RELATIONSHIP BETWEEN PERCENT BODY FAT AS DETERMINED BY 
BIOELECTRICAL IMPEDANCE ANALYSIS AND WAIST-TO-HIP RATIO 
IN CHILDREN AGES 7 TO 9 YEARS

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CHAPTER I
INTRODUCTION

Obesity and overweight are growing global and national epidemics worldwide (World Health Organization [WHO], 2000). Globally, there are more than 1 billion overweight adults, with at least 300 million of them obese. Recent evidence states that 66.3% of adults are either overweight or obese (Ogden et al., 2006). The prevalence of overweight is not only increasing in adults, the same occurrence is also reflected in children. Recent data estimates that 22 million children under the age of five are considered overweight worldwide (WHO, 2000). Prevalence of overweight among children and adolescents has tripled in the past two decades in the United States (Ogden, Flegal, Carroll, and Johnson, 2002). Currently, 18.8% of 6-11 year olds and 17.4% of 12-19 year olds are considered to be overweight (Ogden et al., 2006). These percentages are based on a common measurement known as body mass index (BMI), although different methods may be used to categorize a person into a specific weight group (National Heart, Blood, and Lung Institute, 1998).

Life insurance actuarially based height-weight tables provide a means of assessing a person’s weight status based on gender and bone frame size. The height-weight tables are constructed based on the average ranges of body mass related to stature that are
associated with the lowest mortality rate for people ages 25-59 years. The tables do not take into consideration specific causes of death or quality of health before death. The tables were also developed from data obtained from primarily white populations, which does not account for differences among various ethnic groups (McArdle, Katch, & Katch, 2001). A study by Welham and Behnke (1942) helped prove that the height-weight tables that were being used may not be a good method of classifying an individual into a particular weight category. The study showed that the height-weight tables were inappropriately classifying highly fit men as unfit due to excessive body weight. Body mass index does not take into account actual body composition, which may be a better predictor of health status.

Body composition is a component of physical fitness. More than 30 components of human body composition may be measured, but when considering health as the issue of importance, the principle interest is to determine the relative amount of body fat in proportion to lean tissue mass and the distribution of fat in the body (American College of Sports Medicine [ACSM], 2006). Measurements of body composition are important because a measure of weight alone cannot differentiate between the amount of fat-mass and fat-free mass present in the human body (Heitmann & Garby, 2002). Evidence is strong that obesity, or excess body fat, as well as the distribution of fat, does place a person at increased risk for many chronic diseases. Diseases associated with having excess of body fat include type 2 diabetes mellitus (T2DM), hypertension, hyperlipidemia, metabolic syndrome, coronary artery disease (CAD), and certain types of cancer (National Heart, Lung, and Blood Institute, 1998). No direct in vivo methods are
available to measure body composition, yet there are many indirect methods such as
skinfold measures, magnetic resonance imaging (MRI), bioelectrical impedance analysis
(BIA) and many others; therefore, cost, availability, technician training, individual
characteristics, and performance requirements affect the decision as to which
measurement is to be used.

Body mass index is the ratio of weight in kilograms (kg) to height in meters (m)
squared (kg/m²). Body mass index is widely used in the clinical and research setting to
define overweight and obesity due to the ease in which the measure can be easily
obtained. Overweight in adults is defined as a BMI greater than or equal to 25. Obesity
in adults is defined as a BMI greater than or equal to 30 (National Heart, Blood, and
Lung Institute, 1998). In children, “at risk for overweight” and overweight are defined
based on the Centers for Disease Control and Prevention growth charts for the year 2000
in the U.S. A child is considered “at risk for overweight” with a BMI for age at or above
the 85th percentile when compared to U.S. children that are the same age and gender. A
child with a BMI equal to, or above, the 95th percentile is considered to be “overweight”
(Kuczmarski et al., 2002). As BMI increases throughout the range of overweight, so does
the risk for other health complications. Body mass index has been correlated with
obesity-related comorbid conditions in adults and children. Although BMI does tend to
exhibit a greater association with body fat and disease risk than does looking simply at
height-weight tables, discrepancies still exist in the ability of BMI to accurately predict
the proportion of lean body mass to body fat. Body mass index may be somewhat
accurate in classifying non-athletic adults into a weight category, but when using BMI
with an active individual, precaution should be taken not to inappropriately place a person with a high percentage of lean body mass into an overweight, or even obese category. On the other hand, BMI could mislead a sedentary individual at what is considered a “normal” weight to believe that the person’s health status is “good”, when an excess of body fat is present (McArdle, 2001). The ability of BMI to accurately predict the proportion of fat mass in children has also been questioned (Daniels, Khoury, and Morrison, 1997 & Demerath et al., 2006). Since the actual weight of a person may not be the most important predictor of health status, other methods that may predict body composition or fat patterning may be a better tool for assessing health status.

As mentioned previously, many methods of obtaining body composition exist, ranging from using calipers to measure skinfold thickness, to using the earth’s magnetic fields to create cross-sectional images of the entire body in a procedure known as MRI (ACSM, 2006). Because cost, as well as availability, may be an issue in performing a procedure such as the latter method, and variations of measures have been found between technicians performing the skinfold thickness measure, other methods may be sought to assess body composition. Waist-to-hip ratio (WHR) and BIA are two commonly used methods to assess body composition, which may help to predict health status.
Bibliography


CHAPTER II
THE RELATIONSHIP BETWEEN PERCENT BODY FAT AS DETERMINED BY BIOELECTRICAL IMPEDANCE ANALYSIS AND WAIST-TO-HIP RATIO IN CHILDREN AGES 7 TO 9 YEARS

Abstract

The objective of the study was to identify the relationship between percent body fat (%BF) and waist-to-hip ratio (WHR) in children ages 7 to 9 years. The sample (n=171) was divided into four groups. Bioelectrical impedance analysis was used to estimate %BF. Significant positive correlations were observed between WHR and %BF for black females (r = 0.48), white females (r = 0.66), black males (r = 0.34), and white males (r = 0.55). Although the correlations differed between groups, the amount of variation between the two variables was not significantly different between groups other than black females. Least squares means was used to estimate %BF using an average WHR (.85). Black females had higher %BF than other groups. Percent body fat cannot be fully explained by WHR ($r^2 = 0.32$). Results show a relationship between %BF and WHR, yet predicting %BF from a given WHR may be difficult.
Introduction

The prevalence of overweight and obesity has reached epidemic proportions. In 2003-2004, an estimated 17.1% of US children and adolescents between the ages of 2 to 19 years were categorized as overweight. During the same time period 66.3% of adults were considered overweight or obese, with 32.2% of adults being categorized as obese (Ogden et al., 2006). The trends of overweight and obesity are only continuing to evolve. Comparing results from NHANES 2003-2004 to previous NHANES data, the percentage of obesity among adults has increased for every group with the exception of women. The trend occurring in the prevalence of overweight and obesity is disturbing, especially when considering that weight status during childhood may affect health status during adulthood.

One study published in the Journal of the American Medical Association concluded that severely obese children and adolescents have lower health-related quality of life than others of the same age that are healthy (Schwimmer, Burwinkle, and Varni, 2003). Longitudinal studies suggest that overweight children may grow up to be overweight adults (Serdula, Ivery, Coates, Freedman, and Williamson, 1993). The risk of overweight is further increased if overweight persists into adolescence and if the child’s parents are overweight (Whitaker, Wright, and Pepe, 1997). Questions have arose as to what factors may predispose a person to becoming overweight. Some argue the relationship between genetics and a predisposition to becoming overweight as the cause (Gallagher et al., 1996 & Kimm et al, 2002). Other factors that may be considered include attitudes that may exist among various cultures regarding body size and health.
status; as well as the environment in which a person lives (Dalton & Watts, 2002 & Schreiber et al., 1996). However, the consensus is that the increasing prevalence of overweight is due to the energy input that is exceeding energy output (Luepker et al., 1999 & McMurray et al., 2000).

