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Body mass index and percent body fat as determined by bioelectrical impedance analysis in children, 7-9 years of age

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BODY MASS INDEX AND PERCENT BODY FAT AS DETERMINED BY

BIOELECTRICAL IMPEDANCE ANALYSIS IN CHILDREN,

7-9 YEARS OF AGE.

By

Patrick Alan Grady

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   The purpose of this study was to examine the prevalence of overweight and report mean Body Mass Index (BMI) and percent body fat (%BF) in Black and non-Black children, 7-9 years of age. The study involved 172 students divided as follows: 56 (32.6%) Black females, 45 (26.2%) Black males, 34 (19.7%) non-Black females, and 37 (21.5%) non-Black males. Percent body fat (%BF) was determined by bioelectrical impedance analysis (BIA). Body mass index was calculated as weight (kg)/height (m)². Black females had a statistically greater BMI (19.3 ± 4.8) and %BF (25.7 ± 10.6) than all other groups. Prevalence of at-risk-for-overweight and overweight for the entire sample was 20.9 % and 19.2%, respectively. In conclusion, 40.1 % of 7 to 9 year old children assessed in this study were at-risk-for-overweight

or overweight, and the BMI and %BF for Black females were statistically greater than the other groups.

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CHAPTER I

INTRODUCTION

During the last two decades the prevalence of overweight and obesity has

increased in the United States. Obesity is regarded as a public health problem in

adults and overweight is a significant concern in children (Centers for Disease

Control and Prevention, 2006). For children, 6-11 years of age, the mean weight

increased from 65 pounds in 1963 to 74 pounds in 1999-2002, while mean height

increased only 0.8 inch. This led to an increase in body mass index (BMI) and thus

the increased diagnosis of overweight (Ogden et al., 2004). Obesity afflicts 30% of

American adults and approximately 25% of American youth are overweight.

Approximately 50% of adults are overweight or obese in many countries (Dehghan,

Danesh, & Merchant, 2005). A study by the Centers for Disease Control and

Prevention (CDC) on obesity indicated Mississippi's obesity rate increased from 10-

14% in 1990 to greater than 25% in 2001. By 2004 there were 9 states with a

prevalence of obesity greater than 25%. The prevalence of obesity in the United

States is increasing and Mississippi has the highest obesity rate (Centers for Disease

Control and Prevention, 2006).

Obesity is associated with arterial hypertension and other types of cardiovascular

disease, osteoarthritis, non-insulin dependent diabetes, and some types of cancer

(Daniels et al., 1999). Evidence has shown that atherosclerosis and arterial

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hypertension have an onset in childhood, and it is during this period when exercise and eating habits are established (Abrantes et al., 2002). Studies of overweight children show higher than mean blood pressure, heart rate, and cardiac output when compared to children who are not overweight.

The prevalence of overweight in children is a significant problem that tends to continue into adult life: approximately 50% of the children who are overweight by the sixth month of age and 80% who are overweight at the age of five years will be classified as obese as adults (Abrantes et al., 2002). Data collected by the CDC on the prevalence of obesity showed a definite increase in adult obesity that was associated with increased cardiovascular disease, diabetes, and respiratory problems (Centers for Disease Control and Prevention, 2006). Overweight during childhood is related with the additional health risks of diabetes and cardiovascular disease in adulthood (Abrantes et al., 2002; Berenson, 1993; Daniels et al., 1999; Williams et al., 1992, &).

Determining whether a child or adolescent has a weight problem can be challenging, as it is difficult to know whether excess weight is part of a growth process. It is also difficult for a parent or caregiver to determine if weight will negatively affect a child's health. Along with the rise in childhood overweight, there has been an increase in the incidence and prevalence of medical conditions in children and adolescents that had been rare in the past. Pediatricians and researchers are reporting more frequent cases of weight-related diseases that once were considered adult conditions, such as non-insulin dependent diabetes, asthma and hypertension (Oliveira et al., 2003).

   While BMI is a generally accepted as a screening tool for determining body weight status, there are multiple methods to more directly assess adiposity with some being more practical for field use. One of these methods is bioelectrical impedance analysis (BIA), an emerging technique for measuring body composition.

   The purpose of this study was to examine the mean Body Mass Index (BMI) and mean percent body fat (%BF), as determined by BIA, as well as the prevalence of overweight for children 7-9 years of age. Additionally BMI, %BF and prevalence of overweight were assessed for Black and non-Black males and females.

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CHAPTER II

BODY MASS INDEX AND PERCENT BODY FAT AS DETERMINED BY

BIOELECTRICAL IMPEDANCE ANALYSIS IN CHILDREN,

7-9 YEARS OF AGE.

ABSTRACT

The purpose of this study was to examine the prevalence of overweight and report mean Body Mass Index (BMI) and percent body fat (%BF) in Black and non-Black children, 7-9 years of age. The study involved 172 students divided as follows: 56 (32.6%) Black females, 45 (26.2%) Black males, 34 (19.7%) non-Black females, and 37 (21.5%) non-Black males. Percent body fat (%BF) was determined by bioelectrical impedance analysis (BIA). Body mass index was calculated as weight (kg)/height (m)². Black females had a statistically greater BMI (19.3 ± 4.8) and %BF (25.7 ± 10.6) than all other groups. Prevalence of at-risk-for-overweight and overweight for the entire sample was 20.9 % and 19.2%, respectively. In conclusion, 40.1 % of 7 to 9 year old children assessed in this study were at-risk-for-overweight or overweight, and the BMI and %BF for Black females were statistically greater than the other groups.

INTRODUCTION

Prevalence and Trends of Overweight

Obesity is an epidemic in North America and in other parts of the world. The prevalence of obesity seems to be increasing in most parts of the world, even where it used to be rare (Centers for Disease Control and Prevention, 2006). It is estimated that approximately 22 million children under the age of 5 years are overweight across the world. The number of overweight children in the U.S. has doubled in the last three decades (Deckelbaum & Williams, 2001).

