THE ASSOCIATION OF BODY COMPOSITION MEASURES WITH CARDIOMETABOLIC RISK FACTORS IN A SAMPLE OF MEXICAN ADULTS

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The Association of Body Composition Measures with Cardiometabolic Risk

Factors in a Sample of Mexican Adults

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ABSTRACT OF THE THESIS

The Association of Body Composition Measures with Cardiometabolic Risk Factors in a Sample of Mexican Adults

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Background
With the global rise in obesity, measuring the adiposity status of individuals is of growing importance, especially across different ethnicities and nationalities. An increasing amount of research is being performed to determine which adiposity measures are better in screening for cardiometabolic risk factors and diseases. However, there are conflicting results. This cross-sectional study was designed to compare the associations of body mass index (BMI), waist circumference and waist-to-height ratio with hyperglycemia, hypertension and hypercholesterolemia in a community sample of Mexican adults. The study was also intended to determine optimal cutoff values for the adiposity measures in predicting at least one cardiometabolic risk factor. Methods
Participants were Mexican adults residing in or near the border city of Tecate who attended a yearly community health fair between 2005 and 2009. Linear regression and logistic regression were performed to assess the association between each standardized adiposity measure and each cardiometabolic outcome. Receiver operating characteristic (ROC) curve analysis was employed to compare the adiposity measures in how well they predicted each outcome and to determine optimal cutoff values for the adiposity measures. Results
Of the 1523 observations, 760 were unique adult observations, 266 of which contained enough information to include for analysis (98 men, 168 women). BMI, waist circumference and waist-to-height ratio were similarly statistically associated with log blood glucose in men (p=0.001, p=0.029, p=0.004, respectively). BMI was significantly associated with mean arterial pressure in women (p=0.013). The area under the curve (AUC) for BMI was significantly higher than the AUCs for waist circumference and waist-to-height ratio in predicting hypercholesterolemia (p=0.016, p=0.026, respectively). The AUC for waist-to-height ratio was significantly higher than the AUC for waist circumference in predicting hypertension in women (p=0.008). The optimal cutoff values for predicting at least one cardiometabolic outcome were a BMI of 28.8 kg a waist circumference of 91.8 cm for men and 91.6 cm for women, and a waist-to-height ratio of 0.551 for men and 0.583 for women. Sensitivities for these cutoffs ranged from 45 to 58% and specificities ranged from 55 to 75%. Discussion
BMI tended to perform marginally better than either waist circumference or waist to height ratio for being associated with the outcomes, but was not significantly or consistently so. The confidence intervals for the statistics measuring the strength of association overlapped in each model, suggesting that the adiposity measures were similarly associated with the outcomes. However, the lack of strength and consistency of these associations precluded definite results. The adiposity measure cutoff values derived from this study were similar to published ranges but showed only moderate predictive value.
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CHAPTER 1

INTRODUCTION

The global obesity problem, dubbed ‘Globesity’ by the World Health Organization (WHO), affects children, adolescents and adults around the world. The WHO estimated that in 2008 approximately 1.5 billion adults worldwide were pre-obese, and around 500 million of these adults were obese (WHO, 2010b). Among the larger countries México ranks 7th highest in obesity, just behind the United States (WHO, 2010d). In México, the results from the 2006 Encuesta Nacional de Salud y Nutrición (ENSANUT, the National Health and Nutrition Survey) found that approximately 40% of Mexican adults were pre-obese/at risk for obesity and about 30% of adults were obese. The survey also found disparities between genders: an estimated 35% of Mexican women were obese while an estimated 24% of Mexican men were obese (Barquera et al., 2009).

Along with an unprecedented rise in pre-obesity and obesity, México has also seen a parallel increase in metabolic and cardiovascular risk factors. Between 1993 and 2006 in México, the prevalences of diabetes increased from 7% to 14%, hypertension rose from 24% to 43%, hypercholesterolemia made a large jump from 27% to 44%, high LDL-cholesterol increased from 32% to 46%, metabolic syndrome rose from 27% to 37%, and low HDL-cholesterol remained high at approximately 63%. Of the major cardiometabolic risks, the only improvement seen was a decrease in the prevalence of high triglycerides from 42% to 32% (Villalpando, Shamah-Levy, Rojas, & Aguilar-Salinas, 2010).

BACKGROUND

The body mass index (BMI) has historically been the gold standard for identifying pre-obesity and obesity in adults. However, alternative measures of adiposity have recently been investigated to see if they are better correlated with cardiovascular and metabolic abnormalities. Several studies in adults have found that the waist circumference and waist-to-height ratio may outperform BMI in the strength of their association with cardiometabolic risk factors (Aschner, Ruiz, Balkau, Massien, & Haffner, 2009; Ashwell, 2009; MacKay,
Haffner, Wagenknecht, D'Agostino, & Hanley, 2009). However, other studies in adults have shown no significant difference between BMI and various other adiposity measures in the strength of their associations with cardiometabolic risk factors (Berber, Gómez-Santos, Fanghänel, & Sánchez-Reyes, 2001; Ghandehari, Le, Kamal-Bahl, Bassin, & Wong, 2009). Of concern is the cutoff value for BMI in determining obesity in Mexican populations. The WHO publishes BMI cutoff values of 25 kg/m² for pre-obesity and 30 kg/m² for obesity in the general public. However, the optimal BMI cutoff values derived from research in predicting cardiometabolic outcomes in Mexicans and Mexican-Americans were slightly higher, ranging from 26 to 29 kg/m² (Alonso et al., 2008; Berber et al., 2001; Sánchez-Castillo et al., 2003).

Beyond looking at obesity, the importance of the type of obesity has also recently been studied. For identifying abdominal obesity, the International Diabetes Federation (IDF) has published waist circumference cutoff values according to nationality. Adults from México have the same waist circumference cutoff values as adults from Central America, South America, China, Southern Asia and Japan: 90 centimeters (35.4 inches) for men and 80 centimeters (31.5 inches) for women (IDF, 2010). However, recent research has suggested that the optimal waist circumference cutoff values used to identify abdominal obesity or screen for cardiometabolic disorders in Mexicans may be quite different than the published values; the optimal waist circumference cutoff values associated with at least one cardiometabolic risk factor ranged from 89 to 98 centimeters (35.0 to 38.6 inches) for men and from 84 to 99 centimeters (33.1 to 39.0 inches) for women. More research is needed to identify optimal cutoff values for adiposity measures in screening for health risks in Mexican adults.

**STATEMENT OF THE PROBLEM**

Obesity has become a worldwide epidemic and affects México in particular. Obesity has been shown to be highly correlated with cardiovascular and metabolic risk factors. Research comparing the correlations between obesity measures and cardiometabolic risk factors has yielded mixed results; and there is no consensus for ethnic-specific optimal cutoff values for obesity measures in predicting cardiometabolic risk. More research is needed to
determine which obesity measures are strongly associated with cardiometabolic risk factors and what are the ethnic-appropriate cutoff values.

**PURPOSE OF THE STUDY**

The primary purpose of this study was to determine which measure(s) of obesity, if any, better predicted cardiometabolic risk factors in Mexican adults. The secondary purpose of this study was to determine cutoff values of these obesity measures for use in screening for one or more cardiometabolic risk factors in Mexican adults. The results from this study will help identify which adiposity measures are better for predicting the presence of at least one cardiometabolic risk factor as well as suggest ideal cutoff values for each adiposity measure in screening for these risk factors.

**DATA SOURCE**

The data was preexisting and originated from a yearly community health event coordinated by Dr. Maura Garcia-Castillo, a primary care physician with a private clinical practice in Tecate, México. Over the years Dr. Garcia-Castillo has become concerned with the increasing weight and adiposity experienced by children and adults alike in Tecate, which elevates the risk for obesity-related diseases like diabetes and cardiovascular disease. Beginning in 2005 and through 2009, Dr. Garcia-Castillo coordinated an annual educational walk for the community of Tecate. Families in Tecate would meet on a Saturday morning to receive educational information related to diet, exercise and risk factors for chronic diseases. At the same time, volunteers from local health organizations would collect demographic information and provide optional, free health screening for adults and children for the purpose of informing participants of their health status as well as possible health risks.

**GOALS AND HYPOTHESES**

1. The waist circumference and waist-to-height ratio will both be better than, or at least similar to, the body mass index in predicting at least one of the following cardiometabolic risk factors in Mexican adults: hyperglycemia, hypercholesterolemia or hypertension.

2. The optimal cutoff values for body mass index, waist circumference and waist-to-height ratio to predict at least one cardiometabolic risk factor in Mexican adults will be different than the published cutoff values for the general public or, if available, for the Mexican population.
THEORETICAL BASIS

There are numerous studies that have evaluated body mass index side-by-side with other adiposity measures, many of them in non-Caucasian populations. The results from these studies do not show one particular measure of adiposity that is consistently more highly correlated with one or more cardiometabolic risk factor. Instead, the strength of correlation appears to vary across studies and by nationality and gender. Additionally, the results from these studies suggest different cutoff values for adiposity measures in determining cardiometabolic risk. There are very few studies in Mexican populations comparing measures of obesity in predicting cardiometabolic risk factors or suggesting cutoff values. This study will add to this growing body of literature.

BASIC ASSUMPTIONS

Some basic assumptions of this study were: the instruments used to collect the data were calibrated correctly, the accuracy and precision for these instruments were the same for each data collection year, the study data was recorded and entered correctly, all participants of the community health fair were Mexican and the results are generalizable to the non-institutionalized Mexican population.

DEFINITIONS

**Adiposity** – Obesity; having adipose tissue; the quality or state of being fat.

**AHA/NHLBI** – The American Heart Association/National Heart, Lung and Blood Institute.

**Anthropometric** – Referring to the measurements of the human body.

**Body Mass Index (BMI)** – A measure of overall obesity equal to the body weight in kilograms divided by the square of the body height in meters.

**Cardiometabolic** – A combination of cardiovascular and/or metabolic health factors.

**Cardiovascular** – Referring to the status of the heart and the circulatory system.

**CDC** – The U.S. Centers for Disease Control and Prevention, a national organization for health promotion and disease prevention.

**Central or Abdominal Obesity** – The accumulation of fat in the abdominal or truncal region.

**Dyslipidemia** – Having at least one abnormal blood lipid level.
ENSANUT – La Encuesta Nacional de Salud y Nutrición (The National Health and Nutrition Survey), a national, probabilistic survey conducted every several years in México.

Hypercholesterolemia – Having an abnormally high cholesterol blood level. The U.S. Centers for Disease Control and Prevention (CDC) defines this as a fasting blood cholesterol level of at least 200 mg/dL (CDC, 2010a).

Hyperglycemia – Having abnormally high blood glucose. The National Institutes of Health define this as a fasting blood glucose level of at least 100 mg/dL (National Diabetes Information Clearinghouse, 2010).

Hypertension – Having an elevated blood pressure; defined by the World Health Organization and the International Society of Hypertension (ISH) as a systolic blood pressure of at least 140 mmHg or a diastolic blood pressure of at least 90 mmHg (Whitworth, WHO, & ISH Writing Group, 2003).

IDF – The International Diabetes Federation.

Indirect Obesity Measures – Obesity measures that do not directly measure body fat, but are derived from indirect measures of body fat, such as weight, waist circumference or skin folds of specific sections of the body.

Metabolic – Referring to metabolism. Common metabolic disorders are elevated blood glucose levels, insulin resistance, decreased insulin sensitivity and diabetes.

Metabolic Syndrome – A clustering of cardiovascular and metabolic risk factors. Adults have metabolic syndrome if they have at least three out of these five conditions: abdominal obesity, hyperglycemia, hypertension, abnormally high triglyceride levels, and abnormally low levels of high-density lipoprotein cholesterol.

NCEP ATP III – The National Cholesterol Education Program, Adult Treatment Panel III.

NHANES – The National Health and Nutrition Examination Survey; a national, probabilistic survey conducted yearly in the U.S.

Pre-obese or Pre-obesity – Overweight but not obese, having a BMI between 25 and 30 kg/m² (WHO, 2010b).

Subcutaneous Fat – Fat accumulated in the subcutaneous layer just under the skin.

Visceral or Intra-Abdominal Fat – Fat accumulated inside the peritoneal cavity.