Medical research has clearly established the relationship between excess body weight and the prevalence of certain diseases in adults such as type 2 diabetes mellitus (T2DM), hypertension, hyperlipidemia, metabolic syndrome, coronary artery disease (CAD), and certain types of cancer (National Heart, Lung, and Blood Institute, 1998). Diseases that were once considered to be “adult” diseases are now the diagnoses of many children and adolescents in the United States. Overweight in adults is defined as a BMI greater than or equal to 25. Obesity in adults is defined as a BMI greater than or equal to 30. In children, overweight and “at risk for overweight” is defined based on the Centers for Disease Control and Prevention growth charts for the year 2000 in the U.S (National Heart, Lung, and Blood Institute). A child is considered “at risk for overweight” with a BMI for age that is at or above the 85th percentile when compared to U.S. children that are the same age and gender. A BMI equal to, or above, the 95th percentile places a child in the category of “overweight” (Kuczmarski et al., 2002). Due to changes that are occurring during childhood and adolescents, the accuracy of BMI to predict body fat percentage in children has been questioned.

Because excess body fat, not excess fat-free mass, is responsible for many preventable diseases, a method of predicting body fat accurately is important in. Bioelectrical impedance (BIA) is a method of determining body composition that has
been validated in both adults and children. The leg-to-leg BIA system has proven to be an accurate and convenient method of obtaining body fat percentages. Along with measures such as BIA, other anthropometric measurements have shown to be good indicators of health risks.

Waist-to-hip ratio (WHR) is a common method used in adults to measure fat distribution. Less is known about the accuracy of the WHR measure in children; however, some research has indicated a correlation between WHR and body fat percentage estimates (Daniels, Khoury, and Morrison, 1997). The degree to which WHR and body fat percentage relate may be questionable, but many studies have shown a relationship between adverse health risks and central fat distribution as measured by WHR, particularly the cluster of cardiovascular risk factors otherwise known as the metabolic syndrome (Smoak et al., 1987). Waist circumference is another measure of central fat distribution which has also been shown to be a good indicator of health status (Taylor, Jones, Williams, and Goulding, 2000).

The objective of the current study is to assess the relationship between percent body fat (% BF) and WHR in children ages 7 to 9 years. The measures of % BF and WHR may prove to be of importance when predicting health risks in children.

**Prevalence of Overweight and Obesity in the United States**

Overweight and obesity continue to be leading public health concerns in the United States. Statistics used to report prevalence data on the weight status of the U.S. population are the result of data collected from the National Health and Nutrition Examination Survey (NHANES) (Ogden et al., 2006). NHANES data is a result of a
series of periodic surveys conducted to collect height, weight and other information on a multistage probability sample of the US civilian, non-institutionalized population. Data collected through NHANES is that which is used by the U.S. Department of Health and Human Services and Centers for Disease Control (CDC) to tabulate various national health statistics. To ensure the accuracy of the data, height and weight are measured using standardized protocols and calibrated equipment during a physical examination in a mobile examination center (Centers for Disease Control and Prevention [CDC], 2006).

Despite recent national attention focused on reversing the trend in overweight and obesity, waistlines are continuing to grow. Over the past two decades, the prevalence of obesity has doubled in adults aged 20 years or older while the prevalence of overweight in children and adolescents aged 6 to 19 years has tripled. This increase can be seen by looking at past NHANES data that has been collected. In 1976-1980, NHANES II data showed that 47% of adults between the ages of 20 to 74 years were considered overweight or obese, with 15% of the population falling into the latter category. During the same time period, 7% of children ages 6 to 11 and, 5% of children ages 12 to 19 were categorized as overweight (Kuczmarski, Flegal, Campbell, and Johnson, 1994; Troiano, Flegal, Kuczmarski, Campbell, and Johnson, 1995). A study conducted by Troiano et al. looking at changes of BMI along with measures of % BF found that just as mean BMI had increased, so had mean and median triceps and subscapular skinfold measures between NHANES II and NHANES III. Other studies suggest that BMI is not a reliable measure of fatness for children (Daniels et al., 1997). Looking forward quite a few years to data collected from 1999-2000 an increase in overweight and obesity is seen in both
the adult and child population. In 1999-2000, 64.5% of adults were considered to be overweight or obese, with 30.5% falling into the latter category. The prevalence of overweight in children ages 2 to 19 years was found to be 13.9%, with 15.1% of children ages 6 to 11 years and 14.8% of children ages 12 to 19 years being categorized as overweight. Data from 2001-2002 only showed the trend to be increasing. In 2001-2001, 65.7% of adults were overweight or obese and 30.6% were obese. In children, 15.4% were considered overweight, with 16.3% of children between the ages of 6 to 11 years and 16.7% of those between the ages of 12 to 19 years classified as overweight (Ogden et al., 2006). When deciding upon a particular solution to this problem, one must analyze the results further to determine if there are particular groups within the above mentioned sample that are at greater risk for overweight, and to identify trends that are occurring within the groups.

Overweight and obesity are not just growing public health concerns related to only one or two particular groups in the US. In the previously mentioned study by Ogden et al. (2006), an increase in the prevalence of overweight among children and adolescents and obesity among men had increased significantly from 1999 to 2004. No increase in the prevalence of obesity in women was found; although, among women the prevalence of obesity was still greater than that found in men. In the study by Ogden et al., both male and female subjects were included, as well as various ethnicities and age groups. Ethnicities represented include non-Hispanic white, non-Hispanic black, and Mexican American groups. Among adult men, no differences were found in the prevalence of overweight or obesity between racial/ethnic groups; however, when looking at adult
females, Mexican American and non-Hispanic black women were significantly more likely to be obese when compared with non-Hispanic white women. Other research has shown similar findings. An article by Flegal, Carroll, Ogden, and Johnson (2002) looking at the prevalence and trends of obesity from 1999-2000 NHANES data reported that among women, obesity and overweight prevalence was highest in the non-Hispanic black women. The study also showed that more than 80% of the non-Hispanic black women aged 40 years or older were overweight and more than half were obese. The same occurrence was found when looking at current data (Ogden et al., 2006). Age has also been associated with weight status in adults. Older adults were more likely to be obese than younger individuals. However, once an adult reached the age of 80 years, the likelihood of the group being overweight was not significantly different from that of adults aged 20 to 39 years. As mentioned earlier, females appear to have come to a standstill when looking at the prevalence of obesity. The standstill has allowed for adult men to almost attain the same prevalence of obesity as adult women, with the prevalence of obesity being 31.1% in men compared to 33.2% in females (Ogden et al.).

When looking at children and adolescents, the prevalence of overweight among males is significantly higher in Mexican American males than in non-Hispanic white and non-Hispanic black males, with no significant difference between the latter two. In female children and adolescents, just as seen in adults, Mexican American and non-Hispanic blacks are significantly more likely to be overweight than non-Hispanic white females (Ogden et al, 2006). Similar results have been found in previous studies. The National Heart, Lung, and Blood Institute’s Growth and Health Study data for children 9
and 10 years of age found the mean BMI for black females to be significantly greater than that found for white females (Morrison, Sprecher, Barton, Waclawiw, and Daniels, 1999). NHANES III data for children and adolescents showed the overweight prevalence among non-Hispanic blacks and Mexican Americans to be greater than that for non-Hispanic whites. Although differences were found within genders, no significant difference was found between genders.

The question which one may ask, is to what are these differences among ethnicities attributable to? Perhaps genetics, socioeconomic status, physical inactivity, or maybe even the fact that some cultures accept a larger body size is to blame. Research has shown that genetic variation between different ethnic groups may account for some of the differences found in the prevalence of overweight. However, the genetic pool has not changed drastically enough in the past two decades to account for the increase in the prevalence of overweight and obesity. A study by Faith et al. (1999) looking at pediatric twin samples found both genetic and environmental correlations ($r = 0.74$, $r = 0.67$, respectively) between BMI and % BF. African Americans have been shown to have lower energy expenditures than Caucasians, increasing their vulnerability to becoming overweight (Kimm et al., 2002).