In adults, overweight and obesity can be defined in terms of a body mass index (BMI). Body mass index (BMI) of 30 kg/m² or greater is classified as obesity and overweight is a BMI of 25 or greater in adults. Children are classified as being at risk for overweight if their BMI is between the 85th and 95th percentile for their age and gender; children are classified as overweight if their BMI is above the 95th percentile for their age and gender (Centers for Disease Control and Prevention, 2006).

Body weight is regulated by numerous physiological mechanisms that maintain balance between energy intake and energy expenditure. Obesity is characterized by an excess fat accumulation to the level that ones health and well being are affected (Duerenberg & Yap, 1999). Genetic factors, a lifetime of lack of physical activity, diets composed of excess calories, and parent-child interactions in the home environment are all factors that can predispose an individual towards being overweight or obese (Ebbeling, Pawlak, & Lidwig, 2002).

The world-wide increase in BMI may be due to a westernization of behavior and dietary changes (Deckelbaum & Williams, 2001). A study on childhood overweight in Japan examined 29,052 males and 27,552 females between 6 and 14 years old. The results showed an increase in overweight in males and females from 6.1 and 7.1% respectively in 1976-1980, to 11.1% and 10.2% in 1996-2000. This study clearly showed and increase in prevalence of childhood overweight (Matsushita et al., 2004).

National survey data, such as the National Health and Nutrition Examination Survey (NHANES), show increases in mean BMI and in the prevalence of overweight and obesity for adults and at risk for overweight and overweight in children in the United States (Flegal & Troiano, 2000). According to NHANES, overweight for children, aged 6-11 years, increased from 11.3 % in 1988-94 to 18.8 % in 2003-200. The overweight and obesity rate for adults, 20-74 years of age, increased from 47 % with 15 % being obese to 66 % with 32.9 % being obese (Centers for Disease Control and Prevention, 2006). Mean-difference plots allow qualitative, visual comparisons of the distributions of BMI between surveys. For all sex-age groups, there was an increasing skew with a greater shift in the upper part of the distribution so that, within each group, the heaviest subgroup was heavier in NHANES III than in prior NHANES surveys (Flegal & Troiano, 2000). For the youngest children, the lower part of the BMI distribution showed virtually no change. With increasing age, the whole distribution shifted upward slightly, suggesting an increase in BMI across the entire population. These changes in the distribution of BMI suggest the combination of profound environmental determinants and a

population with a high degree of susceptibility. There was an increase in BMI in seven year old males and females from 15.6 kg/m² in 1963-1970 to 15.8 kg/m²in 1988-94 and in females 15.5 kg/m² to 15.8 kg/m² over the same time period. In eight year olds, BMI increased from 15.9 kg/m² to 16.3 kg/m² in males and 16.0 kg/m² to 16.6 kg/m² in females during the same time period. In nine year olds, BMI increased from16.2 kg/m² to 17.0 kg/m² in males and 16.3 kg/m² to 16.6 kg/m² in females (Flegal & Troiano, 2000). Other studies also show an increasing prevalence of children who are at risk for overweight or overweight. In a study of children, 6-19 years old, visiting primary care practices, 36% of males aged 6-11 years and 35% of males aged 12-17 years were either at risk for being overweight or overweight; 20% and 19% were overweight, respectively. Thirty-five percent of females aged 6-11 years were either at risk for being overweight or overweight (Gauthier, Hickner, & Ornstein, 2000).

A study of 2,365 school children in the age groups 8-9, 11-12, and 15-16 years of age reported an increased prevalence of at risk for overweight and overweight children in comparison to recently published studies (Reich et al., 2002). The prevalence of overweight was elevated in children of lower education level. The study concluded that overweight in children is increasing and is related to socioeconomic status. Also, the higher prevalence of overweight is associated with hypertension even in children at young ages. The study also found that cardiovascular risk is increasing within even normal BMI values; therefore, having a BMI below some of the widely accepted cutoff value does not ensure the lack of increased

cardiovascular risk. This may be a result of the wide range of %BF found within the BMI values (Reich et al., 2002)

Specialized physical activity and nutrition have become necessary in elementary schools due to the increase in the prevalence of childhood overweight. During the past 20 years, there has been a dramatic increase in obesity in the United States. In 1985, only a few states were participation in CDC's Behavior Risk Factor Surveillance System (BRFSS) and providing BMI data. In 1991, four states had obesity prevalence rates of 15-19% and no state had a rate greater than 20%. In 2004 there were 7 states with obesity prevalence rates of 15-19%, 33 states had rates of 20-24%, and 9 states had rates greater than 25%. Mississippi is one of the 7 states with a reported obesity prevalence rate of more than 25% (Centers for Disease Control and Prevention, 2006).

Rates of obesity in adulthood can be expected to increase due to childhood overweight becoming an increasing problem throughout the world. Studies have shown that at risk for overweight and overweight children have an increased risk of becoming overweight and obese adults: approximately 50% of the children who are overweight by the sixth month of age and 80% who are overweight by the age of five years will remain overweight or become obese adults (Abrantes et al., 2002). A study involving children in Australia reported that at least of 25% of primary school children were overweight. Universal preventative strategies have thus far had very little effectiveness. Behavior and biology are important determinants of many adult diseases including obesity. Thus developing healthier behaviors in childhood is an

important action that has the potential to limit adult obesity. An effective approach to reducing obesity in children and thus in adulthood is likely to require synergistic strategies across this age spectrum (Wake & McCallum, 2004). Assessments of the prevalence of obesity and tracking the prevalence over time are much more complicated in children than adults, because there are little criteria to classify children as at risk or overweight. Currently the WHO recommends the use of BMI for age percentiles; however the reference curves are under development (Gauthier et al., 2000).

