Adolescent Girls' Struggles with Weight: Identifying Modifiable Risk Factors Associated with Eating Disturbances, Waist-to-Height Ratio, and Cardiovascular Biomarkers

By

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Abstract

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The present study examines the modifiable risk factors associated with eating disturbances, waist-to-height ratio, and cardiovascular biomarkers among a well-characterized cohort of black and white girls in the United States from the National Heart, Lung, and Blood Institute Growth and Health Study (NGHS). For 10 years, the NGHS followed black and white preadolescent girls, who were recruited from public and parochial schools in Richmond, California, and Cincinnati, Ohio, and from families enrolled in a large health maintenance organization in the Washington, DC area. The dissertation is divided into three papers.

Paper 1 investigates the correlation of parental weight comments and the daughter's unhappiness with her weight with eating disturbances among 874 black and 852 white girls, from adolescence (12-13 years) to late adolescence (18-19 years). Findings showed that either parents' weight comments were positively associated with their daughters' eating disturbance scores. It is important to remind parents that their direct verbal messages can have a lasting impact on their children's likelihood to develop eating disturbances later in life.

Paper 2 examines the two-year time-lagged association between intake of sugary beverages and WHtR among 896 black and 988 white girls, from childhood (9-10 years) to late adolescence (18-19 years). Sugar-sweetened beverage (SSB) consumption among all girls was significantly associated with a slight increase in waist-to-height ratio (WHtR), a sensitive marker of abdominal obesity, while fruit juice or flavored milk was not. The findings about the influence of SSBs have important public health implications as increased WHtR has been linked to insulin resistance, metabolic syndrome, and cardiovascular risk. Since taste preferences in childhood can track into adulthood, it is imperative that public health efforts are directed towards reducing children's consumption of sugary beverages.

Paper 3 investigates the one-year time-lagged association between abdominal obesity measures and cardiovascular biomarkers among 760 black and 719 white girls, from childhood (10-11 years) to late adolescence (18-19 years). The study provides evidence using longitudinal data that abdominal obesity measures are associated with an increased score in cardiovascular biomarkers among young girls. Though BMI is the most commonly used measure of body fat among children, our findings underscore that where children store their fat—especially, near the abdomen—is important in assessing their potential to develop risk factors for heart disease.

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Introduction

While the percentages for youth, ages 2-19, have appeared to plateau between 2003-2012,[1] the current obesity prevalence is still alarmingly high, with approximately 12.7 million (16.9%) children and adolescents suffering from obesity in the United States.[2] The current prevalence substantially differs by racial group; 2-19 year-old black youth (20.3%) are disproportionately obese (BMI for sex, age $\geq 95^{th}$ percentile) compared to the white children (14.3%).[3] Black females are especially affected, with 20.5% classified as obese compared to 15.6% of their white counterparts.[1]

Such high prevalence is especially salient as childhood obesity is associated with Type 2 diabetes, metabolic syndrome, and cardiovascular disease in childhood; and is a predictor of obesity, coronary heart disease, and metabolic disorder in young adulthood.[4,5] Such racial disparities in childhood can lead to health inequities in adulthood: black adults are 80% more likely to be diagnosed with diabetes and twice as likely to die from diabetes compared to whites;[6] black women are 60% more likely to have high blood pressure and 30% more likely to die from heart disease compared to white women.[7,8]

Childhood obesity is an obstinate public health problem, influenced by an array of demographic, behavioral and parental factors and the interaction between them. The risk factors include parental weight labeling, parental income, parental education, childhood dietary intake, and race/ethnicity.[9–11] Research additionally reports that when such risk factors occur during adolescence, they can have long-term effects on young children's eating behaviors and cardiovascular risk factors.[12,13] This dissertation aims to further elucidate the influence of modifiable individual and parental factors on eating behaviors, obesity and cardiovascular risk factors among black and white young girls from adolescence to young adulthood.

Research has shown that certain components of the parent-daughter interaction can influence the daughter's eating behavior. A literature review showed that parental comments or criticism about a child's weight appear to be a consistent correlate of a child's disturbed eating behaviors.[14] While research shows that girls who are dissatisfied with their own weight are more likely to engage in problematic dieting behavior,[15] little is also known about the joint effect of parental comments and a daughter's unhappiness with her weight on her disturbed eating later in life and if this association differs by race.

Children's intake of sugary beverages have been reported as a prevailing contributor to the obesity epidemic.[16,17] Current research on sugary beverage intake and obesity focuses mainly on sugar-sweetened beverage (SSB) consumption and to a lesser extent, flavored milk and 100% fruit juice. Few studies using longitudinal data among children exist in the current literature and even fewer studies have examined the association among ethnic minorities despite the fact that sugary beverage consumption remains particularly high among such groups.[18] Thus, the second objective of this study is to examine the influence of sugary beverage intake and abdominal obesity among minority children using longitudinal data.

It is important to examine not only the dietary factors associated with abdominal obesity, but also the relationship between abdominal obesity and cardiovascular risk factors. Abdominal obesity is more strongly associated with coronary heart disease than overall obesity,[19,20] which may explain the growing number of studies among adults examining the association between abdominal obesity and cardiovascular risk factors after adjusting for body mass index (BMI).[21–24] While a number of studies have shown abdominal obesity measures to be significantly associated with cardiovascular risk factors independent of body mass, there is limited longitudinal evidence

supporting such a relationship among minority children. As important, racial disparities are well documented in the literature, where blacks have a disproportionate prevalence of obesity and cardiovascular risk.[3,25] As a result, studies should further examine how the association between modifiable individual and parental factors and obesity-related conditions differ by race.

The aims of this dissertation are to: 1) investigate the joint effect of parental comments and daughter's unhappiness with weight on her eating disturbances from adolescence (12-13 years) to late adolescence (18-19 years); 2) assess the two-year time-lagged association between intake of sugary beverages and WHtR among preadolescent black and white girls, from childhood (9-10 years) to late adolescence (18-19 years); 3) examine the one-year time-lagged association between abdominal obesity measures and cardiovascular biomarkers among preadolescent black and white girls, from childhood (10-11 years) to late adolescence (18-19 years); and assess if the associations differ by race for all three aims.

This research attempts to deepen our understanding by addressing three gaps in the current literature. First, limited prospective data is available on the association of parental weight comments and daughter's unhappiness with weight with disturbed eating. In particular, there is inconsistent research on influence fathers have on their daughter's eating disturbances. Second, the association between sugary beverages and abdominal obesity among preadolescent girls is still unclear and deserve further investigation. Third, there is limited prospective evidence on the association between abdominal obesity measures and cardiovascular risk factors with adjustment for overall body mass among black and white girls.

Paper 1: The Association of Parental Weight Comment and Daughter's Weight Satisfaction with Eating Disturbances Among Black and White Girls

Abstract

Objective: To investigate the association of parental comment about their daughter being too fat and the daughter's unhappiness with her weight with eating disturbances among a large cohort of black and white girls, from adolescence (12-13 years) to late adolescence (18-19 years).

Design: Prospective cohort study using data from the National Heart, Lung, and Blood Institute Growth and Health Study (NGHS).

Setting: A multicenter study in the San Francisco, Cincinnati, and Washington, DC metropolitan areas.

Participants: Investigators recruited 2,379 girls, ages 9-10 years, for the original study sample. A total of 1,726 (73%) participants, including 852 white and 874 black girls, who had complete or intermittently missing data at all waves of the study were included in the final analysis.

Main Exposures: Mother's weight comment, father's weight comment, and daughter's unhappiness with weight.

Main Outcomes and Measures: Drive for thinness and bulimia symptoms scores.

Results: Mother's comment (1.28, [95% CI, .55, 2.01], p<.01) was significantly associated with a higher score in drive for thinness. Both the father's comment (1.74 [95% CI, .47, 3.01]) and the daughter's unhappiness (.79 [95% CI, .08, 1.51]) but not both together, were associated with a higher score in drive for thinness compared to the girls whose father did not comment and who were happy with their weight. Either the father's comment (.60 [95% CI, .07, 1.13]) or the daughter's unhappiness with her weight (.34 [95% CI, .07, .61]), but not the combination, was significantly associated with a higher bulimia score compared to the girls whose father did not comment and were happy with their weight (p<.05 for both). For black girls, her father commenting on her weight when she is happy with it was associated with a higher score in bulimia symptoms (.61 [95% CI, 0, 1.22], p=.05).

Conclusions and Relevance: Parental weight comments are positively associated with children's disturbed eating. It is important to remind parents that their direct verbal messages can influence their children's perception of their weight and have a lasting impact on their children's likelihood to develop eating disturbances later in life.