Overweight and obesity rates are higher across all age groups in non-Hispanic black females than those found in non-Hispanic white females. Maybe the relationship is purely coincidental, but black females tend to be less likely to perceive themselves as being overweight than white females. The idea has been mentioned by some researchers that the acceptance of being overweight may be related to the fact that black females have
the highest prevalence of overweight and obesity. One study by Schreiber et al. (1996) looked at weight status and self-perceptions of 4,000 14 to 18 year old high school girls. The sample contained an equal number of black and white females. The study found that even though the black females were heavier, the white females were twice as likely to perceive themselves as being overweight and more likely to engage in unhealthy weight loss practices. Another study of over 2,000 black and white, 9 and 10 year old girls found that equal numbers of black and white females were trying to lose weight, while a significantly greater number of black were trying to gain weight (Schreiber et al.). The reason stated for wanting to either gain or lose weight was because the mother had told the child that either she was “too fat” or “too thin”. Black and white adolescent males are more likely to perceive themselves as underweight than their white female peers. The problem overweight is not only one of aesthetics but may be also due to the parents not making the connection between a child’s weight status to health status.

Although being a member of the non-Hispanic black population is a predisposing risk factor for diseases such as hypertension and diabetes, the group may not understand the additive affect that weight status may have on health. One study alluded to in an article by Dalton and Watts (2002) interviewed 100 black parents and caregivers of children being screened for diabetes. Out of the sample interviewed, 44% perceived the child’s weight to be a potential health problem. Although the percentage may seem fairly large, 70% of the children were overweight. Not only are Mexican American and non-Hispanic black Americans at a greater prevalence of overweight and obesity than non-Hispanic white Americans, Popkin and Udry (1998) found that all racial and ethnic
groups, with the exception of Chinese and Filipinos have higher levels of obesity than non-Hispanic whites. Some studies have shown that generation in the U.S. may also play a role in the epidemic of overweight and obesity (Popkin and Udry; Sundquist and Winkleby, 2000). Asian and Hispanic adolescents that are second or higher generation adolescents are more than twice as likely to be obese than their first generation counterparts.

The simple acceptance of a larger body image may explain a part of the reason why this health concern continues to grow, but the blame cannot be placed entirely on acceptance. An inverse relationship has been frequently found between socioeconomic status and overweight or obesity among adult women and sometimes among adult men. Studies in children show a weaker relationship existing between the two variables. Troiano and Flegal (1998) looked at data collected from NHANES III, 1988-1994, and found that the prevalence of overweight among Mexican American and non-Hispanic black children was not related to family income, yet an inverse relationship was found among the variables in non-Hispanic white children. When looking at the association between education status of the family reference person and the prevalence of overweight, an education level of ≥ 13 years was associated with the lowest incidence of overweight.

If variables exist that may not be controllable by an individual, particularly a child, such as education level or socioeconomic status, then maybe unhealthy behaviors are to blame. “We are killing ourselves by our careless behavior” was a statement made in the publication Healthy People 1979 (United States Department of Health and Human
Services [U.S. DHHS], 1979). The U.S. is a country with an abundant and readily available supply of calorically dense foods. Estimates of caloric intake show that adolescents and adults have increased the amount of calories consumed. An increase in caloric intake is not evident in children (Troiani & Flegal, 1998). A factor that may be associated with the increase in the weight status of children is an increase in physical inactivity. Not only is a sedentary lifestyle unhealthy for an individual during childhood, but physical inactivity may also be tracked into adulthood (Gordon-Larson, McMurray, and Popkin, 1999). Children who watch more than 4 hours of television have a greater % BF and greater BMI than their peers spending less time watching television (Anderson, Crespo, Bartlett, Cheskin, and Pratt, 1998). Anderson et al. found that non-Hispanic black children were more likely than either Mexican American or non-Hispanic white children to watch more than 4 hours of television per day. Both Mexican American and non-Hispanic black youth were shown to have lower levels of physical activity than non-Hispanic white youths. Levels of vigorous physical activity are lower among females and minority males than for non-Hispanic white males (McMurray et al., 2000).

When addressing the national trend of childhood inactivity and unhealthy diets, U.S. Surgeon General Richard Camona made the statement that “We are seeing Generation Y grow into Generation XL, and this weight gain has long-term health consequences.” Medical research has clearly established the relationship between excess body weight and the prevalence of certain diseases in adults. The problems that were once considered to be “adult” diseases are now being seen more often in children. T2DM is becoming a common diagnosis in pediatric diabetes clinics throughout the U.S.. One
children’s hospital in Cincinnati, OH reported a 10-fold increase in the number of children and adolescents diagnosed with T2DM between 1982 and 1995. The hospital reported a female to male ratio of T2DM diagnosis of 1.7:1; there were twice as many African-Americans as whites; 38% had a BMI >40 kg/m$^2$, with only a few patients reported as being at normal weight. The patients diagnosed with T2DM had a mean BMI of $35 \pm 1.1$ kg/m$^2$ compared with patients diagnosed with T1DM who had a mean BMI of $20 \pm 0.8$ kg/m$^2$. Of the patients diagnosed with T2DM, 32% were hypertensive (Pinhas-Hamiel et al., 1996). Other than the lipid abnormalities and other cardiovascular risk factor that have already been mentioned, overweight children are also at a greater risk of developing problems such as polycystic ovary syndrome (PCOS), sleep apnea, and gallbladder disease. Longitudinal studies suggest that long-term complications can be anticipated from childhood overweight (Power, Loke, and Coi, 1997; Slyper, 1998). A study published in the Journal of the American Medical Association concluded that severely obese children and adolescents have lower health-related quality of life than others of the same age that are of healthier weights (Schwimmer et al., 2003). Longitudinal studies also suggest that overweight children may grow up to be overweight as adults (Serdula et al., 1993; Whitaker et al., 1997).

The health risks associated with being overweight are disturbing, as is the economic burden that accompanies the health risks. Overweight/obesity in young adulthood and middle age has long-term adverse consequences for health care costs in older age. Wang and Dietz (2002) used a multiyear data file of the National Hospital Discharge Survey, 1979-1999, to analyze changes in obesity-associated diseases and
economic costs in youth ages 6 to 17 years old. From 1979-1981 to 1997-1999 the percentage of discharges with obesity-associated diseases increased. Discharges associated with diabetes (1.43% to 2.36%), obesity (0.36% to 1.07%), gallbladder diseases (0.18% to 0.59%), and sleep apnea (0.14% to 0.75%) all showed increases. To reiterate the association between obesity and health risks, 96% of the discharges with a diagnosis of obesity had obesity listed as a secondary diagnosis. Obesity-associated annual hospital costs increased from $35 million during 1979-1981 to $127 million during 1997-1999.

In order to compress morbidity in a society that is progressively becoming larger, measures should be taken now to reverse this trend. Changing the factors that lead to a person becoming overweight should be targeted such as diet, physical inactivity, and helping people to recognize the health consequences associated with being overweight. Along with targeting some of the causes of obesity and overweight, research should be continued to determine what anthropometric measure is best to predict health risks among different age, gender, and ethnic groups. Although primary prevention would be the ideal method of combating the trend of overweight and obesity, we do not live in a perfect world; therefore, secondary and tertiary prevention are important in preventing and treating health problems that may occur during childhood and escalate through adulthood.

Waist-to-Hip Ratio

In adults, the WHR has been the most commonly used indirect measure of visceral fat (Slyper, 1998). The recommended procedure for obtaining WRH is as follows: Subject standing with light garments waist is measured at the level midway
between the lower rib margin and the iliac crest, with the subject breathing out gently. Hip is measured as the maximum circumference over the buttocks. Both measurements obtained are rounded to the nearest 0.5 cm. The WHR is then calculated by dividing the waist circumference with hip circumference (Salmi, 2003). The World Health Organization suggests a cut-off point of WHR to be a ratio of 0.90 in men and >0.85 in women as an indicator of abdominal obesity. A ratio of 0.94 for men and 0.80 for women has also been suggested (Molarius and Seidell, 1998).

