Summer 2016

The Waist to Height Ratio is a Better Anthropometric Index of Abdominal Obesity and its Association with the Prevalence of Diabetes Among Asian Americans

Yu Xiao
Central Washington University, xiaoyu@cwu.edu

THE WAIST TO HEIGHT RATIO IS A BETTER ANTHROPOMETRIC INDEX OF ABDOMINAL OBESITY AND ITS ASSOCIATION WITH THE PREVALENCE OF DIABETES AMONG ASIAN AMERICANS

A Thesis

Presented to

The Graduate Faculty

Central Washington University

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

Nutrition

---

by

Yu Xiao

July 2016

CENTRAL WASHINGTON UNIVERSITY

Graduate Studies

We hereby approve the thesis of

Yu Xiao

Candidate for the degree of Master of Science

APPROVED FOR THE GRADUATE FACULTY

_____ _____
Dr. David Gee, Committee Chair

_____ _____
Dr. Nicole Stendell-Hollis

_____ _____
Dr. Cen Tsong Lin

_____ _____
Dean of Graduate Studies

ABSTRACT

THE WAIST TO HEIGHT RATIO IS A BETTER ANTHROPOMETRIC INDEX OF ABDOMINAL OBESITY AND ITS ASSOCIATION WITH THE PREVALENCE OF DIABETES AMONG ASIAN AMERICANS

by

Yu Xiao

July 2016

There is limited information about diabetes prevalence among Asian Americans. Diabetes risk factors include abdominal obesity (AO), which can be assessed by measuring waist circumference (WC) or waist-to-height-ratio (WHtR). The purpose of this study was to compare the prevalence of diabetes among Asians with non-Asians in the United States and compare WC and WHtR as predictors of diabetes. Data from the National Health and Nutrition Examination Survey (NHANES) 2011-14 was analyzed using SAS 9.2. There were 8,615 adult non-pregnant non-Asians and 1,224 Asians included in this study. Despite a lower prevalence of obesity among Asians compared to non-Asians (12% vs 38%, p<.001), Asians had a higher age-adjusted prevalence of diabetes (16% vs 11%, p<.001), particularly among normal (10% vs 3%) and overweight Asians (20% vs 8%). The prevalence of AO assessed using WC was greater in non-Asians than Asians overall (58% vs 25%, p<.001) and among those with a normal weight (11% vs 5%, p<.001). In contrast, the AO prevalence assessed using WHtR produced higher rates in both non-Asians and Asians overall (79% vs 65%, p<.001), but a higher prevalence in Asians than non-Asians with normal BMI (51% vs 44%, p<.001). Among

normal weight Asians, AO assessed using WC accounted for just 12% of those with diabetes whereas using WHtR accounted for 93% of those with diabetes. Similarly, among non-Asians, AO assessed with WC accounted for 34% of normal weight diabetics while WHtR accounted for 73% of diabetics. This study is the first to confirm the greater prevalence of diabetes with laboratory measurements among US Asians in a nationally representative survey. The results of this study show that AO when assessed with WHtR but not WC explains the greater prevalence of diabetes among Asians, particularly in those with a normal BMI.

ACKNOWLEDGMENTS

I would like to express my appreciation to my mentor, Dr. David Gee, who was thoughtful, shared his expertise, and was supportive during my undergraduate and graduate studies. I appreciate his time and effort for helping me edit this thesis as well as teaching me how to use SAS computer programming, analyze the data, and interpret the results.

I would also like to thank my other committee professors: Dr. Nicole Stendell-Hollis and Dr. Cen Tsong Lin for their assistance on statistics, editing, and taking their valuable time out from their busy schedules for the proposal and oral defense meetings.

Lastly, I must also acknowledge my parents, Xueli Liu and Luokou Xiao, and my fiancé, Percy Moore. Without their encouragement, motivation, and supporting, I would not have been able to finish my B.S. and M.S. degrees in the United States.