WHO – The World Health Organization, an international organization for health promotion and disease prevention.
CHAPTER 2

LITERATURE REVIEW

Obesity is a common and important risk factor for many diseases, particularly cardiovascular and metabolic diseases such as diabetes, hypertension and dyslipidemia. Obesity is also associated with an increased risk of myocardial infarction, congestive heart failure, angina, coronary heart disease, stroke and heart arrhythmias. Obesity carries an increased risk for non-cardiometabolic diseases and conditions, such as certain cancers, sleep apnea, asthma, abnormal menses, reproductive complications, hepatic disease, osteoarthritis, incontinence and depression (CDC, 2010b).

Over the last two decades, the prevalence of obesity has increased in numerous countries around the globe, including México. The 11th most populous country in the world, México has an estimated 112.3 million residents according to the 2010 census (WHO, 2010a). Just over half of the country is female, and just over two-thirds of the total population is at least 15 years old (Instituto Nacional de Estadística y Geografía, 2010). The most recent national health and nutritional survey, ENSANUT 2006, revealed an alarmingly high prevalence of obesity in the adult population. Based on WHO cutoff values for the body mass index (BMI), an estimated forty percent of adults in México were found to be at risk for obesity, having a BMI between 25.0 – 29.9 kg/m², and another 30% were obese, having a BMI of at least 30 kg/m² (Barquera et al., 2009).

MEASURING ADIPOSITY

Historically, the BMI has been the primary method used to determine overall body adiposity and is calculated as an individual’s weight in kilograms divided by the square of his/her height in meters. Adults with a BMI of at least 25 and up to 30 kg/m² are identified by the WHO as pre-obese individuals and are at risk for obesity. A BMI of at least 30 kg/m² indicates an obese individual (WHO, 2010b). However, lately there has been an increased interest not only in total obesity but in how the excess fat is distributed throughout the body. Even the general public is hearing of the difference in health risks between being ‘apple
shaped’ versus ‘pear shaped’ in regards to the distribution of body fat. The apple-shaped body describes central obesity, or abdominal obesity, in an individual who has an excess of fat predominately in the intra-abdominal region. A pear-shaped body describes an excess of subcutaneous fat that is mainly distributed in the hips and the buttocks. While BMI measures overall adiposity, the waist circumference specifically measures abdominal adiposity. Klein et al. (2010) conceptualized the relation between the BMI and the waist circumference using an analogy of the body as a cylinder. The weight is the cylinder’s mass, the waist circumference is the circumference around the cylinder, and the height is the length of the cylinder. Hence, since the BMI is calculated from the mass and the length, it provides information about body volume but not body composition. Ashwell (2009) noted that one disadvantage of the BMI is that it does not differentiate between those with well-muscled physiques and obese individuals.

On the other hand, the waist circumference does provide information about body shape; it is a measure of intra-abdominal fat and, in many cases, subcutaneous fat. While waist circumference and BMI are both strongly correlated with having excess body fat, the waist circumference is a better measure of intra-abdominal fat than BMI (Klein et al., 2010). The cutoff values for determining abdominal adiposity vary by gender and by ethnicity. For defining abdominal obesity in Mexicans there are currently three main schools of thought. One source, the NCEP ATP III, defines abdominal obesity as a waist circumference of over 102 centimeters (40.2 inches) in males and over 88 centimeters (34.6 inches) in females. Another group, AHA/NHLBI, defines it as a waist circumference of at least 102 centimeters in males and at least 88 centimeters in females. A third organization, IDF, defines it as a waist circumference of at least 90 centimeters (35.4 inches) in males and at least 80 centimeters (31.5 inches) in females (Rojas et al., 2010). Using the IDF criteria, an estimated 76% of Mexican adults had abdominal obesity in 2006, according to the 2006 ENSANUT (Barquera et al., 2009). Interestingly enough, there were significant differences in the prevalence of central obesity between the genders in México. While the prevalences of having a BMI over 25 kg/m² were similar, approximately 73% for women and 69% for men, an estimated 60% of women had abdominal obesity compared to only 22% of the men (Barquera et al., 2009).
A disadvantage of the waist circumference is that the cutoff values for determining obesity are different for each gender, and the values are presumed to vary across ethnicities as well. Because of this, the waist-to-height ratio has been studied recently as a more ideal measure of adiposity. It is simply an individual’s waist circumference divided by his/her height, with both values in the same units. Unlike the waist circumference, using a waist-to-height ratio cutoff value of 0.5 for pre-obese and 0.6 for obesity can be the same for men and women. Because it is calculated using the waist circumference, the waist-to-height ratio may be a more sensitive measure of adiposity than BMI (Ashwell, 2009). However, currently there are no evidence-based cutoff values, recommendations or guidelines for determining abdominal obesity or increased health risk using the waist-to-height ratio issued by organizations or governmental agencies.

Two other waist-related indices that are being investigated for use in screening for cardiometabolic risk factors are the waist-to-hip ratio and the waist-to-thigh ratio. However, Ashwell (2009) noted that these measures may be less helpful for identifying pre-obese and obese individuals because the circumferences of the waist, hip and thigh tend to decrease proportionally with weight reduction. Calculated similarly to the waist-to-height ratio, the waist-to-hip ratio is an individual’s waist circumference divided by his/her hip circumference, with both values in the same units. A systematic review of 28 studies evaluating the association between the waist-to-hip ratio and diagnosing diabetes found that the optimal cutoff values varied by gender, ethnicity and nationality. The optimal cutoff values varied from 0.87 to 0.97 in men and 0.79 to 0.92 in women (Qiao & Nyamdork, 2010). Other studies have identified waist-to-hip ratio ranges between 0.79 and 0.85 for women and 0.90 to 0.95 for men as being associated with increased cardiovascular and metabolic health risk in general. These studies have also found that the cutoff values tend to differ between the genders, likely because of differences in body fat distribution.

Just as with the other waist ratio measures, the waist-to-thigh ratio is an individual’s waist circumference divided by his/her thigh circumference, with both values in the same units. A study based on the U.S. NHANES data found optimal waist-to-thigh cutoff values were 1.92 for Mexican-American men and 1.87 for Mexican-American women (Li, Ford, Zhao, Kahn, & Mokdad, 2010). Similar to the waist-to-height ratio, there are no evidence-based cutoff values, recommendations or guidelines published by organizations or
governmental agencies for using the waist-to-hip or waist-to-thigh ratio to determine abdominal obesity or to screen for increased health risks. Other indirect measures of adiposity used in research are skin folds, arm circumference, neck circumference, the conicity index and the abdominal volume index. Additionally, adiposity can be directly measured as percent body fat using various methods.

**OTHER CARDIOVASCULAR RISK FACTORS**

In addition to obesity, another important risk factor in cardiometabolic disease is type 2 diabetes (identified from here on as diabetes). Diabetes can lead to cardiovascular complications such as angina, myocardial infarction, stroke, peripheral artery disease and congestive heart failure. Other negative health outcomes linked to diabetes are nephropathy, retinopathy, neuropathy, vasculopathy necessitating amputation and premature mortality.

Approximately half of individuals with diabetes die prematurely due to cardiovascular disease causes (van Dieren, Beulens, van der Schouw, Grobbee, & Neal, 2010). The estimated prevalence of diabetes has increased dramatically in México over the last decade, from 6.7% in 1993 to 7.5% in 2000 and 14.4% in 2006 (Villalpando, Shamah-Levy, et al., 2010). The prevalence was higher in Mexican men; around 16% of men had diabetes in 2006, compared to 13% of women (Villalpando, de la Cruz, et al., 2010). The fasting blood glucose is typically used by health professionals to screen for diabetes. The cutoff value for diagnosing diabetes is a fasting blood glucose of at least 125 mg/dL (American Diabetes Association, 2010). Individuals with elevated fasting blood glucose are often given other, more specific tests to verify diabetes. More recently, the medical community has added the category of pre-diabetes, defined by a fasting blood glucose between 100 and 125 mg/dL. In pre-diabetes, blood glucose levels are higher than normal but not high enough for a diagnosis of diabetes. However, many people with pre-diabetes develop diabetes within 10 years (National Diabetes Information Clearinghouse, 2010).

Another large contributor to cardiometabolic disease is elevated blood pressure, or hypertension. Hypertension has been linked to an increased risk for most cardiovascular diseases, including myocardial infarctions, cerebrovascular accidents, congestive heart failure, coronary artery disease and atherosclerosis. Often labeled the ‘silent killer’, hypertension is linked to many other diseases, including renal disease and other organ...
damage, cognitive impairment, blood clots, psoriasis and headaches (Mayo Clinic, 2010). The main organizations that define hypertension are the WHO, the International Society of Hypertension, the USA Joint National Committee on Prevention, Detection, Evaluation and Treatment of High Blood Pressure and the European Societies of Hypertension and Cardiology. For adults without high risk cofactors, these groups define hypertension as a systolic blood pressure (SBP) of at least 140 mmHg or a diastolic blood pressure (DBP) of at least 90 mmHg. The prevalence of hypertension in the adult Mexican population has been increasing; the estimated prevalence rose from 23.8% in 1993 to 30.7% in 2000 and 43.2% in 2006 (Villalpando, Shamah-Levy, et al., 2010). More women in México were affected than men—the 2006 ENSANUT data indicated that an estimated 47.3% of Mexican women had hypertension, compared to approximately 40.3% of the men (Barquera et al., 2010).

Abnormal blood lipid levels, or dyslipidemias, are also significant contributors to cardiometabolic disease and are risk factors for many of the same diseases as hypertension. Primarily, there are four lipid blood levels used to identify dyslipidemia in individuals: total cholesterol, high-density-lipoprotein cholesterol (HDL), low-density-lipoprotein cholesterol (LDL) and triglycerides. The U.S. Centers for Disease Control and Prevention (CDC) has published the abnormal levels for these lipids: total cholesterol of 200 mg/dL or higher, LDL of 100 mg/dL or higher, HDL of 40 mg/dL or lower and triglycerides of 150 mg/dL or higher (CDC, 2010a). In 2006, the ENSANUT revealed that approximately 60.5% of Mexican adults had abnormal HDL levels, 43.6% had high cholesterol, 31.5% had high triglycerides and 46.0% had LDL of 130 mg/dL or higher. There were also large differences in the prevalence of lipid abnormalities between the genders. In 2006 an estimated 54.0% of women had abnormal HDL levels compared to around 68.1% of men, 47.2% of women had high cholesterol compared to 39.3% of men, 26.9% of women had high triglycerides compared to 36.9% of men, and 50.0% of women had high LDL levels compared to 41.4% of men (Aguilar-Salinas et al., 2010).

Diabetes, hypertension and dyslipidemia can be insidious risk factors because of the frequent absence of symptoms and awareness of the conditions, as well as the lack of education and understanding of the role these conditions have in contributing to poor health and premature mortality. A tally of the death certificates in México for 2004 reveals that the most frequently listed cause of death was cardiovascular disease, accounting for 29.3% of the
The second-leading cause of death was diabetes, listed as the cause for 11.6% of the deaths. Among deaths in Mexicans at least 60 years old, cardiovascular disease was listed as the cause of death in 35.7% of the deaths and diabetes was listed in 12.4% of the deaths in 2004 (WHO, 2010c).

**Adiposity Measures and Cardiometabolic Outcomes**

Numerous studies have been conducted to evaluate the role that obesity plays in cardiometabolic disease. Lately, there has been an increase in studies that compare different measures of obesity in predicting risk factors for cardiometabolic diseases, such as diabetes, hypertension and dyslipidemia. Several studies found that BMI was the most useful predictor of cardiometabolic outcomes. A large prospective study in Japanese subjects was performed to evaluate the incidence of hypertension and diabetes and to gauge how well BMI, waist circumference, waist-to-height ratio, waist-to-hip ratio and skinfold thickness predicted the outcomes. After a 10-year follow-up, Chei et al. (2008) determined that only BMI and waist circumference were significant predictors of developing hypertension, and only BMI and skinfold thickness were significant predictors of developing diabetes.

A study in women in the U.K. looked at the outcomes of hypertension, dyslipidemia, abnormal C-reactive protein and plasma fibrinogen. They found that of the four adiposity measures of BMI, waist circumference, waist-to-hip ratio and waist-to-height ratio, BMI was most closely related to hypertension but the waist-to-height ratio was more strongly correlated with the other outcomes (Kwok et al., 2008). Additionally, Bosy-Westphal et al. (2006) compared body fat mass to BMI, waist circumference and waist-to-height ratio in predicting dyslipidemia, hypertension and diabetes in a sample of German adults. They found that in women BMI was the best predictor of HDL and insulin resistance, but the waist circumference and the waist-to-height ratio were stronger predictors of hypertension and dyslipidemias in both genders. In multiple regression analyses the waist-to-height ratio was the strongest predictor of the metabolic risk factors for both genders but only by a small margin.