The patterning of the body’s adipose tissue varies among individuals and has been shown to be a strong predictor of various health risks in adults, with less conclusive evidence in children (Kissebah and Krakower, 1994). An android fat patterning, or accumulation of adipose tissue in the central, particularly the abdominal region has been associated with increased health risks compared with fat accumulation in the lower body segment, which is known as peripheral or gynoid-type obesity (Hartz, Grubb, and Wild, 1990). Central fat distribution is indicative of an altered metabolic profile, meaning that the individual is at greater risk for hyperinsulinemia and glucose intolerance, type 2 diabetes, endometrial cancer, hypertriglyceridemia, hypercholesterolemia, poor lipoprotein profile, hypertension, and atherosclerosis (Grundy, 2005).

Attention is currently being focused on the clustering of diseases that contribute to atherosclerotic cardiovascular disease known as the metabolic syndrome. This syndrome was named after much research had been conducted to understand the fundamental causes of atherosclerotic cardiovascular disease (ASCVD). Major risk factors have been identified that are considered to be direct causes of ASCVD such as advancing age,
insulin resistance, abdominal obesity, cigarette smoking, hypertension, and high serum cholesterol. Underlying risk factors associated with ASCVD have been established as well, and include family history of premature vascular disease, overweight, sedentary lifestyle, and an atherogenic diet (Ford & Giles, 2003; Grundy, 2005). The National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (ATP III) identified five defining components of the metabolic syndrome that make it a multidimensional risk factor for cardiovascular disease (2001). The five components include: atherogenic dyslipidemia, raised blood pressure, insulin resistance or glucose intolerance, proinflammatory state, and prothrombic state.

Atherogenic dyslipidemia consists of elevated serum triglyceride-rich lipoproteins (TGRLP), elevated total apolipoprotein B, small low-density lipoprotein (LDL) particles, and low HDL (Grundy, 2005 and Schilling McCann, 2007). Obesity is one of the underlying risk factors for atherogenic dyslipidemia. The elevation of blood pressure in metabolic syndrome may only be moderate. The WHO defines elevated blood pressure as a systolic pressure of ≥ 140 mm Hg and a diastolic pressure ≥ 90 mm Hg, or the use of anti-hypertensive medication (2000). Both The American Association of Clinical Endocrinologists and ATP III use a systolic pressure of ≥ 130 and a diastolic pressure ≥ 85 as a diagnosis of elevated blood pressure (Ford & Giles, 2003). Insulin resistance or glucose intolerance may be recognized by an elevation of plasma glucose. The elevation of plasma glucose may either be measured in the fasting or postprandial state (Schilling McCann). A prothrombotic state is a state in which an individual exhibits elevations of
procoagulant factors in the blood. Procoagulant factors include the following: plasma plasminogen activator inhibitor-1 (PAI-1), plasma fibrinogen, von Willebrand’s factor (vWF), plasma factor VII, tissue plasminogen activator (tPA) antigen, factor V Leiden, protein C, antithrombin III, and enhanced platelet activity. A proinflammatory state is a state of accelerated atherogenesis. Accelerated atherogenesis may be a result of some of the factors that define metabolic syndrome, as well as the arterial wall’s own response to injury. Obesity puts a person at greater risk for each of the defining components of the metabolic syndrome, particularly abdominal obesity (Grundy).

Although not fully understood, abdominal obesity has been shown to be more strongly correlated to the risk factors of the metabolic syndrome than BMI. In 1998 the WHO proposed working criteria for the metabolic syndrome. In 1999 this criteria was made available to the public. The criteria identifies WHR as a measure of abdominal obesity. ATP III chose to use waist circumference as an indicator of abdominal obesity while the American Association of Clinical Endocrinologists uses BMI rather than a measure of abdominal obesity (Ford & Giles, 2003). Intra-abdominal fat is more resistant to insulin than fat that is stored in other areas. The relationship between intra-abdominal fat and insulin resistance may be obvious when looking at the increase in obesity and overweight that has been occurring along with the increase in type 2 diabetes. When adipose tissue is insulin resistant an influx of non-esterified free fatty acid (NEFA) is transported into the portal system, leading to an increase in apolipoprotein B (ApoB), LDL, and triglyceride levels and a decrease in HDL (Schilling McCann, 2007). When looking at the prothrombic state in metabolic syndrome, the procoagulant factor that is
most often found elevated is PAI-1. Adipose tissue, particularly visceral adipose tissue is capable of producing PAI-1. The PAI-1 elevation may be related to other things as well, but abdominal obesity may be related. The elevation of plasma fibrinogen, as well as enhanced platelet activity, has been linked to obesity. The causes of an elevated blood pressure may be many, but obesity and possibly insulin resistance are associated with an increase in blood pressure (Grundy, 2005; WHO, 2000). The associations between some of the above mentioned factors and abdominal obesity have been well substantiated in adults, while less evidence has been found in children.

Overweight children and adolescents have cardiovascular risk factors that may predict cardiovascular changes that occur during adulthood (Li et al., 2004). Some studies suggest the patterning of fat in children may be an important factor in the development of certain risk factors, while others suggest that the location of excess adipose tissue may not be as strong a predictor of health problems in children as in adults. However, during adolescence both boys and girls tend to accumulate more fat in the abdominal region. This increase in central adiposity seems to be more pronounced in boys than in girls. Central fat distribution for a male at this time may predispose him to increased visceral fat accumulation (Dietz, 1998). The distribution of adipose tissue in children should be monitored because some research has shown that central fat distribution as a child may be a predictor of disease in adulthood. In adults, depending on the study that is looked at, various cut-off points for a WHR that put a person at increased risk for disease. In children, the WHO or any other such organization has yet to set specific criteria for a WHR which puts a child at a high risk for disease, although trunk
fat deposition in children has been shown to have the greatest impact on the clustering of risk factors indicative of metabolic syndrome (Smoak et al., 1987). Despite there being no specific ratio indicative of an increased risk of disease, some studies have shown that WHR may be a good tool for measuring trunk fat deposition.

A study by Daniels, Morrison, Sprecher, Khoury, and Kimball (1999) chose to look at the association of body fat distribution and cardiovascular risk factors in children and adolescents ages 9-17. Dual-Energy X-Ray Absorptiometry (DEXA), which has been validated in both adults and children against the hydrodensitometry method as a valid measurement of lean body mass and fat mass, was used to measure total and regional fat mass. Cardiovascular risk factors measured included fasting lipid and lipoprotein concentrations, systolic and diastolic blood pressures, and left ventricular mass. Researchers found that a greater android fat distribution was significantly and independently related to plasma triglycerides and HDL cholesterol, systolic blood pressure, and left ventricular mass. Most of the children included in the study were of normal weight, and had relatively low truncal fat mass. Participants included in the study were both males and females of the non-Hispanic black and non-Hispanic white races.