Introduction

Drive for Thinness and Bulimia—subscales from the Eating Disorder Inventory (EDI)—have been described as key constructs associated with excessive concern about weight and a tendency toward disturbed eating.[26] Items in Drive for Thinness reflect a strong desire to lose weight, preoccupation with restrictive dieting, and a fear of weight gain. Items in Bulimia reflect the tendency to engage in emotional eating and uncontrollable overeating, and to think about purging. It has been historically perceived that a typical eating disorder case is a young, white, middle-class woman, with few studies targeting ethnic young girls.[27,28] A previous cross-sectional study by Striegel-Moore et al. (2000), using data from the National Heart, Lung, and Blood Institute Growth and Health Study (NGHS), showed that young girls were already reporting higher scores for eating disturbances by age 11.[29] Specifically, black girls scored higher for bulimia symptoms compared to white girls, while the reverse was true for drive for thinness. Additionally, adolescence—a vulnerable, but influential stage—is a particularly sensitive period when internalizing symptoms of disordered eating behavior and psychological distress increase, especially among girls.[30,31] Weight-related concerns in adolescence can have lasting ramifications, with one study reporting that youth who engaged in disordered eating behaviors during adolescence were at increased risk for such behaviors a decade later.[32]

Although two studies reported evidence for a direct pathway from body dissatisfaction to bulimia symptoms among adolescent and young adult females,[33,34] other studies have failed to find evidence to support such pathway,[34–36] suggesting that there could be other factors, including parental comments, that may influence the association between weight dissatisfaction and eating disturbances. A literature review showed that parental comments or criticism about a child's weight appear to be a consistent correlate of a child's drive for thinness and bulimia symptoms.[14] In particular, a review study reported that mother's criticism was the second strongest predictor of bulimia symptoms[37] and direct maternal comments seem to be more influential than modeling of weight management behaviors on child's concern for thinness or dieting.[38] The literature on father's comments is sparse and inconsistent with studies showing that children, who reported that it was important to their father that they be thin, were more likely to be constant dieters[39] and father's criticism was associated with higher score for eating disturbances.[40,41] Yet, other research did not find an association of father's weight comments with child's dieting and bulimia symptoms.[42–44] However, little is currently known about the joint effect of parental comments and daughter's unhappiness with weight on her eating disturbances later in life.

The influence of parental comments on the daughters' body image could potentially operate in different ways for black and white families. Since there is greater acceptance of larger and more diverse body types in the black community,[45] black parents may be less prone to pressure their daughters to diet. This may also explain why black women are more accepting of larger body sizes and report greater body image satisfaction.[46,47] Such attitudinal traits among black women have been suggested as protective factors against eating disorders compared to white women.[48] Studies among white girls, however, have shown that weight concerns and dieting practices are already very common by early adolescence.[49,50] In adulthood, white females—despite being thinner—reported more dietary restraint than their black counterparts.[51]

Thus, this study aims to assess the associations of parental comment, daughter's unhappiness with her weight, and the combination of the two with her risk of eating disturbances

seven years later. The study sample consists of a well-characterized cohort of black and white girls in the United States from the NGHS. There were two hypotheses: 1) it was predicted that, for white girls, the combined effect of mothers' comments and daughters' unhappiness with their weight would be stronger than the effect of either of the two factors alone, and that this combined effect would be smaller for black girls, and 2) given the lack of consistent data for fathers, it was predicted that there would be no associations and interactions between father's comment and daughter's unhappiness.

Methods

Study Design and Sample

For 10 years, NGHS followed black and white preadolescent girls, who were recruited from public and parochial schools in Richmond, California, and Cincinnati, Ohio, and from families enrolled in a large health maintenance organization in the Washington, DC area.[52–54] Each city enrolled approximately similar percentages of black and white girls. Girls were within two weeks of 9-10 years of age at the first clinic visit, self-identified as non-Hispanic black or non-Hispanic white, and their parents/caregivers self-identified as the same race. A total of 2,379 girls were enrolled, including 1,166 white and 1,213 black girls. Girls who had missing data for year 3 (baseline) and 10 were excluded from the analyses (n=653). Complete data was available for 1,726 girls (73%), including 852 white and 874 black girls.

Exposure Variables

To measure the mother's comment about the daughter's weight, the participant was asked, "Has your mother ever told you that you were too fat?" with response options "Yes" or "No." This variable is referred to as "mother's comment." A parallel question about the father was asked and the variable is referred to as "father's comment". To measure daughter's attitude toward her own weight, the participant was asked "How happy or unhappy are you with your present weight?" with response options "Very Happy," "Happy," Unhappy," or "Very Unhappy." Categories were collapsed into two groups: "happy" and "unhappy." This variable is referred to as "daughter's unhappiness." To create a mother-daughter joint effect variable, mother's comment and daughter's unhappiness were collapsed to create a categorical variable with four levels (mother's comment and daughter's unhappiness, mother's comment and daughter's happiness, no mother's comment and daughter's unhappiness, no mother's comment and daughter's happiness) called "mother-daughter dyad." Reference group consisted of mothers who did not comment and daughters who were happy. A separate father-daughter joint effect variable with four levels, called "father-daughter dyad," was created for father's comment and daughter's happiness and the reference group consisted of fathers who did not comment and daughters who were happy.

Outcome Variables

The 7-item Drive for Thinness and 7-item Bulimia subscales of the EDI were administered to assess the tendency toward eating disturbances and have been used often in the literature.[26,55,56] The Drive for Thinness subscale included items capturing a participant's preoccupation about thinness and fear of weight gain, such as "I am preoccupied with the desire to be thinner" and "I am terrified of gaining weight." The Bulimia subscale included items capturing a participant's feelings of shame when eating and tendency to engage in binging and

purging common in bulimia, such as "I eat moderately in front of others and stuff myself when they're gone" and "I have gone on eating binges where I have felt that I could not stop." Girls rated each item on a 6-point scale, from "never" to "always." Scores were recoded by assigning a value of 0 to the three least pathological responses and value of 1, 2, or 3 to the remaining responses, respectively. Items were summed and scores ranged from 0 to 21 with a total possible score of 21 per subscale. A higher score reflected greater drive for thinness or bulimia symptoms. The reliability and validity of each subscale has been well-established.[57] The Cronbach's alpha for the current study were satisfactory for drive for thinness (total r =.82, black: r=.80; white: r=.85)[58] as reported in a previous study. The Cronbach's alpha for bulimia symptoms was not available for this study sample, but its reliability and validity has been previously established.[26,59,60] In the current sample, the subscales were moderately correlated (r= 0.4).

Covariates

Continuous covariates included in the final models were age in years, maturation, and baseline bulimia symptoms or baseline drive for thinness depending on the outcome. Age is the participants' self-reported age at the time of the exam, rounded to the nearest one-tenth of a year. Participant's stage of maturation, a score ranging from 1 to 6, combined the scores of menarchal status and areolar staging by Garn and Falkner.[52,61]

Categorical variables included were household income (<$10,000; $10,000–$19,999; $20,000–$39,999; >$40,000), parent education (high school graduate or less, ≤ 3 years of college, ≥ 4 years of college), number of parents in household (single, both), and race (Non-Hispanic white, Non-Hispanic black). Parent education was the highest educational level reported and race was self-reported via a survey by participants' parents.

Statistical Methods

Descriptive analysis of baseline data stratified by race was conducted. First, multiple linear regressions were used to examine the association between each eating disturbance subscale at late adolescence (years 19-20) as the response variable, and mother's comment and daughter's unhappiness in adolescence (years 12-13) as explanatory variables, controlling for race, two-parent household, age, parental education, household income, maturation, and the baseline measurement of the corresponding subscale. Second, for each subscale, mother's comment and daughter's unhappiness were replaced by the mother-daughter dyad categorical variable. These models are equivalent to adding an interaction between mother's comment and daughter's unhappiness (but with a different interpretation of the coefficients), and we refer to the comparison of the first and second models for each subscale as a test of the mother-daughter interaction. Third, an interaction between mother-daughter dyad and race was added for each response variable. Analogous steps were taken for father's comment. Interactions were assessed with the F-test with 20% significance. Where interactions were significant, we report race-specific associations. All regression coefficients were interpreted as the mean difference in eating disturbance score when compared to the reference group, holding all other covariates constant. A 5% level of significance was used. Analysis was conducted using Stata 13.0.

Results

Table 1.1 reports the overall means with standard deviations or percentages for the baseline characteristics. A higher percentage of white girls had parents with 4 or more years of college education, came from two-parent households, and had parents earning more than $40,000 compared to all other categories of girls. A higher percentage of black girls reported their mothers and fathers commenting about their weight being too fat compared to white girls. Similar percentages of black and white girls reported being unhappy about their body weight.

Drive for Thinness

The F-test showed that the mother-daughter interaction or the race interaction term (mother-daughter dyad x race) were not significant. The first column of **Table 1.2** shows the final model for mothers, which includes the adjusted coefficients for mother's comment and daughter's unhappiness on the outcome of drive for thinness. Mother's comment (1.28, [95% CI, .55, 2.01], p<.01) was significantly associated with a higher score in drive for thinness.

The F-test showed that father-daughter interaction was significant F(1, 1712) = 5.33, p=.02, whereas the race interaction (father-daughter dyad x race) was not significant. **Table 1.3** shows the final model for daughter's drive for thinness, which includes the adjusted coefficients for father's comment alone, daughter's unhappiness alone, and the joint effect of both factors. Both the father's comment (1.74 [95% CI, .47, 3.01]) and the daughter's unhappiness (.79 [95% CI, .08, 1.51]) but not both together, were associated with a higher score in drive for thinness compared to the girls whose father did not comment and who were happy with their weight.