While it is difficult to determine overweight in children, the task becomes increasingly, difficult due to the fact that the definitions of overweight in children differ between epidemiological studies. This makes comparisons across cross-sectional prevalence data difficult. Determining overweight becomes even more complicated when looking at the BMI of children due to its dependency on percentiles for a given age. With measures that can help describe the BMI there would be more specific ways to compare between studies and race.

There are slightly different criteria for classifying a child as being at risk for overweight or overweight compared to adults due to the rather rapid changes in height and weight in children. After BMI is calculated for children, the BMI value is plotted on the BMI for age growth charts to obtain a percentile ranking. Percentiles are the most often used indicator to determine the size and growth patterns of individual children in the US. The percentile shows the relative position of the child's BMI among other children of the same gender and age. Less than the 5th percentile is

underweight, 5%-85% is healthy, at risk for overweight is 85%-95%; over-weight is

95% or higher (Centers for Disease Control and Prevention, 2006).

A study by Oliveria and colleagues (2003) on family detection of at-risk-of-

overweight and over-weight showed that the individuals responsible for obtaining

child treatment for overweight do not always view the child's weight as a problem.

They assessed the weight status of six hundred and ninety-nine students, as well as

the parents' view of their weight

status. Nine and three-tenths percent (9.3%) viewed their child as being overweight.

This is well below the actual prevalence of overweight. There were no statistical

differences for race or gender (Oliveira et al., 2003). This study gives a good

indication of how parents or caregivers perceive the weight status of their children. It

presents the idea that treatment is not likely to be received in most children who are at

risk for overweight or overweight due to lack of parental recognition. This provides a

good rationale for the measurement and assessment of children at early ages in order

to determine health risks and prevention strategies.

Ultimately the prevention and treatment of overweight in children involves eating

less and being more physically active. This may sound simple but long term weight

loss is very difficult (Ebbeling, Pawlak, & Lidwig, 2002). The relative intellectual

and psychological immaturity of children compared with adults, and their

susceptibility to peer pressure present additional practical obstacles to the successful

treatment of childhood overweight. For this reason most efforts to reduce obesity on children have used either family-based or school-based approaches (Ebbeling, Pawlak, & Lidwig, 2002).

Health Risk Associated with Overweight

There is an increased risk of cardiovascular disease in overweight children and this correlates with an increased risk as an adult. Studies have shown that in roughly 60% of overweight children from 5-10 years of age a cardiovascular disease risk factor can be identified and in more than 20% of overweight children there are two or more risk factors. These are factors that substantially increase the risk of individuals for earlier cardiovascular disease (Deckelbaum et al., 2001).

Surveillance of overweight among children is important in view of the clinical consequences, which are measurable and quantifiable currently in school age children. Body mass index is commonly preferred as the simplest and most powerful variable to assess the degree of overweight. The increase of health risk with increased BMI is continuous and includes: increased blood pressure, increased risk for heart disease and certain types of cancer are all conditions that show up in overweight or obese individuals (Reich et al., 2002). Other studies have shown that overweight and obese individuals are at increased risk for many diseases and health conditions, including: hypertension, dyslipidemia, type 2 diabetes, coronary heart disease, stroke, gallbladder disease, osteoarthritis, sleep apnea, respiratory problems, and some cancers such as breast and colon. In order to aid in the prevention of these conditions it is necessary to have a method to assess body composition of children to determine

progress that has been made in weight loss programs (Centers for Disease Control and Prevention, 2006).

Childhood overweight is a multi-system disease with devastating consequences if not controlled. With children as in adults overweight causes hypertension, dyslipidemia, chronic inflammation, increased blood clotting tendency, endothelial dysfunction, and hyperinsulinaemia. The increase in childhood complications can be seen in the prevalence of type 2 diabetes. Which was once almost unrecognized in adolescence, now accounts for around half of all new diagnosis in some populations. This increase is almost completely in response to the childhood overweight epidemic, although other factors such as family history and lifestyle factors affect individual risk (Ebbeling, Pawlak, & Lidwig, 2002).

Studies have shown a difference in prevalence of overweight between races and the increased risk of health conditions that are associated with overweight. A study looking at overweight among inner city Hispanic-American children and adolescents found that 38% were overweight and 22% at risk for overweight. Compared to their normal weight counterparts, the overweight youth had significantly higher systolic blood pressure. In this study group, the prevalence of overweight and at risk for overweight was twice the national mean. This study did not find a significant difference in the occurrence of overweight or at risk for overweight between genders (Mirza et al., 2004). Cardiovascular disease risk in young adulthood is highly related to the degree of adiposity as early as 13 years of age. In adults an increased risk of death from cardiovascular disease has been found for individuals whose BMI was

greater than 75th percentile when they were adolescents. It is reported that about 60%
of children and adolescents with BMI greater than 95th percentile have at least one
risk factor for future cardiovascular disease, and over 25% have two or more risk
factors (Freedman et al., 1999).

The problems, complications, dangers, and failures of treatment for at risk for
over-weight and overweight make a strong argument for an approach that prevents
excessive weight gain. The prevalence and trends data support a preventive approach
beginning in childhood (Penman, 2000). Studies have shown that improvements in
BMI have the potential to improve an array of health conditions including total
cholesterol, blood pressure, and insulin insensitivity. These results will be very
helpful when counseling families with overweight children (Kirk et al., 2005).

Body Mass Index

Body Mass Index is calculated from a child's weight in kilograms and height in
meter squared {weight (kg)/height (m²)}. It has been shown to be a reliable indicator
of body fatness for most children and teens (Centers for Disease Control and
Prevention, 2006). Body mass index does not measure body fat directly or any other
component of body composition. Body mass index is generally accepted as an
alternative for direct measurement of body fat. Additionally, BMI is an inexpensive
and easy to perform method of screening for weight status and determining children
who are at risk of overweight or overweight, that may lead to health problems
(Centers for Disease Control and Prevention, 2006).