Ferguson et al. (1998) wanted to determine the association between both general and visceral adiposity and hemostatic measures in overweight children ages 7 to 11 years. Overweight was determined using a tricep skinfold thickness measurement. Children participating in the study were placed at or above the 85th percentile of children within the same age group for the measure of tricep skinfold thickness. Forty-one, apparently healthy, children were used. Although these subjects were all considered overweight,
there was a large variation in % BF. Subjects included both males and females of the non-hispanic black and non-Hispanic white races. Several measures of adiposity, such as weight, subcutaneous abdominal adipose tissue (SAAT), total fat mass (TFM), percent body fat, and BMI were significantly greater in blacks than in whites. Again, DEXA was the measure used to provide values for % BF. Visceral adipose tissue (VAT) and SAAT were determined using magnetic resonance imaging (MRI). The MRI system used was validated as a part of the study. Hemostatic measures taken include PAI-1, D-dimer, and fibrinogen. For PAI-1, higher amounts of VAT and fat-free mass were significant predictors. Insulin levels were also positively associated with PAI-1 concentrations. For D-dimer, ethnicity was significant predictor. Significant positive correlations were found between fibrinogen and %BF, SAAT, TFM, and BMI. Studies do show a relationship present between both abdominal adiposity and excess VAT and certain cardiovascular risk factors, yet DEXA was the method used to determine the distribution of body fat. MRI was also used, and may be considered somewhat a “gold standard” when assessing central fat distribution, yet there is a high cost associated with the use of MRI. DEXA, as mentioned previously, has been shown to be a very precise measure of body composition and is somewhat less expensive than MRI; although, availability could still be a problem in some settings (Treuth, Hunter & Kekes-Szabo, 1995). Because of the possible relationship between central, or abdominal, adiposity and risk factors for disease, a simple anthropometric measurement is necessary for routine evaluation of regional fat distribution. Due to the possible errors that could occur when performing a measure such as WHR, particularly when attempting such a measure with children, one may question
the usefulness of WHR as a predictor of body composition or risk of disease.

Taylor, Jones, Williams, and Goulding (2000) sought to assess the relative abilities of waist circumference, the WHR, and the conicity index to correctly identify children ages 3 to 19 years with high trunk fat mass. The measures were compared to measures taken by DEXA. Results showed that waist circumference performed significantly better as an index of trunk fat mass than did the other two measures used. The 80th percentile for waist circumference correctly identified 89% of girls and 87% of boys with high trunk fat mass and 94% of girls and 92% of boys with low trunk fat mass. The areas under the curves (AUC) were calculated to determine the validity of each measure. Values > 0.5 were considered desirable, with a value of 1 implying perfect performance, and that of 0.5 indicating that the measure was no more than just chance. The following AUCs were found for girls and boys respectively: 0.97 and 0.97 for waist circumference, 0.80 and 0.81 for conicity index, and 0.73 and 0.71 for WHR. The results suggest that the measure of WHR shows some predictability for identifying high trunk fat mass, although better methods may exist; however, the study was not representative of various races. A large sample size of 580 males and females was used, yet all participants were of the non-Hispanic white race. WHR may also be highly age dependent, accounting for the use of WHR in the adult population being substantiated, yet not in children. However, another study suggests that WHR may be a useful tool in estimating the extent of abdominal adiposity in children if changes that occur during growth in children are accounted for. Normal values for WHR have been shown to decrease with age; therefore, Asayama et al. (1997) set out to determine an equation that
would allow WHR to be a useful tool for assessing the distribution of body fat in children. Correlations were tested between anthropometric measurements of Japanese children ages 6 to 15. Researchers found that the ratio of WHR to Ht was expressed as a linear function of age for each sex. Asayama et al. determined that the standard deviation score (SDS) of the WHR/Ht may be a useful tool for assessing the distribution of body fat in children. A previous study by Asayama et al. (1995) showed the same equation to be correlated with serum lipid and apolipoprotein levels in a group of obese Japanese children ages 6-12 years old. Other indices for assessing overweight or adiposity were not related to the cardiovascular risk factors mentioned. Using the equation established by Asayama would eliminate the limitation of age that has been shown to reduce the usefulness of WHR in children. One limitation for transferring this type of equation to use in other populations would be that the study looked strictly at Japanese children; however, the author reported the same equation to be validated by use in children from other races.

Even though Taylor and colleagues (2000) found that WHR may not be the best choice for identifying high trunk fat mass in children and adolescents, other research has shown correlations between the WHR measure and risk factors for disease. A study by Zwiauer, Pakosta, Mueller, and Widhalm (1992) took various measures of obesity and WHR in children and compared the measures with cardiovascular risk factors. Cardiovascular risk factors included serum lipids, lipoproteins, apolipoproteins, glucose, insulin, uric acid, and systolic (SBP) and diastolic blood pressure (DBP). Correlations between the measures differed between genders. In males, an association was found
between all measures and WHR, with the exception of SBP, DBP, and uric acid levels, which were more closely related to BMI, %BF, % overweight, and skinfold measures. In girls, lipid measures and atherogenic ratios were correlated with WHR, as well as the other measures of obesity. Glucose, insulin, SBP, and DBP showed the highest correlation with WHR in females. Another similar study by Gillum (1987) chose to look only at the association between WHR and blood pressure, serum cholesterol, and serum uric acid in children and youth ages 6 to 17 years using NHANES data. Results showed WHR to be significantly associated with SBP and uric acid levels in youth and with DBP in children. The study included a wide range of ages, allowing for comparisons to be made among different age groups. The author found ratios to decline with increasing age and boys to have consistently higher WHR than girls. Differences between races were inconsistent. The same type of pattern was also found in a study looking at Cuban scholars aged 4.5 to 20.5 years (Martinez, Devesa, Bacallao, and Amador, 1994). In the study, WHR was reported to be higher in boys than in girls throughout the pediatric ages. In boys, WHR appeared to decrease gradually with age, while in girls, 2 sharp reductions were seen between the ages of 10 to 13 years and 13 to 16 years. Zonderland and colleagues (1990) made the conclusion that WHR as a measure of fat distribution in children is needed, but that age may play a role in its usefulness. The sample used in Zonderland and colleagues’ study consisted of 124 white boys and girls approximately 10 years of age. The WHR in pre and early pubertal girls seemed to have an impact on plasma lipids and apoprotein profile similar to that seen in adults, yet the relationship may not be seen until later in puberty with boys.
To further investigate the effects that WHR may have on the development of cardiovascular risk factors in different age, sex, and race groups, a study by Freedman, Serdula, Srinivasan, and Berenson (1999b) examined the relationship between body fat distribution and measurements of lipid and insulin concentrations among 2996 children and adolescents aged 5 to 17 years. The study showed abdominal adiposity to be related to adverse concentrations of triacylglycerol, LDL-C, HDL-C, and insulin independent of race, sex, age, weight, and height. The association existed no matter the method used to measure fat distribution, although waist circumference was the better predictor of adverse health effects than either WHR or measures of skinfold-thickness.

Although waist circumference has been shown to be a better predictor of abdominal obesity than WHR in some cases, WHR does provide a measure of fat distribution, which may be an important consideration. Research is lacking in children, but studies in adults have shown that fat accumulation in the gluteal region may be protective against some cardiovascular risk factors. One study showed that lean adults with an increased WHR were at greater health risk than obese individuals with similar measures of WHR. The accumulation of subcutaneous fat may have possibly guarded against visceral fat (Pouliot et al., 1992). Terry, Stefanick, Haskell, and Wood (1991) reported favorable effects of gluteal fat distribution on the serum lipid profiles of 130 overweight premenopausal women ages 25 to 49 years. After adjusting for waist circumference, favorable independent correlations were found between thigh girth and serum triglyceride and HDL-C, but not with total cholesterol or HDL-C.

All measures of body fat, as well as body fat distribution have been shown to
predict various health risks depending on the population being studied as well as the risk factor in question. Plotting BMI on growth charts is the method currently used to identify children who are overweight or at risk for overweight. Daniels and colleagues (1997) found that WHR was a significant independent predictor of % BF, and that BMI may not accurately predict WHR or % BF among children of various ages, races, or genders; therefore, a variety of measures should be considered.

