*SGA – small for gestational age (<10th percentile birthweight for gender, race, and gestational age), AGA – appropriate for gestational age (10 - <90th percentile birthweight for gender, race, and gestational age), overweight/obese: ≥85th percentile

†Solid line represents population mean (μ = 0), dashed line represents group mean (value provided)

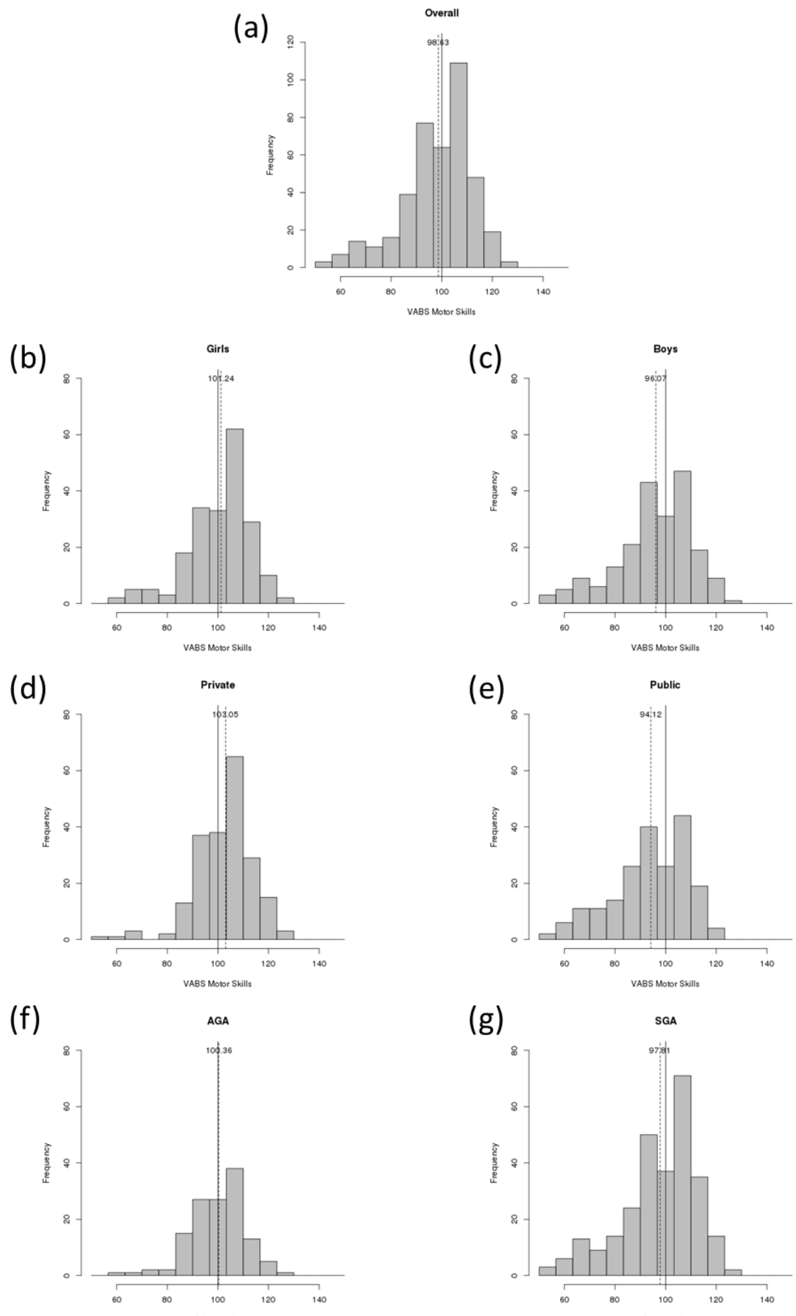
Figure A3.3: Histograms of Vineland Adaptive Behavior Scales (VABS) daily living score in the Follow-Up Development and Growth Experiences (FUDGE) Study – overall (a) and stratified by gender (b-c), hospital of birth (d-e), and small for gestational age (SGA) status (f-g)*†



*SGA – small for gestational age (<10th percentile birthweight for gender, race, and gestational age), AGA – appropriate for gestational age (10 - <90th percentile birthweight for gender, race, and gestational age), overweight/obese: ≥85th percentile

†Solid line represents population mean (μ = 0), dashed line represents group mean (value provided)

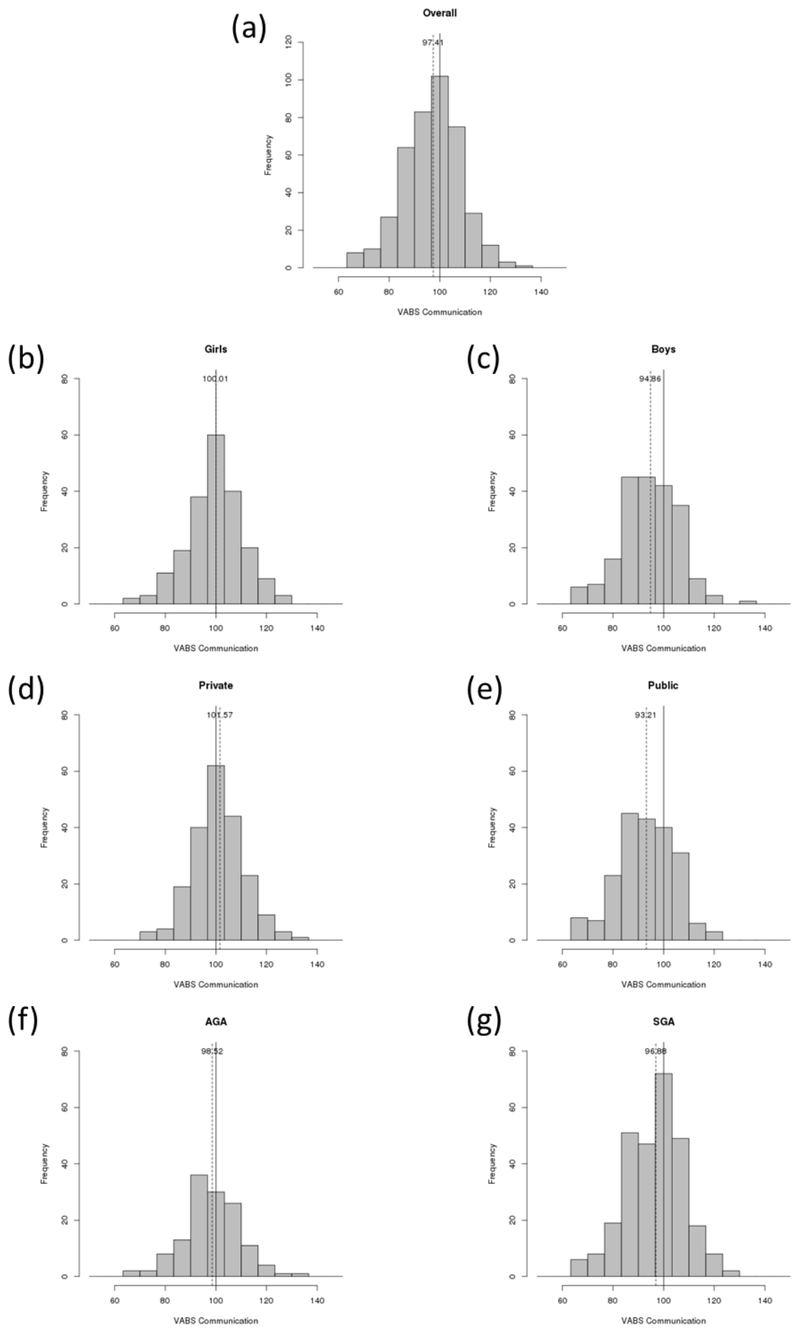
Figure A3.4: Histograms of Vineland Adaptive Behavior Scales (VABS) motor skills score in the Follow-Up Development and Growth Experiences (FUDGE) Study – overall (a) and stratified by gender (b-c), hospital of birth (d-e), and small for gestational age (SGA) status (f-g)*†



*SGA – small for gestational age (<10th percentile birthweight for gender, race, and gestational age), AGA – appropriate for gestational age (10 - <90th percentile birthweight for gender, race, and gestational age), overweight/obese: ≥85th percentile

†Solid line represents population mean (μ = 0), dashed line represents group mean (value provided)

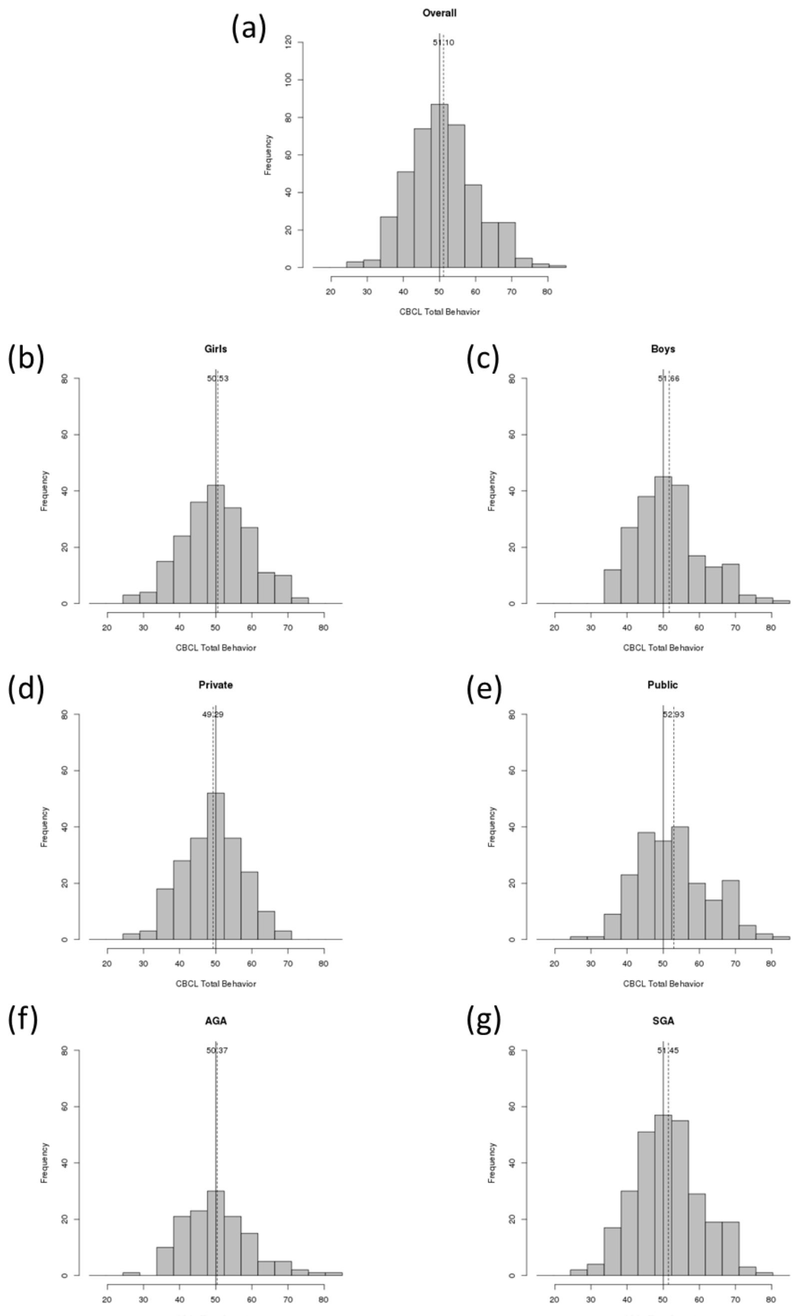
Figure A3.5: Histograms of Vineland Adaptive Behavior Scales (VABS) communication score in the Follow-Up Development and Growth Experiences (FUDGE) Study – overall (a) and stratified by gender (b-c), hospital of birth (d-e), and small for gestational age (SGA) status (f-g)*†



*SGA – small for gestational age (<10th percentile birthweight for gender, race, and gestational age), AGA – appropriate for gestational age (10 - <90th percentile birthweight for gender, race, and gestational age), overweight/obese: ≥85th percentile

†Solid line represents population mean (μ = 0), dashed line represents group mean (value provided)