For the assessment of body fat percentage in epidemiological studies, a weight-height index is the simplest method. It requires almost no equipment. A study completed at the University of Wageningen in the Netherlands used 1229 subjects (521 males and 708 females) with a wide range of BMI, and an age range from 7-83 years. Body composition and overweight status were determined by densitometry and anthropometry, respectively. The study determined that through internal and external cross-validation of the prediction formulas based on BMI that the formulas gave valid estimates of body fat in males and females of all ages. However in the obese subjects, body fat was slightly overestimated. The correlation between %BF and BMI was more highly correlated in adults than children. This is due to the greater variability of children's height and body composition throughout the growth stages. This weakness of BMI presents reasoning for a more direct method of determining %BF (Storey et al., 2003).

There are limitations to BMI, mainly due to the fact that it does not take into account an individual's body composition, such as very muscular individuals. A study by Gallagher et al. (2000) on the ability of BMI to indicate body fatness in adults by age, sex, and race, indicated that BMI is age and sex dependent when used as an indicator of actual body fatness. However, the relationship between BMI and body fatness was not affected by race in this study. The study found that for the same BMI, women had more body fat than men. If this is true for children, then it can be assumed that BMI might be more appropriate when assessing child health if it is supplemented with a more direct measurement such as BIA (Gallagher et al., 2000).

Percent body fat (%BF) varies within the same BMI values, so there is a concern that there will be mislabeling of children. Children with high BMI values who are not over-fat could mistakenly be classified as at risk for overweight or overweight, while children who have an unhealthy level of fatness but a normal BMI go unrecognized as overweight (Baylor College of Medicine, 2000). There is also a chance of changing body composition by losing fat through dieting and exercise, but not decreasing body weight. This effect can come from adding muscle mass while losing fat during the weight loss process. Thus there might be even more of a change in body composition than would be expected by the change in BMI.

Another concern with the use of BMI is that there are differences in the BMI between Black and non-Black children. In a study done on the percentiles of BMI in American children, 5-17 years old, it was found that mean BMI tends to be slightly higher for females than for males. Although there were no substantial differences in mean BMI between non-Black and Black males, the BMI of Black females was significantly higher than non-Black females (Rosner et al., 1998).

Studies have shown variability between racial and ethnic groups with regard to body composition at different BMI values. A study comparing the level of body fatness at various BMI values in New Zealand, European, Maori, and Pacific Island children found that for a BMI of 30 kg/m², the predicted %BF of 43.5% of the European females was equal to the %BF at BMI of 34 for the Maori and Pacific Island females. The Maori and Pacific Island females were 3.7 %BF less than European females (Rush et al., 2003). There was not a similar relationship for males

since %BF of European males at a given BMI was not significantly different

compared to other ethnic groups examined. It is known that Polynesian adults with

the same body mass as European adults have a higher fat free mass and lower fat

mass (Rush et al., 2003). This study shows that there are differences in %BF at

different BMI values between ethnic groups. Since there are differences in %BF

between races for a BMI value, different BMI cut-off points been to be established

for at risk for overweight and overweight for various racial groups (Rush et al., 2003).

Body Mass Index (BMI) is a weight(kg)/height(m)^2 ratio that is currently used to

determine overweight in children and adults, due to its simplicity and the fact that it

has been linked with health risks. It is accepted as a reliable, but BMI can be

misleading because if its inability to determine body composition and thus its

inability to distinguish between a high BMI value due to increased muscularity or due

to increased adiposity (Nevill et al., 2006). It is expected that there is a reasonable

level of comparison between %BF and BMI values. While there are certainly

variances in percent body fat within a BMI value, especially for race and gender, a

close association has been found between the two (Sung et al., 2001). A study done

by Giugliano and Carneiro (2004) found that the concordance between excess

adiposity and overweight and obesity ranged between 95.2% for males and 97.3% for

females, which indicates a low occurrence of false positives for at risk for overweight

and overweight when the BMI for age was used for classification purposes.

Nevertheless, five out of ever 100 males and 3 out of every 100 females classified as

overweight or obese would have been misclassified.

The relationship between body fat percentage and BMI has shown variance between races so BMI cut-off points have to be race-specific. Adapting cut off points could have important consequences for prevalence data in some countries as the prevalence of individuals classified as overweight or obese may increase or decrease dramatically (Duerenberg et al., 1999).

The health assessment of children is of increasing interest due to the rise in childhood obesity. Finding more efficient and accurate methods of determining over fat/ overweight could lead to better health care plans as well as more effective ways to assesses the changes taking place during growth and health management (Nunez et al., 1999).

Bioelectrical Impedance Analysis

Bioelectrical impedance analysis (BIA) is a simple, noninvasive method of determining body composition. It uses electrodes to send and receive electrical impulses through the body, which is used to determine the composition of the body. The BIA device uses input data such as height and population specific equations to calculate the composition of the body from the resistance to flow to the electrical current and input data such as height. Bioelectrical impedance analysis (BIA) has been shown to give reliable estimates of body composition, with the leg-to-leg BIA being of special interest. Rubiano et al. (1999) compared leg-to-leg BIA with dual energy x-ray absorptiometry (DEXA). The results suggested that leg-to-leg BIA provided an accurate estimate of body composition. This study concluded that leg-to-

leg BIA could be used as an assessment of health in individuals of varying age and fitness levels (Rubiano et al., 1999).