TABLE OF CONTENTS

Chapter Page

I LITERATURE REVIEW ……....1

Introduction ……..……..1
Diabetes ……..……...3
Obesity ……..……....6
Abdominal Obesity ……..…..…..9
Weight-to-Height Ratio ……..…..……...12
National Health and Nutrition Examination Survey ……...14

REFERENCES ……....……..15

II THE WAIST TO HEIGHT RATIO IS A BETTER ANTHROPOMETRIC INDEX OF ABDOMINAL OBESITY AND ITS ASSOCIATION WITH THE PREVALENCE OF DIABETES AMONG ASIAN AMERICANS……..24

Abstract ……...25
Introduction ……..…..26
Methods ……..……..…..28
Results ……..…..30
Discussion ……..……..…..32
Conclusion ..……..…..36

REFERENCES ……....……...42

LIST OF TABLES

Table		Page
1	Characteristics of 10, 354 Subjects≥20 Years of Age by Race and Ethnicity, NHANES 2011-2014	38
2	Prevalence of Diabetes by Ethnicity and BMI Categories	39
3	Prevalence of Abdominal Obesity by WC and WHtR	40
4	Prevalence of Diabetes by Ethnicity, BMI Category, and Abdominal Obesity Assessments: WC and WHtR	41

CHAPTER I

LITERATURE REVIEW

Introduction

Over the last few decades, the population of Asian American have tripled from 1.4% to 5.4% between 1980-2014 (1,2). According to the United States Census Bureau, the Asian American population is estimated to reach 9.3% by 2060 (1). This ethnic group is comprised of Chinese, Filipino, Asian Indian, Vietnamese, Korean, Japanese, and others of Asian descent (3). Based on a recent report from the American Immigration Council, two-thirds of U.S. Asians are foreign born; therefore, international migration could be the driving force behind the increase among this ethnic group (4). Although the Asian population has been increasing rapidly in the U.S., there is limited research focused on the trends of major health issues among Asian Americans when compared to other ethnic groups.

The World Health Organization (WHO) stated that the prevalence of diabetes has doubled worldwide in the last decade (5). A few studies reported that Asian Americans have a higher risk of diabetes at lower body mass index (BMI) levels when compared to Caucasian counterparts (6,7). Obesity is the major contributor of the diabetes epidemic in the U.S. and internationally (5). Even though the prevalence of obesity is generally low in Asian populations, the rates of obesity and overweight have been increasing among Asian Americans, especially in younger generations who were born in the U.S. (8). BMI is a commonly used indicator for weight status, but it cannot reflect the lean body mass and may incorrectly estimate the weight category among athletes and seniors. Additionally,

WHO has been debating whether BMI cutoff points should be lower for Asian populations (9). Studies showed that diabetes and cardiovascular diseases are highly associated with abdominal obesity, which is a specific form of obesity (10,11).

Abdominal obesity is also called central obesity and identified as unhealthy apple shape. Asians tend to have larger amounts of intra-abdominal and visceral fat than Caucasians within similar BMI levels (12,13). Abdominal obesity is usually assessed by the waist circumference (WC) or waist-to-hip ratio (WHT); however, both measurements have disadvantages. For example, WC cannot accurately distinguish subcutaneous fat and visceral fat, while WHT may overestimate the amounts of visceral fat. Additionally, none of these measurements consider the differences between individuals' heights. Differences, such as body height or fat distribution, can influence the assessment for obesity and abdominal obesity among different ethnic groups. Waist-to-height ratio (WHtR), another measurement for assessing abdominal obesity, may be a better anthropometric index for detecting central obesity, because height is considered along with WC.

The purpose of this study was to compare the prevalence of diabetes among Asian Americans and Non-Asians as well as to evaluate whether WHtR is a better predictor of diabetes than WC among Asian Americans by using the National Health and Nutrition Examination Survey (NHANES) datasets from 2011-2014. The hypotheses of this study were:

1. The prevalence of diabetes is higher among Asian Americans when compared to Non-Asians.

2. WHtR cannot only assess abdominal obesity accurately but better screen and detect for diabetes.

Diabetes

Definition and Diagnosis

Diabetes mellitus is a complex metabolic disease that is characterized by a high fasted blood glucose level or dysglycemia. The body usually breaks down the carbohydrate in food into glucose after eating, and then the glucose will enter into the blood cells for energy use with the help of a hormone called insulin. However, if someone has diabetes, his or her body will either produce insufficient insulin or does not produce insulin at all. Therefore, the glucose level will accumulate in the blood stream and lead to an elevated blood glucose level. The risk factors that are highly associated with diabetes are race/ethnicity, age, family history, and other health conditions, such as abdominal obesity and hypertension (14). People with uncontrolled diabetes could develop some serious complications over time, including kidney failure, amputations, and heart disease.