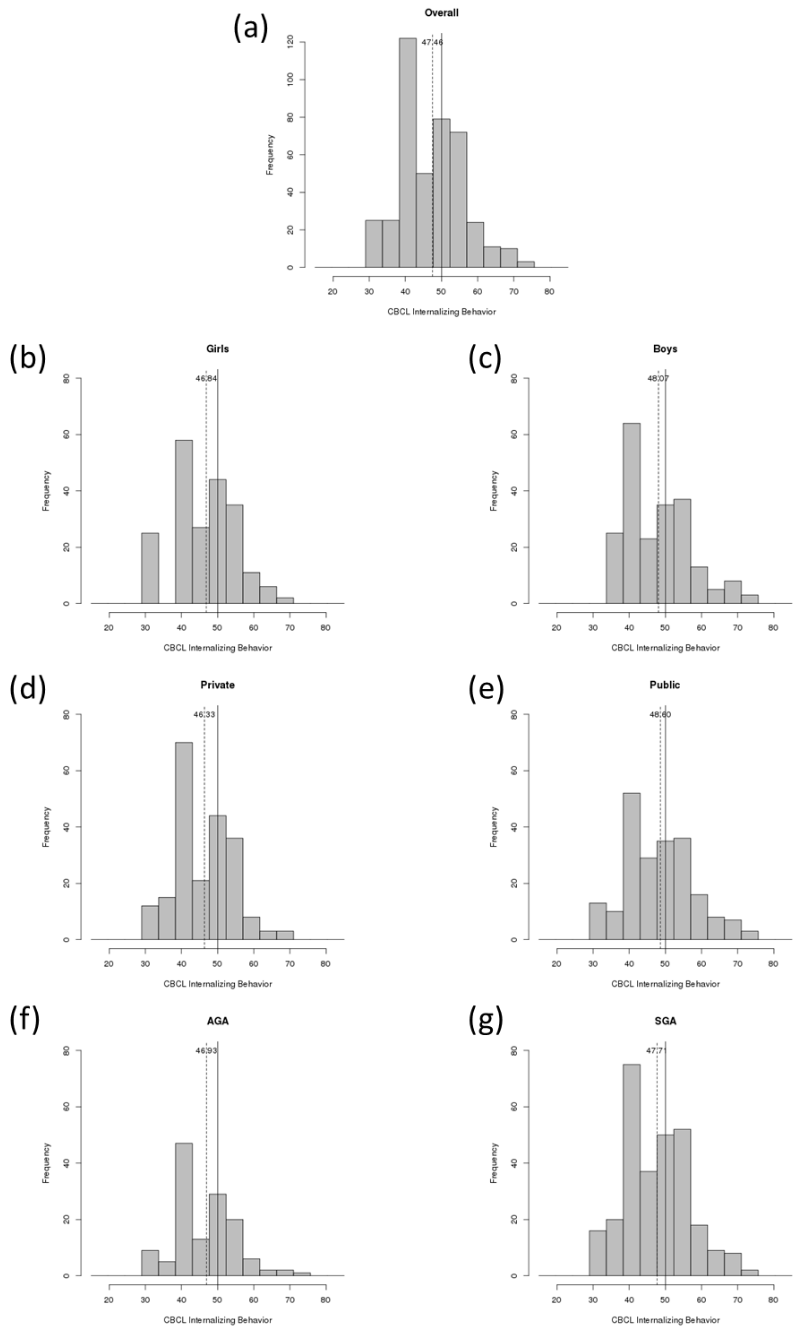
Figure A3.6: Histograms of Child Behavior Checklist (CBCL) total behavior score in the Follow-Up Development and Growth Experiences (FUDGE) Study – overall (a) and stratified by gender (b-c), hospital of birth (d-e), and small for gestational age (SGA) status (f-g)*†



*SGA – small for gestational age (<10th percentile birthweight for gender, race, and gestational age), AGA – appropriate for gestational age (10 - <90th percentile birthweight for gender, race, and gestational age), overweight/obese: ≥85th percentile

†Solid line represents population mean (μ = 0), dashed line represents group mean (value provided)

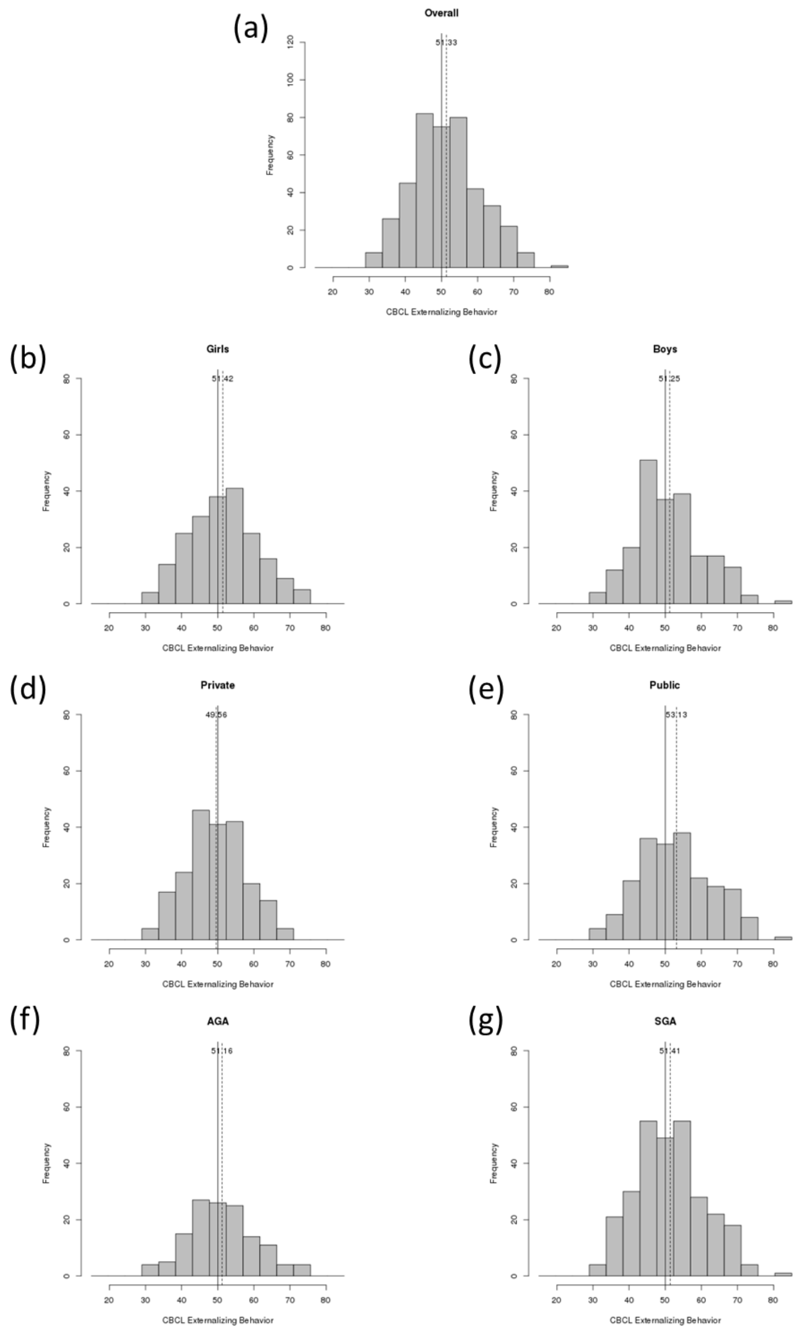
Figure A3.7: Histograms of Child Behavior Checklist (CBCL) internalizing behavior score in the Follow-Up Development and Growth Experiences (FUDGE) Study – overall (a) and stratified by gender (b-c), hospital of birth (d-e), and small for gestational age (SGA) status (f-g)*†



*SGA – small for gestational age (<10th percentile birthweight for gender, race, and gestational age), AGA – appropriate for gestational age (10 - <90th percentile birthweight for gender, race, and gestational age), overweight/obese: ≥85th percentile

†Solid line represents population mean (μ = 0), dashed line represents group mean (value provided)

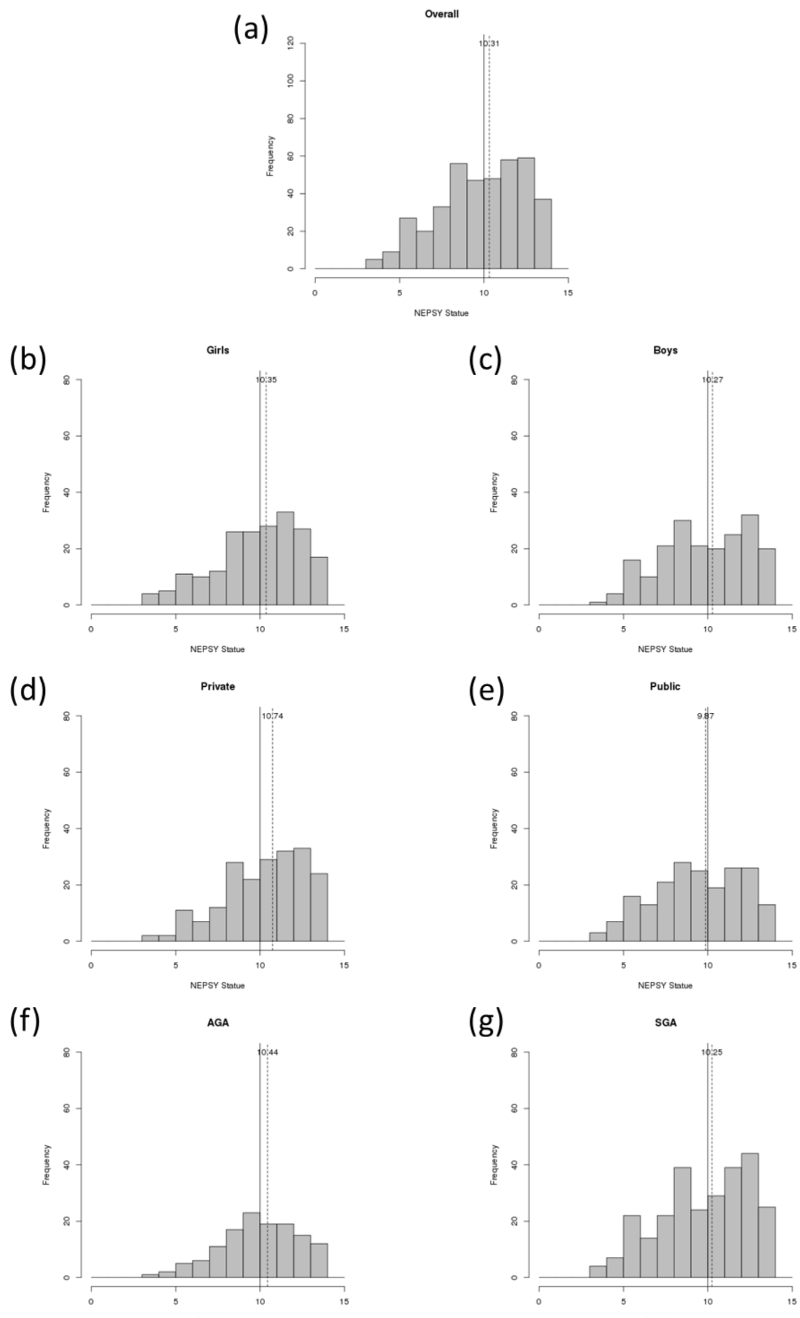
Figure A3.8: Histograms of Child Behavior Checklist (CBCL) externalizing behavior score in the Follow-Up Development and Growth Experiences (FUDGE) Study – overall (a) and stratified by gender (b-c), hospital of birth (d-e), and small for gestational age (SGA) status (f-g)*†



*SGA – small for gestational age (<10th percentile birthweight for gender, race, and gestational age), AGA – appropriate for gestational age (10 - <90th percentile birthweight for gender, race, and gestational age), overweight/obese: ≥85th percentile

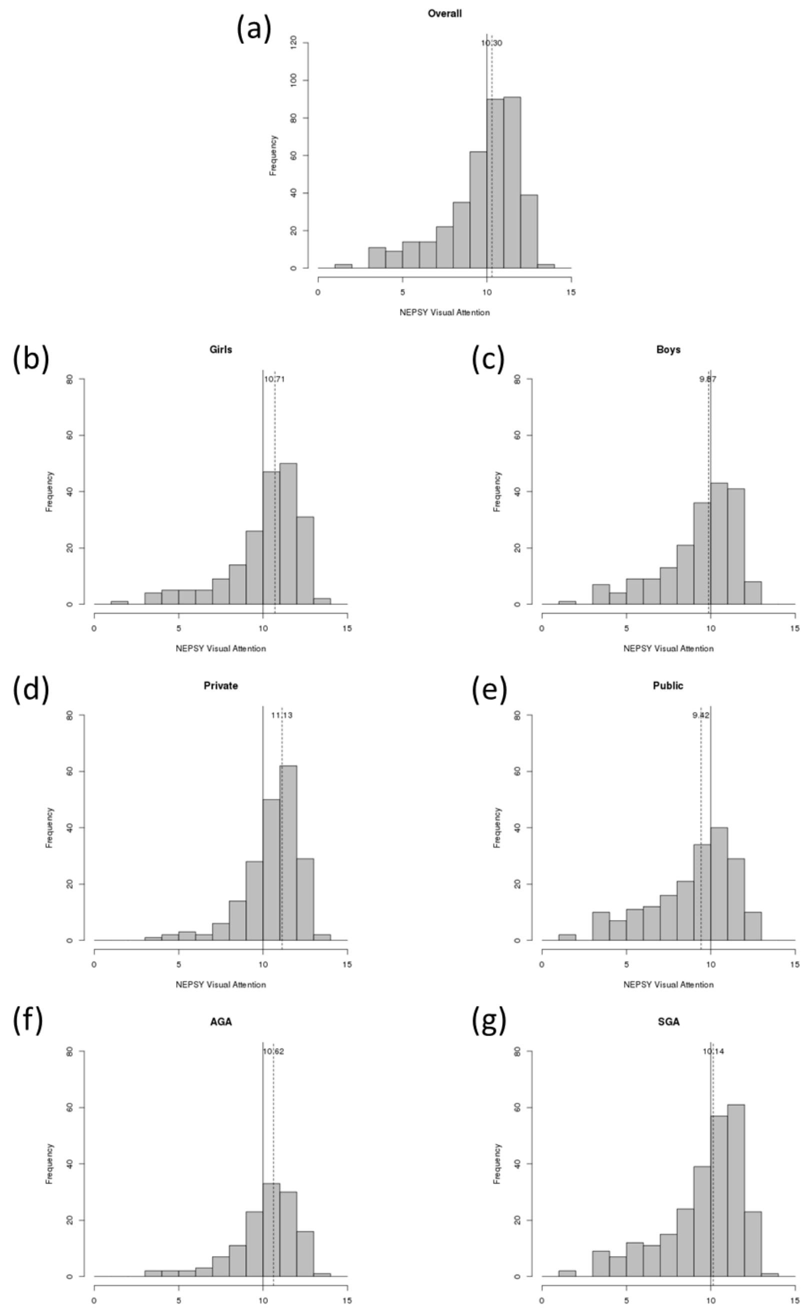
†Solid line represents population mean (μ = 0), dashed line represents group mean (value provided)