**Percent Body Fat**

Body fat percentage is defined by the American College of Sports Medicine (ACSM) (2006) as “the amount, expressed as a percentage, of the body that is made up of fat tissue.” Although there are no direct methods available for determining % BF, various indirect methods are available. Indirect methods available for estimating % BF are either property-based or component-based. Property-based methods are measurements of specific properties, such as body volume, decay properties of specific isotopes, or electrical resistance, while component-based methods depend on well-established models of measurable quantities of components that are assumed to be constant no matter the individual. When using either of the methods to determine % BF, either the relation is known between the measure taken and the component of interest or a regression equation is used that makes use of the known component to determine the unknown. The known and unknown components are measured in the same subjects to develop this equation. Regression equations are used for estimating % BF using the skinfold method or BIA. Some of the common methods of assessing body composition include skinfolds, BIA, near-infrared interactance, hydrodensitometry, CT or MRI scans,
plethysmography, and dual-energy x-ray absorptiometry (DEXA). The first three methods mentioned are considered to be doubly indirect methods. Doubly indirect methods make use of a variety of methods to estimate unknown components. The latter four of the methods are considered to be indirect measures (ACSM, 2006).

Hydrostatic weighing, or hydrodensitometry, is considered to be the “gold standard” when measuring body composition (Dempster and Aitkens, 1995). Hydrodensitometry makes use of Archimede’s principle (Density = Mass/Volume) to determine body density. Body density can then be used to determine fat mass and fat-free mass (ACSM, 2006). Other methods have been tested against this particular method. Bioelectrical impedance analysis is a method of determining body composition that makes use of the fact that fat tissue contains little water compared to fat-free mass. Water is a good conductor of electricity; therefore, a small electrical current is passed into the body and the resistance to the current is measured. Bioelectrical impedance analysis estimates total body water and uses the measurement to determine % BF. Differences in water content and body density between genders, ages, ethnicities, races, and physical activity status can be accounted for by the BIA machine.

Bioelectrical impedance analysis has been validated as a reliable method of determining body composition. A study by Biaggi et al. (1999) compared measurements of body composition in healthy adults using air-displacement plethysmography, BIA, and hydrostatic weighing. Results showed some differences between the measures; however, measures were not significantly different from each other. The study used a particular BIA machine that required the subject to lie while electrodes were positioned on the
body. Other machines are available which allow more ease in obtaining the measure.

Leg-to-leg BIA machines are available that allow subject to simply remove footwear and step onto a scale-like device in order to obtain measures of body composition. The leg-to-leg BIA machine has been validated using DEXA as a comparison. DEXA has been shown to be a very precise measure of body composition (Treuth et al., 1995). Austin, Heymsfield, and Nieman (1998) found no significant difference in fat-free mass (FFM) or % BF when comparing results from DEXA and leg-to-leg BIA methods in a sample of 255 females with a mean age of 42.9 ± 15.6 years and with BMIs ranging from 15.9 to 41.9 kg/m². Another study by Rubiano, Nunez, and Heymsfield (1999) chose to validate the consumer model BIA leg-to-leg machine. Subjects included 83 health individuals with a mean age of 35.5 ± 24.3 years, and mean BMI of 24.3 ± 6.8 kg/m² with fitness levels ranging from recreational to competitive athletes. The consumer machine was tested against two available clinical models, as well as against measurements obtained from DEXA. A high correlation ($r^2 = 0.95$, $p < 0.001$, $SEE = 2.44$) was found between the two clinical models and the consumer BIA model. Estimates obtained from the two clinical BIA models were found to be highly correlated with measures from DEXA ($r^2 = 0.84$, $p < 0.001$, $SEE = 4.78$; $r^2 = 0.84$, $p < 0.001$, $SEE = 4.37$).

The above studies chose to look at the ability of BIA to correctly predict % BF in the adult population; however, BIA has been validated in children 7 years of age and older as well. Nunez et al. (1999a) compared the body composition estimates of 96 children with DEXA and leg-to-leg BIA machines. The mean age of subjects was 11.9 ±
3.3 years. A high correlation was found for % BF estimates \( (r = 0.89, p<0.001, \text{SEE} = 4.56) \). Linear regression analysis of FFM obtained by each method also revealed a high correlation between the methods \( (r = 0.98, p<0.001, \text{SEE} = 2.56 \text{ kg}) \). Another study by Nunez et al. (1999b) compared FFM estimates obtained from leg-to-leg BIA and DEXA methods in 96 children ranging in age from 5 to 17 years. Subjects had BMI measurements between 13.2 and 30.8 kg/m\(^2\). A high correlation \( (r = 0.98, p<0.001, \text{SEE} = 2.62 \text{ kg}) \) was found between FFM measures obtained from both BIA and DEXA. Tyrrell et al. (2001) found leg-to-leg BIA measurements to be accurate when compared to DEXA measurements in European and Pacific Islander children.

The validation of the leg-to-leg BIA system is of particular importance due to the increase in overweight and obesity that is occurring in the U.S. with both adults and children. Body mass index is the current method used to determine obesity or overweight; however, obesity is defined as an excess of body fat; therefore, a method that determines actual body composition may be a better predictor of health risks. If a practical method such as the leg-to-leg BIA machine provides a correct estimate of % BF, then a variety of settings could benefit from the use of an assessment tool such as leg-to-leg BIA.

Diseases that have been previously thought of as adult diseases are becoming more and more common among children and longitudinal studies suggest that long-term complications can be anticipated from childhood overweight (Slyper, 1998). Therefore, one may ponder the question as to whether or not BMI is an accurate predictor of % BF in children. In male and female adults ages 20 to 94, both black and white races, a study
by Gallagher et al. (1996) demonstrated a strong influence of age and sex, but not ethnicity on the relationship between % BF and BMI. The method of measuring % BF was a four-compartment body composition model. A four-compartment model does not take into account differences between ages, sex, or ethnicity. The older subjects had higher % BF when compared to younger subjects with similar BMIs. Women also had significantly greater amounts of body fat throughout the age group studied when compared to men. Body mass accounted for 25% of variance between individuals for % BF; however, when age and sex were added as variables to the regression model, BMI accounted for 67% of the variance. A study by Demerath et al. (2006) showed the relationship between the measures of % BF and BMI to be age and sex dependent. Subjects were 494 white boys and girls ages 8 to 18 participating in a longitudinal study. In females, as age increased, the increase in BMI was more closely related to an increase in fat-mass; whereas in boys, the increase in BMI was attributed to an increase in fat-free mass with decreases in fat-mass. A rise, then a fall was seen with increasing age for boys. Another finding was that as heavy girls got older, they had a greater increase in adiposity for the same increase in BMI percentile than did lighter girls. The same phenomena occurred with boys, except the increase in adiposity was accompanied by an increase in lean body mass. The American Academy of Pediatrics concluded from the study by Demerath et al. that clinicians should continue to chart children and adolescents on recommended CDC growth charts, paying close attention to changes in BMI to identify excessive weight gain. Although no specific criteria has been set for the % BF that would identify a child as overweight or obese, a study by Asayama et al. (1995)
suggests identifying a child as obese with a body fat percentage above 25% in boys and 30 to 35% in girls during childhood.

Daniels et al. (1997) looked at 192 children between the ages of 7 to 17 years, both black and white. DEXA was used to assess body composition. A relationship existed between BMI and % BF dependent upon maturation stage, age, race, gender, and WHR in children, suggesting that when using BMI as a predictor of body fat, caution should be taken. Sexual maturation stage showed to affect % BF more than just age, meaning that if two children of the same age and gender with the same BMI were assessed at a given time and one was more sexually matured than the other, differences would be evident in the measure of fat mass and fat-free mass. The researches found similar trends as other studies regarding % BF across genders. Girls had higher measures of % BF than boys. White children had higher % BF than did black children. Gallagher et al. (1996) found no difference between races among adults. Daniels et al. also found WHR to be a significant independent predictor of % BF after including other variables in the model. Subjects with higher % BF were found to have higher WHRs. When added to the multiple regression model, WHR increased the multiple $R^2$ from 0.74 to 0.77 and did result in a significant multiple regression coefficient. Body mass index alone may not accurately predict % BF if other factors are not accounted for. Body mass index alone may also not identify children with high WHRs, which could put them at risk for certain metabolic abnormalities.