There are different types of diabetes; however, the two major classifications defined by the American Diabetes Association (ADA) are type 1 and type 2 (14). Type 1 diabetes, which is developed genetically and irreversible, accounts for about 5% of total diagnosed diabetic cases in the U.S. (14,15). Patients with type 1 diabetes usually need insulin injections or an insulin pump because their body does not produce any insulin (15). The most prevalent cases of diabetes are type 2, which can be caused by different risk factors, such as low physical activity level and unhealthy eating pattern. If the

patients do not control their blood glucose levels by changing their lifestyles, they will gradually develop insulin resistance or insufficient insulin production (14). Some common signs and symptoms of type 2 diabetes include unintentional weight loss/gain, fatigue, and excessive hungry. There are several laboratory tests for diagnosing diabetes (14):

1. Hemoglobin A1c test: hemoglobin A1c (HbA1c) level equal to or above 6.5% over the past 3 months
2. Fasting plasma glucose test: fasting glucose level equal to or above 126mg/dl
3. Oral glucose tolerance test: the 2-hour glucose level equal to or above 200mg/dl

In this study, diabetes was classified if the subject's HbA1c level was above 6.5% or if he/she reported to be using insulin or oral hypoglycemic medications. The reason this study did not include fasting blood glucose level as the diagnostic criteria was due to the far smaller number of subjects with their blood values. When the NHANES program started collecting laboratory data, participants were asked to choose either the morning or afternoon sessions. The participants who came to the morning session would be required to fast, but only about 30% of them provided their fasting blood glucose level. Additionally, HbA1c is a primary laboratory test for diabetes. The World Health Organization International Expert Committee recommends the HbA1c test, especially for diagnosing type 2 diabetes, because it can reflect the average glucose level over the past 3 months and maybe more sensitive in detecting those with undiagnosed diabetes or prediabetes (16). The diabetes related questionnaires from NHANES program includes the following questions (17):

1. Have you ever been told by a doctor or health professional that you have diabetes or sugar diabetes?
2. Are you now taking diabetic pills to lower your blood sugar? Those are sometimes called oral or oral hypoglycemic agents.

There are other types of diabetes, such as gestational diabetes and impaired glucose tolerance (IGT). Gestational diabetes is usually diagnosed during the second or third trimester of pregnancy, while patients with IGT are referred to as having prediabetes (14,15). Prediabetes is a condition when someone has an abnormal blood glucose level that is above the normal value and near to the borderline of diabetes (15). Diabetes can be prevented and managed with healthy dietary eating patterns, physical activity, and oral hypoglycemic medications. According to WHO, diabetes is highly associated with increased WC and BMI (14).

Prevalence

The prevalence of diabetes has dramatically increased worldwide over the last decade. The National Diabetes Statistics report showed that the prevalence rates of diabetes and prediabetes increased about 5% among U.S. adults, and it was significantly higher among the younger age group whose BMI was normal in 2014 (15). The report also concluded that 9.3% of the total U.S. population has diabetes, and almost 30% diabetic patients are undiagnosed (15). Using National Health Interview Survey (NHIS) data from 1997-2008, Lee et al. reported on the prevalence of type 2 diabetes among Asian Americans (7). As pointed out in that article, although Asian Americans had a lower mean BMI, they were 40% more likely to have diabetes when compared with Caucasians (7). According to a regional study from the New York City area, Asian

Americans had the highest prevalence of prediabetes than non-Hispanic Whites, non-Hispanic Blacks, and Mexican Americans (18). Additionally, a study of Japanese immigrants stated that even though Japanese Americans had a lower prevalence of obesity, the rate of diabetes doubled when compared to their Caucasian counterparts (19).

Fujimoto et al. pointed out that the second generation of Japanese Americans who were diagnosed with diabetes tend to have higher amount of intra-abdominal fat (19). Body size and body composition could be the explanations for the higher prevalence of diabetes among U.S. Asians. Furthermore, acculturation factors of immigrants, such as dietary changes could influence one's weight status, cholesterol level, or blood glucose level (19). These results sparked an interest in uncovering the factors and predictors that may be highly associated with the increasing diabetes rate among Asian Americans.