Bulimia Symptoms

For the outcome of bulimia symptoms, the F-test indicated that the mother-daughter interaction term and the race interaction term (mother-daughter dyad x race) were not significant. The final model for mothers includes the main effects of mother's comment and daughter's unhappiness, as shown in the second column of **Table 1.2**. The association between daughter's unhappiness (.25 [95% CI, 0, .51], p=.05) and bulimia symptoms was significant.
The F-test showed that the father-daughter interaction term was significant F(1, 1712) = 3.13, p=.08, and the race interaction term (father-daughter dyad x race) was significant F(3, 1709) = 1.55, p=.20. As shown in **Table 1.3**, either the father's comment (.60 [95% CI, .07, 1.13]) or the daughter's unhappiness with her weight (.34 [95% CI, .07, .61]), but not the combination, was significantly associated with a higher bulimia score compared to the girls whose father did not comment and were happy with their weight (p<.05 for both). **Table 1.4** shows the final model for fathers, which includes the adjusted coefficients for father's comment alone, daughter's unhappiness alone, and the joint effect of both factors, stratified by race. For black girls, her father commenting on her weight when she is happy with it was associated with a higher score in bulimia symptoms (.61 [95% CI, 0, 1.22], p=.05). There was no evidence to support any other associations in this model.

Discussion

The study examined the association of parental comment about their daughter being too fat and the daughter's unhappiness with her weight with eating disturbances among a large cohort of black and white girls, from adolescence (12-13 years) to late adolescence (18-19 years). All associations of a parent's comment alone with eating disturbances were positive, and

all but one were significant. All, except one, associations between a daughter's unhappiness with her weight and eating disturbances were positive and significant. There was no evidence to support a joint effect that girls whose parents commented on their weight and who were unhappy with their weight were more strongly associated with eating disturbances compared to girls who only reported one or the other.

Our findings contribute to the limited research on the influence of father's direct comments on eating disturbances, which remains inconsistent. Among mainly white female undergraduates, Baker et al. (2000) found that perceived paternal criticism was significantly associated with a higher score for eating disturbances,[48] whereas Gross and Nelson (2000) did not find evidence for a correlation between paternal negative comments and global eating disturbance.[62] Our final sample size of daughters was much larger than either of the studies' sizes (n=47 and 221, respectively), included a substantially higher percentage of black participants, and were much younger at baseline, which may explain the differences in findings. A unique finding is that even after adjusting for baseline eating disturbance score, a father's comment was still significantly associated, suggesting that a paternal comment made during adolescence may have a longitudinal influence on daughter's risk of disturbed eating. More prospective studies are needed to confirm the current findings.

Several studies have consistently shown that a mother's comment or criticism is strongly related to disturbed eating.[40,43,44,62,63] In this study, even after adjusting for baseline eating disturbance scores, a mother's negative comment was positively associated with eating disturbances, though not consistently significant. The reason for the lack of significance is unclear, yet the results still suggest that a mother's comment is related to a higher score for disturbed eating. In agreement with other studies, [33,34,64,65] our finding of a relationship between an adolescent girl's unhappiness and her eating disturbances seven years later supports the theoretical models proposed by Hutchinson et al. (2010) and Stice (2001) that there may be a direct pathway between a girl's body dissatisfaction and disturbed eating.

Only one significant racial difference was found: for black girls who were happy with their weight, a higher score in bulimia symptoms was observed for those whose father commented about their weight and no such difference was found for white girls. While the association was statistically significant, the clinical significance remains unclear. More research is needed to examine racial differences as it is lacking in the current literature, with most studies targeting predominantly white, female, young adults.[14,35] Additionally, children of different racial and ethnic backgrounds could vary in how they interpret their parents' comments and how unhappy they are with their weight based on differences between their assimilated culture and culture of origin,[66] underscoring the need to sample diverse ethnic groups when examining eating disturbances.

A limitation of the study is that data were acquired through self-report. Although this method has been shown to be valid in identifying eating disturbances,[67] it is still amenable to misreporting. Second, the study sample was not a nationally representative sample which limits the generalizability of the findings. Nevertheless, a high percentage of the sample was black and participants came from diverse socioeconomic backgrounds. Given that most of the current literature involves cross-sectional data,[64] this study allowed for the investigation of the prospective influence of parental comments on eating disturbances over seven years. In addition, loss to follow-up was moderately low with data available for 72% of the original sample.

In summary, this study contributes to the body of literature on the influence of parental

comment on eating disturbances. Our data suggest that parental weight comments are positively associated with children's disturbed eating. It is important to remind parents that their direct verbal messages can influence their children's perception of their weight and have a lasting impact on their children's likelihood to develop eating disturbances later in life. As important, more research is needed to examine the influence of parent's comments across different ethnic groups, as their children's risk may vary based on their cultural values. Future research should continue to include fathers' influence and explore the relative importance of their impact compared to mothers' comments. These results suggest that in order to prevent adolescent girls from developing excessive weight concern and bulimia symptoms, parents should be targeted for intervention.

Table 1.1 Means (Standard Deviation)[a] of baseline characteristics of adolescent girls in the NHLBI Growth and Health Study, stratified by race. (n=1,726)

Characteristics	**White (n =852)**	**Black (n = 874)**
Age, year	11.96 (.58)	12.08 (.58)
Maturation Stage	3.20 (1.31)	4.02 (1.22)
Two-Parent Household (%)	719 (84.39)	534 (61.10)
Parental Edu (%)		
≤High Grad	153 (17.96)	244 (27.92)
≤ 3 Years of College	258 (30.28)	428 (48.97)
≥ 4 Years of College	441 (51.76)	202 (23.11)
Parental Income (%)		
<$10,000	53 (6.22)	220 (25.17)
$10,000–$19,999	68 (7.98)	164 (18.76)
$20,000–$39,999	275 (32.28)	260 (29.75)
≥ $40,000	456 (53.52)	230 (26.32)
Mothers who commented about weight (%)	87 (10.21)	212 (24.26)
Fathers who commented about weight (%)	58 (6.81)	133 (15.22)
Daughters who were unhappy with weight (%)	235 (27.58)	213 (24.37)
Drive for Thinness	4.13 (5.41)	4.51 (5.16)
Bulimia Symptoms	1.23 (2.73)	2.32 (3.66)

[a]Unless otherwise indicated.

Table 1.2 Mean differences in eating disturbance scores for associations with mother's comment about child being too fat and daughter's unhappiness with weight in the NHLBI Growth and Health Study.[a] (n=1,726)

	Daughter's Drive for Thinness		Daughter's Bulimia Symptoms	
	Mean Difference (95% CI)	p-value	Mean Difference (95% CI)	p-value
Mother's comment	1.28 (.55, 2.01)	.001	.16 (-.14, .46)	.31
Daughter's unhappiness	.39 (-.30, 1.07)	.27	.25 (0, .51)	.05

[a]Associations adjusted for race, two-parent household, age, parental education, household income, maturation, baseline drive for thinness or bulimia symptoms respective to outcome.

Table 1.3 Mean differences for associations between father's comment about child being too fat and eating disturbance score, stratified by daughter's unhappiness with weight in the NHLBI Growth and Health Study.[a] (n=1,726)

	Daughter's Drive for Thinness		
	Daughter's Unhappiness		
Father's comment	No	Yes	Yes[b]
No	0 (ref)	.79 (.08, 1.51)*	0 (ref)
Yes	1.74 (.47, 3.01)*	.55 (-.58, 1.68)	-.24 (-1.38, .89)
Yes[c]	0 (ref)	-1.19 (-2.82, .43)	
	Daughter's Bulimia Symptoms		
	Daughter's Unhappiness		
Father's comment	No	Yes	Yes[b]
No	0 (ref)	.34 (.07, .61)*	0 (ref)
Yes	.60 (.07, 1.13)*	.31 (-.12, .73)	-.03 (-.50, .44)
Yes[c]	0 (ref)	-.29 (-.94, .36)	

[a]Associations adjusted for race, two-parent household, age, parental education, household income, maturation, baseline drive for thinness or bulimia symptoms respective to outcome.
[b]Association of father's comment within strata of daughter's unhappiness.
[c]Association of daughter's unhappiness within strata of father's comment.
*p< .05
F-test p-value for multiplicative interaction for outcomes of drive for thinness and bulimia symptoms: .02 and .08, respectively.

Table 1.4 Mean differences for associations between father's comment about child being too fat and bulimia symptoms score, stratified by daughter's unhappiness and race in the NHLBI Growth and Health Study.[a] (n=1,726)

Whites			
	Bulimia Symtoms		
	Daughter's Unhappiness		
Father's comment	No	Yes	Yes[b]
No	0 (ref)	.28 (-.09, .64)	0 (ref)
Yes	-.55 (-1.76, .67)	.15 (-.53, .83)	-.13 (-.85, .59)
Yes[c]	0 (ref)	.70 (-.67, 2.06)	
Blacks[d]			
	Bulimia Symptoms		
	Daughter's Unhappiness		
Father's comment	No	Yes	Yes[b]
No	-.28 (-.55, 0)	.14 (-.29, .57)	0 (ref)
Yes	.61 (0, 1.22)*	.14 (-.41, .70)	.01 (-.61, .63)
Yes[c]	0 (ref)	-.46 (-1.22, .29)	

[a]Associations adjusted for race, two-parent household, age, parental education, household income, maturation, baseline bulimia symptoms score.
[b]Association of father's comment within strata of daughter's unhappiness.
[c]Association of daughter's unhappiness within strata of father's comment.
[d]Reference group is white father did not comment and white daughter is happy with her weight.
*p=.05
F-test p-value for multiplicative race interaction: .20

Paper 2: The Association Between Sugary Beverage Intake and Waist-to-Height Ratio Among Black and White Girls

Abstract

Objective: To assess the two-year time-lagged association between intake of sugary beverages and waist-to-height ratio (WHtR) among a large cohort of black and white girls, from childhood (9-10 years) to late adolescence (18-19 years).