Figure A3.9: Histograms of Developmental Neuropsychology Assessment (NEPSY) statue score in the Follow-Up Development and Growth Experiences (FUDGE) Study – overall (a) and stratified by gender (b-c), hospital of birth (d-e), and small for gestational age (SGA) status (f-g)
***†**



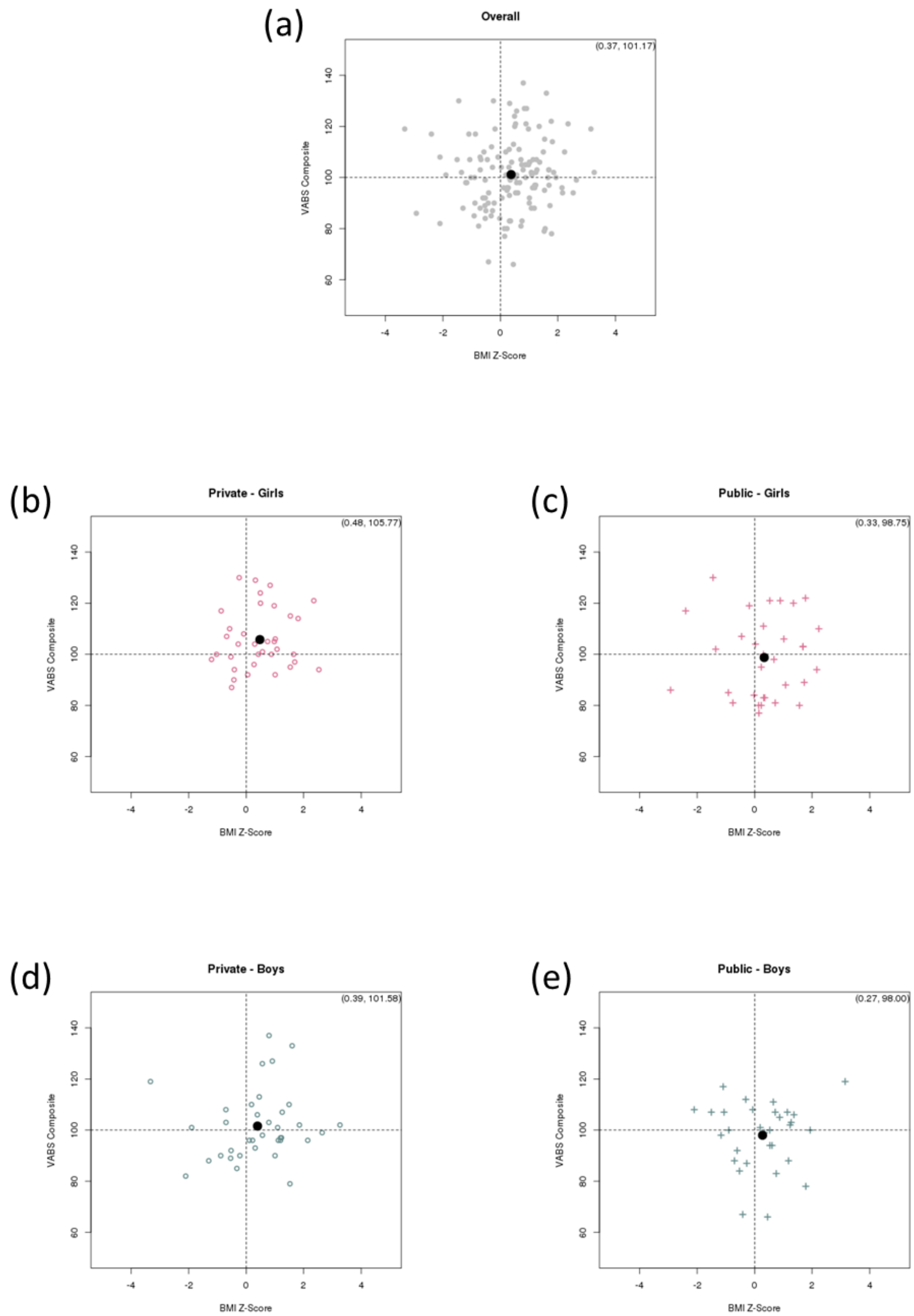
*SGA – small for gestational age (<10th percentile birthweight for gender, race, and gestational age), AGA – appropriate for gestational age (10 - <90th percentile birthweight for gender, race, and gestational age), overweight/obese: ≥85th percentile
†Solid line represents population mean ($\mu = 0$), dashed line represents group mean (value provided)

Figure A3.10: Histograms of Developmental Neuropsychology Assessment (NEPSY) visual attention score in the Follow-Up Development and Growth Experiences (FUDGE) Study – overall (a) and stratified by gender (b-c), hospital of birth (d-e), and small for gestational age (SGA) status (f-g)
***†**



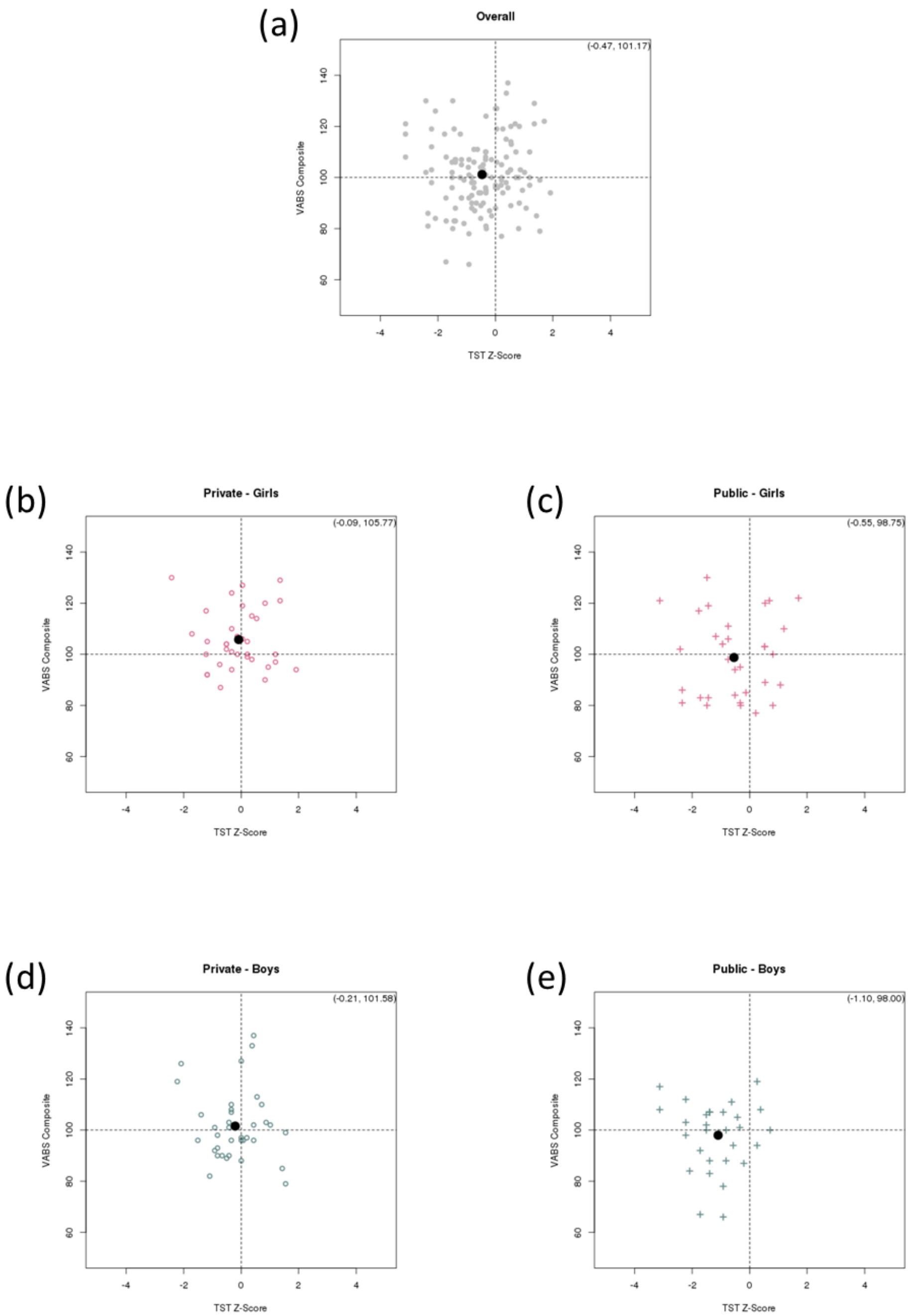
*SGA – small for gestational age (<10th percentile birthweight for gender, race, and gestational age), AGA – appropriate for gestational age (10 - <90th percentile birthweight for gender, race, and gestational age), overweight/obese: ≥85th percentile
†Solid line represents population mean ($\mu = 0$), dashed line represents group mean (value provided)

Figure A3.11: Scatter plots of body mass index (BMI) Z-score versus Vineland Adaptive Behavior Scales (VABS) composite score in the Follow-Up Development and Growth Experiences (FUDGE) Study among children born appropriate for gestational age (AGA) – overall (a) and stratified by gender and hospital of birth (b-e)*†



*AGA – appropriate for gestational age (10 - <90th percentile birthweight for gender, race, and gestational age), overweight/obese: ≥85th percentile
† The dot represents the centroid of each scatter plot, mean values provided in the upper right-hand corner

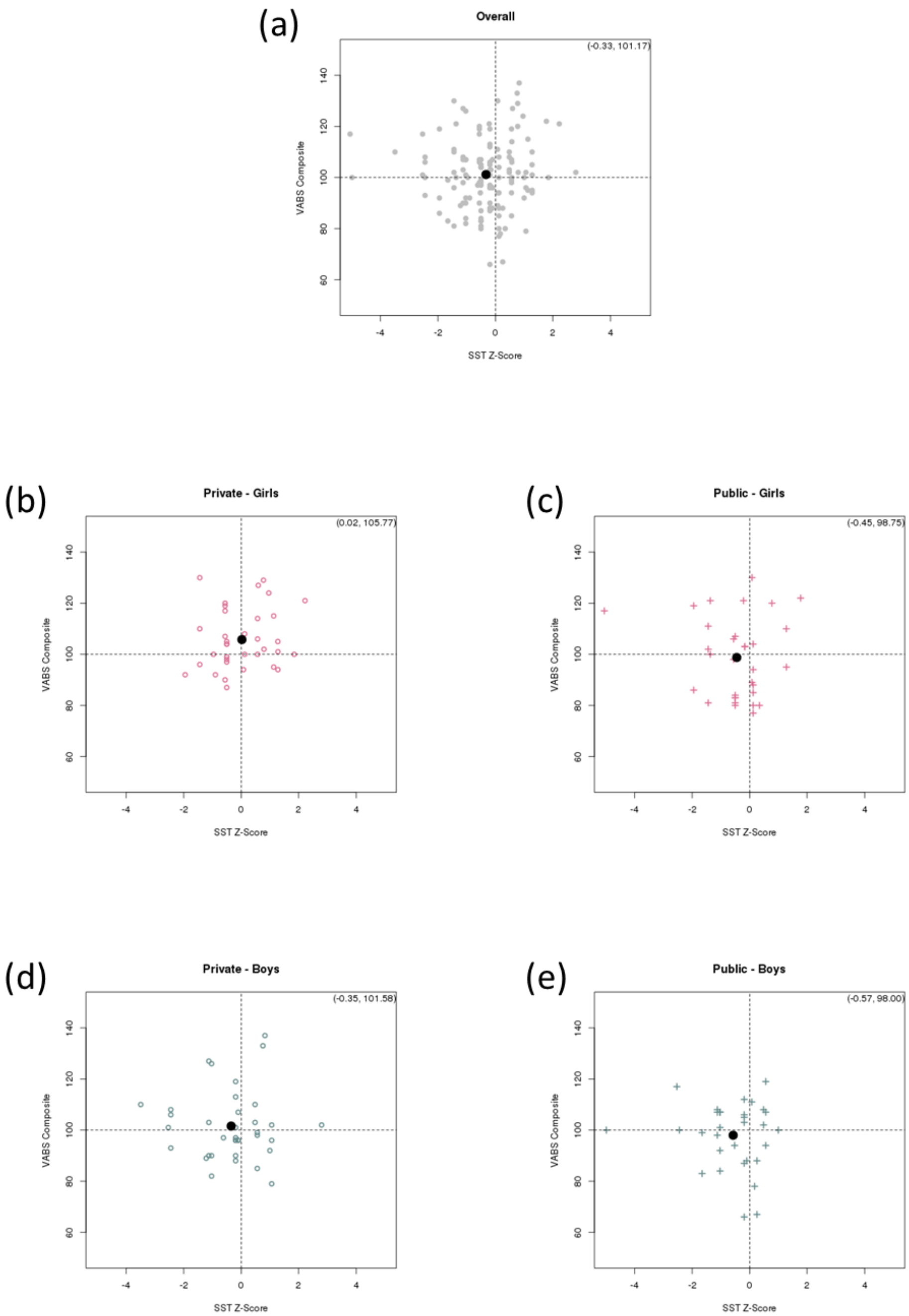
Figure A3.12: Scatter plots of triceps-skinfold-thickness (TST) Z-score versus Vineland Adaptive Behavior Scales (VABS) composite score in the Follow-Up Development and Growth Experiences (FUDGE) Study among children born appropriate for gestational age (AGA) – overall (a) and stratified by gender and hospital of birth (b-e)*†