Obesity

Prevalence and Definition

According to the WHO, the prevalence of obesity has almost doubled internationally over the last decade (20). Obesity has become a major health issue in the U.S. since the early 1960s (21). In 2010, about 36% of U.S. adults were obese, while almost 6% were extremely obese (21). Although the prevalence of obesity stayed stable in recent years, a significant increase were seen in U.S. men, non-Hispanic Black women, and Mexican American women (21,22). The National Institute of Diabetes and Digestive and Kidney Diseases stated that non-Hispanic Blacks had the highest obesity rate (49.5%), while approximately 39% of Mexican Americans were considered to be obese in 2009-2010 (22). The obesity prevalence was found to be lower among Asian

Americans when compared to other ethnic groups (23). Studies showed the U.S. born Asians tend to have a higher body weight and BMI than foreign-born Asians (23,24). Lauderdale and Rathouz reported that U.S. born women have more than 3 times the risk of being obese than foreign born women (24). There are many risk factors associated with obesity, such as the behavioral factors of sedentary lifestyle and unhealthy eating patterns.

The Physical Activity Guidelines for Americans (PAG) recommended that adults should maintain at least 150 minutes of moderate-intensity aerobic physical activity every week, while children and adolescents age 6-17 years old should exercise at least an hour each day (25). Although people know physical activity can help control body weight and improve the overall health, only 21% of U.S. adults meet the PAG recommendations (26). Additionally, the report from the HealthyPeople 2020 showed that Asian Americans and Mexican Americans were less likely to meet the PAG recommendations (17.5% vs 15.1 %, respectively) when compared to other ethnic groups (non-Hispanic Whites, Blacks) (27). According to the 2015-2020 Dietary Guidelines for Americans, a healthy eating pattern should include a variety of fruits and vegetables, whole grains, low-fat dairy, proteins, and oils (28). However, many people are following an unhealthy eating pattern, which includes high amounts of saturated fat, added sugar, and refined grains. The National Center for Health Statistics showed about 11% of U.S. adults consume nearly 12% of their total daily calories from fast food (29). Some other factors that can influence obesity rate are race/ethnicity, metabolic stress, and acculturation.

Acculturation means the cultural adjustments or changes among a group of people, particularly for immigrants. The length of residence in the U.S. is an important

acculturation factor. In addition, dietary changes could be another explanation for the increased obesity rate among Asian Americans. The study conducted by the California Health Interview Survey 2003 reported that the longer the residency in the U.S., the higher the prevalence of weight gain among Asian Americans (30). Cho et al. suggested that lifestyle and dietary changes among Korean Americans were highly associated with the prevalence of obesity (30). The Seattle Japanese Americans Community Diabetes research also reported that the dietary pattern among Japanese Americans were similar to a Western diet, especially in the second and third generations. Fujimoto et al. also stated that the dietary changes could be the major factor that contributed to the increased rates of obesity and diabetes among Japanese American population (19).

The healthcare team, which includes physicians, dietitians, and public health practitioners, play a key role in evaluating weight status as well as providing therapies for obese or overweight patients. Assessing weight status is the first step for weight management. BMI is a common and inexpensive assessment for measuring overweight and obese subjects. It estimates the overall percentage of body fat based on height and weight. The standard BMI cutoff points defined by the Center for Disease Control and Prevention (CDC) and WHO are as follows (31,32):

1. Underweight: BMI < 18.5
2. Normal weight: BMI between 18.5-24.9
3. Overweight: BMI between 25-29.9
4. Obese: BMI > 30

BMI between 30-34.9, 35-39.5, or over 40 are also classified as obesity Class I, II, and III, respectively (32–34). The American Heart Association suggested that if ones BMI were over 40, he or she would be considered extremely or morbidly obese (34).

Although BMI is the most common method for determining total body fat mass, it has many disadvantages. For example, it does not reflect the percentage of lean body mass, and it may also under or overestimate body fat among athletes, seniors, or different ethnic groups. Studies have debated whether Asians should use different BMI cutoff points (33,36). In 2014, the American Diabetes Association (ADA) released a position statement on new BMI cutoff points for detecting diabetes among Asian Americans. They recommended that Asian Americans should screen for diabetes when their BMIs reach 23 or higher (36). BMI does not account for the distribution of fat; therefore, BMI cannot predict abdominal obesity, which is highly associated with diabetes and other metabolic diseases (9). Although obesity is a primary risk factor of metabolic related chronic diseases, studies showed that abdominal obesity has highly predictive properties for screening diabetes (10).