Just as in adults, an increased % BF has been associated with negative health outcomes in children. A study by Ferguson et al. (1998) looked at the relationship
between fat distribution and hemostatic measures in obese children. Fibrinogen, which is a defining factor in metabolic syndrome, was positively associated with % BF ($r = 0.42$, $P < 0.01$). D-dimer was also found to be positively associated with % BF ($r = 0.40$, $P < 0.01$). For fibrinogen, % BF, along with sex, explained a significant independent portion of the variance found. A study by Gutin et al. (1994) looked at the effect of body fatness, aerobic capacity, and fat distribution on cardiovascular risk factors in children ages 7 to 11 years. Subjects were of both white and black races with % BF ranging from 10 to 58%. % BF was measured using DEXA. A treadmill test determined aerobic capacity. Fat distribution was expressed as WHR. Blood pressure, as well as lipoproteins and apoproteins were combined to make one atherogenic index. The measure of % BF was related to the atherogenic index ($r = 0.38$, $p > 0.01$) and insulin level ($r = 0.78$, $P > 0.001$). Aerobic capacity was inversely related to the atherogenic index and insulin levels ($r = -0.27$, $P > 0.05$; $r = -0.72$, $P > 0.001$; respectively). The WHR had no effect on the atherogenic index, and no variable had an affect on blood pressure. % BF was the only measure that explained a significant portion of the variance with multiple regression.

Zonderland et al. (1990) found a relationship between plasma lipids and apoproteins and both % BF and WHR in Caucasian children approximately 10 years of age. Each measure of body composition affected the cardiovascular risk factors differently. Gender also influenced the relationship between the measures taken and risk factors measured. While studies do show that % BF may be a good predictor of disease in children, others show that the distribution of body fat as measured by WHR or waist
circumference may also be good predictors (Daniels et al., 1999; Zwiauer et al., 1992; Zonderland et al.).

Due to the changes that occur during childhood that affect body composition, and the fact that the changes are dependent upon the gender and possibly the race of the child, the current measure of BMI may not correctly identify children that may have an increased % BF. Body mass index may also be a better indicator of an increase in body fat if the child is already in one of the higher percentiles for BMI (Demerath et al., 2006). Measures such as WHR may be more reflective of % BF than BMI, and may also be helpful in identifying certain health risks (Daniels et al., 1997 & Daniels et al., 1999). All measures should be considered in order to detect health problems that are already present and the problems which the individual may be at risk for.

**Methods**

**Data Collection Procedures**

Implementation of a coordinated school health program at an elementary school (grades K-2) in Starkville, Mississippi was funded through a Special Research Initiative of the Mississippi Agriculture and Forestry Experiment Station, Mississippi State University. Data were collected on teachers/staff, kindergarteners, second graders, and their families to describe baseline characteristics of students, the school, teachers, and families. Data were kept confidential and codes were used rather than names to identify subjects. Institutional Review Board (IRB) approval was obtained from Mississippi State University’s IRB as a part of the larger study
Subjects/Sampling Strategy

Prior to data collection, parents were asked to provide consent for their children to participate in anthropometric measurements. Consent forms were sent to all parents/guardian of second grade students (n = 320).

Measurements of Children

Anthropometric measurements, including height, weight, and waist and hip circumferences, were collected on second grade students (n = 185, 57.8%), with parental consent. Trained investigators and a school official were present at the time of the measurements. Parents were sent a letter on the day prior to data collection requesting that all participants wear light clothing and minimal hair accessories for measurements. Participants were asked to remove shoes, belts, sweaters, coats, etc. prior to measurements. Height was measured to the nearest 0.1 cm on a portable stadiometer. The Tanita TBF-300A Body Composition Analyzer (Tanita/Itin Scale Company, Brooklyn, NY) was used to collect bioelectrical impedance analysis measurements as well as weight for these participants. Alcohol spray (70% isopropyl alcohol) was used on the scale to clean it between participants. Methods for obtaining height, weight, waist, and hip circumference measurements followed the School Physical Activity and Nutrition (SPAN) Project Protocol. These protocols were developed for use with the Child and Adolescent Trial for Cardiovascular Health (CATCH) study (CATCH Texas, 2003a; CATCH Texas, 2003b). Waist-to-Hip Ratio (WHR) was calculated as waist circumference (cm)/hip circumference (cm).
**Data Analysis**

Data were analyzed using SAS (version 9.1.2, 2005, SAS Institute Inc., NC, USA.). Only subjects that were grouped as black male, white male, black female, or white female were used during the statistical procedure. Pearson correlation coefficients were tested for each of the 4 groups to measure the relationship between % BF and WHR. If these variables were completely unrelated, then a correlation of 0 would be found. Ranges of this test vary from -1.00 to 1.00, which indicates either a negative or positive correlation between the 2 variables. Trends in the relationship of % BF and WHR between the groups was tested by analysis of variance to determine if the relationship between groups differed significantly using the generalized linear model procedure. Least squares means was used to estimate % BF at an average WHR (0.85).

**Results**

The study investigated the relationship between % BF as determined by BIA and WHR in children ages 7 to 9 years. Of the 185 subjects with parental consent to participate in the study, 14 subjects of “other” ethnicities were excluded, and 5 subjects were absent. The study sample was comprised of 171 students divided into 4 groups as follows: 56 (32.8%) non-Hispanic black females, 44 (25.7%) non-Hispanic black males, 34 (19.9%) non-Hispanic white females, and 37 (21.6%) non-Hispanic white males. Hip and waist circumferences were used to calculate WHR. Bioelectrical impedance analysis was used to estimate % BF.

Simple statistics were used to find the minimum and maximum WHR and % BF for each group, as well as the mean for each variable (see Table 1). The group black
females had the highest mean % BF compared to other groups who had similar percentages. Not only did the group black females have the highest mean % BF, when looking at the maximum % BF, the group had the greatest percentage followed by black males, white males, and white females. When looking at WHR, all groups had similar mean WHR measures; however, both male groups had lower minimum and maximum measures of WHR than the female groups.

**TABLE 1**

PERCENT BODY FAT (% BF) AND WAIST-TO-HIP RATIO (WHR)

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean % BF</th>
<th>Range of % BF</th>
<th>Mean WHR</th>
<th>Range of WHR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Minimum</td>
<td>Maximum</td>
<td>Minimum</td>
</tr>
<tr>
<td>White Males</td>
<td>19.5%</td>
<td>8.20%</td>
<td>45.1%</td>
<td>0.85</td>
</tr>
<tr>
<td>White Females</td>
<td>20.4%</td>
<td>6.10%</td>
<td>39.5%</td>
<td>0.85</td>
</tr>
<tr>
<td>Black Males</td>
<td>21.0%</td>
<td>11.1%</td>
<td>49.2%</td>
<td>0.84</td>
</tr>
<tr>
<td>Black Females</td>
<td>25.9%</td>
<td>6.20%</td>
<td>53.3%</td>
<td>0.86</td>
</tr>
</tbody>
</table>

Significant positive correlations were found between WHR and % BF for black females ($r = 0.48, P = 0.0002$), white females ($r = 0.66, P < 0.0001$), black males ($r = 0.34, P = 0.025$), and white males ($r = 0.55, P = 0.0004$). The F-test for analysis of variance included all groups: black female, white female, black male, white male.

Although the degree to which correlations existed between WHR and % BF differed for each of the groups, there was evidence that the relationship was similar among groups. The least squares means procedure was used to predict % BF using an average WHR (0.85), because the slopes of the lines predicting % BF were not significantly different between groups.
When using the least squares means to predict % BF from a WHR, an average WHR of 0.85 was used. With this average WHR, the group black females were the only one found to have a significantly higher % BF than other groups (see Table 2).