Design: Prospective study using data from the National Heart, Lung, and Blood Institute Growth and Health Study (NGHS).

Setting: A multicenter study in the San Francisco, Cincinnati, and Washington, DC metropolitan areas.

Participants: A total of 2,379 girls, ages 9-10 years, were recruited into the study. A total of 2,064 (89%) participants, including 988 white girls and 896 black girls, who had complete or intermittently missing data at all waves of the study were included in the final analysis.

Main Exposures: Three-day average intake of sugar-sweetened beverage (SSB) was measured in grams; intake of fruit juice and flavored milk was dichotomized into consumers and non-consumers.

Main Outcome and Measure: Measured WHtR.

Results: SSB intake, but not fruit juice, was associated with WHtR: for each additional can of SSB, the mean WHtR was estimated to increase by .001, adjusting for all covariates. For black girls, consuming flavored milk was significantly associated with a .003 lower WHtR (p=.009) compared with not consuming flavored milk, whereas no statistically significant difference was found for white girls.

Conclusions and Relevance: High consumption of SSBs have important public health implications as increased WHtR has been linked to insulin resistance, metabolic syndrome, and cardiovascular risk. Since taste preferences in childhood can track into adulthood, it is imperative that public health efforts are directed towards reducing children's consumption of sugary beverages.

Introduction

While childhood obesity prevalence has appeared to plateau recently, the current prevalence is still alarmingly high in the US.[2] In particular, abdominal obesity in childhood has been reported to be a stronger marker of metabolic syndrome in early adulthood compared to overall obesity.[68,69] Waist-to-height ratio (WHtR) has emerged as a sensitive marker of abdominal obesity and has been shown to be more superior than body mass index (BMI) in capturing cardiometabolic risk among children and adolescents.[70–73]

In parallel with the rising obesity prevalence, children's intake of sugary beverages have dramatically increased over the past decades[74,75] and have been reported as a prevailing contributor to the obesity epidemic.[18,19] Sugary beverages defined in this paper are drinks containing added or naturally occurring sugars. Current research on beverage intake and obesity focuses mainly on sugar-sweetened beverage (SSB) consumption and to a lesser extent, flavored milk and 100% fruit juice. SSBs continue to be the largest contributor of added sugar—typically in the form of high fructose corn syrup—in the US diet among youth.[19] Fructose has been shown to increase *de novo* lipogenesis, which is linked to higher visceral fat deposition and increased abdominal obesity.[76–79]

Research on the influence of fruit juice and flavored milk on obesity development is inconclusive, with limited focus on abdominal obesity. Some research shows that 100% fruit juice intake among children is positively associated with obesity measures and weight gain,[80–83] while others have shown no association.[84–88] A review study by Crowe-White et al. (2016) found that statistically significant differences in weight status between high and low fruit juice consumers were reported only in studies that did not adjust for total energy intake, suggesting that 100% fruit juice does not have an independent influence on weight status which may explain the discrepant findings.[89] While one study showed that flavored milk consumers lost less body fat and gained more weight than non-consumers,[90] a review study found that across most studies, no differences were shown between consumers and non-consumers of flavored milk for obesity measures.[91] Since protein is known to increase satiety[92] and beverages with mixed macronutrient composition of protein, carbohydrates and fat are more satiating compared to ones with only sugar,[93] the nutrient composition of milk may increase satiety compared to the typical sugar-sweetened beverage, likely explaining the why most studies reported no associations. Few studies have examined the association among ethnic minorities despite the fact that sugary beverage consumption remains particularly high among such groups.[18]

Sugary beverage consumption varies across racial groups in the US.[94] Based on the National Health and Nutrition Examination Survey (NHANES), black girls drink more fruit juice than white girls ages 6-11 years while for the same sex and age group, whites drink more regular carbonated soft drinks than blacks.[95] Although milk is the main beverage of choice among young boys and girls of all races/ethnicities, white children ages 6-11 years consume significantly more milk than blacks.[96]

A previous publication by Streigel-Moore et al. (2006), which used data from the National Heart, Lung, and Blood Institute Growth and Health Study (NGHS), investigated the consumption of an array of beverages (all types of cow's milk, SSBs, fruit juice, fruit drinks, diet soda, coffee/tea) on weight status.[97] The aim of the present study is to extend the work of Streigel-Moore et al. (2006) to assess correlations between three predominant sugary beverages and WHtR, a sensitive marker of abdominal obesity, by taking a time-lagged approach to ensure that the exposure variables occurred before the outcome. Associations were adjusted for potential

confounders including age, maturation, parental demographics, lifestyle factors, and baseline BMI. SSB intake was hypothesized to have a positive association with WHtR among black and white girls participating in the NGHS. A race interaction term was considered and it was hypothesized there would be a stronger association between SSB and WHtR among white girls compared to black girls.

Methods

Study Design and Sample

NGHS is a 10-year prospective cohort study, examining the biochemical, anthropometric, and socioeconomic factors associated with the development of obesity and cardiometabolic risk among black and white preadolescent girls.[60] Participants were recruited from families enrolled in a health maintenance organization in the Washington, DC area and from public and parochial schools in Richmond, California, and Cincinnati, Ohio.[60–62] Similar percentages of black and white girls were enrolled in each city. Girls were within two weeks of 9-10 years at the first visit; self-identified as non-Hispanic black or non-Hispanic white and their parents/caregivers self-identified as the same race, completed a survey, and gave consent. A total of 2,379 girls were recruited into the study. Participants who had complete or intermittently missing data were included in the analysis, while those who were missing data for all waves were excluded (n=315), resulting in a final analytic sample size of 2,064 (89%). At baseline, complete data was available for 1,884 girls, including 988 white girls and 896 black girls. The analysis included 10 years of data, though not all variables were measured every year.

Exposure Variables

Three variables relating to sugary beverages were considered in the analyses: sugar-sweetened beverages, flavored milk, and fruit juice. SSBs included sweetened flavored drinks (Kool-Aid, Hi-C, Tang) and non-diet carbonated beverages. Flavored milk included chocolate-flavored drinks, strawberry-flavored drinks and instant breakfast made with milk. Fruit juice included 100% fruit or vegetable juice; bottled, canned, fresh, frozen, sweetened or unsweetened. Dietary intake was recorded using food diaries over 3 consecutive days (2 weekdays, 1 weekend). Coding and nutrient analysis was completed by the University of Minnesota Nutrition Coordinating Center. Consumption of sugar-sweetened beverages, flavored milk, and fruit juice were measured in grams and averaged over the 3 days. Fruit juice intake decreased from 50% to 25% of the sample over the study period (year 1 to year 9, respectively). Similarly, flavored milk intake decreased from 25% to 10% of the sample (year 1 to year 9, respectively). Due to the limited variability in fruit juice and flavored milk intakes, both variables were modeled as dichotomous (consumers vs. non-consumers). SSB intake increased from 75% to 90% of the sample (year 1 to year 9, respectively) and was modeled as a continuous variable.

Outcome Variable

Waist-to-height ratio is considered an effective measure for abdominal obesity, which is linked to increased cardiometabolic risk among children and adolescents.[72,98] WHtR was derived by dividing waist circumference (cm) by height (cm). Waist circumference was defined as the minimum above-waist circumference (the smallest circumference of the torso, at the "natural waist" against the skin). Girl's height was measured with her heels together, toes apart at a 45-degree angle, and her head in the Frankfort horizontal plane. Height and weight were collected

annually, starting on year 1; whereas waist circumference was collected annually, starting on year 2. WHtR has been reported to be an effective measure for abdominal obesity in the clinical setting because the cut-point is easier to recall (≥.5 for high risk); it does not require clinicians to reference percentile tables; and it is independent of sex, age, and race.[98]

Covariates

Continuous covariates included in the models were age in years, maturation, total energy intake in kilocalories/day, total fiber intake in grams, and physical activity in METs. Age is the participants' self-reported age at the time of the exam. Quadratic and cubic terms for age (age^2 and age^3, respectively) were included in the final model to account for nonlinear relationships with that covariate. Participant's stage of maturation, a score ranging from 1 to 6, combined the scores of menarchal status and Garn-Falkner areolar staging.[60,69] Total energy intake was calculated by averaging the daily total calories consumed (grams) using 3-day food diaries. Total fiber intake was calculated by averaging the daily total fiber consumed (grams) using 3-day food diaries. Physical activity was the girls' usual after-school physical activity, calculated as metabolic equivalents (METs) per week using the duration per week of various forms of exercise, weighting each activity by its intensity level.