Other research has shown that, of the indirect adiposity measures, waist circumference may be superior in predicting cardiometabolic outcomes. Surveys have
identified subgroups of populations whose BMI is within the normal range, and thus they wouldn’t be considered obese, except they have abdominal obesity. Data from the 2006 ENSANUT revealed that 14.9% of Mexican adults with abdominal obesity were found to have a normal BMI (Barquera et al., 2009). A study in 12 Latin American countries identified subgroups of the study population who had normal BMI values but were abdominally obese by the IDF definition (25.4% of men and 42.1% of women) as well as by the NCEP ATP III definition (1.5% of the men and 10.7% of the women; Aschner et al., 2009). Thus, the waist circumference may be more sensitive in identifying obesity in individuals whose BMI values are within the normal range but have up to a moderate excess of abdominal fat.

Several studies have shown that the waist circumference may be more useful than the BMI when looking at cardiometabolic outcomes. One author used the analogy of an iceberg, suggesting that measuring BMI only allows us to see the tip of the iceberg when it is too late, but measuring the waist circumference can identify risk factors much earlier and may prompt preventive medicine measures (Després, 2001). Using a Canadian sample, Després et al. (1990) found that the waist circumference alone was more effective than BMI for predicting not only hypertension, cardiovascular disease, diabetes but also newer risk factors, such as hyperinsulinemia, high apoprotein B, high levels of small dense lipoprotein particles, glucose intolerance, cholesterol-to-LDL ratio, insulin resistance and altered hemostatic variables. Researchers who evaluated a short exercise intervention in Canadian subjects found that while BMI did not change over the course of the intervention, the waist circumference decreased significantly along with several parameters associated with diabetes risk (Dekker et al., 2007).

Several studies carried out in the last decade have shown that the waist-to-height ratio has strong associations with cardiometabolic risks. A national survey of British adults revealed that approximately 35% of men and 14% of women with a normal BMI had a waist-to-height ratio of 0.5 or greater. Data from this survey also showed that, compared to BMI, the waist-to-height ratio was more closely associated with cardiovascular risk factors among both men and women (Ashwell & Gibson, 2009). Wu, Xu, Chen and Zhang (2009) looked at the correlations of BMI, waist circumference, waist-to-hip ratio and waist-to-height ratio with visceral and subcutaneous fat accumulation in Chinese men, measured by computed
tomography. They found that the waist-to-height ratio was a stronger predictor of visceral fat accumulation than BMI, waist circumference and waist-to-hip ratio; however, the four adiposity indices were similar predictors of subcutaneous fat accumulation.

A study in German adults compared five measures of adiposity—BMI, waist circumference, hip circumference, waist-to-hip ratio, and waist to height ratio—in predicting metabolic syndrome, diabetes and dyslipidemia. They found that the waist-to-height ratio was significantly more correlated than the other adiposity measures to cardiometabolic outcomes in women and type 2 diabetes in men (Schneider et al., 2007). A study in a sample of non-obese Italians done by Mombelli, Zanaboni, Gaito, and Sirtori (2009) evaluated the association of BMI, waist circumference and waist-to-height ratio with serum lipids, hypertension and hyperglycemia. They found that the waist-to-height ratio was better than BMI and waist circumference in identifying cardiometabolic risk factors. Furthermore, using the cutoff value of 0.5 for waist-to-height ratio in both genders was found to be more predictive of the risk factors than using the published cutoff values for BMI and waist circumference.

Hsieh and Muto (2006) published results of a study comparing BMI, waist circumference and waist-to-height ratio in screening for metabolic syndrome in Japanese adults. They showed that a waist-to-height ratio of at least 0.5 was the most sensitive predictor of metabolic syndrome in both genders. Furthermore, a study in a large sample of Taiwanese adults was performed to evaluate the associations of BMI, waist circumference, waist-to-height ratio and waist-to-hip ratio with hypertension, diabetes and dyslipidemia. This study found the waist-to-height ratio to be a stronger predictor of cardiometabolic risk factors than BMI, waist circumference and waist-to-hip ratio (Lin et al., 2002).

Recent research has also revealed that combining the waist circumference with a waist ratio measure may be more useful in predicting cardiometabolic risk factors than just looking at each adiposity measure alone. Chehrei, Sadrnia, Keshteli, Daneshmand, and Rezaei (2007) looked at BMI, waist circumference and waist-to-height ratio in a sample of Iranian adults and found that both waist circumference and waist-to-height ratio predicted dyslipidemia better than BMI, but none of the indices showed any association with fasting blood sugar. Esmaillzadeh, Mirmiran, and Azizi (2006) performed a study in Tehranians investigating the association of the four different body composition measures of BMI, waist
circumference, waist-to-hip ratio and waist-to-height ratio in predicting hypertension, dyslipidemia and diabetes. They found that the waist circumference showed the strongest associations to the risk factors in the women and the waist-to-hip ratio showed the strongest associations in men. Park, Choi, Lee and Park (2009) studied the association of cardiovascular risk factors to BMI, waist circumference and waist-to-height ratio in Korean adults. They found that the waist-to-height ratio best predicted diabetes and hypertension in men and women, but waist circumference was a better predictor for abnormal HDL levels in men. Another study was done in normotensive Pakistani adults to evaluate the linear associations between blood pressure and various measures of adiposity: BMI, waist circumference, hip circumference, waist-to-hip ratio and waist-to-height ratio. They found that both waist circumference and waist-to-height ratio had the strongest linear association with blood pressure in the men, but BMI had the strongest association in women (Khan et al., 2008).

A handful of studies have found that the waist-to-hip ratio or the waist-to-thigh ratio was the most useful predictor of various cardiometabolic risk factors. A large, prospective study performed in the United Kingdom looked at adiposity measures and developing coronary heart disease. The nine-year average follow-up showed that while BMI, waist circumference and waist-to-hip ratio were all associated with an increase risk of developing coronary heart disease, only the waist-to-hip ratio was independently and consistently predictive of coronary heart disease (Canoy et al., 2007). Additionally, Li and McDermott (2010) looked at the association of cardiometabolic disorders with BMI, waist circumference, waist-to-hip ratio and waist-to-height ratio among indigenous Australians. Using the outcomes of diabetes, hypertension, and dyslipidemia, the authors found that the waist-to-hip ratio was the strongest predictor of the outcomes while BMI was the weakest.

Jeong, Seo, Kim, Kweon, and Nam (2005) compared BMI, waist circumference, waist-to-height ratio and waist-to-hip ratio in a sample of Korean adults and found that the waist-to-hip ratio had the strongest association with abnormal lipid levels—over 10-fold stronger than BMI, waist circumference and waist-to-height ratio. Additionally, there were significant associations between quartiles of dyslipidemias and waist circumference, waist-to-height ratio and waist-to-hip ratio, but not BMI. A study using data from the NHANES examined the relationship between diabetes and BMI, waist circumference, waist-to-height
ratio, waist-to-hip ratio and waist-to-thigh ratio in U.S. adults. The waist-to-thigh ratio had the strongest association with diabetes in men but the waist-to-hip ratio had the strongest association with diabetes in women (Li et al., 2010).

A study in Iraqi adults was conducted to determine the association between diabetes or hypertension and BMI, waist circumference, waist-to-hip ratio or waist-to-height ratio. Mansour and Al-Jazairi (2007) found that the waist-to-hip ratio had the strongest association with diabetes but the waist-to-height ratio had the strongest association for hypertension. Other researchers came up with similar results; Ko, Chan, Cockram, and Woo (1999) looked at BMI, waist-to-hip ratio, waist circumference and waist-to-height ratio associated with cardiovascular risk factors in a sample of Chinese men and women. In both genders the waist-to-hip ratio and waist-to-height ratio had the strongest relationships with both diabetes and hypertension. All four indices were associated with dyslipidemia and albuminuria, although the associations were weaker. A prospective study in Brazilians investigated the incidence of hypertension with various adiposity measures. After an average follow-up time of 5.6 years, Fuchs et al. (2005) found that while BMI was not a significant predictor of the onset of hypertension, the waist circumference, waist-to-height ratio and waist-to-hip ratio were all significant predictors.

On the other hand, several studies have found that these indirect obesity measures were similar to one another in their correlation with cardiometabolic risk factors. A study performed in a sample of non-obese Spanish women evaluated relationships between serum lipids and three central adiposity measures: waist circumference, waist-to-hip ratio and waist-to-height ratio. The results showed that each measure was independently and similarly associated with serum lipids (Moreira-Andrés et al., 2004). A prospective study in Jamaicans looked at the association of BMI, waist circumference, waist-to-height ratio or waist-to-hip ratio with incident diabetes. After following the subjects for an average of four years, Sargeant, Bennett, Forrester, Cooper, and Wilks (2002) found that each adiposity measure was an independent predictor of diabetes and none was “clearly superior” (Sargeant et al., 2002, p. 792). A large study in the U.S. found similar results with cardiovascular outcomes. Using data from the Physician’s Health Study and the Women’s Healthy Study, an analysis was performed to investigate the associations of BMI, waist circumference, waist-to-height ratio and waist-to-hip ratio to the outcomes of heart attack, stroke and death. The results
showed that waist-to-height ratio was most strongly associated with cardiovascular disease. However, the differences in cardiovascular risk assessment between BMI, waist circumference, waist-to-height ratio and waist-to-hip ratio were small and likely not clinically consequential (Gelber et al., 2008).

Lu, Ye, Adami, and Weiderpass (2006) reported results from a prospective study on Swedish women. They found that waist-to-hip ratio, waist-to-height ratio and waist circumference had very similar risk ratios for incident stroke cases. However, after adjusting for hypertension and diabetes the risk ratios decreased. Furthermore, a study in French and Irish subjects evaluated the associations between coronary events and BMI, waist circumference, waist-to-height ratio and waist-to-hip ratio. The results revealed that although the waist-to-height ratio best predicted dyslipidemia, hypertension and diabetes in middle-aged men, the differences between the measures of adiposity were slight (Gruson et al., 2010). Łopatyński, Mardarowicz, and Szcześniak (2003) performed a study where a glucose tolerance test was administered to a sample of Polish adults to evaluate the predictive power of BMI, waist circumference, waist to height ratio and waist to hip ratio on glucose tolerance. They found that the four adiposity measures were similarly associated with both glucose disturbance and glucose intolerance.

**STUDIES IN MEXICAN AND LATINO POPULATIONS**

While there have been studies of adiposity measures in various ethnicities, there have been only a small number of these studies in Mexican populations. One study looked at the relationship between body stature and body fat. López-Alvarenga, Montesinos-Cabrera, Velázquez-Alva, and González-Barranco (2003) noted that the Mexican population had a high prevalence of short stature and found that Mexican adults who were short-statured had a higher percentage of body fat than those who were not short-statured. The authors suggested that the BMI criteria for diagnosing pre-obesity and obesity may be different depending upon the stature characteristics of the population or ethnicity.

A couple of studies found BMI to be a useful obesity measure in adult Mexican populations. Berber et al. (2001) evaluated the correlations of BMI, waist circumference, waist-to-height ratio and waist-to-hip ratio with diabetes, hypertension and dyslipidemia in a Mexican sample. The authors found that hypertension and dyslipidemia were significantly
predicted by the waist-to-hip ratio in men and waist circumference in women. However, of
the four adiposity measures, only the BMI was significant for all three outcomes in both
genders. A smaller study was conducted in Mexicans to evaluate how well insulin resistance
was predicted by BMI, waist circumference, mid-arm circumference, percent body fat and
various skinfold thicknesses. The best predictors of insulin resistance were seen with BMI,
the bicipital skinfold thickness and the mid-arm circumference (Gómez-García, Nieto-

Other studies have found measurements involving the waist to be useful. One study in
both Mexicans and Mexican-Americans looked at how well BMI, waist circumference,
waist-to-height ratio and waist-to-hip ratio predicted diabetes. The results showed that the
waist-to-hip ratio was the best predictor of having diabetes in Mexican-American men and
Mexican men and women, but the waist-to-height ratio was the better predictor in Mexican-
American women (Lorenzo et al., 2007). A larger study in Mexicans compared the BMI and
waist circumference in predicting either hypertension or diabetes. The waist circumference
was associated more strongly with both hypertension and diabetes in men and women
(Sánchez-Castillo et al., 2003). Sánchez-Viveros, Barquera, Medina-Solis, Velázquez-Alva,
and Valdez (2008) evaluated data in older Mexicans, looking at the associations of BMI,
waist circumference and conicity index with hypertension and diabetes. The conicity index is
a fairly new alternate measure of adiposity, highly correlated with waist-to-height ratio,
calculated from an individual’s waist and height. The authors found that the waist
circumference and conicity index were more associated with diabetes but BMI was more
associated with hypertension. Additionally, Neufeld, Jones-Smith, García, and Fernald
(2007) conducted a study in young Mexican women, evaluating six measures: BMI, waist
circumference, waist-to-hip ratio, the sum of skinfold thicknesses, the conicity index and the
abdominal volume index, which is a geometry-derived calculation using the waist and hip
circumferences. The authors looked at the outcomes of pre-diabetes, pre-hypertension and
high triglycerides. The waist-to-hip ratio and the conicity index were the least predictive
variables for each of the outcomes; the other four adiposity measures were similar in the
strength of association with the outcomes.