### TABLE 2

**ESTIMATED PERCENT BODY FAT (% BF) FROM AN AVERAGE WAIST-TO-HIP RATIO (WHR) OF 0.85**

<table>
<thead>
<tr>
<th>Group</th>
<th>% BF</th>
</tr>
</thead>
<tbody>
<tr>
<td>White Males</td>
<td>19.5%</td>
</tr>
<tr>
<td>White Females</td>
<td>20.7%</td>
</tr>
<tr>
<td>Black Males</td>
<td>21.5%</td>
</tr>
<tr>
<td>Black Females</td>
<td>25.3%</td>
</tr>
</tbody>
</table>

The R-square value was obtained to measure how successful the fit was in explaining the variation in the data. R-square is the square of the correlation between the response values and the predicted response values. R-square can take on any value between 0 and 1, with a value closer to 1 indicating that a greater proportion of variance is accounted for by the model. A relationship does exist between %BF and WHR; however, it may be difficult to make a prediction as to the value of one measure by simply having the other variable ($r^2 = 0.32$).
Discussion

The escalating problem of childhood overweight is alarming. The measurement currently being used to identify the weight status of children is BMI. The BMI was developed as a tool for estimating body composition after recognizing that other tools being used, such as height-weight tables, were not accurate in discerning between the presence of fat-mass and fat-free mass. An excess of fat-mass, not fat-free mass, is responsible for health problems that are common in overweight individuals. In adults, an increase in BMI has been correlated with an increase in health risk factors and measures of % BF. In children, the relationship between and increase in BMI and an increase in % BF and associated health risks has been questioned, giving rise to the importance of using other measurements to identify children that may be at risk for health problems.

Numerous studies have shown the relationship between BMI and % BF to be dependent upon age, maturation level, gender, and race. Other researchers have identified WHR as a variable that helps to explain the variance between BMI and % BF. Both measures to estimate % BF and calculations of WHR have been shown to predict health problems in children. An increased WHR in children has been more strongly correlated to an altered metabolic profile than weight status alone. Because the accuracy of BMI to predict % BF or health problems has been questioned in children, measures of % BF and WHR may be considered for use. One would expect a relationship between the measure of % BF and WHR to exist. Visually, as WHR increases, one would notice a larger circumference of the abdominal region compared to the hip circumference. One child that appears to have a greater central fat distribution than another may be assumed
In a group of children ages 7 to 9 years, significant positive correlations were found between % BF as determined by BIA and WHR for black females (r = 0.48, P = 0.0002), white females (r = 0.66, P < 0.0001), black males (r = 0.34, P = 0.025), and white males (r = 0.55, P = 0.025). Although the correlations for each group differed, the differences between the two variables were found to be constant across groups. Regression analysis was used to predict % BF from an average WHR taken from the entire sample was used. At the average WHR (0.85), black females had a significantly greater % BF (25.3%) than black males (21.5%), white females (20.7%), and white females (19.5%). Results from the study showed a relationship to exist between % BF and WHR in children ages 7 to 9 years; however, WHR alone was found to be a weak predictor of % BF. These findings are consistent with others that have found % BF to increase with an increase in WHR, but WHR alone cannot be used to predict % BF.

Looking at the sample of children participating in the study, variations were seen between actual measures of % BF and WHR. The group black females had the highest mean % BF compared to other groups who all had similar percentages. Not only did the group black females have the highest mean % BF, when looking at the maximum % BF, the group black females had the greatest % BF followed by black males, white males, and white females. The fact that the group black females had the highest % BF was not surprising. Research has shown % BF, BMI, and amounts of abdominal adipose tissue to be higher in black children than in white children; however, other studies have found white children to have higher % BF than black children. Numerous studies agree that
females have higher % BF than males throughout all age groups. Prevalence data in children also shows the group black females to have the highest percentage of overweight when compared to white females, white males, and black males.

All groups had similar mean measures of WHR; however, both male groups had lower minimum and maximum measures of WHR than the female groups. Various research studies have shown males to have higher measures of WHR than females due to body structure. The measure of WHR, as well as % BF, changes throughout the period of growth in children. In males, WHR declined with increasing age, whereas in females, sharp decreases were seen in WHR measures starting at the age of 10. As a child ages, females tend to accumulate a greater % BF; whereas, males tend to have a greater increase in fat-free mass. Due to the changes that occur with age and maturation level with WHR and % BF specific cut-points have been difficult to identify in children. Some researchers have suggested using equations to account for changes that occur with age to improve the usefulness of the measures; however, most studies have shown an increase in health risk factors to be correlated with both WHR and % BF.

Although measures of % BF and fat distribution have been shown to be related to health risk factors in children; limitations do exist in the use of such measures. It has been documented through studies that measures taken to assess the weight status of children are largely dependent upon age and maturation level. In the current study, children ranged in age from 7 to 9 years. The difference in the maturation stages of children at these ages could be substantial, which would affect % BF, as well as body fat distribution. Another thing to consider is that the relationship between the measures of
WHR and % BF were tested for both male and female groups as one test. No standard cut-off point for WHR has been set for children; however, the literature has pointed out that male children have a larger WHR than females due to differences in body proportions among genders. If the male body were proportioned to have a “normal” WHR that was larger than that for the female, then at the average WHR the male groups would naturally have a lower % BF than the female group. Technical limitations could also be an issue when using both the BIA and WHR in children of this age group.

The study consisted of children ranging from age 7 to 9 years. Bioelectrical impedance analysis has only been validated for use in children 7 years of age and older, giving rise to the question as to how accurate the measure may be in young children. Another consideration with the use of the BIA, is that hydration status does affect the accuracy of the measure. In children, it may be difficult to get an accurate recall in order to predict hydration status or to limit fluids, foods, and activity prior to the use of BIA. The measure of WHR found in children could also be skewed by a few factors. The parents of the children were asked to dress their children in light clothing and coats were removed prior to obtaining waist and hip circumferences; however, the amount and thickness of the clothing differed from child to child. Clothing of any type would add to the circumference of a measure, but if clothing were uniform among the children, a factor for the thickness of the clothing could be subtracted from the measures. Variations in measures of waist and hip circumferences may also have occurred depending on the technician taking the measures and the level of cooperation exhibited from the child.

In the current study, looking at an average WHR taken from all subjects, black
females were the only group to have significantly higher %BF. Black females also had higher mean, minimum and maximum % BF compared to other groups. These findings were consistent with other studies that have shown members of the black race to have higher % BF when compared to members of the white race. Prevalence data among children also shows a trend among genders and races. Body mass index, which is the measure used to compile prevalence data, may not be a good predictor of either % BF or WHR but, the greater prevalence of overweight seen in black females could indicate that a greater number of the black females would have higher %BF. Results from the current study, as well as findings from past research, indicates that black females do have higher %BF when compared to both black and white males and females. Since the group black females have a greater prevalence of overweight than any other group throughout the lifespan, health promotion initiatives should be developed that take into account cultural differences.

Research shows that as the amount of time that a child spends in front of the television increases, so does the child’s chance of becoming overweight. Black children have been shown to spend more time in front of the television than do white children. The time that a child spends in front of the television is time that the child is being inactive. Physical inactivity has been shown to be a larger culprit in childhood overweight than an increase in calorie intake; although, the black population has been shown to consume a diet which may support excess weight gain. Again, black children tend to be less active than white children, and males tend to participate in more vigorous physical activity than females. Another problem specific to the black female population
that should be targeted is the attitudes that exist accepting of a larger body image. It has also been documented through studies that caregivers of black children are unaware of the health risks associated with being overweight.

In conclusion, other studies have shown a relationship between WHR and % BF and more research should be done to determine this relationship, as well as the effect of increased abdominal adiposity may have on health risks independent of %BF. During a time period in which the prevalence of overweight is increasing in children, as well as the increase in health problems, the use of multiple measures may be considered for use in identifying health risks in children; however, many limitations do exist for both obtaining % BF using BIA and waist and hip circumferences. Studies have shown that the current method of identifying those children that are overweight may not be accurately estimating %BF or WHR, which may be indicators of health risks in children. Although these measures have been linked to risk factors for health in children, other studies should also be conducted taking into account age, gender, and maturation level when looking at the relationship between the measure of % BF and WHR.
Bibliography