Measurement methods that are used for a program that is attempting to create a healthier lifestyle and body composition should have a high reliability and low variance. With measures such as anthropometry human error must be considered. BIA has been shown to provide accurate and precise measurements when looking at changes in fat-free mass, providing simple and reliable assessment of obese or overweight individuals (Kushner et al., 1990). A study by Kushner et al. (1990) studied body composition in twelve obese women. Subjects were measured after an overnight fast and height and weight were recorded. Total body water was measured by deuterium dilution and estimated by BIA. Also, seven-site skinfold anthropometry was performed. The study concluded that BIA was a clinically useful technique for measurement of changes in body composition in obese populations. The study also concluded that BIA was more accurate than skinfold measurement. It was noted that a limitation of BIA was that the equations must be population specific, and the assumed hydration constant requires a normal range of hydration in order to accurately measure body fatness (Kushner et al., 1990).

Hydrodensitometry, or underwater weighing, has become the gold standard for assessing lean body mass that other techniques are validated against (Young and Sinha, 1999). However, the technique is difficult and cumbersome. It involves the determination of lung volumes and is less suitable for studies that involve children. Another way to measure body composition is anthropometric measurements, but

these measures require skilled persons and measurements can vary between investigators. Other forms of body composition measurement such as ultrasound, DEXA or positron emission tomography are expensive. These methods are not suitable for field use on large populations especially those involving children. Bioelectrical impedance analysis (BIA) is much more suited for these "field" measurements since it is simple and quick, non-invasive and inexpensive. A study on BIA validity in West Indian populations used densitometric measures as a reference and found that BIA estimated %BF as accurately as other simple techniques that were used in other populations (Young & Sinha, 1999).

Studies are examining the feasibility and reliability of using BIA to determine body composition of children due to an increased incidence of childhood obesity and health problems that are associated with overweight and obesity. Studies have shown that BIA is a reliable measurement in determining adipose tissue mass in children. A study on the validity of leg-to-leg BIA in children indicated a high correlation between the % fat estimates from BIA and DEXA (Nunez et al., 1999). Austin et al. (1998) concluded that BIA accurately assessed fat free mass and body fat in females when compared with DEXA. These studies show a potential for BIA as an assessment tool for examining body composition (Austin et al., 1998).

For maximum accuracy with BIA percent body fat should be calculated using equations that are specific for the individual's racial or ethnic group. A study examining the predictive accuracy of BIA for estimating body composition in Native American women compared body density calculated from BIA with values obtained

using hydrostatic weighing and DEXA. Fat free mass was significantly overestimated using equations for all methods. The authors developed a more appropriate equation for Native American females. This study shows that while BIA is not interchangeable with other measures, it is reliable and can be used for different racial groups if appropriate equations are used (Stolaczyk et al., 1994).

Applications for use of BIA are the identification and treatment of childhood obesity. Bioelectrical impedance analysis may be a useful field based method for the assessment of children with widely varying body composition. This is important due to the likelihood this could give greater insight into childhood obesity and the changes that are taking place during weight loss and gain. If weight loss is desired as it is in overweight and obese children, then having an accurate way to assess the body fat of the subject in a noninvasive and in expensive way is vital. This would enable observers to monitor, with greater detail, progress that is being made.

Bioelectrical impedance analysis is generally simple and well accepted by individuals. As already stated individuals with the same BMI may have different body compositions. DEXA is a well recognized measure for determining percent body fat (Sung et al., 2001; Elbert et al, 2004). Compared to standard reference methods, such as DEXA and hydrostatic weighing, for determining body composition, BIA is a relatively simple and less time consuming method. A study involving 2,382 healthy children, aged 7-16 years, found that BIA measures agreed 95% with DEXA (Sung et al., 2001). This study concluded that BIA was a valid alternative to DEXA for the purpose of measuring body fat.

When assessing body composition of either an individual or large study group, it is important to have a reliable, valid and easy to use method. Anthropometry is used to determine body composition in many studies; however, this measure requires skilled persons to perform measures and suffers from variability between measurers. A study by Gutin et al. (1996) reported that BIA had less variance in percentage of body fat compared with DEXA and skinfolds in children from 9-11 years of age. The study also found a high correlation between BIA, skinfolds, and DEXA (Gutin et al., 1996).

There are some limitations with BIA. Bioelectrical impedance analysis may be less sensitive when measuring very small changes in body composition in a short term study. A study done by Vasquez and Janosky (1991) on the validity of BIA for measuring changes in lean body mass during weight loss involved two groups of eight obese women. Lean body mass was determined by BIA and nitrogen balance, which was used as the criterion method. All BIA equations overestimated the loss of lean body mass as calculated by nitrogen balance; however, anthropometry also overestimated the loss of lean body mass. In this study BIA did not appear to be a valid method by which to measure small changes in lean body mass (Vasquez & Janosky, 1999).

The methodological problems that have been identified for BIA can be addressed by careful planning of the measurement times and conditions. However, when working with children it is difficult to recreate ideal conditions due to noncompliance. Accuracy may be compromised when attempting to assess a large number of subjects within one time period. If many subjects have to be measured consecutively, then it is

difficult to measure all of the participants in the fasting state. Other factors can cause variation in measurements; the BIA measurements may be affected by physical activity and other variables that change the subjects' hydration state. Performance of BIA three to five hours after a meal could lead to a significant underestimation of body fat mass as BIA measures should be measured in the morning in a fasting state and after emptying the bladder (Tanita, 2006).

The purpose of this study was to examine the prevalence of at risk for overweight and overweight, mean Body Mass Index (BMI) and percent body fat (%BF), determined using BIA for children 7-9 years of age. Also, difference between Black and non-Black individuals, as well as between males and females were examined.

METHODS

Data collection procedures

Data were collected for implementation of a coordinated school health program at an elementary school (grades k-2) in a university town in Mississippi. In January of 2005, data were collected on second graders in order to describe baseline characteristics of the students.