Categorical variables include household income (<$10,000; $10,000–$19,999; $20,000–$39,999; >$40,000), parent education (high school graduate or less, ≤ 3 years of college, ≥ 4 years of college), number of parents in household (single, both), race (Non-Hispanic white, Non-Hispanic black), and baseline BMI-for-age (<85th percentile, ≥ 85th percentile). Girls' parents self-reported their highest educational level and race via a survey. Dietary variables were collected every study year, except 6 and 9. Physical activity was collected every study year, except 2, 4, and 6. All remaining covariates were measured in every study year, starting on year 1.

Statistical Methods

Descriptive analysis of baseline data stratified by race and BMI percentile categories was conducted. Linear mixed models were used to examine the two-year time-lagged associations between sugary beverage consumption in years 1, 3, 5, 7, 8 and WHtR in years 3, 5, 7, 9, 10, respectively. Subject-specific random intercepts and robust standard errors were included in all models. An autoregressive covariance structure was included for the error term to account for serial correlation across observations, as data closer together in time are more likely to be similar than observations farther apart in time.

Multiplicative interactions with race were considered to assess differences in the relationship between beverage type and WHtR between black and white girls. This interaction was tested with the likelihood ratio test with 20% significance. Where interactions were significant, race-specific associations were reported. The SSB variable (grams) was divided by 366 grams, the weight of a 12 oz can of soda per a commercial food scale, to yield an interpretation of the mean difference in WHtR for every additional can of soda consumption, holding all other covariates constant. The p-values from each model were used to determine if the association between the exposure variables and WHtR were significant with α set at 0.05. Analysis was conducted using Stata 13.0.

Results

Correlations were assessed between all three exposure variables. At baseline, flavored milk (r= .040) and fruit juice (r=-.001) consumption were not significantly correlated with SSB intake, similar to findings in another study.[99] Beverages remained uncorrelated for all subsequent years. **Table 2.1** reports the overall means with standard deviations or percentages for the baseline characteristics. Girls are stratified by BMI-for-age percentiles and race. Since waist circumference was not collected during baseline, WHtR for year 2 is shown and the sample sizes across BMI percentile categories (White < 85th, White ≥ 85th, Black < 85th, and Black ≥ 85th) are 697, 250, 554, and 318, respectively. A higher percentage of white girls who are not overweight (< 85th percentile) came from two-parent households, had parents with 4 or more years of college education, and had parents earning more than $40,000 compared to overweight white girls, overweight black girls and non-overweight black girls. Overweight and non-overweight black girls consumed a higher amount of SSB and flavored milk compared to overweight and non-overweight white girls.

Race interactions were not significant for either SSB and fruit juice intake. In main-effect models (**Table 2.2**), SSB intake, but not fruit juice, was associated with WHtR: for each additional can of SSB, the mean WHtR was estimated to increase by .001, adjusting for all covariates. In contrast, we observed significant heterogeneity of the association between flavored milk and WHtR by race (LR p-value=.01, **Table 2.3**). For black girls, consuming flavored milk was significantly associated with a .003 lower WHtR (p=.009) compared with not consuming flavored milk, whereas no statistically significant difference was found for white girls.

Discussion

The correlations among all three sugary beverages was low, suggesting that the girls had a beverage of choice. The study examined the two-year time-lagged association between intake of sugary beverages and WHtR among a large cohort of black and white girls, from childhood (9-10 years) to late adolescence (18-19 years). Consistent with the first hypothesis, SSB consumption among all girls was significantly associated with a slight increase in WHtR. In the study, girls reported drinking as many as 5 cans of SSBs daily/year. Based on our findings, those participants drinking an average of 5 cans would be expected to have a .006 greater WHtR two years later than girls consuming zero cans, controlling for other factors. Considering that the study employed minimum waist circumference, the actual magnitude of associations are conservative and could in fact be stronger. Not consistent with the second hypothesis, black girls who consumed flavored milk had a significantly lower WHtR than black non-consumers, suggesting that flavored milk may have a protective influence among black adolescents. Alternatively, this very modest finding could be spurious and flavored milk is a proxy for another health behavior, such as being an athlete or eating more family meals together where milk may be the beverage of choice.

The finding that sugar-sweetened beverage intake is significantly associated with a higher WHtR, a score that measures abdominal obesity, is consistent with two previous prospective studies. Among British children, an increase in SSB intake at age 10-13 years was correlated with higher waist circumference at age 13 even after adjusting for total adiposity.[100] Non-Hispanic white girls who consumed more sugar-sweetened beverages at age 5 years had higher scores for waist circumference up to 10 years later.[90] Neither of the studies sampled a large percentage of minority children, who tend to consume more servings of SSBs[100] and are

disproportionately affected by abdominal obesity.[101] To our knowledge, this is the first prospective study to examine the time-lagged association between sugary beverage intake and WHtR among preadolescent black and white girls over 10 years.

Limited evidence from two prospective studies and one randomized controlled trial, examining the association between flavored milk intake and obesity measures, is unclear. One cohort study found that overweight/obese British children who consumed flavored milk at age 10 years lost less body fat and gain more weight compared to non-consumers at age 11 to 13 years.[95] Whereas, Vanselow et al. (2009) reported no differences in 5-year BMI among ethnically diverse US children who drank flavored milk compared to those who did not.[99] A randomized controlled trial showed that replacing SSBs with flavored milk over 16 weeks had beneficial effects on lean body mass and growth in Chilean children, despite no changes in percent body fat.[102] The present study had a longer follow-up, examined WHtR as the outcome, and used a time-lagged analysis, which may explain the differences in the findings. It has been reported that flavored milk intake increases satiety compared to SSBs,[103] likely due to its protein content.[104,105] This may explain the negative association between flavored milk intake and WHtR reported in the current literature, however, it is still unclear why this was observed among only blacks in our study and should be further explored in other studies. Overall, more longitudinal research is needed to assess racial differences in beverage consumption and WHtR.

Research on the association between fruit juice intake and obesity measures is inconclusive. The null results in this study are consistent with previous prospective studies[85,86,99] and two review studies[89,106] that did not find a positive association between 100% fruit juice intake and obesity or body composition. However, two other prospective studies did find a positive association. Faith et al. 2006 found a positive association among only overweight/obese US children aged 1 to 5 years, had a shorter follow-up period, and did not adjust for total calorie intake.[107] Libuda et al. 2008 examined the association among white adolescent girls only and did not have physical activity data available.[85] Another factor that may account for the discrepant findings may be due to the differences in type of fruit juice consumed by age group.[108] Younger children tend to consume more apple juice while older children drink more orange juice,[109] which has a lower fructose content and may explain the differences in weight gain and obesity measures.[110] While the present study did not differentiate between the different type of fruit juices, future research should examine the differential influence of high versus low fructose content in a variety of fruit juices.

The major limitation in the study is the self-report nature of the dietary data, which is subject to recall errors and underestimation of intake; however, the rigorous collection of the 3-day diet record has been validated.[111] NGHS is not a nationally representative sample of girls and did not include other ethnic minorities, thus limiting its generalizability. Nevertheless, the prospective design of NGHS permitted a time-lagged analysis of the association between beverage intake and WHtR over a critical period when childhood obesity rates were highest and increasing rapidly compared to any other period in the US. This is one of the largest cohort studies among black and white girls with a high retention rate (89%) over 10 years.

Our findings about the influence of SSBs have important public health implications as increased WHtR has been linked to insulin resistance, metabolic syndrome, and cardiovascular risk.[26,78] The mechanism is not precisely understood, but it has been reported that the added sugars is related to such conditions. More longitudinal research is needed to understand the pathways that lead to an increased WHtR. Since taste preferences in childhood can track into

adulthood, it is imperative that public health efforts are directed towards reducing children's consumption of sugary beverages.

Table 2.1 Means (Standard Deviations)[a] of baseline characteristics of adolescent girls in the NHLBI Growth and Health Study, stratified by race and weight status. (n=1,884)

	White < 85th n=729[b]	**White ≥ 85th n=259[b]**	**Black < 85th n= 568[b]**	**Black ≥ 85th n= 328[b]**
Characteristics				
Age, year	9.97 (.56)	9.97 (.55)	10.04 (.57)	10.12 (.56)
WHtR[c]	.41 (.03)	.50 (.04)	.41 (.03)	.50 (.06)
Maturation Stage	1.40 (.77)	1.68 (.92)	1.88 (1.01)	2.43 (1.21)
Physical Activty, METs	34.01 (19.35)	32.37 (18.32)	31.22 (19.81)	30.52 (18.12)
Two-Parent Household (%)	611 (83.81)	193 (74.52)	338 (59.51)	192 (58.54)
Parental Edu (%)				
≤High Grad	118 (16.19)	61 (23.55)	155 (27.29)	93 (28.35)
≤ 3 Years of College	205 (28.12)	97 (37.45)	283 (49.82)	159 (48.48)
≥ 4 Years of College	406 (55.69)	101 (39.00)	130 (22.89)	76 (23.17)
Parental Income (%)				
<$10,000	35 (4.80)	28 (10.81)	146 (25.70)	70 (21.34)
$10,000–$19,999	53 (7.27)	28 (10.81)	103 (18.13)	59 (17.99)
$20,000–$39,999	235 (32.24)	92 (35.52)	174 (30.63)	111 (33.84)
≥ $40,000	406 (55.69)	111 (42.86)	145 (25.53)	88 (26.83)
Diet				
Total Energy, kcals/d	1,791.20 (436.58)	1,839.70 (492.08)	1,877.41 (618.12)	1,852.33 (578.69)
Fiber, g/d	11.56 (4.41)	11.85 (5.08)	11.77 (5.35)	11.27 (4.94)
Sugar-Sweetened Beverage, g/d	301.79 (219)	311.02 (216.12)	352.25 (230.60)	345.15 (220.94)
Flavored Milk, (%)	451 (61.87)	154 (59.46)	384 (67.61)	214 (64.24)
Fruit Juice, (%)	350 (48.01)	143 (55.21)	274 (48.24)	164 (50.00)

[a]Unless otherwise indicated.