*AGA – appropriate for gestational age (10 - <90th percentile birthweight for gender, race, and gestational age), overweight/obese: ≥85th percentile

† The dot represents the centroid of each scatter plot, mean values provided in the upper right-hand corner

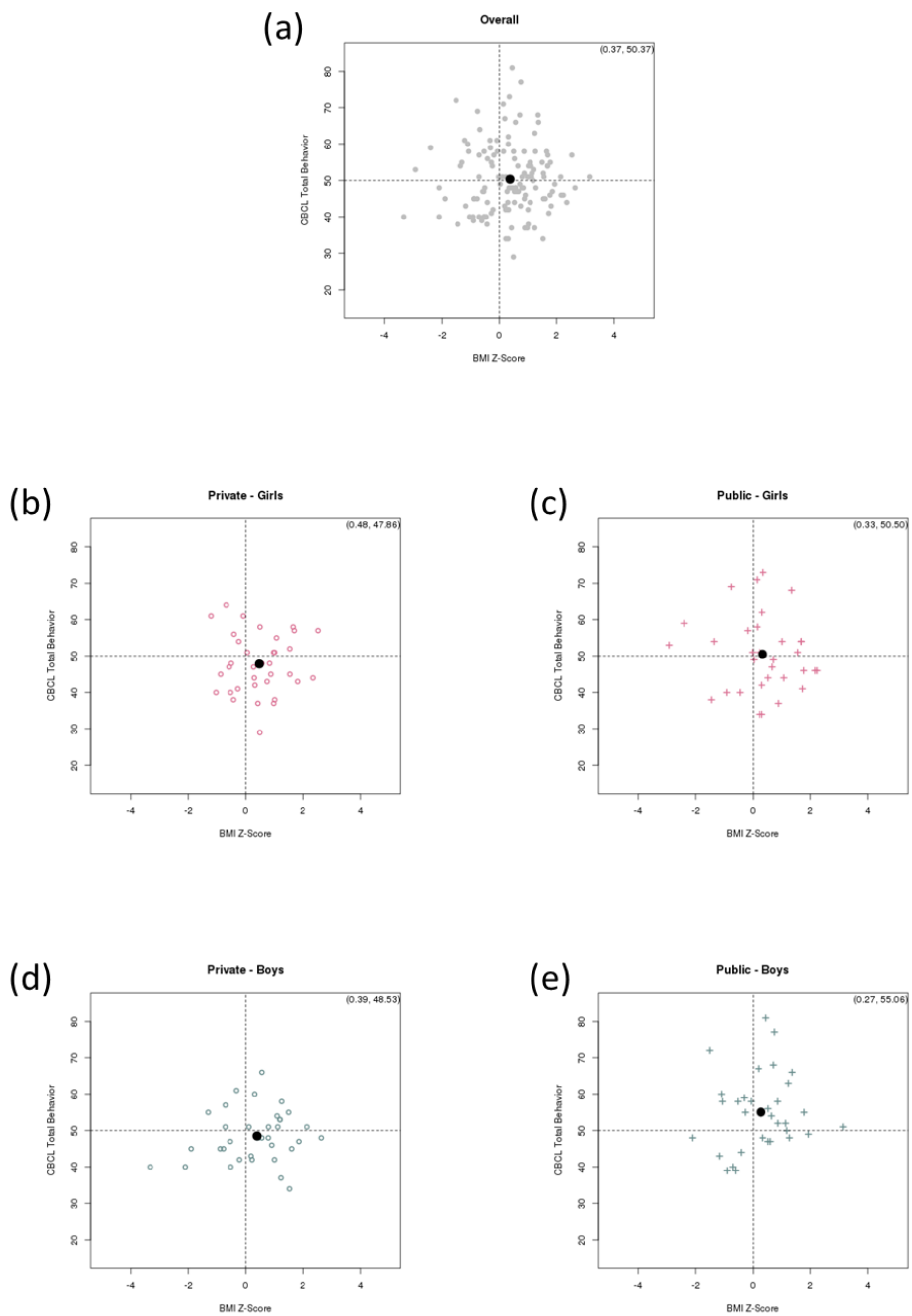
Figure A3.13: Scatter plots of subscapular-skinfold-thickness (SST) Z-score versus Vineland Adaptive Behavior Scales (VABS) composite score in the Follow-Up Development and Growth Experiences (FUDGE) Study among children born appropriate for gestational age (AGA) – overall (a) and stratified by gender and hospital of birth (b-e)*†



*AGA – appropriate for gestational age (10 - <90th percentile birthweight for gender, race, and gestational age), overweight/obese: ≥85th percentile

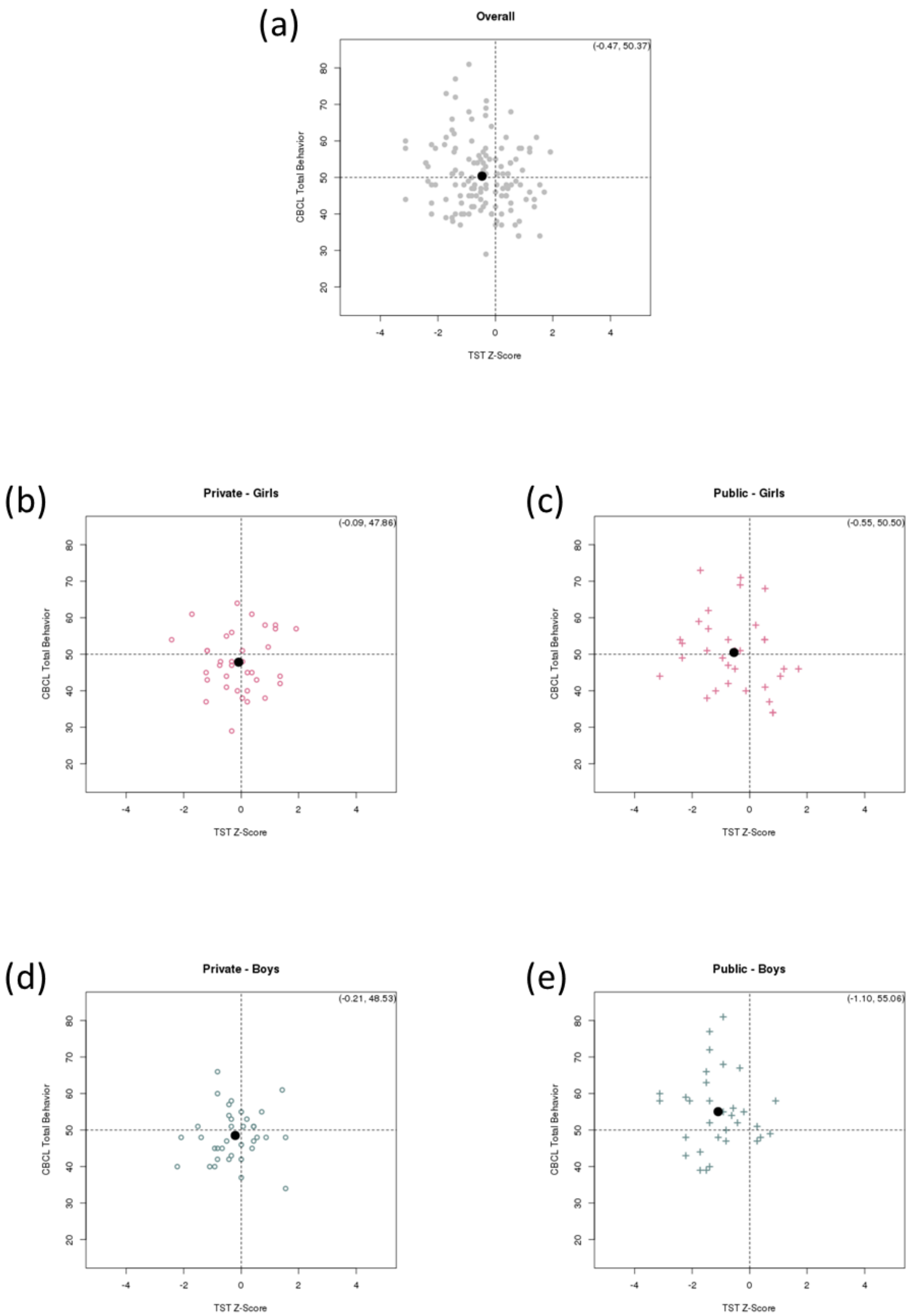
† The dot represents the centroid of each scatter plot, mean values provided in the upper right-hand corner

Figure A3.14: Scatter plots of body mass index (BMI) Z-score versus Child Behavior Checklist (CBCL) total behavior score in the Follow-Up Development and Growth Experiences (FUDGE) Study among children born appropriate for gestational age (AGA) – overall (a) and stratified by gender and hospital of birth (b-e)
***†**



*AGA – appropriate for gestational age (10 - <90th percentile birthweight for gender, race, and gestational age), overweight/obese: ≥85th percentile
† The dot represents the centroid of each scatter plot, mean values provided in the upper right-hand corner

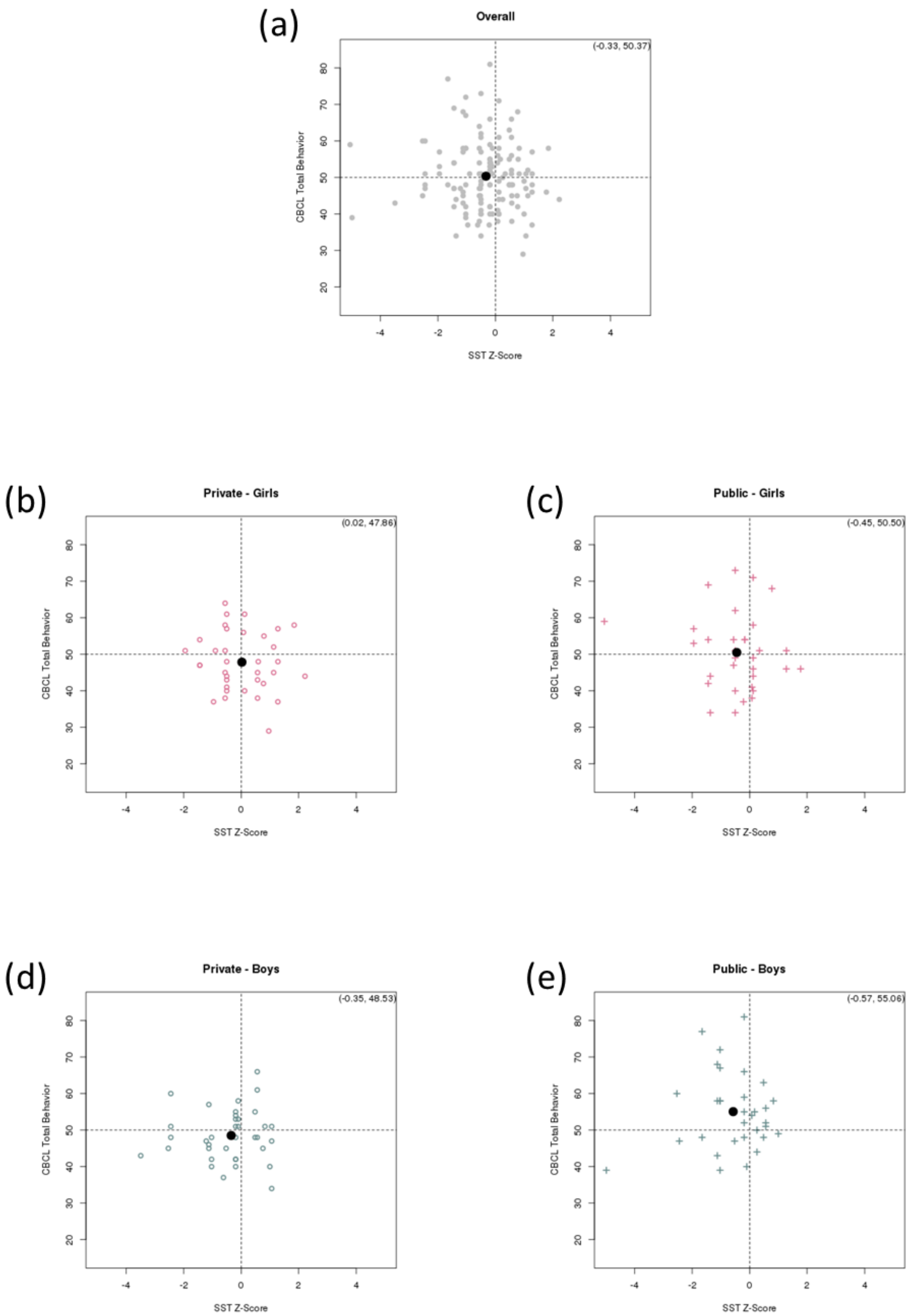
Figure A3.15: Scatter plots of triceps-skinfold-thickness (TST) Z-score versus Child Behavior Checklist (CBCL) total behavior score in the Follow-Up Development and Growth Experiences (FUDGE) Study among children born appropriate for gestational age (AGA) – overall (a) and stratified by gender and hospital of birth (b-e)*†