Subjects/sampling strategy

Participants were recruited at an elementary school by obtaining consent from a parent or guardian. In order to participate in the study, parents completed and returned a form that was sent home with second grade students. Second graders were chosen due to the age limitations of the BIA technique; it has only been validated for

children 7 years of age or older. Consent was obtained for 184 students out of 320

total second graders. Subjects were apparently healthy children, aged 7-9 years, who

were part of a larger school based study. Race was reported by parents. Only Black

and White, referred to here as non-Black, subjects were included due to limited

participants of other races. Data for 12 students were excluded from the study due to a

very small participant number for their particular racial group. There were 172

participants divided into 4 groups: Black females n: 56 (32.8% of participants), Black

males n: 45 (26.16% of participants), non-Black females n: 34 (19.9% of

participants), and non-Black males n: 37 (21.6% of participants).

Measurements

Height was measured to the nearest millimeter (without shoes) using a portable

stadiometer. Two sets of measurements were taken and the mean was used in the

calculation of BMI values. Weight was measured, in kilograms, by the BIA

instrument during the measurement of body composition. Body Mass Index (BMI)

was calculated as weight(kg)/height(m)^2.

The SAS statistical analysis software was used to determine BMI percentile and

classify participants. Participants below the 85th percentile for body weight for height,

age and gender were classified as normal/underweight, participants between the 85th

and 95th percentile were classified as at risk for overweight, and participants above

the 95th percentile were classified as overweight.

Percent body fat was measured on a Tanita foot-to-foot BIA instrument (Tanita

Corp., Arlington Heights, Illinois). The Tanita bioelectrical impedance analyzer

directly measures weight and uses regression equations to estimate percentage of

body fat. The BIA instrument uses multiple regression analysis, which enables an

unmeasurable component, in this case body fat, to be predicted from one or more

measured components. The measured or input components include total body water,

body mass, height, sex, age, clothing weight (0.5 pounds), and exercise status

(standard or athletic). All participants were measured with the standard setting.

Bioelectrical impedance analysis (BIA) measures resistance in the body to an

electrical current, which enables total body water to be calculated. The percent body

fat is estimated from the measured total body water and other variables. Participants

were required to remove shoes and socks or stockings in order to provide adequate

foot contact with the electrodes and comply with recommended procedures for the

BIA instrument (Tanita Corporation). The optimal conditions for BIA measurement

are for the participants to be measured with an empty bladder and at least two hours

after eating. Practical reasons prevented the replication of these conditions in an

elementary school environment. Participants were measured in the morning,

approximately 2 hours after breakfast and before their noon meal, in order to measure

as many children as possible with the appropriate protocol.

Data analysis

Data were analyzed using SAS (version 9.1.2, 2005; SAS Institute Inc., Cary, NC).

For the statistical analysis, only data for participants who were grouped as Black

male, non-Black male, Black female, or non-Black male were used. Means and

standard deviations were calculated for BMI and %BF. BMI was used to classify

subjects into three groups: underweight/normal, at risk for overweight, and

overweight. Underweight and normal were analyzed together for statistical purposes

since there was a lack of sufficient subjects classified as underweight.

RESULTS

This study examined the prevalence of at-risk-for-overweight and overweight,

body mass index (BMI), and percent body fat (%BF) for children, 7-9 years of age,

analyzed for race and gender.

The mean age in months, weight (kg), and height (cm) for each group were

determined. Body weight of the black females, 33.1 ± 12.1 kg, was significantly

greater than the body weight of non- Black females, 28.0 ± 5.7 kg. There were no

other statistical differences between groups for body weight. Black males were

significantly greater for age, 99.4 ± 7.2 months, and height, 132.8 ± 6.1 cm,

compared to the age, 95.5 ± 5.1 months, and height, 127.9 ± 4.0, of non-Black males

(Table 2.1). There were no other statistical differences between groups for age and

height.

Table 2.1

Participant Characteristics: Age, Weight, and Height of Children, 7 to 9 Years of Age

Group	Black Females (n=56)	Black Males (n=45)	Non- Black Females (n=34)	Non-Black Males (n=37)
Mean age (months)	96.1 ± 4.0	99.4 ± 7.2*	95.1 ± 4.5	95.5 ± 5.1
Mean weight (kg)	33.1 ± 12.1 ¶	32.4 ± 7.2	28.0 ± 5.7	28.6 ± 6.4
Mean height (cm)	129.9 ± 8.7	132.9 ± 6.1*	127.3 ± 5.7	127.9 ± 4.0

Data are mean ± standard deviation
* $p < 0.05$, Black males vs. non-Black males
¶ $p < 0.05$, Black females vs. non-Black females

The mean BMI for Black females, 19.3 ± 4.8 kg/m², was significantly greater than the BMI value of 17.1 ± 2.6 kg/m² for non-Black females (Table 2.2). There was no significant difference between Black, 18.3 ± 3.2 kg/m², and non-Black males, 17.5 ± 3.2 kg/m². Black females had a significantly greater %BF, 25.7 ± 10.6 %, than non-Black females, 20.4 ± 8.9 %. There was no significant difference for %BF between Black males 21.1 ± 8.1 % and non-Black males 19.4 ± 7.4 %.

Table 2.2

Body Mass Index (BMI) and Percent Body Fat (%BF) for Children, 7-9 Years of Age

Group	Black Females (n=56)	Black Males (n=45)	Non-Black Females (n=34)	Non-Black Males (n=37)
BMI (kg/m²)	19.3 ± 4.8*	18.3 ± 3.2	17.1 ± 2.6	17.5 ± 3.2
%BF	25.7 ± 10.6*	21.1 ± 8.1	20.4 ± 8.9	19.4 ± 7.4

Data are mean ± standard deviation
*p<0.05, Black females vs. non-Black females

When data were pooled in order to compare Blacks with non-Blacks for BMI and

%BF, there were no differences between groups (Table 2.3).