[b]Total baseline sample size is 1,884. An additional 180 girls whose data were not collected at baseline, but were available in subsequent years were included for a final study sample of 2,064.

[c]Waist-to-height ratio (WHtR) was calculated as minimum waist circumference in centimeters divided by height in centimeters. Values are shown for year 2 as data was not collected in year 1. Sample sizes for WHtR across the row are: 697, 250, 554, and 318, respectively.

Table 2.2 Adjusted mean differences and 95% confidence interval (CI) for the association between 2-year time-lagged sugary beverage intake and waist-to-height ratio among black and white girls in the NHLBI Growth and Health Study (n=2,064).

No. of observations	7,323
No. of girls	2,064
	Mean Difference (95% CI)[a] x 1000
No fruit juice consumption Any fruit juice consumption	Reference group 0.7 (-0.1, 1.6)
Each additional can of SSB	1.2 (3.1, 2.0)

[a]Associations adjusted for age, age^2, age^3, maturation, fiber, physical activity, total energy, household income, two-parent household, parental education, baseline body mass index.

Table 2.3 Adjusted mean differences and 95% confidence interval (CI) from a multilevel model for waist-to-height ratio, showing the interaction between flavored milk and race among black and white girls in the NHLBI Growth and Health Study (n=2,064).

No. of observations	7,323		
No. of girls	2,064		
	Mean Difference [a] (95% CI) x 1000		
Flavored Milk Intake	White	Black compared to white	Black[b]
No	0 (ref)	-.9 (-4.6, 2.8)	0 (ref)
Yes	0.6 (-1.0, 2.3)	-3.8 (-7.6, 0.12)	-2.8 (-5.0, -0.71)

[a]Associations adjusted for age, age^2, age^3, maturation, fiber, physical activity, total energy, household income, two-parent household, parental education, baseline body mass index.
[b]Associations of flavored milk intake within strata of black girls.
Likelihood ratio p-value for interaction: .01

Paper 3: The Association of Waist-to-Height Ratio and Waist Circumference with Cardiovascular Biomarkers Among Black and White Girls

Abstract

Importance: To investigate the association of waist-to-height ratio (WHtR) and waist circumference (WC) with cardiovascular biomarkers after adjusting for body mass index (BMI) among black and white preadolescent girls.

Objective: To examine the one-year time-lagged association between WHtR, WC and levels of cardiovascular biomarkers among black and white girls over 9 years and assess if such associations differ by race.

Design: Prospective cohort study using data from the National Heart, Lung, and Blood Institute Growth and Health Study (NGHS).

Setting: A multicenter study in the San Francisco, Cincinnati, and Washington, DC metropolitan areas.

Participants: Investigators recruited 2,379 girls, ages 9-10 years, for the original study sample. A total of 1,961 (82%) girls who had complete or intermittently missing data at all waves of the study were included in the final analysis.

Main Exposures: Measured WHtR and WC.

Main Outcomes and Measures: Triglycerides/high-density lipoprotein cholesterol (TG/HDL) and Apolipoprotein B/A1 ratios (ApoB/A1).

Results: After adjusting for BMI and other covariates, associations were more pronounced for white than black girls for both TG/HDL and ApoB/A1. For black girls, the mean increase in TG/HDL per standard deviation increase in the abdominal obesity measures was estimated as (.27 [95% CI, .16, .38]) for WHtR and (.36 [95% CI, .25, .48]) for WC, and the corresponding estimates for white girls were (.56 [95% CI, .42, .70]) for WHtR and (.60 [95% CI, .46, .74]) for WC. For black girls, the mean increase in ApoB/A1 per standard deviation increase in the abdominal obesity measures were estimated as (.03 [95% CI, .01, .04]) for WHtR and (.03 [95% CI, .02, .05]) for WC, and for white girls the corresponding estimates were (.05 [95% CI, .04, .07]) for WHtR and (.05 [95% CI, .03, .06]) for WC

Conclusions and Relevance: Abdominal obesity measures are associated with higher cardiovascular biomarker values, more strongly for white girls than black girls after adjusting for BMI. Public health advocates, researchers, and clinicians should to continue to examine the utility of WHTR and WC in clinical practice.

Introduction

Childhood obesity is an especially salient public health problem as it is associated with Type 2 diabetes, metabolic syndrome, and cardiovascular disease in childhood; and is a predictor of obesity, coronary heart disease, and metabolic disorder in young adulthood.[4,5] In particular, abdominal obesity, defined as excess visceral fat accumulated in the intra-abdominal area, is associated with altered hepatic lipid metabolism, an elevated inflammatory profile, and reduced insulin signaling,[112–115] increasing one's risk of hypertriglyceridemia, hypertension, insulin resistance and cardiovascular disease.[116–120] Gold standard assessments of visceral fat deposition—magnetic resonance imaging (MRI)[121] and computed tomography (CT)[122]—are very costly and impractical for daily screening. More research has focused on anthropometry as a cost-effective alternative to imaging techniques in assessing visceral fat deposition.[70,123,124]

While body mass index (BMI) is the most commonly used anthropometric measure, it does not describe body fat distribution and has been shown to misclassify cardiometabolic health among a US nationally representative sample.[125] Using BMI to classify adults, Tomiyama et al[125] showed that over 30% of normal-weight US adults were in fact cardiometabolically unhealthy while nearly 50% of overweight and 29% of obese individuals were cardiometabolically healthy. Further, two studies have shown that black females have lower amounts of visceral fat for a given BMI compared to white females, suggesting that current BMI cut-points may represent varying amounts of visceral fat by race and thus, may underestimate or overestimate cardiometabolic risk in different racial/ethnic groups.

Two abdominal obesity measures, waist circumference (WC) and waist-to-height ratio (WHtR), have been reported to be useful in assessing increased visceral fat accumulation among children.[126–128] Increased WC is associated with an increased risk of metabolic syndrome, insulin resistance, and cardiovascular risk among children and adolescents.[129–131] WHtR has emerged as a simple measure for assessing abdominal obesity[24] and is associated with cardiometabolic risk factors among normal weight children.[25] WHtR has been shown to be associated with cardiometabolic risk across different racial/ethnic groups of children and adolescents.[73,132–135] In particular, abdominal obesity is more strongly associated with coronary heart disease than overall obesity,[19,20] which may explain the growing number of studies among adults examining the association between abdominal obesity and cardiovascular risk factors after adjusting for body mass.[21–24] While a number of longitudinal studies among older adults have shown increased abdominal obesity to be significantly associated with metabolic disturbances and cardiovascular disease risk independent of BMI,[136–140] there is limited longitudinal evidence supporting such a relationship among minority children.

Thus, this study aims to assess the association between WHtR, WC and cardiovascular biomarkers after adjusting for BMI. The study sample consists of a well-characterized cohort of black and white girls from the National Heart, Lung, and Blood Institute Growth and Health Study (NGHS). We hypothesized that abdominal obesity measures would be independently associated with cardiovascular biomarkers after controlling for BMI among blacks than whites.

Methods

Study Design and Sample

NGHS, a 10-year prospective cohort study, assessed risk factors for cardiometabolic disease among black and white preadolescent girls.[42] Investigators recruited participants from public and parochial schools in Richmond, California, and Cincinnati, Ohio, and from families

enrolled in Group Health Association (GHA), a large health maintenance organization, in the Washington, DC area.[42–44] Each city enrolled similar percentages of black and white participants. Eligibility criteria were: 1) girls self-identified as non-Hispanic black or non-Hispanic white, 2) girls were within two weeks of 9 or 10 years of age at the first clinic visit 3) their parents/caregiver self-identified as the same race, completed a survey, and gave consent.

A total of 2,379 girls were enrolled in the study. Girls who had intermittently missing or complete data for all the regression models were included so that the sample size remained constant across models, whereas those who were missing data for all waves were excluded (n=418), resulting in a final analytic sample size of 1,961 (82%). At baseline, complete data was available for 1,479 girls, including 719 white and 760 black girls. The analysis included 9 years of data, though not all variables were measured every year.