While few studies on this topic have been conducted in Mexican populations, there
are several studies in residents of the U.S. who are of Mexican, Hispanic or Latino ethnicity.
A handful of fairly recent studies in these populations have found the waist circumference to be useful in predicting cardiovascular outcomes. Perry, Wang, and Kuo (2008) studied the associations of BMI, waist circumference and waist-to-hip ratio with hypertension, diabetes and dyslipidemia in Hispanic-American women in the U.S. They found that the BMI and the waist-to-hip ratio were not significantly associated with any of the outcomes; only waist circumference was associated with elevated blood glucose. Lorenzo, Williams, Stern, and Haffner (2009) looked at data from a prospective study in Mexican-Americans comparing waist circumference alone, waist circumference adjusted for height, and waist-to-height ratio in predicting incident diabetes. They found that including height did not predict diabetes better than that of waist circumference alone.

Haffner (2000) evaluated the association of BMI, body weight, waist circumference and waist-to-hip ratio with diabetes in Mexican-Americans. While each adiposity measure was an independent predictor of diabetes, the waist circumference was the strongest, with a predictive power greater than the BMI and waist-to-hip ratio combined. The association between waist circumference and diabetes was stronger in individuals with a BMI under 27 kg/m² than those with a BMI over 27 kg/m², suggesting that distribution of body fat, especially abdominal localization, was more important than the overall adiposity for predicting diabetes. Zhu et al. (2005) analyzed the data from the 1988-1994 NHANES, comparing BMI with waist circumference in predicting diabetes, hypertension and dyslipidemia. The results showed that for the Mexican-American subgroup, the waist circumference had stronger correlations with individual risk factors but the BMI was more predictive of having risk factors overall.

Other studies have found the waist ratio measures to be more useful. Using a subsample of Mexican-Americans from NHANES, Diaz, Mainous, Baker, Carnemolla, and Majeed (2007) examined the association between BMI, waist circumference and waist-to-height ratio with diabetes and found that the most sensitive predictor of diabetes for adults at least 40 years old was the waist-to-height ratio. In a sample of residents of Central and South American countries, Herrera et al. (2009) estimated the association of BMI, waist circumference and waist-to-hip ratio with coronary heart disease risk, calculated using the Framingham equation. The results showed that the waist-to-hip ratio was the most accurate
indicator of the outcome, and that BMI was “almost uninformative” (Herrera et al., 2009, p. 568).

However, two studies found no difference among the adiposity measures in Latino populations in the United States. MacKay et al. (2009) evaluated data from a 5-year prospective study on incident diabetes in a multi-ethnic sample in the U.S. They concluded that overall and among the Hispanic subgroup, adiposity measures specific for central adiposity—waist circumference, waist-to-height ratio, hip circumference and waist-to-hip ratio—were no better than BMI, percent body fat and sum of skinfold thickness in predicting the onset of diabetes. Also, Bermudez, and Tucker (2001) evaluated adults in the U.S. from Puerto Rico and the Dominican Republic and found that both BMI and waist circumference were similarly associated with the presence of diabetes.

**Optimal Cutoff Values for Adiposity Measures**

Research has been conducted recently to identify adiposity measure threshold values with optimal sensitivity for determining hyperglycemia, hypertension and dyslipidemia. The optimal cutoff values are determined by plotting a Receiver Operating Characteristic (ROC) curve, a plot of the sensitivity (or the true positive rate) versus 1–specificity (or the false positive rate). The optimal cutoff for an adiposity measure is the value where the sensitivity equals 1–specificity; this point identifies the value associated with maximum sensitivity and minimal sacrificing of specificity.

Several studies have been published which suggest optimal cutoff values of adiposity measures for predicting cardiometabolic risk factors in Mexicans and other Latino populations. A study in young Mexican women by Neufeld et al. (2007) used ROC curve analysis to identify cutoff values that maximized sensitivity and specificity for pre-diabetes, pre-hypertension and high triglycerides. The BMI cut-off values ranged from 27.7 to 28.4 kg/m², and the waist circumference cutoff values ranged from 89.3 to 91.2 centimeters (35.2 to 35.9 inches). A large study by Sánchez-Castillo et al. (2003) in Mexicans evaluated two outcomes: hypertension and diabetes. The optimal BMI cutoff values from the ROC curve analysis for predicting diabetes were around 26.9 kg/m² for men and 28.3 kg/m² for women and for predicting hypertension were approximately 26.6 kg/m² for men and 28.1 kg/m² for women. Waist circumference cutoff values for predicting diabetes ranged from 93 to 98
centimeters (36.6 to 38.6 inches) for men and 94 to 99 centimeters (37.0 to 39.0 inches) for women, and cutoff values for predicting hypertension ranged from 92 to 96 centimeters (36.2 to 37.8 inches) for men and 93 to 96 centimeters (36.6 to 37.8 inches) for women. Alonso et al. (2008) evaluated Mexicans living in Mexico City for the optimum waist circumference to predict metabolic syndrome and determined from the ROC curves that the cutoff value for men was 98 centimeters (38.6 inches) while for women it was 84 centimeters (33.1 inches).

A study by Berber et al. (2001) looked at the outcomes of diabetes, hypertension and dyslipidemia in a Mexican sample. The optimal BMI cutoff value from ROC curve analysis to predict all outcomes was approximately 25.9 kg/m² for both men and women, and the optimal waist circumference cutoff values were 90 centimeters (35.4 inches) for men and 85 centimeters (33.5 inches) for women. The optimal waist-to-hip ratio cutoff value was 0.90 for men and 0.85 for women, and the optimal waist-to-height ratio cutoff value was around 0.53 for men and women. Zhu et al. (2005) analyzed a subsample of Mexican-Americans from the 1988-1994 NHANES using ROC curve analysis and found that the waist circumference cutoff values that corresponded to a BMI of 25 kg/m² were 88.7 centimeters (34.9 inches) for men and 83.1 centimeters (32.7 inches) for women. The cutoff values that corresponded to a BMI of 30 kg/m² were 101.2 centimeters (39.8 inches) for men and 93.6 centimeters (36.9 inches) for women. Another study looked at adiposity measures predicting diabetes in adult Mexican-Americans at least 40 years old. From the ROC curve analysis, the resulting cutoff values were BMI of 27.8 kg/m² for men and 30.4 kg/m² for women, waist circumference of 100.4 centimeters (39.5 inches) for men and 103.7 centimeters (40.8 inches) for women, and waist-to-height ratio of 0.624 for men and 0.677 for women (Diaz et al., 2007).

Summarizing these studies, the optimal waist circumference cutoff values derived using ROC curve analysis associated with at least one cardiometabolic risk factor had quite large ranges. Optimal cutoff values for BMI ranged from 25.9 to 30.4 kg/m². Optimal cutoff values for waist circumference ranged from 90 to 98 centimeters (35.4 to 38.6 inches) for men and from 84 to 99 centimeters (33.1 to 39.0 inches) for women. Only two articles calculated optimal cutoff values for waist-to-height ratio and these were 0.53 for both genders, 0.624 for Mexican-American men and 0.677 for Mexican-American women.
SUMMARY

There is considerable debate as to which measures of adiposity have the strongest associations with increased risk of cardiovascular and metabolic diseases. The strengths of these associations also seem to vary across ethnicities, nationalities and genders. There have been few studies in Mexican populations to evaluate the association of adiposity measures with cardiometabolic risk factors. Additionally, there is no evidence-based consensus for optimal cutoff values of adiposity measures in screening for increased cardiometabolic risk factors in Mexican adults. This study will add to the body of research by comparing side-by-side the associations of body mass index, waist circumference and waist-to-height ratio to cardiometabolic outcomes and will suggest optimal cutoff values in screening for increased cardiometabolic risk.
CHAPTER 3

METHODS

Using existing, deidentified data collected during a yearly community health fair in Tecate México, a cross-sectional study was conducted to evaluate the associations of body mass index, waist circumference and waist-to-height ratio with hyperglycemia, hypertension and dyslipidemia in a community sample of Mexican adults residing in or around Tecate. The yearly community health fair was coordinated and organized by Dr. Maura Garcia-Castillo, a primary care physician in Tecate. The purpose of the event was to give residents of Tecate the opportunity to be screened for cardiometabolic health risks, receive optional counseling by a physician and participate in a community walk. The data was not collected for the purpose of epidemiological or statistical analysis; it was collected to give the participants information on several of their health risks. The study was verified as exempt by the Institutional Review Board at San Diego State University.

STUDY POPULATION

Tecate is the second most populous of the five municipalities in Baja California, the most northwestern of México’s 31 states. According to recent Mexican censuses, Tecate had approximately 77,800 residents in 2000 and around 91,000 residents in 2005. Approximately 52.8% of the residents of the Tecate municipality were men; about half were between 15 and 64 years old; and over half lived in the county seat, a city also named Tecate (Instituto Nacional de Estadística y Geografía, 2010). The prevalence of pre-obesity and obesity combined among adults at least 20 years old in 2006 was approximately 68% in Baja California and approximately 73% along the entire México-U.S.A. border (Cuevas Nasu et al., 2007).

The existing data for this study originated from a series of cross-sectional samples collected yearly at the community health fair in Tecate, México between 2005 and 2009. Each year, promotion for the event occurred for several months prior to the health fair with advertisements on television and radio, advertising via megaphone on cars driving through
neighborhoods, posters placed in multiple locations in the city of Tecate and advertisements in newspapers and with local community organizations. Additionally, approximately 15,000 flyers were distributed two or three months before the yearly event in most of the elementary schools in Tecate. Teachers made announcements to classes and parents, emphasizing that participation in the event was free and that minors must bring a parent or guardian. All residents of the city of Tecate were encouraged to attend and all recruitment material specified that participants should be fasting if they wanted their blood chemistry levels measured.

Starting in 2005, each year on a Saturday morning in October families would converge in a specified area to receive educational information related to nutrition, physical activity and risk factors for cardiometabolic diseases. Participants who wished to be screened for health risks would visit stations to have several body measurements and blood measurements taken. The participants then had the option of a one-on-one consultation with a physician regarding these results. Afterwards, all interested persons would participate in a community walk through the town to emphasize the importance of physical exercise for improved health. Participants were children, adolescents and adults who resided in or near the city of Tecate, México at the time of each yearly health fair. The data from these health fairs is thought to be representative of non-institutionalized residents in a typical border town in Northern México. All individuals who attended the event could participate and have the screenings performed; nobody who arrived at the event was turned away for any reasons, except for minors without a parent or guardian.

Individuals younger than eighteen years old, the age of majority in México, were excluded from this study due to the differences between adults and children/adolescents in measuring body composition and cardiometabolic risk factors. Additionally, an observation was excluded from the present analysis if there was insufficient data to perform all of the analyses described in this chapter. For individuals who attended more than one annual event, only the data from their initial event was included in the analysis. The total number of participants included in the analyses was 266. Figure 1 demonstrates how the final population for the analysis was derived. The adult observations that were included in the analysis were statistically similar to those not included except those included had a significantly higher mean cholesterol and lower mean waist circumference than those not included.
SCREENING INTAKE

The staff coordinating the health screenings was comprised solely of volunteers, all of whom attended a one-day training session led by Dr. Garcia-Castillo before the event each year. There were teachers as well as clinicians who volunteered each year to help with staffing the health event. The teachers were trained on recording demographic information, such as the participant’s name, age in years and gender. The clinical staff consisted of volunteers from several health care fields. Students from the Department of Nutrition at the
Universidad Iberoamericana in Tijuana, México were trained by a registered nutritionist to measure the height, weight and waist circumference of each participant. At the body measurement screening station, the height was measured in unshod participants using portable stadiometers on a flat, carpeted surface; height was recorded to the nearest centimeter. The weight was measured in unshod participants on Tanita Model WB-110A portable electronic scales placed on a flat, solid surface; weight was recorded to the nearest 0.1 kilogram. The waist circumference was measured using flexible measuring tape around the waist at the level of the umbilicus and recorded to the nearest centimeter.