*AGA – appropriate for gestational age (10 - <90th percentile birthweight for gender, race, and gestational age), overweight/obese: ≥85th percentile

† The dot represents the centroid of each scatter plot, mean values provided in the upper right-hand corner

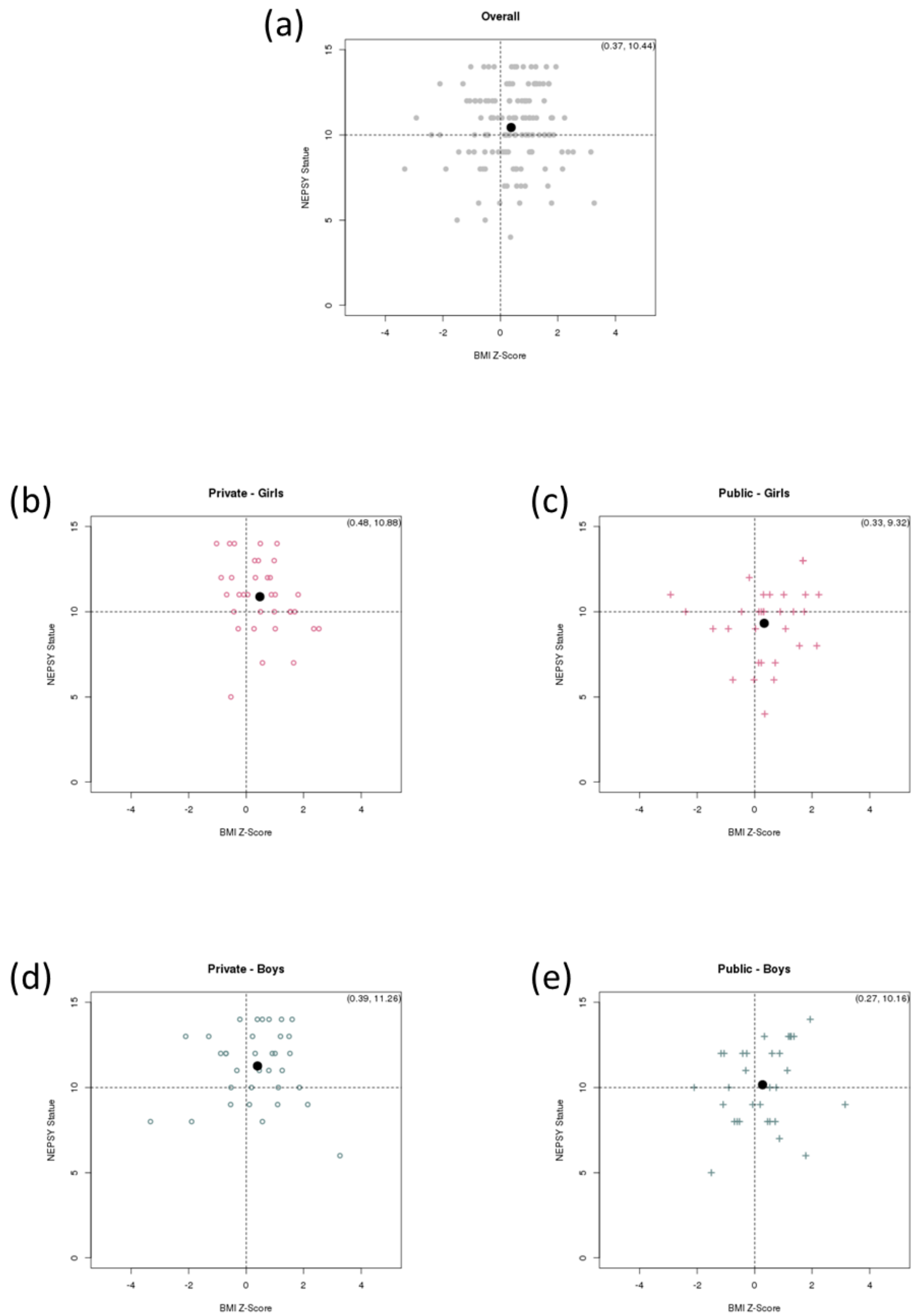
Figure A3.16: Scatter plots of subscapular-skinfold-thickness (SST) Z-score versus Child Behavior Checklist (CBCL) total behavior score in the Follow-Up Development and Growth Experiences (FUDGE) Study among children born appropriate for gestational age (AGA) – overall (a) and stratified by gender and hospital of birth (b-e)*†



*AGA – appropriate for gestational age (10 - <90th percentile birthweight for gender, race, and gestational age), overweight/obese: ≥85th percentile

† The dot represents the centroid of each scatter plot, mean values provided in the upper right-hand corner

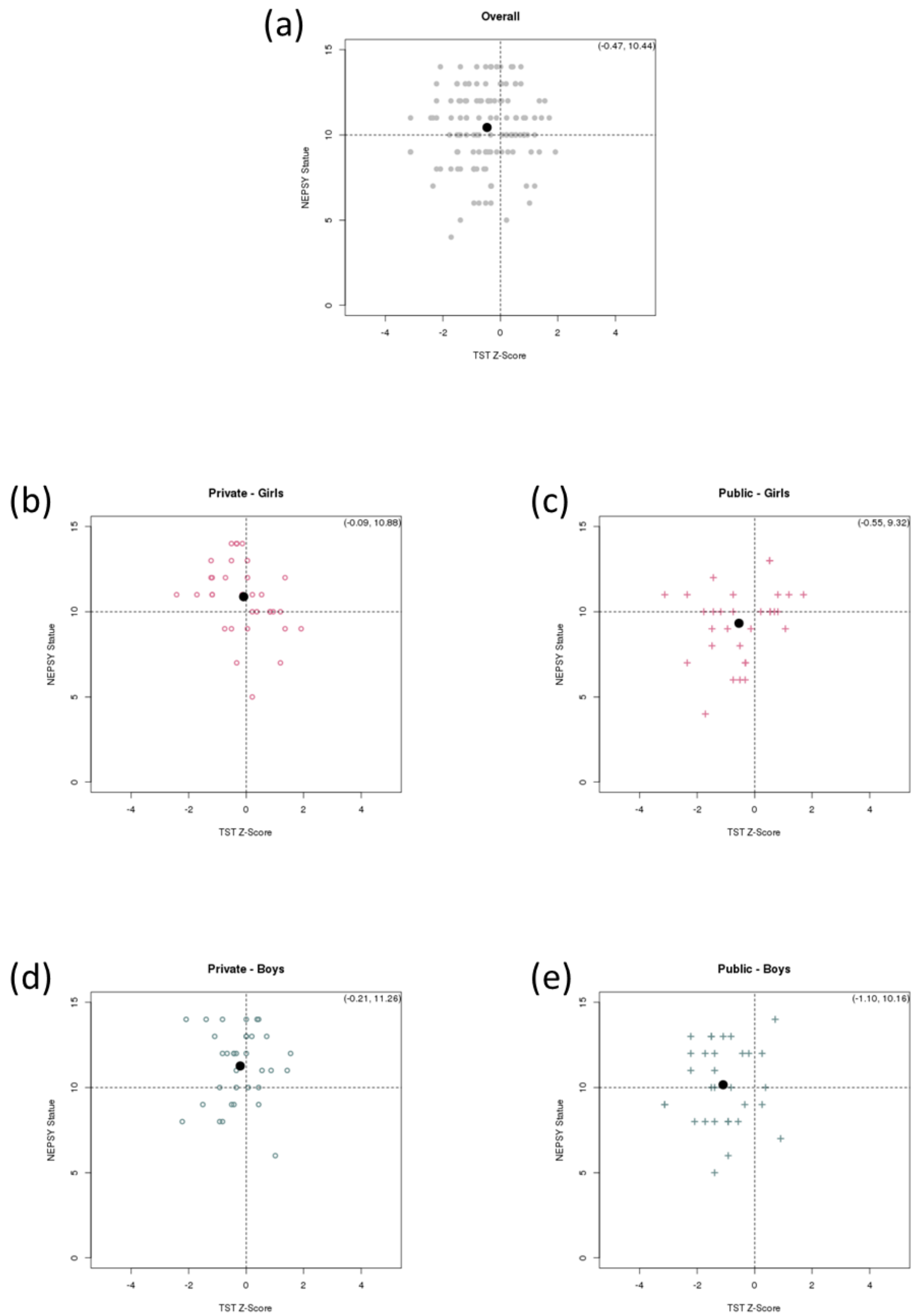
Figure A3.17: Scatter plots of body mass index (BMI) Z-score versus Developmental Neuropsychology Assessment (NEPSY) statue score in the Follow-Up Development and Growth Experiences (FUDGE) Study among children born appropriate for gestational age (AGA) – overall (a) and stratified by gender and hospital of birth (b-e)*†



*AGA – appropriate for gestational age (10 - <90th percentile birthweight for gender, race, and gestational age), overweight/obese: ≥85th percentile

† The dot represents the centroid of each scatter plot, mean values provided in the upper right-hand corner

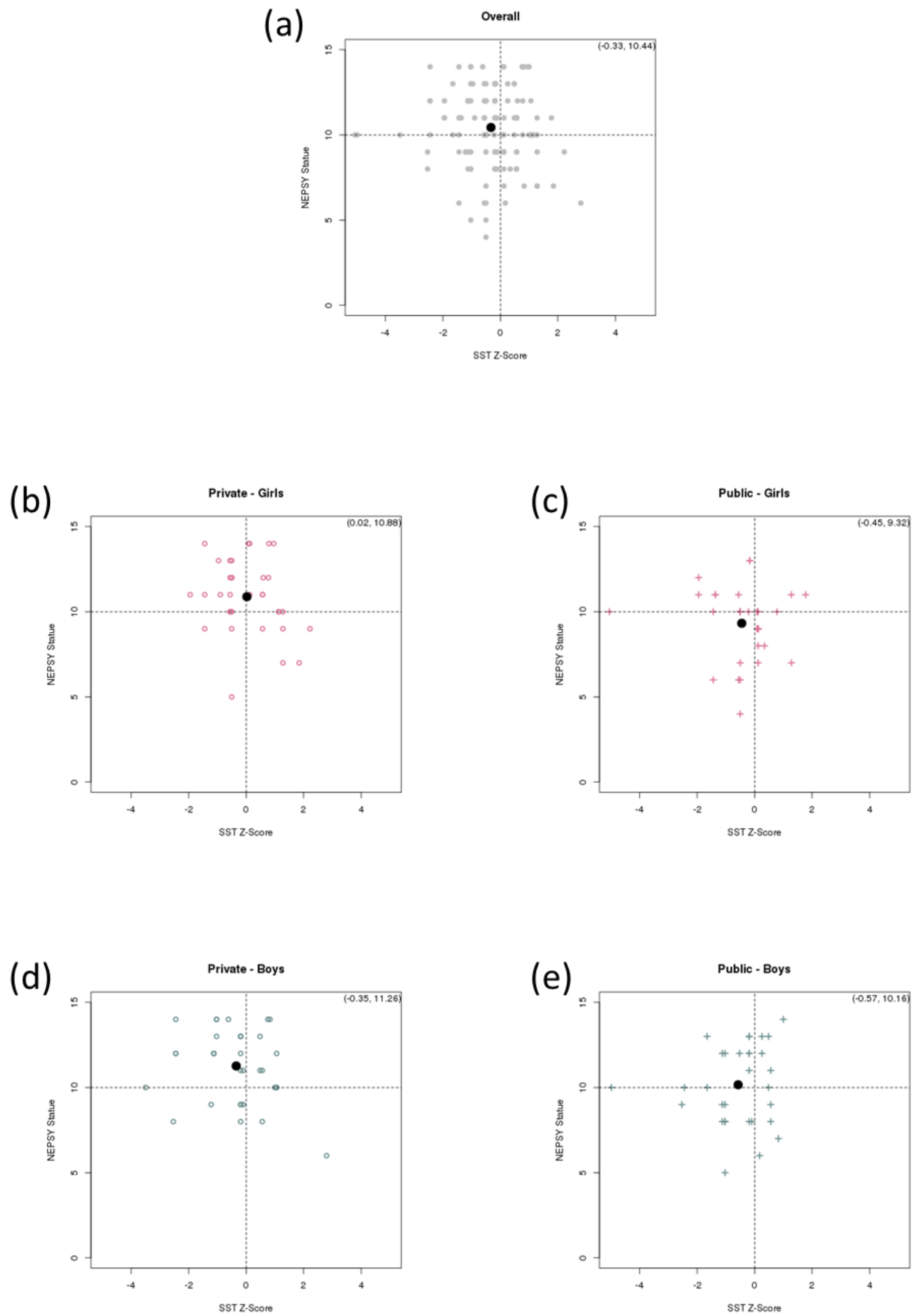
Figure A3.18: Scatter plots of triceps-skinfold-thickness (TST) Z-score versus Developmental Neuropsychology Assessment (NEPSY) statue score in the Follow-Up Development and Growth Experiences (FUDGE) Study among children born appropriate for gestational age (AGA) – overall (a) and stratified by gender and hospital of birth (b-e)*†