Exposure Variables

Three anthropometric measures were considered in the analyses: WHtR, WC, and BMI. Higher WC and WHtR have been shown to be positively associated with cardiovascular risk factors[23,26] and WHtR, in particular, has emerged as a promising and effective measure since its cut-point (>.5) is the same for males, females, and different ethnic groups.[98] WC was defined as the minimum above-waist circumference (the smallest circumference of the torso, at the "natural waist" against the skin) was measured in centimeters. WHtR was defined as waist (cm) divided by height (cm). Each girl's height was measured while she was wearing socks with her heels together and toes apart at a 45-degree angle. BMI was defined as weight (kg) divided by squared height (m^2). Weight was measured with an electronic scale (Health-O-Meter). Girls wore either a paper hospital gown or a large T-shirt provided by the center and all measurements were taken twice and repeated a third time if the first 2 measurements differed by >2 cm for height or 0.3 kg for weight. Weight and height were measured annually, starting on year 1; whereas waist circumference was collected annually, starting on year 2.

Outcome Variables

Two biomarkers assessing cardiovascular disease risk factors were considered in the analyses: ratio of triglycerides (mg/dL) to high-density lipoprotein cholesterol (mg/dL) (TG/HDL) and ratio of apolipoprotein B (mg/dL) to apolipoprotein A1 (mg/dL) (ApoB/A1). Twelve-hour fasting blood assessments were measured in the morning for ApoB/A1 (using radial immunodiffusion), high-density lipoprotein cholesterol, and triglycerides.[42] TG/HDL ratio is considered an effective biomarker for assessing cardiovascular risk and is shown to be a highly significant predictor of myocardial infarction—even more effective than either total cholesterol/ high-density lipoprotein cholesterol or low-density lipoproteins/high-density lipoproteins cholesterol scores.[141–143] ApoB/A1 ratio is an emerging biochemical marker used to assess fatal[144] and acute[145] myocardial infarction risk in adults—though limited research has examined this variable longitudinally among children. Increasing TG/HDL or ApoB/A1 score is associated with increased risk of cardiovascular disease.[146,147] Both biomarkers were collected in years 1, 3, 5, 7, and 10.

Covariates

Continuous covariates included in the models were age in years (linear and quadratic) and maturation. Age is the participants' self-reported age at the time of the exam, rounded to the

nearest one-tenth of a year. Participant's stage of maturation, a score ranging from 1 to 6, combined the scores of menarchal status and areolar staging by Garn and Falkner.[52,61] Categorical variables include household income (<$10,000; $10,000–$19,999; $20,000–$39,999; >$40,000), parent education (high school graduate or less, ≤ 3 years of college, ≥ 4 years of college), number of parents in household (single, both), and race (Non-Hispanic white, Non-Hispanic black). Parent education was the highest educational level reported and race was self-reported via a survey by participants' parents. All covariates were measured in every study year, starting on year 1.

Statistical Methods

Descriptive analysis of baseline data stratified by race was conducted. Linear mixed models were used to assess the one-year time-lagged association between obesity measures in years 2, 4, 6, 9 and cardiovascular biomarkers in years 3, 5, 7, 10, respectively. Each obesity measure (WHtR, WC, and BMI) was modeled separately per outcome. Subject-specific random intercepts were included and robust standard errors were used. To account for serial correlation, an autoregressive residual covariance structure was included. The average variance inflation factor was assessed and was considered moderate.

Subsequently, the influence of each abdominal obesity measure on each cardiovascular biomarker was investigated in separate models, controlling for BMI. Multiplicative interactions with race (WHtR x race, WC x race) were considered to assess differences in the relationship between each abdominal obesity measure and cardiovascular biomarkers among black and white girls. These interactions were tested with likelihood ratio tests at a 20% level of significance. We reported race-specific coefficients when interactions were significant. Since WHtR, WC, and BMI have different units, these variables were standardized for direct comparisons (Z-score) using the respective standard deviations for each obesity measure. The regression coefficient can be interpreted as the mean change in the biomarker score per one standard deviation change in the obesity measure, holding all other covariates constant. As a check for sensitivity, all parameters were estimated again without adjustment for BMI. A 5% level of significance was used to test these regression coefficients. Analysis was conducted using Stata 13.0.

Results

BMI was highly correlated with WHtR ($r > .9$, $P < .0001$) and WC ($r > .9$, $P < .0001$) at each time point for each race, which are similar to the correlations reported in two other studies.[148,149] **Table 3.1** reports the overall means with standard deviations or percentages for the baseline (year 2) characteristics between black and white girls. A higher percentage of white girls came from two-parent households, had parents with 4 or more years of college education, and had parents earning more than $40,000 compared to black girls. Black girls showed slightly higher values for WHtR, WC, and BMI and slightly lower values of TG/HDL and ApoB/A1 than white girls.

In the main-effects models (**Table 3.2**), separate regression models were used for each obesity measure. WHtR, WC, and BMI showed significant associations with cardiovascular biomarkers after adjusting for age, two-parent household, maturation stage, parental education, parental income, and race. The mean increase in TG/HDL per standard deviation increase in the obesity measures was estimated as (.35 [95% CI, .30, .41]) for WHtR, (.36 [95% CI, .31, .42]) for WC, and (.33 [95% CI, .28, .39]) for BMI. The mean increase in ApoB/A1 per standard

deviation increase in the obesity measures was estimated as (.06 [95% CI, .05, .06]) for WHtR, (.06 [95% CI, .05, .06]) for WC, and (.05 [95% CI, .05, .06]) for BMI. All regression coefficients for each outcome were significant with p<0.001.

In the models adjusting for BMI, the mean changes of the abdominal obesity measures were significantly different between black and white girls for TG/HDL (LR p-value <.001 for both WHtR and WC) and for ApoB/A1 (LR p-value = .001 for WHtR and .02 for WC; **Table 3.3**). The associations were more pronounced for whites than blacks for both TG/HDL and ApoB/A1. For black girls, the mean increase in TG/HDL per standard deviation increase in the abdominal obesity measures was estimated as (.27 [95% CI, .16, .38]) for WHtR and (.36 [95% CI, .25, .48]) for WC, and the corresponding estimates for white girls were (.56 [95% CI, .42, .70]) for WHtR and (.60 [95% CI, .46, .74]) for WC. For black girls, the mean increase in ApoB/A1 per standard deviation increase in the abdominal obesity measures was estimated as (.03 [95% CI, .01, .04]) for WHtR and (.03 [95% CI, .02, .05]) for WC, and for white girls the corresponding estimates were (.05 [95% CI, .04, .07]) for WHtR and (.05 [95% CI, .03, .06]) for WC. **Table 3.3** also shows the corresponding mean changes without BMI-adjustment and the pattern of findings were similar.

Discussion

This study examined the association between prior-year obesity measures and biomarkers of cardiovascular disease risk among a large cohort of black and white girls, from childhood (10-11 years) to late adolescence (18-19 years). There were two key findings: 1)WHtR, WC, and BMI were positively associated with TG/HDL and ApoB/A1; and 2) across all models, the associations between abdominal obesity measures and cardiovascular biomarkers was stronger for white than black girls independent of BMI. Our findings provide evidence using 10-year follow-up data that abdominal obesity measures are associated with increased cardiovascular biomarkers independent of body mass among a biracial cohort of preadolescent girls, underscoring the important independent influence that abdominal obesity may have on a child's cardiometabolic risk as they enter adulthood.

Only one other prospective study examined associations of WHtR, WC, BMI and cardiovascular risk factors among children using longitudinal data. Mrizaei et al[150] found that 3-year change in BMI was a better predictor of blood pressure than change in WC or WHtR among Australian schoolchildren, ages 8-10 years. The present study had a longer follow-up, examined lipid biomarkers as the outcome, and used a time-lagged analysis. More research should compare the magnitudes of associations between the three common obesity measures and cardiometabolic disturbances among children. While current prospective studies on adults use predictive modeling to assess risk of heart disease incidence or death,[148,149,151] future research on children could extend this analysis by using receiver operating characteristic (ROC) analysis to assess which anthropometric measure is the best predictor of incident diabetes or other cardiometabolic conditions.

To our knowledge, the finding that WHtR and WC remained positively and significantly associated with cardiovascular biomarkers after adjusting for body mass using longitudinal data is a new contribution and we have not found other prospective studies that examined such associations among black and white girls. The relationship between abdominal obesity measures and cardiovascular biomarkers was significant and stronger for white than black girls. Without imaging methods to assess visceral fat deposition, it is unclear if white girls had more visceral fat

accumulation, thereby increasing their level of cardiovascular biomarkers. Thus, the reason for racial differences remains unclear and should be further explored in other studies. Covariates were carefully selected to adjust for known confounders for obesity and cardiovascular risk factors, however, residual confounding may have influenced our results. The racial differences in WHtR and WC associations with cardiovascular biomarkers suggest a different mechanism for metabolic disturbances for black and white individuals, which have been examined in a previous study,[152] and should be explored further.

Although our results could not distinguish if WHtR is superior to WC, it has been reported that using WHtR over WC and BMI may advantages in the clinical setting: it does not require clinicians to reference percentile tables and it is independent of sex, age, and race.[24] WC can overestimate or underestimate risk for short and tall individuals with similar WCs as it does not adjust for height differences.[15] For young children, it is especially important to account for height because their risk continues to change as they grow in stature. BMI can be more difficult to explain its meaning and interpretation to patients, and studies have indicated that cardiovascular disease are higher in relatively shorter individuals,[153] underscoring the need to adjust for height when using WC.