At the blood pressure screening station, the seated blood pressure of the participant was measured by volunteer paramedics from the Red Cross as well as fifth-year medical students at the Universidad Autónoma de Baja California in Tecate. Manual blood pressure cuffs were used with manual sphygmomanometers to measure and record the systolic and diastolic blood pressures; these were recorded to the nearest 10 mmHg in most cases and the nearest 1 mmHg in some cases. At the blood chemistry measuring station, volunteer chemists from the pharmaceutical companies AstraZeneca and Pfizer joined the medical students in collecting a blood sample from participants via fingerstick. Blood levels of glucose, cholesterol, triglycerides, HDL and LDL were measured on-site immediately following the fingerstick using Cholestech machines and recorded to the nearest 1 mg/dL. All of the information gathered at the screening stations was recorded on site by the volunteers onto forms at the time of screening, later inputted into an electronic database, and then deidentified by the staff of the event coordinator.

VALIDATION OF THE DATASET

The validation of the dataset was performed using Predictive Analytics SoftWare® v17 (formerly SPSS®; IBM, Somers, NY) and Statistical Analysis Software® v9.1.3 for Windows (SAS Institute, Cary, NC) and included range-checking, identifying possible errors in data entry and checking for normality of the variables’ distributions. Initially, one data entry error was identified as readily correctable. Approximately half of the waist circumference values entered in 2008 seemed to have been entered as inches rather than centimeters. A histogram plot was constructed to visualize which observations likely were incorrectly entered in inches and showed two distinct peaks with no overlap—one centered
around 30 and the other centered around 90. The other anthropometric measurements of each participant were referred to in order to verify that the waist circumferences were physiologically plausible as inches rather than centimeters, and the values were then transformed into centimeters by multiplying by 2.54 centimeters/inch.

Other data entry errors were not as readily apparent. Manual range-checking entailed a visual inspection of the values on the high and low range of each variable and evaluating the physiological plausibility of those values. Several erroneous entries were identified this way, for example, if the diastolic blood pressure was greater than the systolic blood pressure. For such observations that were physiologically implausible, the erroneous value was deleted but the remainder of the participant’s record remained in the dataset. Additionally, two observations were deleted because of a physiologically implausible combination of height, weight and waist circumference.

To validate the dataset overall, the means and standard deviations of height, weight, BMI, waist circumference, blood pressure and hyperglycemia were compared to statistics published from the national health survey in México, ENSANUT in 2006. Most of the study statistics were determined to be similar; the only differences were that the average weight of the sample dataset was approximately 13 pounds higher (for both men and women), the average BMI was about 1.5 kg/m² higher, and the percent of blood glucose over 110 mg/dL was approximately 4.5% lower compared to the ENSANUT 2006 averages (Aguilar-Salinas et al., 2010; Barquera et al., 2010; Rojas et al., 2010).

The individual variables were examined to estimate the degree of normality. Each variable was plotted in histogram form and visually inspected for similarity to the normal distribution. Additionally, the skewness and kurtosis of each variable were determined and examined for extreme departures from normality. Finally, two additional tests were employed to quantify the degree of departure from normality for each variable: the Kolmogorov-Smirnov test and the Shapiro-Wilk test. Upon reviewing the histograms and the results from the above tests, the fasting blood glucose and cholesterol were identified as straying from a suitable normal distribution. Both of these variables then were log-transformed for use in the linear regression analysis and the resulting distributions were checked again for departure from normality. They both were determined acceptable in approximating a normal distribution for the purposes of this data analysis.
Additionally, a series of residual analyses was run to assess data linearity and homoscedasticity as well as identify any extreme outliers. The log fasting blood glucose was run in a polynomial regression with the independent variables of age, gender, and BMI to compute the standardized residuals. The scatter plot of the residuals versus predicted values was inspected for linearity by how closely the residuals were centered around zero and for homoscedasticity by how well the scatter plot showed consistent width. This process was repeated with each adiposity measure and each outcome. The results for each variable indicated reasonable linearity and homoscedasticity.

**Variables Used in Data Analysis**

The overall goal of this study was to perform side-by-side comparisons of how well different adiposity measures would predict cardiometabolic outcomes and to suggest cutoff values for these adiposity measures. To accomplish this, three statistical analyses were employed: linear regression, logistic regression and ROC curve analysis.

For the linear regression analysis, a series of models were constructed, one for each adiposity measure paired with each cardiometabolic outcome, allowing for a side-by-side comparison of the strength of each association. The adiposity measures used were the continuous variables of BMI, waist circumference and waist-to-height ratio. BMI was calculated as the participant’s weight in kilograms divided by the square of the participant’s height in meters; the units were kilograms per meter-squared. The waist circumference was in centimeters. The waist-to-height ratio was calculated as the participant’s waist circumference in centimeters, divided by 100 to convert to meters, and then divided by the participant’s height in meters. The waist-to-height ratio was unitless. Each adiposity measure was standardized to a mean of zero and a standard deviation of one before each analysis in order to allow for side-by-side comparisons using the same scale. The cardiometabolic outcomes used were the continuous variables: log fasting blood glucose, mean arterial pressure (MAP) and log fasting blood cholesterol. Mean arterial pressure is a function of several cardiovascular attributes and is very highly correlated to both systolic and diastolic blood pressures. Mean arterial pressure has also been shown to be highly linked to cardiovascular risk outcomes in men under 60 years old and similarly to systolic and diastolic blood pressure in the correlation with BMI (Lee, Entzminger, Lohsoonthorn, & Williams,
The estimated mean arterial pressure for each participant was calculated from systolic and diastolic blood pressure variables using the following equation: \( \text{MAP} = \text{diastolic blood pressure} + \frac{1}{3} (\text{systolic blood pressure} - \text{diastolic blood pressure}) \).

For the logistic regression analysis, a series of models were constructed, one for each adiposity measure paired with each cardiometabolic outcome. Again, the adiposity measures used were the continuous variables of BMI, waist circumference and waist-to-height ratio. The cardiometabolic outcomes were the dichotomous variables of hyperglycemia, hypertension and hypercholesterolemia, which were calculated from fasting blood glucose, blood pressure and fasting blood cholesterol. Fasting blood glucose was categorized as hyperglycemia if the glucose level was at least 100 mg/dL. The cutoff value of 100 mg/dL identifies individuals with possible pre-diabetes or diabetes (National Diabetes Information Clearinghouse, 2010). Blood pressure was categorized as hypertension if either the systolic blood pressure was at least 140 mmHg or the diastolic blood pressure was at least 90 mmHg. These cutoff values indicate stage 1 hypertension or higher in clinical practice (Whitworth et al., 2003). Fasting blood cholesterol was categorized as hypercholesterolemia if the cholesterol level was at least 200 mg/dL, according to the CDC recommendations (CDC, 2010a). All three of these variables were coded as one for elevated and zero for not elevated.

The purpose of the ROC curve analysis was twofold: to provide a third side-by-side comparison of the association between each adiposity measure and each cardiometabolic outcome as well as to provide suggested cutoff values for each adiposity measure in predicting each cardiometabolic outcome. A series of plots of sensitivity versus 1–specificity were constructed for each adiposity measure paired with each cardiometabolic outcome. As before, the adiposity measures used were the continuous variables of BMI, waist circumference and waist-to-height ratio. The cardiometabolic outcomes were the dichotomous variables of hyperglycemia, hypertension and hypercholesterolemia as described above.

**COVARIATES**

The covariate of age was accounted for in the linear regression and the logistic regression analyses. Age was kept as a continuous variable in years and was included in each linear regression model and each logistic regression model. Additionally, the covariate of
gender was accounted for by stratifying the results of linear regression, logistic regression and ROC curve analysis by gender.

**DATA ANALYSIS**

All data analysis was performed using Statistical Analysis Software® v9.1.3 for Windows (SAS Institute, Cary, NC) and MedCalc® Software v11.5.1 (MedCalc Software bvba, Gent, Belgium). An alpha level of 0.05 was used to determine statistical significance in all analyses.

To describe the characteristics of the dataset and evaluate differences between the genders, a univariate analysis was performed on each variable for the total sample and separately for both genders. Significant differences between genders were determined using two-sample, unpaired Student’s t-tests for continuous variables and using chi-square tests for dichotomous variables. Because of the departure from normality of the fasting blood glucose and cholesterol, two-sided Wilcoxon-Mann-Whitney tests were used to determine statistical differences between genders for these two variables.

The purpose of the linear regression analysis was to compare the strengths of association between each continuous risk factor and each continuous outcome, after adjusting for age. Using `PROC STANDARD` in SAS®, the adiposity measures BMI, waist circumference and waist-to-height ratio were standardized to a mean of zero and a standard deviation of one before proceeding with each linear regression analysis. By standardizing the adiposity measures, each risk factor could be compared to the outcome on the same scale. Then, using `PROC REG` in SAS®, a series of linear regressions was performed for each adiposity measure paired with each outcome: log glucose, mean arterial pressure or log cholesterol. Individual hypothesis testing was performed by evaluating the p-values of the beta coefficients for the adiposity measure in each model. Comparison between adiposity measures was evaluated from overlap between the 95% confidence intervals of the beta coefficients. The r-square values (coefficients of determination) from each model were also compared. These values indicate the amount of variability in the model due to the association of the independent variables with the outcome, after accounting for the variability that each variable alone contributed to the model. The linear regression analysis was performed for both genders combined and then repeated separately for men and for women.
The logistic regression analysis was performed to compare the strengths of association between each risk factor and each dichotomous outcome, after adjusting for age. Again, the standardized measures of adiposity were used with a mean of zero and a standard deviation of one to allow for side-by-side comparisons on an equal scale. Using PROC LOGISTIC in SAS®, a series of models was constructed to evaluate each adiposity measure paired with each dichotomous outcome: hyperglycemia, hypertension or hypercholesterolemia. The odds ratio, the 95% confidence interval of the odds ratio and the p-value of the odds ratio from each model were compared. Comparison between adiposity measures was evaluated from overlap between the 95% confidence intervals of the odds ratios. This series of tests was performed for both genders combined as well as separately for men and women, using standardized adiposity measures. The fit of each model was assessed using the Hosmer-Lemeshow goodness-of-fit test.

In the receiver operating characteristic (ROC) curve analysis, each adiposity measure was plotted to determine its optimal cutoff value and how well it predicted each dichotomous outcome: hyperglycemia, hypertension or hypercholesterolemia. The ROC curve analysis was chosen from the MedCalc® ROC curve menu, and the options were selected for the DeLong et al. methodology and to list the criterion values with test characteristics. Results included the area under the curve (AUC), the p-value and 95% confidence interval for the AUC, and the coordinates of each plot with the corresponding sensitivity and specificity. Each ROC plot was constructed with 1–specificity on the x-axis and sensitivity on the y-axis. An AUC of 1.0 indicated that the adiposity measure was a perfect predictor of the outcome, and an AUC of 0.5 indicated the adiposity measure was not significantly different from chance in predicting the outcome. To compare the adiposity measures with one another, a combined plot was constructed for each cardiometabolic outcome using the ‘Comparison of ROC curves’ option from the ROC analysis menu, again selecting the DeLong et al. methodology. Results included the 95% confidence interval and p-value of the difference between the AUCs for each pair of adiposity measures. This series of tests was performed for both genders combined as well as separately for men and women.