Table 2.3

Body Mass Index (BMI) and Percent Body Fat (%BF) for Black and non-Black
Children, 7-9 Years of Age

Race	Black (n=101)	Non-Black (n=71)
BMI (kg/m²)	18.9 ± 4.2	17.3 ± 3.0
%BF	23.7 ± 9.8	19.9 ± 8.1

Data are mean ± standard deviation

When data were combined in order to compare males with females there were no

differences between the groups (Table 2.4).

Table 2.4

Body Mass Index (BMI) and Percent Body Fat (%BF) for Male and Female Children, 7-9 Years of Age

Gender	Male (n= 82)	Female (n=90)
BMI (kg/m²)	18.0 ± 3.2	18.5 ± 4.2
%BF	20.4 ± 7.8	23.7 ± 10.2

Data are mean ± standard deviation

Using BMI and standards set by the Centers for Disease Control (CDC),

participants were classified as underweight, normal weight, at risk for overweight,

and overweight. Participants classified as underweight or normal weight were

combined for statistical purposes due to the low number of participants classified as

underweight. For males, 48 (58.4%) were classified as underweight or normal weight,

21 (25.6%) were classified as at risk for being overweight, and 13 (15.9%) were

classified as overweight (Table 2.5). For females, 55 (61.1%) were classified as

underweight or normal weight, 15 (16.7%) were classified as at risk for overweight,

and 20 (22.2%) were classified as overweight.

Table 2.5

Frequency of At Risk for Overweight and Overweight for Male and Female Children

Class	Male (n=82)	Female (n=90)
Underweight/ Normal	48 (58.4 %)	55 (61.1 %)
At Risk for Overweight	21 (25.6 %)	15 (16.7 %)
Overweight	13 (15.9 %)	20 (22.2 %)

Data are number of participants in a given weight classification and percentage of participants.

The number and percentage of Black and non-Black children classified as underweight and normal weight, at risk for overweight, or overweight was examined (Table 2.6). Fifty-one (50.5%) Black children were categorized as underweight or normal weight while 27 (26.7%) were classified as at risk for overweight and 23 (22.8%) were classified as overweight. For non-Blacks 52 (73.2%) where classified as underweight or normal weight, 9 (12.7 %) were classified as at risk for overweight, and 10 (14.0 %) were labeled overweight.

Table 2.6

Frequency of At Risk for Overweight and Overweight for Black and non-Black
Children

Classification	Black (n=101)	Non-Black (n=71)
Underweight/ Normal	51 (50.5 %)	52 (73.2 %)
At Risk for Overweight	27 (26.73 %)	9 (12.7 %)
Overweight	23 (22.8 %)	10 (14.1 %)

When subjects were examined based on gender and race, 29 Black females (51.8 % of Black females) were classified as underweight or normal weight, 12 Black females (33.3 %) were classified as at risk for overweight, and 15 (26.8 %) were classified as overweight. For Black males, there were 22 subjects (48.9 %) who were classified as underweight or normal weight, 15 (33.3 %) were at risk for overweight, and 8 (17.8 %) were overweight. For non-Black females, 26 participants (76.5 %) were classified as underweight or normal, 3 (8.8%) were classified as at risk for overweight, and 5 (14.7 %) were classified as overweight. For non-Black males, 26 participants (70.8 %) were classified as underweight or normal weight, 6 (16.2 %) were classified as at risk for becoming overweight, and 5 (13.5 %) were classified as

overweight. One hundred and three subjects (59.9 %) were classified as either

underweight or normal weight (Table 2.7). Thirty-six subjects (20.9 %) were

classified as at risk for overweight and 33 subjects (19.2 %) were classified as

overweight.

Table 2.7

Frequency of At Risk for Overweight And Overweight by Gender For Black And
Non-Black Children

Classification	Black Females (n=56)	Black Males (n=45)	Non- Black Females (n=34)	Non-Black Males (n=37)	Total (n=172)
Underweight/ Normal	29 (51.8 %)	22 (48.9 %)	26 (76.5 %)	(26) (70.3%)	(103) 59.9 %
At Risk for Overweight	12 (21.4 %)	15 (33.3 %)	3 (8.8 %)	6 (16.2 %)	36 (20.9 %)
Overweight	15 (26.8 %)	8 (17.8 %)	5 (14.7 %)	5 (13.5 %)	33 (19.2 %)

DISCUSSION

 Elementary school children, 7 to 9 years of age, were classified into BMI

categories in order to determine the prevalence of children who were at risk for

overweight or overweight. There are four BMI classifications for children:

underweight, normal weight, at risk for overweight, and overweight. Due to the low

number of participants in the underweight category and for statistical purposes,

underweight and normal weight children were group together. Children were

classified as underweight/normal weight, at risk for overweight, or overweight by plotting BMI on a growth chart specific for age and gender. Children who were below the 85th percentile were classified as underweight/normal weight. Children who were between the 85th and 95th percentile for weight for height based on age and gender were classified as at risk for overweight. Children who were above the 95th percentile for BMI were classified as overweight. For all the children measured, 19.2 % were classified as overweight, which is less than the 25 % of children in the U.S. who were classified as overweight (Dehghan et al. 2005). However, these findings were similar to NHANES data for children, age 6-11 years, which reported prevalence of overweight as 18.8% (CDC, 2006). When the participants were grouped on the basis of age and gender, overweight was more prevalent in the females (22.2 %) than in males (15.9%). The prevalence of overweight for the females was similar to that found in previous studies (Dehghan et al., 2005 ; McMaster et al., 2005). Indication of females having a greater prevalence of overweight than males has been found in previous studies (McMaster et al., 2005). However, these data showed a greater difference in the prevalence between the genders, when compared to a study by McMaster et al. (2005), which indicated that for children between 4.2 and 7.9 years of age there was an overweight prevalence in males of 25% and 26% in females.