One limitation lies in the measurement of waist circumference. There is not a universal standard for where to measure waist circumference; measurements can be taken at the smallest circumference of the torso, the midpoint between the rib and iliac crest, or the largest circumference at the navel.[154] This study focused on minimal waist circumference, measured at the smallest circumference of the torso. Young girls may have had much larger waist lines and thus, there could have been a clearer distinction between the two abdominal obesity measures. Such studies with a less conservative approach should be conducted to better distinguish the strengths of association for the two abdominal obesity measures. Second, fat distribution was measured anthropometrically and there was no direct measure of visceral fat using imaging techniques; however, WHtR and WC have been shown to be useful in assessing increased visceral fat tissue accumulation.[14] Third, the study sample consisted of only two races, was not designed to be reflective of any specific population, and was not a nationally representative sample of preadolescent children, thus limiting its generalizability.[155] Nonetheless, the study sampled a high percentage of black girls, who came from diverse socioeconomic backgrounds. The prospective design permitted a one-year time-lagged analysis of the correlation between obesity measures and cardiovascular biomarkers over a critical period when childhood obesity rates were highest and rapidly increasingly compared to any other period in the US. Data at subsequent time points were available for 82% of the original sample.

Conclusion

Though BMI is the most commonly used measure of body fat among children,[156] our findings underscore that where children store their fat—especially, near the abdomen—is important in assessing their potential to develop risk factors for heart disease. Abdominal obesity measures are simple, affordable assessments that clinicians can use to estimate cardiometabolic health and public health advocates, researchers, and clinicians should continue to examine their utility in clinical practice.

Table 3.1 Means (Standard Deviation)[a] of baseline (year 2) characteristics of adolescent girls in the NHLBI Growth and Health Study, stratified by race. (n=1,479)[b]

Variable	White (n=719)	Black (n=760)
Sociodemographic Characteristics		
Age, y	10.95 (.55)	11.05 (.56)
Two-Parent Household, No. (%)	592 (82.34)	456 (60.00)
Maturation Stage	2.15 (1.10)	2.98 (1.30)
Parental Edu, No. (%)		
≤High Grad	123 (17.11)	205 (26.97)
≤ 3 Years of College	211 (29.35)	371 (49.82)
≥ 4 Years of College	385 (53.55)	184 (24.21)
Parental Income, No. (%)		
<$10,000	35 (4.87)	174 (22.89)
$10,000–$19,999	61 (8.48)	137 (18.03)
$20,000–$39,999	229 (31.85)	245 (32.24)
≥ $40,000	394 (54.80)	204 (26.84)
Cardiometabolic Indicators		
WHtR	.43 (.05)	.44 (.06)
WC, cm	63.39 (7.73)	66.23 (9.56)
BMI, kg/m^2	18.78 (3.42)	20.24 (4.53)
TG/HDL, mg/dl	1.87 (1.39)	1.37 (.82)
ApoB/A1	.62 (.18)	.59 (.18)

[a] Unless otherwise indicated.

[b] An additional 482 girls whose data were not collected at baseline were included in the multilevel linear analysis for a final sample of 1,961.

Table 3.2 Adjusted mean change in cardiovascular biomarkers and 95% confidence interval (CI) for 1-year time-lagged associations of BMI, WHtR, and WC among black and white girls in the NHLBI Growth and Health Study. (n=1,961)

	TG/HDL		**ApoB/A1**	
No. of observations	5,067		5,067	
No. of girls	1,961		1,961	
Variable	**Mean Change (95% CI)[a] x 10**	**p-value**	**Mean Change (95% CI)[a] x 10**	**p-value**
BMI-z	3.34 (2.77, 3.92)	<0.001	.54 (.47, .61)	<0.001
WHtR-z	3.51 (2.96, 4.07)	<0.001	.55 (.48, .61)	<0.001
WC-z	3.64 (3.07, 4.22)	<0.001	.55 (.48, .62)	<0.001

Abbreviations: CI, confidence interval; BMI, body mass index; WHtR, waist-to-height ratio; WC, waist circumference; TG/HDL, triglycerides/high-density lipoproteins; ApoB/A1, apolipoprotein B/A1; z, Z-score. Each coefficient corresponds to a separate regression model.
[a]Associations adjusted for age, age^2, two-parent household, maturation, parental education, household income, and race.

Table 3.3 Adjusted mean change in cardiovascular biomarkers and 95% confidence interval (CI) for 1-year time-lagged associations for abdominal obesity measures by race among girls in the NHLBI Growth and Health Study. (n=1,961)

No. of observations	5,067			
No. of girls	1,961			
TG/HDL				
	Adjusted for all covariates[a] Mean Change (95% CI) x 10		**Adjusted for all covariates[a] + BMI Mean Change (95% CI) x 10**	
Variable	Black	White	Black	White
WHtR-z	2.43 (1.90, 2.97)	5.38 (4.29, 6.47)	3.26 (2.01, 4.51)	6.11 (4.52, 7.70)
WC-z	2.74 (2.19, 3.29)	5.18 (4.15, 6.21)	3.70 (2.35, 5.05)	6.03 (4.45, 7.62)
ApoB/A1				
	Adjusted for all covariates[a] Mean Change (95% CI) x 10		**Adjusted for all covariates[a] + BMI Mean Change (95% CI) x 10**	
Variable	Black	White	Black	White
WHtR-z	.47 (.39, .55)	.68 (.58, .79)	.42 (.24, .60)	.64 (.46, .81)
WC-z	.50 (.42, .58)	.63 (.53, .74)	.34 (.15, .53)	.50 (.32, .68)

Abbreviations: CI, confidence interval; WHtR, waist-to-height ratio; WC, waist circumference; TG/HDL, triglycerides/high-density lipoproteins; ApoB/A1, apolipoprotein B/A1; z, Z-score.
[a]Associations adjusted for age, age^2, two-parent household, maturation, parental education, parental income, race, and body mass index residuals for each abdominal obesity measure.

Conclusion

The present research aimed to examine the influence of modifiable risk factors on eating disturbances, waist-to-height ratio, and cardiovascular biomarkers among black and white girls from preadolescence to late adolescence, using longitudinal data from the National Heart, Lung, and Blood Institute Growth and Health Study (NGHS). All three papers found significant associations of individual and parental factors with their respective outcomes.

Paper 1 found a significant association of parental weight comments and a daughter's unhappiness with her weight with eating disturbances from adolescence (12-13 years) to late adolescence (18-19 years). Given the limited and inconsistent research on father's influence, it was important include fathers' weight comments in our analysis. Generally, girls who reported that their fathers called them fat were significantly and positively associated with a higher score for eating disturbances seven years later. Similar associations were found for mothers' comments. Only one significant racial difference was found: a higher score in bulimia symptoms was observed among black girls whose father commented about their weight compared to white girls whose fathers did not comment and who were happy with their weight. While the association was statistically significant, the clinical significance remains unclear. Overall, our results underscore the strong influence of parents' comments on their daughters' eating behaviors. It is important to remind parents that their direct verbal messages can have a lasting impact on their children's likelihood to develop eating disturbances later in life.

Paper 2 assessed the two-year time-lagged association between intake of sugary beverages and WHtR from childhood (9-10 years) to late adolescence (18-19 years). SSB consumption among all girls was significantly associated with a slight increase in WHtR. In the study, girls reported drinking as many as 5 cans of SSBs daily/year. Based on our findings, those participants drinking an average of 5 cans compared those drinking zero cans would be expected to have a .006 greater WHtR two years later, controlling for other factors. Interaction with race was significant, with black girls who consumed flavored milk compared to black non-consumers showing a significant but slight decrease in WHtR. This suggests that flavored milk may have a protective influence among black adolescence. Alternatively, this very modest finding could be spurious and flavored milk is a proxy for another health behavior, such as being an athlete or eating more family meals together where milk may be the beverage of choice. In summary, our findings about the influence of SSBs have important public health implications as increased WHtR has been linked to insulin resistance, metabolic syndrome, and cardiovascular risk. Since taste preferences in childhood can track into adulthood, it is imperative that public health efforts are directed towards reducing children's consumption of sugary beverages.

Paper 3 investigated the one-year time-lagged association between obesity measures and cardiovascular biomarkers from childhood (10-11 years) to late adolescence (18-19 years). There were two key findings: 1)WHtR, WC, and BMI were positively associated with TG/HDL and ApoB/A1; and 2) across all models, the associations between abdominal obesity measures and cardiovascular biomarkers was stronger for white than black girls independent of BMI. Without imaging methods to assess visceral fat deposition, it is unclear if white girls had more visceral fat accumulation, thereby increasing their level of cardiovascular biomarkers. The reason for racial differences remains unclear and should be further explored in other studies. Although our results could not distinguish if WHtR is superior to WC, it has been reported that using WHtR over WC and BMI may advantages in the clinical setting: the cut-point is easier to recall ($\geq$.5 for high risk); it does not require clinicians to reference percentile tables; and it is independent of sex,

age, and race.[26] In conclusion, abdominal obesity measures are simple, affordable assessments that clinicians can use to estimate cardiometabolic health and public health advocates, researchers, and clinicians should continue to examine their utility in clinical practice.

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