The optimal cutoff values were derived from the point of intersection of the lines of sensitivity and 1–specificity. This point of intersection identified the adiposity measure value with the maximum number of true positives and true negatives. Thus, the optimal cutoff
value was determined where sensitivity most closely equaled specificity, and this value was
determined from the coordinates of the ROC curve. The average cutoff value of each
adiposity measure was applied to the sample to calculate the sensitivity, specificity, positive
predictive value and negative predictive value for predicting at least one of the study’s
cardiometabolic outcomes. The sensitivity was calculated as the number of observations
above the adiposity measure cutoff with the outcome (true positives) divided by the total
number of observations with the outcome. The specificity was calculated as the number of
observations below the adiposity measure cutoff without the outcome (true negatives)
divided by the number of observations without the outcome. The positive predictive value
was calculated as the number of true positives divided by the total number of observations
above the adiposity measure cutoff. The negative predictive value was calculated as the
number of true negatives divided by the total number of observations below the adiposity
measure cutoff. These calculations were made for the entire sample and for men and women
separately.
CHAPTER 4

RESULTS

A total of 266 participants met the inclusion criteria for this study. The sample was comprised of significantly more females than males (p<0.0001), with 168 women (63.2%) and 98 men (36.8%). The mean age for the entire sample was 42.2 years (SD=13.6 years) and was similar for men versus women. For the entire sample, the average weight was 75.5 kilograms (166 pounds), the average height was 160 centimeters (5 feet and 3 inches) and the average waist circumference was 89.7 centimeters (35.3 inches). The mean BMI was 29.5 kg/m² and the mean waist-to-height ratio was 0.562. On average, the men were significantly taller than the women (p<0.0001); despite this, the women had a significantly higher weight (p<0.0001) and BMI (p=0.0210) than the men. While the mean waist circumferences were not significantly different across genders (90.1 centimeters, 35.5 inches, for the women and 89.0 centimeters, 35.0 inches, for the men), the women’s mean waist-to-height ratio was significantly higher than the men’s (p<0.0001) due to the differences in height.

While the average fasting blood glucose level was 99.9 mg/dL, only approximately 30% of the total sample had a fasting blood glucose level of at least 100 mg/dL and were considered hyperglycemic. The positive skewness of the blood glucose variable was mitigated by log transforming the blood glucose for the linear regression analysis. The average blood pressure was 123/78 mmHg, and approximately 28% of the total sample was considered hypertensive with a systolic blood pressure of at least 140 mmHg and/or a diastolic blood pressure of at least 90 mmHg. The average fasting blood cholesterol level was 204 mg/dL, and roughly 52% of the entire sample had hypercholesterolemia as evidenced by a blood cholesterol level of at least 200 mg/dL. On average, these characteristics were not significantly different between the genders. Table 1 contains demographic characteristics of the study population for the entire sample and by gender.
Table 1. Characteristics of a Sample of Mexican Adults Attending a Community Health Event in Tecate, México between 2005 and 2009

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Total Sample (n=266)</th>
<th>Men (n=98)</th>
<th>Women (n=168)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>42.2 (13.6)</td>
<td>42.5 (13.5)</td>
<td>42.1 (13.8)</td>
<td>0.8024 §</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>75.5 (14.6)</td>
<td>80.1 (13.9)</td>
<td>72.7 (14.3)</td>
<td>&lt;0.0001 §</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>160 (9.0)</td>
<td>167 (8.04)</td>
<td>156 (6.55)</td>
<td>&lt;0.0001 §</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>29.45 (5.37)</td>
<td>28.5 (4.17)</td>
<td>30.0 (5.90)</td>
<td>0.0210 §</td>
</tr>
<tr>
<td>Waist circumference (cm)</td>
<td>89.7 (16.1)</td>
<td>89.0 (15.5)</td>
<td>90.1 (16.4)</td>
<td>0.5707 §</td>
</tr>
<tr>
<td>Waist-to-height ratio</td>
<td>0.562 (0.10)</td>
<td>0.532 (0.09)</td>
<td>0.580 (0.11)</td>
<td>&lt;0.0001 §</td>
</tr>
<tr>
<td>Glucose (mg/dL)</td>
<td>99.9 (32.8)</td>
<td>100.7 (38.7)</td>
<td>99.4 (28.9)</td>
<td>0.6113 ‡</td>
</tr>
<tr>
<td>% hyperglycemia</td>
<td>81 (30.4%)</td>
<td>30 (30.6%)</td>
<td>51 (30.4%)</td>
<td>0.9652 †</td>
</tr>
<tr>
<td>SBP (mmHg)</td>
<td>122.6 (18.6)</td>
<td>123.5 (17.0)</td>
<td>122.1 (19.5)</td>
<td>0.5713 §</td>
</tr>
<tr>
<td>DBP (mmHg)</td>
<td>78.3 (11.0)</td>
<td>79.9 (10.2)</td>
<td>77.3 (11.3)</td>
<td>0.0605 §</td>
</tr>
<tr>
<td>MAP (mmHg)</td>
<td>93.1 (12.4)</td>
<td>94.4 (10.9)</td>
<td>92.2 (13.2)</td>
<td>0.1648 §</td>
</tr>
<tr>
<td>% hypertension</td>
<td>77 (28.9%)</td>
<td>29 (29.6%)</td>
<td>48 (28.6%)</td>
<td>0.8595 †</td>
</tr>
<tr>
<td>Cholesterol (mg/dL)</td>
<td>204.1 (57.2)</td>
<td>199.7 (61.7)</td>
<td>206.6 (54.5)</td>
<td>0.1879 ‡</td>
</tr>
<tr>
<td>% with high cholesterol</td>
<td>137 (51.5%)</td>
<td>44 (44.9%)</td>
<td>93 (55.4%)</td>
<td>0.0997 †</td>
</tr>
</tbody>
</table>

Notes: Hyperglycemia is a fasting blood glucose ≥ 100 mg/dL, SBP is systolic blood pressure, DBP is diastolic blood pressure, MAP is mean arterial pressure calculated as DBP + 1/3(SBP-DBP), hypertension is an SBP ≥ 140 and/or a DBP ≥ 90 and high cholesterol is a blood cholesterol ≥ 200mg/dL. p-values for the difference between genders calculated using: § two-sample, unpaired Student’s t-test, ‡ two-sided Wilcoxon-Mann-Whitney test normal approximation, † chi-square test

LINEAR REGRESSION RESULTS

The linear regression analysis resulted in two statistical values with which to compare the strengths of association between each adiposity measure and each cardiometabolic outcome: the r-square (coefficient of determination) values, seen in Table 2, and the beta coefficient values along with their corresponding 95% confidence intervals, shown in Table 3. The side-by-side comparison of the r-square values from each set of analyses showed that, with two exceptions, BMI was more strongly associated with each outcome than either waist circumference or waist-to-height ratio. Both of the exceptions to this were regarding log
Table 2. Coefficients of Determination (r-Square Values) from a Linear Regression of Adiposity Measures on Cardiometabolic Outcomes in a Sample of Mexican Adults Attending a Community Health Event in Tecate, México between 2005 and 2009

<table>
<thead>
<tr>
<th>Coefficient of Determination (r-square)</th>
<th>log Blood Glucose</th>
<th>Mean Arterial Pressure</th>
<th>log Blood Cholesterol</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total sample (n=266)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BMI</td>
<td>0.0309</td>
<td>0.272</td>
<td>0.0799</td>
</tr>
<tr>
<td>WC</td>
<td>0.0346</td>
<td>0.262</td>
<td>0.0625</td>
</tr>
<tr>
<td>WHtR</td>
<td>0.0371</td>
<td>0.259</td>
<td>0.0626</td>
</tr>
<tr>
<td><strong>Men (n=98)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BMI</td>
<td>0.1071</td>
<td>0.180</td>
<td>0.0996</td>
</tr>
<tr>
<td>WC</td>
<td>0.0493</td>
<td>0.170</td>
<td>0.0792</td>
</tr>
<tr>
<td>WHtR</td>
<td>0.0836</td>
<td>0.167</td>
<td>0.0796</td>
</tr>
<tr>
<td><strong>Women (n=166)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BMI</td>
<td>0.0452</td>
<td>0.338</td>
<td>0.0690</td>
</tr>
<tr>
<td>WC</td>
<td>0.0531</td>
<td>0.325</td>
<td>0.0566</td>
</tr>
<tr>
<td>WHtR</td>
<td>0.0505</td>
<td>0.326</td>
<td>0.0574</td>
</tr>
</tbody>
</table>

Note: All analyses were adjusting for age. BMI (body mass index), WC (waist circumference) and WHtR (waist-to-height ratio) were standardized to mean=0 and standard deviation=1. log blood glucose was calculated from blood glucose in mg/dL, mean arterial pressure was in mmHg, and log blood cholesterol was calculated from blood cholesterol in mg/dL.

Blood glucose: in the entire sample, the waist-to-height ratio was the most strongly associated, and in women the waist circumference was most strongly associated with log blood glucose. However, overall the r-square values of all of the models showed fairly weak correlations between the adiposity measures and the outcomes, even after taking into account the log transformations of blood glucose and blood cholesterol. The highest r-square value observed was 0.338, resulting from the model with women’s BMI and mean arterial pressure. For this model, the r-square value can be interpreted as approximately 34% of the variation in women’s mean arterial pressure can be explained by BMI and age together.

An evaluation of the beta coefficients from the linear regression models revealed mixed results. Looking at the entire sample, each cardiometabolic outcome had different adiposity measures that were significantly associated with it, if only marginally. BMI was significantly associated with mean arterial pressure and marginally associated with log blood cholesterol. Waist circumference was marginally associated with log blood glucose and marginally associated with mean arterial pressure. Waist-to-height ratio was marginally
Table 3. Results from a Linear Regression of Adiposity Measures on Cardiometabolic Outcomes in a Sample of Mexican Adults Attending a Community Health Event in Tecate, México between 2005 and 2009

<table>
<thead>
<tr>
<th>Total sample (n=266)</th>
<th>log Blood Glucose</th>
<th>Mean Arterial Pressure</th>
<th>log Blood Cholesterol</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMI</td>
<td>0.0285 (-0.001, 0.058)</td>
<td>1.851* (0.563, 3.139)</td>
<td>0.0378* (0.005, 0.071)</td>
</tr>
<tr>
<td>WC</td>
<td>0.0325* (0.003, 0.062)</td>
<td>1.389* (0.077, 2.703)</td>
<td>0.00425 (-0.030, 0.038)</td>
</tr>
<tr>
<td>WHtR</td>
<td>0.0350* (0.005, 0.065)</td>
<td>1.218 (-0.105, 2.541)</td>
<td>0.00478 (-0.029, 0.039)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Men (n=98)</th>
<th>log Blood Glucose</th>
<th>Mean Arterial Pressure</th>
<th>log Blood Cholesterol</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMI</td>
<td>0.0892* (0.037, 0.142)</td>
<td>2.016 (-0.017, 4.048)</td>
<td>0.0470 (-0.012, 0.106)</td>
</tr>
<tr>
<td>WC</td>
<td>0.0629* (0.007, 0.119)</td>
<td>1.758 (-0.368, 3.884)</td>
<td>0.0182 (-0.044, 0.080)</td>
</tr>
<tr>
<td>WHtR</td>
<td>0.0823* (0.027, 0.138)</td>
<td>1.676 (-0.461, 3.813)</td>
<td>0.0194 (-0.043, 0.082)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Women (n=166)</th>
<th>log Blood Glucose</th>
<th>Mean Arterial Pressure</th>
<th>log Blood Cholesterol</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMI</td>
<td>0.0056 (-0.029, 0.040)</td>
<td>2.097* (0.447, 3.746)</td>
<td>0.0309 (-0.010, 0.072)</td>
</tr>
<tr>
<td>WC</td>
<td>0.0212 (-0.013, 0.056)</td>
<td>1.522 (-0.147, 3.191)</td>
<td>-0.0055 (-0.046, 0.036)</td>
</tr>
<tr>
<td>WHtR</td>
<td>0.0178 (-0.017, 0.053)</td>
<td>1.543 (-0.140, 3.227)</td>
<td>-0.0096 (-0.051, 0.032)</td>
</tr>
</tbody>
</table>

Note: All analyses were adjusting for age. BMI (body mass index), WC (waist circumference) and WHtR (waist-to-height ratio) were standardized to mean=0 and standard deviation=1. log blood glucose calculated from glucose in mg/dL, mean arterial pressure in mmHg, log blood cholesterol calculated from cholesterol in mg/dL. * p-value < 0.05 for beta coefficient.
associated with log blood glucose. However, upon limiting the analyses by gender, some of those associations disappeared. Of all the outcomes for women, only BMI was significantly associated with mean arterial pressure and no adiposity measure was significantly associated with either log blood glucose or log blood cholesterol. For men, all three adiposity measures were moderately significantly associated with log blood glucose; BMI and waist-to-height ratio were more strongly associated than waist circumference but not significantly so. However, none of the adiposity measures were significantly associated with mean arterial pressure or log blood cholesterol. The highest beta coefficient observed was 2.097, resulting from the model with women’s BMI and mean arterial pressure. For this model, the beta coefficient can be interpreted as after adjusting for age, there was an average increase of 2.1 mmHg in women’s mean arterial pressure with each one-unit increase in standardized BMI, or with each 5.91 kg/m² increase in BMI.