When the participants were grouped by race, almost 27% of Blacks were at risk for overweight and an additional 22.8% were classified as overweight. Approximately one-half of the 7 to 9 year old Black children were either at risk for overweight or overweight. For non-Black children there were 12.7 % who were classified as at risk

for overweight and 14.1% who were classified as overweight. These findings for non-Black children were below the national mean reported by NHANES. With a larger sample size there might be statistical difference between races for BMI. Ranges of %BF within a BMI level should also be examined. Deurenberg et al. (1998) reported a difference in BMI for the same percent body fat between races. For the same percent body fat, age and gender, the BMI of Blacks was 1.3 kg/m² lower than Whites and the BMI of Polynesians was 4.5 kg/m² lower than Whites.

   The population was divided by gender and race. For non-Black males, 16% were at risk for overweight and 13.5% were overweight. Approximately 9% of non-Black females were at risk for becoming overweight and 14.7% were overweight. The prevalence of at-risk-for-overweight and overweight for non-Blacks was below the levels reported by NHANES (Centers for Disease Control and Prevention, 2006). Considering Mississippi is one of the leaders of adult overweight and obesity it might be hypothesized that a greater proportion of children might be at-risk-for-overweight or overweight compared to the national average. Thirty-three percent of Black males were at risk for being overweight and 17.8% were overweight, this approached prevalence data for children, 6-11 years of age, reported in the NHANES data. Black females was the only group with prevalence of overweight levels above those found by NHANES, 21.4% were classified as at risk for overweight and almost 27% were classified as overweight.

   When BMI was calculated for race, mean BMI for non-Black children (17.3 kg/m²), was 1.2 kg/m² lower than the mean BMI for Black children (18.5 kg/m²). This

coincides with other studies that have shown that Black children have a greater BMI than non-Black children (Ogden et al., 2002).

When BMI was calculated for gender, male children had a BMI of 18.0 kg/m², and female children had a BMI of 18.5 kg/m² a difference of 0.5 kg/m². This was not a statistically significant difference. This was in contrast to a study by Perry et al. (1991), which examined sixth graders with a mean age of 11.7 years. In this population, males had a mean BMI of 23.6 kg/m² versus a mean BMI for females of 20.2 kg/m². However, the difference in physical development due to age could account for this difference. According to this previous study, males would be expected to have a greater BMI than females.

Percent body fat was determined using bioelectrical impedance for Black and non-Black males and females children. For Black children the mean %BF was 23.7% compared to a mean %BF of non-Blacks of 19.9%. Female children had a %BF of 23.7% which was greater than the %BF of male children, 20.3%. When %BF was determined for each subgroup, Black females had a significantly greater %BF than non-Black females. There was no significant difference for %BF between Black and non-Black males.

When mean %BF and BMI were compared, Black females had a BMI of 19.3 kg/m² and a %BF of 25.7 %. Non-Black females had a BMI 17.1 kg/m² and a %BF of 20.4%. This was a difference in BMI and %BF of 2.2 kg/m² and 5.3 %, respectively. Black males had a mean BMI of 18.3 kg/m² with a corresponding mean percent body fat of 21.1%. Non-Black males had a BMI of 17.5 kg/m² and a %BF of 19.4 %. This

is a difference in BMI and %BF of 0.8 kg/m² and 1.6 %, respectively. Deurenberg et al. (1998) examined the relationship between %BF and BMI in children and found variance in BMI for the same percent body fat. In order to more accurately define BMI cut-off points for children of different gender and race, further study of the relationship between BMI and %BF in these groups is needed.

Childhood overweight has become an epidemic in developed countries. According to NHANES data, 18.8% of children in the United States are overweight (Centers for Disease Control and Prevention, 2006). The prevalence of childhood overweight is much greater in some states, such as Mississippi. The causes of childhood overweight are not completely understood, but it is believed to be a condition with multiple causes. Environmental factors, lifestyle preferences and the cultural environment are strong influences and even predictors of a risk of being overweight. Most researchers agree that prevention is the key to controlling childhood overweight and adult obesity. Children should be considered the primary target group when attempting to control obesity, since 80% of children who are overweight at the age of 5 years are obese as adults (Abrantes et al., 2002; Dehghan et al., 2005).

Medical and health professionals typically treat overweight and obesity with behavior modification, family-based diet, and exercise programs. Efforts to promote weight control in children must be a comprehensive effort involving parents, support programs, and school programs (Schwarzenberg, 2005).

The present study showed a greater %BF and BMI in Black females compared to Black males, non-Black females, and non-Black males. This should be examined in

future studies examining the prevalence of at-risk-for-overweight and overweight in children. A study by Oliviera et al. (2003) showed that only approximately 9% of parents considered their children as overweight. The actual prevalence of overweight in this study was determined to be 13.7 %. When a parent or caregiver of an overweight child does not associate the child's weight with health risks, the probability that treatment for overweight will be achieved is greatly reduced. If the results of this study are confirmed that Black females, 7 to 9 years of age, do have greater BMI and %BF values than the other groups, then a lack of recognition by parents could lead to an increase in health problems for this.

In conclusion, non-black males and females had the lowest BMI and %BF. Percent body fat was slightly greater in females than males, this was to be expected and numerical values were close. Black females had a significantly higher BMI and %BF than all other groups. The prevalence of overweight in the non-Black children was lower than the national average based on NHANES data (Centers for Disease Control and Prevention, 2006) but was greater than the national average for Black children. An observation of mean BMI and %BF appears to indicate that BMI could produce a false positive or negative for at-risk-for-overweight or overweight in borderline children. This could lead to unrecognized cases of at-risk-for-overweight and overweight, which could prevent proper treatment. Future studies should consider the ranges of adiposity within each BMI class in order to determine the prevalence of over-or under-recognition of overweight in children.

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