*AGA – appropriate for gestational age (10 - <90th percentile birthweight for gender, race, and gestational age), overweight/obese: ≥85th percentile

† The dot represents the centroid of each scatter plot, mean values provided in the upper right-hand corner

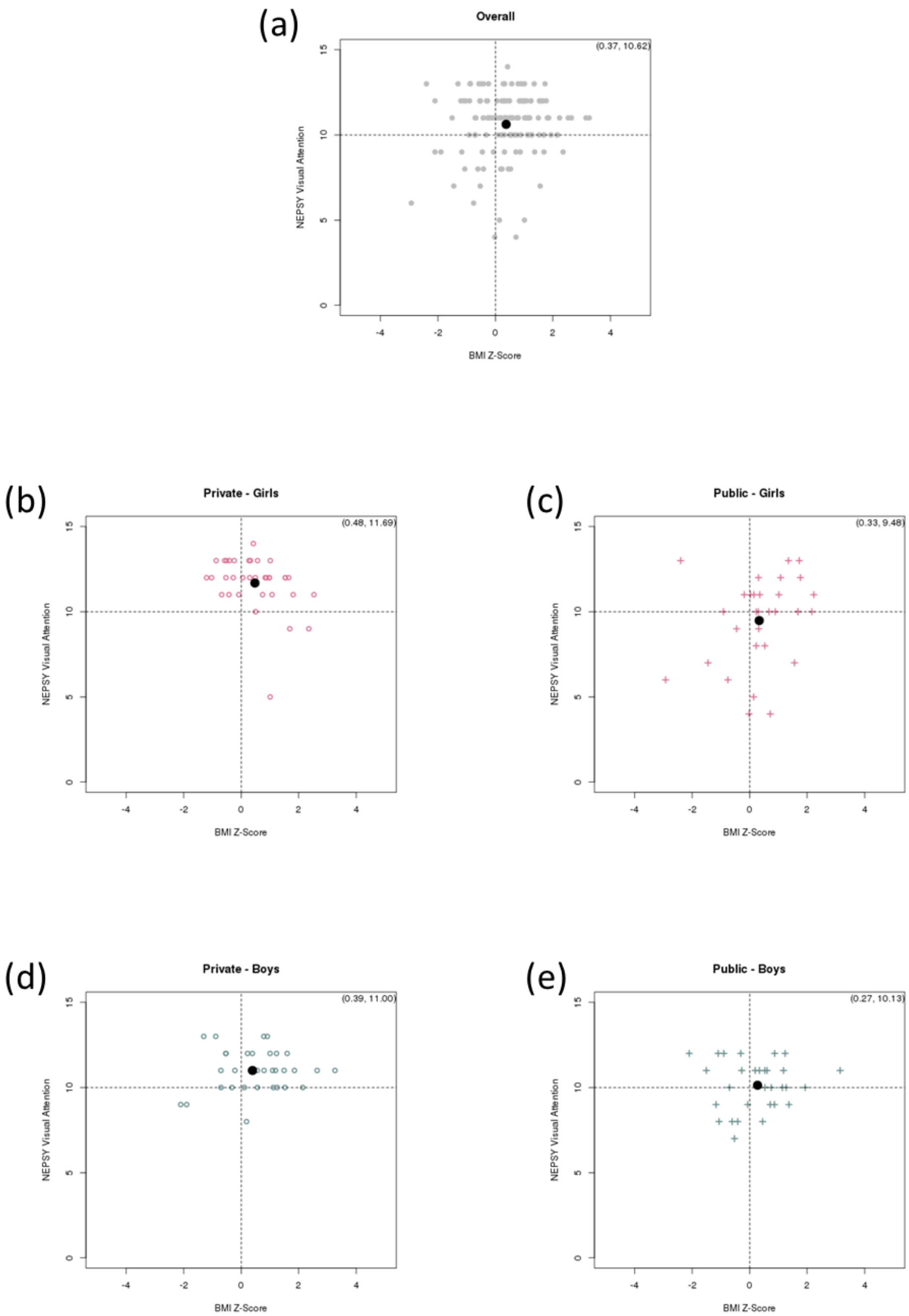
Figure A3.19: Scatter plots of subscapular-skinfold-thickness (SST) Z-score versus Developmental Neuropsychology Assessment (NEPSY) statue score in the Follow-Up Development and Growth Experiences (FUDGE) Study among children born appropriate for gestational age (AGA)– overall (a) and stratified by gender and hospital of birth (b-e)*†



*AGA – appropriate for gestational age (10 - <90th percentile birthweight for gender, race, and gestational age), overweight/obese: ≥85th percentile

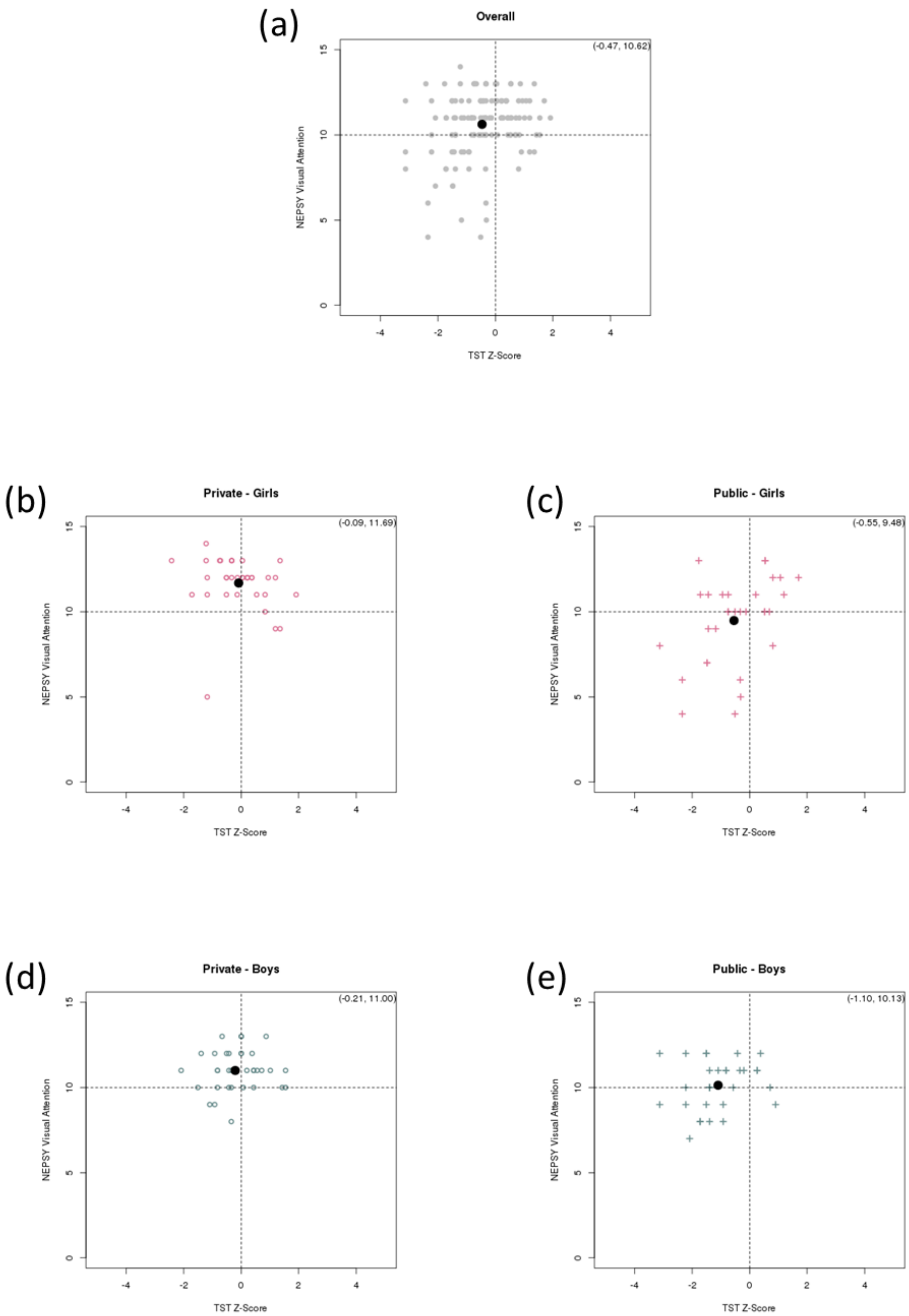
† The dot represents the centroid of each scatter plot, mean values provided in the upper right-hand corner

Figure A3.20: Scatter plots of body mass index (BMI) Z-score versus Developmental Neuropsychology Assessment (NEPSY) visual attention score in the Follow-Up Development and Growth Experiences (FUDGE) Study among children born appropriate for gestational age (AGA) – overall (a) and stratified by gender and hospital of birth (b-e)*†



*AGA – appropriate for gestational age (10 - <90th percentile birthweight for gender, race, and gestational age), overweight/obese: ≥85th percentile
† The dot represents the centroid of each scatter plot, mean values provided in the upper right-hand corner

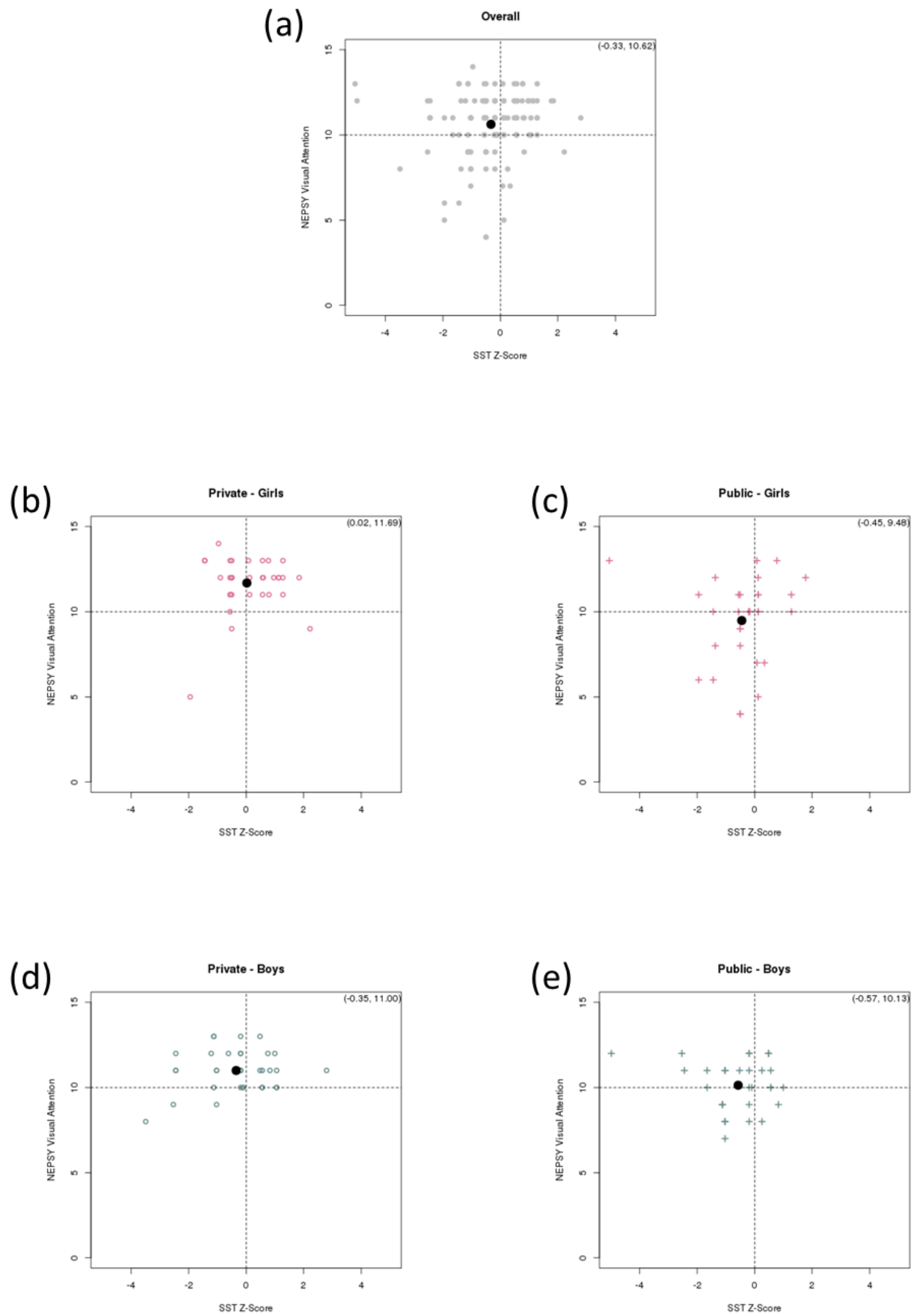
Figure A3.21: Scatter plots of triceps-skinfold-thickness (TST) Z-score versus Developmental Neuropsychology Assessment (NEPSY) visual attention score in the Follow-Up Development and Growth Experiences (FUDGE) Study among children born appropriate for gestational age (AGA) – overall (a) and stratified by gender and hospital of birth (b-e)*†