As seen in Figure 2, a side-by-side inspection of the 95% confidence intervals for the beta coefficients shows graphically that all of the 95% confidence intervals of the adiposity measures overlap. This suggests that none of the adiposity measures are significantly more strongly associated to each outcome than the others. However, the adiposity measures were only marginally associated or less with the outcomes.

**LOGISTIC REGRESSION RESULTS**

The logistic regression analysis resulted in odds ratios and corresponding 95% confidence intervals that were used to compare the strengths of association between each adiposity measure and each cardiometabolic outcome, as seen in Table 4. A Hosmer-Lemeshow test was conducted to evaluate the fit of each logistic regression model. In all models, the test was not significant, indicating that each model was not a bad fit. The lowest p-value for these tests was 0.1048.

Like the linear regression results, an evaluation of the odds ratios and corresponding 95% confidence intervals produced mixed results. Upon evaluating the entire sample, BMI was marginally associated with hypercholesterolemia and all three adiposity measures were marginally associated with hyperglycemia and hypertension each. Upon evaluating the men separately, only BMI was marginally associated with hypercholesterolemia and no adiposity measure was significantly associated with either hyperglycemia or hypertension. For the
Figure 2. Beta coefficients and 95% confidence intervals from a linear regression of adiposity measures on cardiometabolic outcomes in a sample of Mexican adults attending a community health event in Tecate, México between 2005 and 2009. Note: BMI is body mass index in kg/m², WC is waist circumference in centimeters, WHtR is waist-to-height ratio (unitless). Error bars are 95% confidence intervals of the beta coefficients. All models were adjusted for age.
Table 4. Results from a Logistic Regression of Adiposity Measures on Cardiometabolic Outcomes in a Sample of Mexican Adults Attending a Community Health Event in Tecate, México between 2005 and 2009

<table>
<thead>
<tr>
<th></th>
<th>Hyperglycemia</th>
<th>Hypertension</th>
<th>Hypercholesterolemia</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total sample</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(n=266)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BMI</td>
<td>1.368* (1.051, 1.781)</td>
<td>1.501* (1.099, 2.051)</td>
<td>1.332* (1.030, 1.723)</td>
</tr>
<tr>
<td>WC</td>
<td>1.356* (1.029, 1.788)</td>
<td>1.395* (1.002, 1.943)</td>
<td>1.043 (0.814, 1.337)</td>
</tr>
<tr>
<td>WHtR</td>
<td>1.397* (1.060, 1.842)</td>
<td>1.407* (1.014, 1.950)</td>
<td>1.070 (0.833, 1.373)</td>
</tr>
<tr>
<td><strong>Men</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(n=98)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BMI</td>
<td>1.538 (0.797, 2.415)</td>
<td>1.519 (0.895, 2.575)</td>
<td>1.726* (1.086, 2.742)</td>
</tr>
<tr>
<td>WC</td>
<td>1.301 (0.812, 2.083)</td>
<td>1.255 (0.713, 2.208)</td>
<td>1.298 (0.838, 2.009)</td>
</tr>
<tr>
<td>WHtR</td>
<td>1.521 (0.934, 2.479)</td>
<td>1.301 (0.735, 2.304)</td>
<td>1.305 (0.842, 2.023)</td>
</tr>
<tr>
<td><strong>Women</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(n=168)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BMI</td>
<td>1.357 (0.969, 1.899)</td>
<td>1.554* (1.039, 2.324)</td>
<td>1.178 (0.859, 1.616)</td>
</tr>
<tr>
<td>WC</td>
<td>1.472* (1.037, 2.091)</td>
<td>1.520* (1.001, 2.308)</td>
<td>0.934 (0.684, 1.276)</td>
</tr>
<tr>
<td>WHtR</td>
<td>1.424* (1.005, 2.019)</td>
<td>1.519* (1.006, 2.294)</td>
<td>0.921 (0.672, 1.261)</td>
</tr>
</tbody>
</table>

Note: All analyses were adjusting for age. BMI (body mass index), WC (waist circumference) and WHtR (waist-to-height ratio) were standardized to mean=0 and standard deviation=1. Hyperglycemia was defined as a fasting blood glucose > 100 mg/dL, hypertension was a systolic blood pressure > 140 and/or a diastolic blood pressure > 90 and hypercholesterolemia was a fasting blood cholesterol > 200mg/dL. * p-value < 0.05
women, only waist circumference and waist-to-height were marginally associated with hyperglycemia and all three adiposity measures were marginally associated with hypertension. The highest odds ratio of all of the models was 1.729 for the association between BMI and hypercholesterolemia in men. This can be interpreted as after adjusting for age, the odds of men having a blood cholesterol level of at least 200 mg/dL were 1.73 times higher for each one-unit increase in standardized BMI, or for each 4.17 kg/m² increase in BMI.

Similar to the linear regression results, Figure 3 shows a side-by-side comparison of the 95% confidence intervals for the odds ratios. All of the 95% confidence intervals for the odds ratios of the adiposity measures overlapped. However, as with the linear regression results, the adiposity measures were only marginally associated or less with each of the cardiometabolic outcomes, and further stratifying by gender made little difference.

**ROC Curve Results**

The ROC curve analysis resulted in an area under the curve (AUC) value for each adiposity measure paired with each cardiometabolic outcome. The AUCs were then used to compare the adiposity measures side by side in their ability to predict each outcome. These comparisons also generated mixed results, as seen in Table 5. For the entire sample, waist circumference and waist-to-height ratio significantly predicted hyperglycemia and hypertension each, and BMI significantly predicted hyperglycemia and hypercholesterolemia each. For men, BMI significantly predicted hypercholesterolemia, and waist circumference and waist-to-height ratio each marginally predicted hypertension. For women, BMI and waist circumference significantly predicted hyperglycemia, while waist-to-height ratio significantly predicted hyperglycemia and hypertension each. A pairwise comparisons of AUC values showed that the AUC for BMI was significantly higher than the AUCs for waist circumference and waist-to-height ratio (p=0.0155 and p=0.0264, respectively) for predicting hypercholesterolemia in the entire sample. Additionally, the AUC for waist to height ratio was significantly higher than the AUC for waist circumference for predicting hypertension in the women (p=0.0075). Figures 4-6 show the series of ROC plots for the entire sample, for men only and for women only.
Figure 3. Odds ratios and 95% confidence intervals from a logistic regression of adiposity measures on cardiometabolic outcomes in a sample of Mexican adults attending a community health event in Tecate, México between 2005 and 2009. Notes: BMI is body mass index in kg/m2, WC is waist circumference in centimeters, WHtR is waist-to-height ratio (unitless). Error bars are 95% confidence intervals of the odds ratios. All models were adjusted for age.
Table 5. Results from a Receiver Operating Characteristic Curve Analysis of Adiposity Measures and Cardiometabolic Outcomes in a Sample of Mexican Adults Attending a Community Health Event in Tecate, México between 2005 and 2009

<table>
<thead>
<tr>
<th>Total sample (n=266)</th>
<th>Hyperglycemia</th>
<th>Hypertension</th>
<th>Hypercholesterolemia</th>
</tr>
</thead>
<tbody>
<tr>
<td>AUC</td>
<td>p-value</td>
<td>AUC</td>
<td>p-value</td>
</tr>
<tr>
<td>BMI</td>
<td>0.605</td>
<td>0.006</td>
<td>0.571</td>
</tr>
<tr>
<td>WC</td>
<td>0.592</td>
<td>0.017</td>
<td>0.608</td>
</tr>
<tr>
<td>WHtR</td>
<td>0.606</td>
<td>0.006</td>
<td>0.620</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Men (n=98)</th>
<th>Hyperglycemia</th>
<th>Hypertension</th>
<th>Hypercholesterolemia</th>
</tr>
</thead>
<tbody>
<tr>
<td>AUC</td>
<td>p-value</td>
<td>AUC</td>
<td>p-value</td>
</tr>
<tr>
<td>BMI</td>
<td>0.606</td>
<td>0.095</td>
<td>0.586</td>
</tr>
<tr>
<td>WC</td>
<td>0.564</td>
<td>0.311</td>
<td>0.627</td>
</tr>
<tr>
<td>WHtR</td>
<td>0.593</td>
<td>0.145</td>
<td>0.632</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Women (n=168)</th>
<th>Hyperglycemia</th>
<th>Hypertension</th>
<th>Hypercholesterolemia</th>
</tr>
</thead>
<tbody>
<tr>
<td>AUC</td>
<td>p-value</td>
<td>AUC</td>
<td>p-value</td>
</tr>
<tr>
<td>BMI</td>
<td>0.603</td>
<td>0.034</td>
<td>0.596</td>
</tr>
<tr>
<td>WC</td>
<td>0.608</td>
<td>0.027</td>
<td>0.597†</td>
</tr>
<tr>
<td>WHtR</td>
<td>0.614</td>
<td>0.019</td>
<td>0.629†</td>
</tr>
</tbody>
</table>

Note: AUC is area under the curve, BMI is body mass index in kg/m², WC is waist circumference in centimeters, and WHtR is waist-to-height ratio (unitless). Hyperglycemia was a fasting blood glucose > 100 mg/dL, hypertension was a systolic blood pressure > 140 and/or a diastolic blood pressure > 90 and hypercholesterolemia was a fasting blood cholesterol > 200mg/dL.
† or ‡ AUC values were significantly different (p<0.05).

The ROC curves were also used to derive optimal cutoff values for each adiposity measure paired with each cardiometabolic outcome. Table 6 shows the resulting adiposity measure cutoff values for each outcome and the average across all outcomes. The cutoff values across the cardiometabolic outcomes were all within 3% of each other, and the cutoff values across genders were all within 3% of each other except the waist-to-height ratio cutoff values of men were 6% different than those for women. The average BMI cutoff values were 28.5 kg/m² for men, 29.1 kg/m² for women and 28.8 kg/m² for both men and women. The average waist circumference cutoff values were 91.8 centimeters (36.1 inches) for men, 91.6 centimeters (36.1 inches) for women and 92.1 centimeters (36.3 inches) for both men and women. The average waist-to-height ratio cutoff values were 0.551 for men, 0.583 for women and 0.570 for both men and women.

These average cutoff values were then applied to the study sample to calculate their sensitivity, specificity and positive and negative predictive values for predicting at least one cardiometabolic outcome of hyperglycemia, hypertension or hypercholesterolemia. As seen in Table 7, the sensitivities of all three adiposity measures were roughly similar but low,
Figure 4. Results from receiver operating curve plots of adiposity measures predicting cardiometabolic outcomes in a sample of Mexican adults attending a community health event in Tecate, México between 2005 and 2009 (n=266).
Figure 5. Results from receiver operating curve plots of adiposity measures predicting cardiometabolic outcomes in a sample of Mexican men attending a community health event in Tecate, México between 2005 and 2009 (n=98).
Figure 6. Results from receiver operating curve plots of adiposity measures predicting cardiometabolic outcomes in a sample of Mexican women attending a community health event in Tecate, México between 2005 and 2009 (n=168).
Table 6. Optimal Cutoff Values of Adiposity Measures for Cardiometabolic Outcomes from a Receiver Operating Characteristic Curve Analysis in a Sample of Mexican Adults Attending a Community Health Event in Tecate, México between 2005 and 2009

<table>
<thead>
<tr>
<th></th>
<th>Hyperglycemia</th>
<th>Hypertension</th>
<th>Hypercholesterolemia</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BMI</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total sample</td>
<td>28.9</td>
<td>28.8</td>
<td>28.7</td>
<td>28.8</td>
</tr>
<tr>
<td>Men</td>
<td>28.6</td>
<td>28.6</td>
<td>28.3</td>
<td>28.5</td>
</tr>
<tr>
<td>Women</td>
<td>29.2</td>
<td>29.0</td>
<td>29.0</td>
<td>29.1</td>
</tr>
<tr>
<td><strong>WC</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total sample</td>
<td>91.8</td>
<td>92.5</td>
<td>91.2</td>
<td>91.8</td>
</tr>
<tr>
<td>Men</td>
<td>91.5</td>
<td>93.5</td>
<td>91.5</td>
<td>92.2</td>
</tr>
<tr>
<td>Women</td>
<td>91.8</td>
<td>91.8</td>
<td>91.2</td>
<td>91.6</td>
</tr>
<tr>
<td><strong>WHtR</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total sample</td>
<td>0.571</td>
<td>0.575</td>
<td>0.565</td>
<td>0.570</td>
</tr>
<tr>
<td>Men</td>
<td>0.550</td>
<td>0.556</td>
<td>0.548</td>
<td>0.551</td>
</tr>
<tr>
<td>Women</td>
<td>0.586</td>
<td>0.587</td>
<td>0.577</td>
<td>0.583</td>
</tr>
</tbody>
</table>

Note: Total sample n=266, men n=98, women n=168. Hyperglycemia was a fasting blood glucose > 100 mg/dL, hypertension was a systolic blood pressure > 140 and/or a diastolic blood pressure > 90 and hypercholesterolemia was a fasting blood cholesterol > 200mg/dL. BMI is body mass index in kg/m², WC is waist circumference in centimeters, and WHtR is waist-to-height ratio (unitless).

Table 7. Results of Adiposity Measure Cutoff Values Derived from an ROC Curve Analysis in Predicting at Least One Cardiometabolic Risk Factor in a Sample of Mexican Adults Attending a Community Health Event in Tecate, México between 2005 and 2009

<table>
<thead>
<tr>
<th></th>
<th>Cutoff</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
<th>PPV (%)</th>
<th>NPV (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BMI</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Sample</td>
<td>28.8</td>
<td>52</td>
<td>58</td>
<td>76</td>
<td>33</td>
</tr>
<tr>
<td>Men</td>
<td>28.5</td>
<td>45</td>
<td>63</td>
<td>71</td>
<td>36</td>
</tr>
<tr>
<td>Women</td>
<td>29.1</td>
<td>56</td>
<td>55</td>
<td>78</td>
<td>30</td>
</tr>
<tr>
<td><strong>WC</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Sample</td>
<td>91.8</td>
<td>55</td>
<td>66</td>
<td>80</td>
<td>37</td>
</tr>
<tr>
<td>Men</td>
<td>92.2</td>
<td>53</td>
<td>69</td>
<td>78</td>
<td>42</td>
</tr>
<tr>
<td>Women</td>
<td>91.6</td>
<td>48</td>
<td>68</td>
<td>81</td>
<td>32</td>
</tr>
<tr>
<td><strong>WHtR</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Sample</td>
<td>0.570</td>
<td>54</td>
<td>67</td>
<td>80</td>
<td>37</td>
</tr>
<tr>
<td>Men</td>
<td>0.551</td>
<td>45</td>
<td>75</td>
<td>79</td>
<td>40</td>
</tr>
<tr>
<td>Women</td>
<td>0.583</td>
<td>58</td>
<td>61</td>
<td>81</td>
<td>34</td>
</tr>
</tbody>
</table>

Note: BMI is body mass index in kg/m², WC is waist circumference in centimeters, and WHtR is waist-to-height ratio (unitless). Total sample n=266, men n=98, women n=168. PPV is positive predictive value, NPV is negative predictive value

ranging from 45% to 58%. The specificities were modestly higher for waist circumference (68% to 69%) than for BMI (55% to 63%), and were somewhat high for waist-to-height ratio (61% for women, 75% for men and 67% for the entire sample). The positive predictive values were moderately high, ranging from 71 to 81%, and the negative predictive values were rather low, ranging from 30 to 42%.
CHAPTER 5
DISCUSSION

The overarching purpose of this study was to compare three measures of adiposity in their association with select cardiometabolic outcomes. Body mass index, waist circumference and waist-to-height ratio were compared in a side-by-side manner to ascertain if the three measures were similar, independent predictors of hyperglycemia, hypertension and hypercholesterolemia. The results neither upheld nor disproved this. Although there was generally no significant difference between the adiposity measures in their association with these outcomes, the adiposity measures themselves were not strongly enough associated with the outcomes to conclude that they were statistically similar.

This study tested two hypotheses; the first was that waist circumference and waist-to-height ratio would perform at least as well as BMI in predicting one or more cardiometabolic outcome. Both the linear regression and logistic regression analyses yielded mixed results and failed to support this hypothesis consistently. In all but two models, the adiposity measures were not significantly associated or only marginally associated with the cardiometabolic outcomes, after adjusting for age. The only exceptions to this were the associations between blood glucose and BMI and waist-to-height ratio in men and the associations between BMI and mean arterial pressure in women and in the entire sample. Contrary to the hypothesis, BMI tended to perform marginally better than either waist circumference or waist to height ratio as far as being associated with the outcomes, but the lack of strong associations precluded significant findings regarding this apparent trend.

The ROC curve analysis similarly produced mixed results that failed to support the first hypothesis. Pairwise comparisons of the adiposity measures performed for each cardiometabolic outcome showed no significant difference in the ability to predict the outcome except for women—the waist-to-height ratio was a significantly better predictor of hypertension than waist circumference alone. However, the adiposity measures in general were not consistently strong predictors of the outcomes, which also precluded significant findings of trends.
The second hypothesis was that the optimal cutoff values for BMI, waist circumference and waist-to-height ratio derived from this study would differ from published values for the general public or, if available, for the Mexican population. Overall, this hypothesis was not supported. The cutoff values used by the CDC and the WHO for defining pre-obesity and obesity in the general public are 25 and 30 kg/m², respectively (CDC 2010b, WHO 2010b). Additionally, research in Mexican populations has suggested BMI cutoff values ranging from 25.9 to 30.4 kg/m² when looking at cardiometabolic outcomes. The BMI cutoff values proposed by this study to identify at least one cardiometabolic outcome were 28.5 kg/m² for men and 29.1 kg/m² for women. These values are within the range of cutoff values from previous studies, although they lie on the high end of the published range. They are also within the range published by the CDC and WHO, although they are nearer the high end of this range as well.

The published range for waist circumference cutoff values to identify abdominal obesity is 90 to 102 centimeters (35.4 to 40.2 inches) for Mexican men and 80 to 88 centimeters (31.5 to 34.6 inches) for Mexican women (Rojas et al., 2010). Additionally, previous studies in Mexicans and Mexican-Americans evaluating waist circumference in predicting cardiometabolic outcomes found cutoff measures ranging from 90 to 98 centimeters (35.4 to 38.6 inches) for men and 84 to 99 centimeters (33.1 to 39.0 inches) for women. Interestingly enough, the optimal waist circumference cutoff values derived from this study for predicting at least one cardiometabolic risk were quite similar between the genders: 92.2 centimeters (36.3 inches) for men and 91.6 centimeters (36.1 inches) for women. For predicting at least one cardiometabolic risk factor, the men’s optimal waist circumference cutoff value derived from this study was within the range of published values and recommendations. However, for women the waist circumference cutoff value derived from this study was higher than the cutoff values published by the AHA/NHLBI, NCEP ATP III and IDF but similar to the cutoff values from previous studies.

Only recently being evaluated as a measure for determining obesity or screening for health risk, the waist-to-height ratio has relatively few published studies identifying cutoff values, and no cutoff values have been formally published by an organization or association. Published research by Ashwell (2009) suggests a cutoff in both genders of 0.5 for pre-obesity/at risk for obesity and 0.6 for obesity. Two other studies identified optimal cutoff
values for waist-to-height ratio as 0.53 for Mexican adults, 0.624 for Mexican-American men and 0.677 for Mexican-American women (Berber et al., 2001; Diaz et al., 2007). The results from this study yielded an optimal cutoff of 0.551 for men and 0.583 for women, suggesting that in a Mexican population, applying the same cutoff to both genders may not be beneficial. These cutoff values were much lower than those identified by Diaz et al. but were within the range suggested by Ashwell.

The low sensitivities and negative predictive values associated with this study’s suggested cutoff values indicate that more research may be needed in determining adiposity measure optimal cutoff values for predicting cardiometabolic risk in Mexican adults. According to one researcher, “AUCs of 0.6–0.7 are considered poor and 0.7–0.8 are fair” in their predictive ability (Shiwaku et al., 2005, p. 57). The results from the ROC analysis in this study did not indicate that the adiposity measures were strong predictors of cardiometabolic risks; the largest AUC was 0.634.

**Strengths**

The two biggest strengths of this study were the approach of using more than one type of analysis and the ability to evaluate the adiposity measures in a side-by-side fashion for three different cardiometabolic outcomes in a Mexican population. Some preceding studies in Mexican adults were limited to one type of analysis, such as receiver operating characteristics curve analysis. Other studies limited the comparison of adiposity measures to only one outcome, such as diabetes. This study looked at three outcomes thought to be related to metabolic disease, and used a multifactorial approach in comparing the adiposity measures.

**Limitations**

This study had several limitations, the most prominent of which was the use of existing data that was collected for purposes other than epidemiological analyses. This likely led to the large quantity of missing data, which in turn led to a relatively small sample size and a reduced statistical power, especially for the men subsample. For example, in 2007 the blood glucometers were malfunctioning so the fasting blood glucose was not measured that year for any participant. Out of 827 unique observations for adults, only 266 ended up being
included in the analysis. There was not enough data on the excluded observations to
determine if and how they were different from the included observations.

The source of the data also led to a few potential sources of information bias. The
group of volunteers who staffed the community health event each year may not have received
consistent training in measuring, collecting and recording data. Also, the one-day session to
train volunteers may have varied each year. Furthermore, the volunteers’ skill levels may
have varied each year, especially if different volunteers participated from year to year. These
situations may have led to measurement biases. Different instruments and equipment for
measuring biological and anthropometric data may have been used at each yearly event,
possibly with different calibrations, leading to possible instrument biases. Data was not
gathered on education level, socioeconomic factors, dietary habits, and other attributes which
may act as effect modulators and/or confounders to affect the relationship between obesity
status and cardiometabolic risk factors. Possibilities for misclassification biases were present;
the participants themselves may not have adequately fasted, or may not have realized that
fasting included abstaining from beverages with sugars in them, such as fruit juices. The
‘white coat hypertension’ phenomenon may have occurred, where an individual was so
anxious about having a clinical evaluation that this anxiety itself elevated the blood pressure.

Another significant limitation of this study was that medical and pharmacotherapeutic
histories were not collected from participants. Thus, an individual may have been previously
diagnosed with hypertension and possibly taking medications to control the condition at the
time of data collection. This type of misclassification bias would have yielded a lower
cardiometabolic risk than might have been expected based on the anthropomorphic data of
that individual and would have skewed the results toward the null. Alternatively, a
participant may have been taking a pharmaceutical treatment that increased blood sugar,
blood lipids or blood pressure, such as certain antipsychotics and steroids. This type of
misclassification bias would have elevated the measured cardiometabolic risk more than
would be expected from the anthropometric measurements and would have biased the results
away from the null. These situations also would have affected the positive and negative
predictive values calculated from the cutoff values, since they are affected by disease
prevalence in the sample. Additionally, information regarding comorbidities, pregnancy
status and familial medical history was absent, all of which may have affected measures of cardiometabolic risk factors and measures of obesity.

Other limitations pertained to sampling methodology. There was a large volunteer bias in this study; individuals who attended the community health fairs and agreed to have their measurements recorded likely had a higher interest in nutrition, fitness and/or health than the general community. Conversely, the sample may have been disproportionately composed of individuals who were pre-obese or obese, didn’t know much about nutrition or health and wanted to learn. Thus, the study sample may not have been very representative of Mexicans living in a border community, which would decrease external validity. One of the assumptions of the study is that all participants were ethnic Mexicans. Information regarding nationality and ethnicity was not collected, so this assumption could not be measured or evaluated. There may have been attendees who were not residents of México or of Latino ethnicity. Furthermore, the age distribution of the analytic sample was skewed; there were only eighteen adults younger than 25 years old included in the analysis, suggesting that the event may have appealed to a certain subset of the population. There were not enough individuals who attended multiple annual events to perform a meaningful time-series or cohort-style analysis, so this study used a cross-sectional design even though data was collected yearly over five years.

**Conclusions**

Had the results of this study been more significant and more consistent, this study would have been a valuable addition to the growing volume of literature comparing adiposity indices and cardiometabolic outcomes in Latino populations. More research is still needed to evaluate and compare different adiposity measures in their ability to screen for cardiovascular and metabolic risk factors across nationalities and ethnicities. To a limited degree, the cutoff values derived from this study can contribute to building evidence for cutoff value ranges of adiposity measures specific for Mexican adults. Future studies with sound epidemiological methods are needed to derive optimal adiposity cutoff measures for different nationalities and ethnic groups.
REFERENCES


Lee, M., Entzminger, L., Lohsoonthorn, V., & Williams, M. A. (2006). Risk factors of hypertension and correlates of blood pressure and mean arterial pressure among patients receiving health exams at the Preventive Medicine Clinic, King Chulalongkorn Memorial Hospital, Thailand. *Journal of the Medical Association of Thailand, 89*(8), 1213-1221.