*AGA – appropriate for gestational age (10 - <90th percentile birthweight for gender, race, and gestational age), overweight/obese: ≥85th percentile

† The dot represents the centroid of each scatter plot, mean values provided in the upper right-hand corner

Figure A3.22 Scatter plots of subscapular-skinfold-thickness (SST) Z-score versus Developmental Neuropsychology Assessment (NEPSY) visual attention score in the Follow-Up Development and Growth Experiences (FUDGE) Study among children born appropriate for gestational age (AGA) – overall (a) and stratified by gender and hospital of birth (b-e)*†



*AGA – appropriate for gestational age (10 - <90th percentile birthweight for gender, race, and gestational age), overweight/obese: ≥85th percentile

† The dot represents the centroid of each scatter plot, mean values provided in the upper right-hand corner

Table A3.1: Change in Vineland Adaptive Behavior Scales composite score in children classified as overweight/obese using body mass index (BMI), triceps-skinfold-thickness (TST), and subscapular-skinfold-thickness (SST), compared with normal weight children, overall and stratified by gender and hospital of birth in the Follow-Up Development and Growth Experiences Study; estimate (95% CI)*†‡

		Crude / Pooled	By gender		By hospital of birth	
			Girls	**Boys**	**Private**	**Public**
Model 1 (Crude)	**BMI**	1.77 (-2.04, 5.58)				
	TST	1.56 (-4.80, 7.93)				
	SST	-1.01 (-6.17, 4.14)				
Model 2	**BMI**	0.62 (-3.02, 4.28)	0.49 (-4.88, 5.88)	0.22 (-4.93, 5.39)	-0.74 (-5.85, 4.36)	1.79 (-3.51, 7.10)
	TST	-1.77 (-7.74, 4.20)	2.16 (-5.28, 9.62)	**-11.05 (-21.65, -0.45)**	-3.82 (-11.18, 3.52)	2.48 (-7.58, 12.54)
	SST	-2.50 (-7.28, 2.28)	-0.52 (-7.22, 6.18)	-5.22 (-12.31, 1.85)	-5.48 (-11.57, 0.59)	2.28 (-5.37, 9.93)
Model 3	**BMI**	-0.04 (-3.82, 3.73)	-0.06 (-5.67, 5.54)	-0.36 (-5.73, 5.00)	-1.05 (-6.37, 4.26)	0.99 (-4.51, 6.50)
	TST	-1.74 (-7.87, 4.38)	2.32 (-5.48, 10.12)	**-10.68 (-21.32, -0.04)**	-3.13 (-10.83, 4.57)	2.09 (-8.17, 12.37)
	SST	-2.45 (-7.35, 2.43)	0.08 (-6.91, 7.08)	-5.23 (-12.38, 1.92)	-4.63 (-11.01, 1.74)	1.81 (-6.04, 9.68)

*CI – confidence interval

†Overweight/obese: ≥85th percentile

‡Bold font indicates model results are significant at α = 0.05. Model 1 was unadjusted, Model 2 was adjusted for gender (when appropriate), hospital of birth (when appropriate), small for gestational age status, and prenatal alcohol consumption. Model 3 was adjusted for gender (when appropriate), hospital of birth (when appropriate), small for gestational age status, prenatal alcohol consumption, race, prenatal maternal smoking, current maternal smoking, maternal age, and maternal pre-pregnancy BMI.

Table A3.2: Change in Vineland Adaptive Behavior Scales socialization score in children classified as overweight/obese using body mass index (BMI), triceps-skinfold-thickness (TST), and subscapular-skinfold-thickness (SST), compared with normal weight children, overall and stratified by gender and hospital of birth in the Follow-Up Development and Growth Experiences Study; estimate (95% CI)*†‡

		Crude / Pooled	By gender		By hospital of birth	
			Girls	**Boys**	**Private**	**Public**
Model 1 (Crude)	**BMI**	0.50 (-4.00, 5.02)				
	TST	2.58 (-4.95, 10.11)				
	SST	-0.01 (-6.12, 6.09)				
Model 2	**BMI**	-0.49 (-4.92, 3.94)	-3.46 (-9.91, 2.97)	3.12 (-3.18, 9.43)	-3.13 (-9.56, 3.28)	2.11 (-4.13, 8.37)
	TST	-0.30 (-7.54, 6.94)	0.95 (-8.00, 9.92)	-4.95 (-18.06, 8.15)	-2.48 (-11.77, 6.80)	4.57 (-7.27, 16.41)
	SST	-1.42 (-7.23, 4.38)	-3.77 (-11.81, 4.26)	1.11 (-7.61, 9.84)	-4.98 (-12.67, 2.71)	3.94 (-5.06, 12.94)
Model 3	**BMI**	-1.23 (-5.81, 3.34)	-3.71 (-10.46, 3.03)	1.58 (-4.98, 8.16)	-3.26 (-9.98, 3.46)	1.20 (-5.25, 7.67)
	TST	0.38 (-7.05, 7.82)	1.76 (-7.65, 11.19)	-4.14 (-17.30, 9.00)	-1.18 (-10.95, 8.58)	5.07 (-6.97, 17.12)
	SST	-1.17 (-7.12, 4.76)	-2.91 (-11.35, 5.52)	0.18 (-8.62, 9.00)	-4.16 (-12.26, 3.93)	3.54 (-5.67, 12.77)

*CI – confidence interval

†Overweight/obese: ≥85th percentile

‡Bold font indicates model results are significant at α = 0.05. Model 1 was unadjusted, Model 2 was adjusted for gender (when appropriate), hospital of birth (when appropriate), small for gestational age status, and prenatal alcohol consumption. Model 3 was adjusted for gender (when appropriate), hospital of birth (when appropriate), small for gestational age status, prenatal alcohol consumption, race, prenatal maternal smoking, current maternal smoking, maternal age, and maternal pre-pregnancy BMI.

Table A3.3: Change in Vineland Adaptive Behavior Scales daily living score in children classified as overweight/obese using body mass index (BMI), triceps-skinfold-thickness (TST), and subscapular-skinfold-thickness (SST), compared with normal weight children, overall and stratified by gender and hospital of birth in the Follow-Up Development and Growth Experiences Study; estimate (95% CI)*†‡

		Crude / Pooled	By gender: Girls	By gender: Boys	By hospital of birth: Private	By hospital of birth: Public
Model 1 (Crude)	**BMI**	2.82 (-0.54, 6.19)				
	TST	0.99 (-4.63, 6.62)				
	SST	-0.23 (-4.79, 4.33)				
Model 2	**BMI**	1.66 (-1.74, 5.08)	3.25 (-1.51, 8.03)	-0.16 (-5.20, 4.87)	1.71 (-3.10, 6.52)	1.51 (-3.44, 6.48)
	TST	-0.99 (-6.58, 4.59)	2.92 (-3.71, 9.56)	-9.60 (-19.97, 0.77)	-1.78 (-8.74, 5.17)	0.82 (-8.58, 10.24)
	SST	-1.02 (-5.50, 3.46)	0.77 (-5.20, 6.74)	-3.32 (-10.26, 3.61)	-3.04 (-8.81, 2.72)	2.30 (-4.85, 9.46)
Model 3	**BMI**	0.68 (-2.82, 4.18)	2.19 (-2.72, 7.10)	-0.43 (-5.62, 4.74)	0.57 (-4.39, 5.54)	1.06 (-4.03, 6.16)
	TST	-1.59 (-7.28, 4.09)	2.11 (-4.73, 8.96)	-9.09 (-19.38, 1.19)	-2.22 (-9.41, 4.97)	1.49 (-8.02, 11.02)
	SST	-1.57 (-6.12, 2.97)	0.05 (-6.08, 6.20)	-2.66 (-9.60, 4.27)	-3.20 (-9.17, 2.77)	2.66 (-4.61, 9.95)

*CI – confidence interval

†Overweight/obese: ≥85th percentile

‡Bold font indicates model results are significant at α = 0.05. Model 1 was unadjusted, Model 2 was adjusted for gender (when appropriate), hospital of birth (when appropriate), small for gestational age status, and prenatal alcohol consumption. Model 3 was adjusted for gender (when appropriate), hospital of birth (when appropriate), small for gestational age status, prenatal alcohol consumption, race, prenatal maternal smoking, current maternal smoking, maternal age, and maternal pre-pregnancy BMI.

Table A3.4: Change in Vineland Adaptive Behavior Scales motor skills score in children classified as overweight/obese using body mass index (BMI), triceps-skinfold-thickness (TST), and subscapular-skinfold-thickness (SST), compared with normal weight children, overall and stratified by gender and hospital of birth in the Follow-Up Development and Growth Experiences Study; estimate (95% CI)*†‡

		Crude / Pooled	By gender		By hospital of birth	
			Girls	**Boys**	**Private**	**Public**
Model 1 (Crude)	**BMI**	3.16 (-0.56, 6.89)				
	TST	0.23 (-5.96, 6.43)				
	SST	-1.31 (-6.33, 3.70)				
Model 2	**BMI**	2.36 (-1.23, 5.95)	2.04 (-2.83, 6.91)	1.37 (-4.02, 6.76)	1.21 (-3.37, 5.80)	3.40 (-2.12, 8.93)
	TST	-2.58 (-8.43, 3.25)	1.44 (-5.24, 8.14)	-10.91 (-21.99, 0.15)	-3.53 (-10.13, 3.07)	0.19 (-10.23, 10.62)
	SST	-2.54 (-7.23, 2.13)	0.51 (-5.49, 6.52)	-6.19 (-13.57, 1.19)	-4.09 (-9.57, 1.37)	0.32 (-7.61, 8.25)
Model 3	**BMI**	2.18 (-1.51, 5.89)	1.69 (-3.35, 6.74)	1.28 (-4.35, 6.92)	1.70 (-3.04, 6.45)	2.41 (-3.25, 8.09)
	TST	-2.70 (-8.69, 3.29)	1.50 (-5.48, 8.49)	**-11.68 (-22.82, -0.55)**	-2.96 (-9.84, 3.91)	-1.43 (-11.95, 9.08)
	SST	-2.31 (-7.10, 2.47)	1.24 (-5.01, 7.51)	-6.08 (-13.58, 1.40)	-3.25 (-8.96, 2.45)	-0.28 (-8.33, 7.76)

*CI – confidence interval

†Overweight/obese: ≥85th percentile

‡Bold font indicates model results are significant at α = 0.05. Model 1 was unadjusted, Model 2 was adjusted for gender (when appropriate), hospital of birth (when appropriate), small for gestational age status, and prenatal alcohol consumption. Model 3 was adjusted for gender (when appropriate), hospital of birth (when appropriate), small for gestational age status, prenatal alcohol consumption, race, prenatal maternal smoking, current maternal smoking, maternal age, and maternal pre-pregnancy BMI.

Table A3.5: Change in Vineland Adaptive Behavior Scales communication score in children classified as overweight/obese using body mass index (BMI), triceps-skinfold-thickness (TST), and subscapular-skinfold-thickness (SST), compared with normal weight children, overall and stratified by gender and hospital of birth in the Follow-Up Development and Growth Experiences Study; estimate (95% CI)*†‡

		Crude / Pooled	By gender		By hospital of birth	
			Girls	Boys	Private	Public
Model 1 (Crude)	BMI	-0.25 (-3.23, 2.73)				
	TST	1.52 (-3.45, 6.50)				
	SST	-0.67 (-4.70, 3.35)				
Model 2	BMI	-1.00 (-3.79, 1.78)	0.27 (-3.71, 4.26)	-3.09 (-7.12, 0.93)	-1.55 (-5.52, 2.41)	-0.75 (-4.79, 3.27)
	TST	-1.14 (-5.70, 3.41)	1.19 (-4.33, 6.72)	-6.53 (-14.90, 1.83)	-3.51 (-9.23, 2.21)	2.81 (-4.82, 10.45)
	SST	-1.86 (-5.51, 1.78)	1.24 (-3.72, 6.21)	**-6.12 (-11.65, -0.59)**	-3.95 (-8.69, 0.78)	1.06 (-4.75, 6.88)
Model 3	BMI	-1.09 (-3.96, 1.76)	0.20 (-3.90, 4.31)	-2.94 (-7.09, 1.19)	-1.69 (-5.80, 2.41)	-0.86 (-5.01, 3.28)
	TST	-1.01 (-5.67, 3.64)	1.53 (-4.18, 7.25)	-5.93 (-14.23, 2.36)	-3.00 (-8.95, 2.95)	1.90 (-5.83, 9.64)
	SST	-1.62 (-5.34, 2.09)	2.23 (-2.88, 7.34)	**-6.04 (-11.56, -0.52)**	-2.96 (-7.90, 1.98)	0.15 (-5.77, 6.08)

*CI – confidence interval

†Overweight/obese: ≥85th percentile

‡Bold font indicates model results are significant at α = 0.05. Model 1 was unadjusted, Model 2 was adjusted for gender (when appropriate), hospital of birth (when appropriate), small for gestational age status, and prenatal alcohol consumption. Model 3 was adjusted for gender (when appropriate), hospital of birth (when appropriate), small for gestational age status, prenatal alcohol consumption, race, prenatal maternal smoking, current maternal smoking, maternal age, and maternal pre-pregnancy BMI.

Table A3.6: Change in Child Behavior Checklist total behavior score in children classified as overweight/obese using body mass index (BMI), triceps-skinfold-thickness (TST), and subscapular-skinfold-thickness (SST), compared with normal weight children, overall and stratified by gender and hospital of birth in the Follow-Up Development and Growth Experiences Study; estimate (95% CI)*†‡

		Crude / Pooled	By gender		By hospital of birth	
			Girls	**Boys**	**Private**	**Public**
Model 1 (Crude)	**BMI**	0.65 (-1.84, 3.16)				
	TST	0.36 (-3.69, 4.43)				
	SST	-1.59 (-4.95, 1.76)				
Model 2	**BMI**	0.87 (-1.66, 3.42)	-0.89 (-4.46, 2.67)	2.68 (-1.03, 6.41)	1.59 (-1.75, 4.94)	0.61 (-3.27, 4.51)
	TST	1.35 (-2.69, 5.41)	1.80 (-3.00, 6.60)	1.42 (-6.30, 9.15)	2.23 (-2.41, 6.87)	1.35 (-6.02, 8.73)
	SST	-1.04 (-4.37, 2.27)	0.75 (-3.59, 5.09)	-2.65 (-7.95, 2.64)	-0.74 (-4.72, 3.23)	-1.03 (-6.65, 4.58)
Model 3	**BMI**	0.80 (-1.82, 3.43)	-0.88 (-4.59, 2.81)	2.52 (-1.37, 6.41)	1.66 (-1.84, 5.17)	0.16 (-3.85, 4.18)
	TST	1.18 (-2.97, 5.35)	1.69 (-3.29, 6.69)	1.75 (-6.02, 9.52)	1.84 (-3.02, 6.71)	0.92 (-6.57, 8.42)
	SST	-1.51 (-4.91, 1.88)	-0.01 (-4.53, 4.51)	-3.45 (-8.83, 1.92)	-1.58 (-5.75, 2.58)	-2.00 (-7.74, 3.72)

*CI – confidence interval

†Overweight/obese: ≥85th percentile

‡Bold font indicates model results are significant at α = 0.05. Model 1 was unadjusted, Model 2 was adjusted for gender (when appropriate), hospital of birth (when appropriate), small for gestational age status, and prenatal alcohol consumption. Model 3 was adjusted for gender (when appropriate), hospital of birth (when appropriate), small for gestational age status, prenatal alcohol consumption, race, prenatal maternal smoking, current maternal smoking, maternal age, and maternal pre-pregnancy BMI.

Table A3.7: Change in Child Behavior Checklist internalizing behavior score in children classified as overweight/obese using body mass index (BMI), triceps-skinfold-thickness (TST), and subscapular-skinfold-thickness (SST), compared with normal weight children, overall and stratified by gender and hospital of birth in the Follow-Up Development and Growth Experiences Study; estimate (95% CI)*†‡

		Crude / Pooled	By gender		By hospital of birth	
			Girls	Boys	Private	Public
Model 1 (Crude)	BMI	0.14 (-2.23, 2.52)				
	TST	-0.10 (-3.97, 3.76)				
	SST	-2.30 (-5.50, 0.88)				
Model 2	BMI	0.16 (-2.28, 2.61)	-1.07 (-4.29, 2.13)	1.50 (-2.25, 5.26)	0.89 (-2.35, 4.13)	0.00 (-3.72, 3.74)
	TST	0.43 (-3.47, 4.34)	0.62 (-3.70, 4.96)	1.48 (-6.30, 9.26)	2.81 (-1.67, 7.29)	-2.64 (-9.71, 4.42)
	SST	-1.92 (-5.12, 1.27)	-0.02 (-3.93, 3.88)	-3.34 (-8.67, 1.98)	-1.32 (-5.17, 2.52)	-2.14 (-7.52, 3.23)
Model 3	BMI	-0.13 (-2.68, 2.40)	-1.18 (-4.52, 2.14)	1.03 (-2.89, 4.96)	0.70 (-2.69, 4.10)	-0.94 (-4.76, 2.87)
	TST	0.30 (-3.72, 4.32)	0.62 (-3.88, 5.13)	1.67 (-6.14, 9.49)	2.79 (-1.91, 7.49)	-3.68 (-10.80, 3.43)
	SST	-2.33 (-5.60, 0.94)	-0.23 (-4.31, 3.84)	-4.17 (-9.57, 1.22)	-1.96 (-5.99, 2.06)	-3.57 (-9.01, 1.86)

*CI – confidence interval
†Overweight/obese: ≥85th percentile
‡Bold font indicates model results are significant at α = 0.05. Model 1 was unadjusted, Model 2 was adjusted for gender (when appropriate), hospital of birth (when appropriate), small for gestational age status, and prenatal alcohol consumption. Model 3 was adjusted for gender (when appropriate), hospital of birth (when appropriate), small for gestational age status, prenatal alcohol consumption, race, prenatal maternal smoking, current maternal smoking, maternal age, and maternal pre-pregnancy BMI.

Table A3.8: Change in Child Behavior Checklist externalizing behavior score in children classified as overweight/obese using body mass index (BMI), triceps-skinfold-thickness (TST), and subscapular-skinfold-thickness (SST), compared with normal weight children, overall and stratified by gender and hospital of birth in the Follow-Up Development and Growth Experiences Study; estimate (95% CI)*†‡

		Crude / Pooled	By gender		By hospital of birth	
			Girls	Boys	Private	Public
Model 1 (Crude)	BMI	1.11 (-1.32, 3.55)				
	TST	2.23 (-1.71, 6.19)				
	SST	-0.62 (-3.90, 2.65)				
Model 2	BMI	1.18 (-1.29, 3.66)	-0.26 (-3.77, 3.25)	2.39 (-1.20, 6.00)	2.86 (-0.36, 6.09)	-0.31 (-4.12, 3.49)
	TST	2.92 (-1.01, 6.87)	3.56 (-1.15, 8.27)	2.61 (-4.86, 10.09)	3.28 (-1.19, 7.76)	3.77 (-3.43, 10.97)
	SST	-0.31 (-3.55, 2.92)	1.46 (-2.80, 5.73)	-2.19 (-7.33, 2.94)	-0.23 (-4.09, 3.62)	-0.03 (-5.53, 5.46)
Model 3	BMI	1.16 (-1.40, 3.72)	-0.36 (-4.03, 3.29)	2.28 (-1.46, 6.03)	3.00 (-0.38, 6.39)	-0.56 (-4.48, 3.35)
	TST	2.57 (-1.47, 6.63)	3.18 (-1.74, 8.11)	2.98 (-4.47, 10.45)	2.55 (-2.17, 7.27)	3.38 (-3.92, 10.69)
	SST	-0.86 (-4.18, 2.45)	0.46 (-4.01, 4.93)	-3.00 (-8.17, 2.17)	-1.28 (-5.34, 2.77)	-0.72 (-6.32, 4.88)

*CI – confidence interval
†Overweight/obese: ≥85th percentile
‡Bold font indicates model results are significant at α = 0.05. Model 1 was unadjusted, Model 2 was adjusted for gender (when appropriate), hospital of birth (when appropriate), small for gestational age status, and prenatal alcohol consumption. Model 3 was adjusted for gender (when appropriate), hospital of birth (when appropriate), small for gestational age status, prenatal alcohol consumption, race, prenatal maternal smoking, current maternal smoking, maternal age, and maternal pre-pregnancy BMI.

Table A3.9: Change in scores on the Developmental Neuropsychology Assessment statue test in children classified as overweight/obese using body mass index (BMI), triceps-skinfold-thickness (TST), and subscapular-skinfold-thickness (SST), compared with normal weight children, overall and stratified by gender and hospital of birth in the Follow-Up Development and Growth Experiences Study; estimate (95% CI)
***†‡**

		Crude / Pooled	By gender		By hospital of birth	
			Girls	Boys	Private	Public
Model 1 (Crude)	BMI	0.16 (-0.51, 0.85)				
	TST	-0.90 (-2.05, 0.23)				
	SST	**-1.13 (-2.03, -0.22)**				
Model 2	BMI	0.13 (-0.56, 0.82)	0.09 (-0.86, 1.05)	0.11 (-0.92, 1.15)	**-1.03 (-2.00, -0.06)**	1.20 (0.22, 2.18)
	TST	-1.13 (-2.27, 0.01)	-1.27 (-2.54, 0.00)	-0.31 (-2.89, 2.25)	**-1.64 (-3.06, -0.22)**	-0.34 (-2.22, 1.53)
	SST	**-1.25 (-2.14, -0.36)**	**-1.79 (-2.92, -0.65)**	-0.40 (-1.85, 1.05)	**-2.25 (-3.36, -1.14)**	-0.07 (-1.51, 1.35)
Model 3	BMI	0.10 (-0.61, 0.81)	0.25 (-0.74, 1.25)	-0.15 (-1.24, 0.93)	-0.94 (-1.95, 0.07)	1.06 (0.05, 2.06)
	TST	-0.93 (-2.11, 0.24)	-1.01 (-2.35, 0.31)	-0.11 (-2.70, 2.46)	-1.16 (-2.67, 0.34)	-0.40 (-2.30, 1.48)
	SST	**-1.20 (-2.11, -0.29)**	**-1.67 (-2.86, -0.47)**	-0.57 (-2.05, 0.89)	**-1.99 (-3.16, -0.81**)	-0.31 (-1.77, 1.13)

*CI – confidence interval
†Overweight/obese: ≥85th percentile
‡Bold font indicates model results are significant at α = 0.05. Model 1 was unadjusted, Model 2 was adjusted for gender (when appropriate), hospital of birth (when appropriate), small for gestational age status, and prenatal alcohol consumption. Model 3 was adjusted for gender (when appropriate), hospital of birth (when appropriate), small for gestational age status, prenatal alcohol consumption, race, prenatal maternal smoking, current maternal smoking, maternal age, and maternal pre-pregnancy BMI.

Table A3.10: Change in scores on the Developmental Neuropsychology Assessment visual attention test in children classified as overweight/obese using body mass index (BMI), triceps-skinfold-thickness (TST), and subscapular-skinfold-thickness (SST), compared with normal weight children, overall and stratified by gender and hospital of birth in the Follow-Up Development and Growth Experiences Study; estimate (95% CI)*†‡

		Crude / Pooled	By gender		By hospital of birth	
			Girls	**Boys**	**Private**	**Public**
Model 1 (Crude)	**BMI**	0.52 (-0.10, 1.14)				
	TST	0.74 (-0.26, 1.74)				
	SST	0.06 (-0.76, 0.88)				
Model 2	**BMI**	0.40 (-0.18, 0.99)	0.65 (-0.17, 1.47)	0.07 (-0.78, 0.92)	-0.11 (-0.80, 0.58)	0.93 (-0.03, 1.90)
	TST	0.20 (-0.73, 1.13)	0.56 (-0.54, 1.68)	-0.41 (-2.15, 1.32)	-0.18 (-1.14, 0.77)	1.04 (-0.77, 2.86)
	SST	-0.19 (-0.94, 0.56)	0.18 (-0.82, 1.19)	-0.45 (-1.61, 0.70)	-0.29 (-1.09, 0.50)	0.02 (-1.37, 1.41)
Model 3	**BMI**	0.38 (-0.22, 0.99)	0.63 (-0.22, 1.49)	0.18 (-0.71, 1.07)	-0.29 (-1.02, 0.42)	0.91 (-0.07, 1.89)
	TST	0.17 (-0.78, 1.12)	0.60 (-0.55, 1.76)	-0.38 (-2.13, 1.35)	-0.20 (-1.20, 0.79)	0.70 (-1.12, 2.53)
	SST	-0.23 (-1.00, 0.53)	0.30 (-0.74, 1.36)	-0.54 (-1.71, 0.63)	-0.35 (-1.19, 0.48)	-0.10 (-1.51, 1.29)

*CI – confidence interval

†Overweight/obese: ≥85th percentile

‡Bold font indicates model results are significant at α = 0.05. Model 1 was unadjusted, Model 2 was adjusted for gender (when appropriate), hospital of birth (when appropriate), small for gestational age status, and prenatal alcohol consumption. Model 3 was adjusted for gender (when appropriate), hospital of birth (when appropriate), small for gestational age status, prenatal alcohol consumption, race, prenatal maternal smoking, current maternal smoking, maternal age, and maternal pre-pregnancy BMI.