Abdominal Obesity

Prevalence and Definition

Abdominal obesity, also called central obesity, is characterized by the apple body shape. The overweight or obese individuals who have high waist circumferences are closely associated with developing diabetes, cardiovascular diseases, and hypertension (10). The study by using NHANES 1988-2004 datasets shows that more than 50% of U.S. adults had abdominal obesity (37). Another recent NHANES study stated that even

though the overall obesity rate has been stable over the past few years, the prevalence of abdominal obesity increased significantly, especially among U.S. women (58%-65%) (38). The prevalence of abdominal obesity has increased worldwide. In England, the rate of abdominal obesity doubled among women between 1993-2008 (39). During a similar time frame in China, a study reported that the prevalence of abdominal obesity increased from 11% to 21% among normal weight Chinese people (40). Du et al. concluded that 65% of normal weight Chinese people would not be diagnosed with abdominal obesity if they were only screened with BMI (40). Another U.S. study suggested that the elevated prevalence of metabolic risks among Asian Americans was due to greater amounts of abdominal and visceral fat in this population (13).

Assessments

There are many different measurements to assess abdominal obesity and the most commonly used method is to measure WC. Studies showed that WC is one of the indicators of metabolic syndrome and is also highly associated with abdominal obesity (41). The International Day for the Evaluation of Abdominal Obesity (IDEA) study, a global cross-sectional survey program, stated that when WC increased, the rate of abdominal obesity increased 3-fold in men and almost 6-fold in women (42). However, the optimal value of WC to predict abdominal obesity has been debated. According to International Diabetes Federation 2005 (IDF), abdominal obesity can be defined as a WC over 80 centimeters in women or 94 centimeters in men; additionally, they recommend the establishment of different cutoff points for different ethnic groups (43). For instance, the specific ethnic WC values among Chinese, Japanese, and South Asians are 90 centimeters in men and 80 centimeters in women. However, the current cutoff points that

are used in the U.S. are over 88 centimeters in women and 102 centimeters in men (44). Therefore, the different values of WC cutoff points could be a problem for assessing abdominal obesity in different ethnicities. Additionally, another study has discussed that WC may not be able to indicate an accurate percentage of intra-abdominal fat, and WC cannot distinguish abdominal subcutaneous fat or total body fat (45).

WC is just one of the possible indicators of abdominal obesity. A more recent method for assessing abdominal obesity is the sagittal abdominal diameter (SAD). This assessment is not only able to estimate the regional body fat distribution, but it is also cheaper than computerized topography (CT) and magnetic resonance imaging (MRI). Studies showed a significant association between SAD and intra-abdominal adipose tissue. SAD may have similar effectiveness as CT, waist-to-hip ratio (WHT), and WC in males and females (46). Peterson et al. stated that SAD is a better anthropometric marker for evaluating insulin resistance and level of serum C-reactive protein among Middle East and native Swedish immigrants (47). However, these studies only included a small sample size and also excluded other ethnic groups. Therefore, more research into the effectiveness of SAD's determination of abdominal obesity is required.

WHT is another commonly used anthropometric measurement of abdominal obesity. WHT, which was first proposed in the 1990s, is calculated by using WC divided by the hip circumference (48). If WHT is at or above 0.9 in men and at or above 0.85 in women, he or she can be considered abdominally obese (48). One meta-analysis study, which included over 258,000 participants pooled from 15 prospective studies, showed that there was a positive link between cardiovascular diseases and elevated WHT values (48). In 2007, a study reported WC and WHT had similar effectiveness for detecting

diabetes (49). However, Seidell et al. pointed out that WHT negatively correlated with metabolic syndrome risk factors and could not predict the body fat distribution after adjusting for BMI, age, and gender (50). Therefore, WHT and WC may have limited impact on screening for abdominal obesity among specific ethnic groups, such as Asians, because the height differences among individuals were not considered.

Waist-to-Height Ratio

Waist-to-height ratio (WHtR) is a simple and practical anthropometric assessment that may allow the same threshold for different ethnic groups. It can be calculated by using the waist circumference divided by the body height. In 1995, WHtR was first proposed to the scientific community, and it became an early warning indicator of abdominal obesity-related risks among males and females (51). Some meta-analyses suggested that WHtR is better at predicting diabetes, hypertension, and dyslipidemia when compared to BMI, WC, and WHT (52,53). In order to avoid over-complication involving different boundary values, Browning et al. stated that 0.5 could be a better global threshold for detecting abdominal obesity; however, the value may decrease among children and adolescents due to height differences (54). WHtR of 0.5 sends a simple message that adults need to keep their WC at less than half of their height (54). One systematic review article concluded that WHtR is not an appropriate predictor of diabetes for non-Caucasian populations, which might have been due to differing methods within the study (55). However, another recent article pointed out that WHtR was superior over all other anthropometric assessments in several ethnic groups for predicting cardio-metabolic risk factors (56).

Although the average body size among Asians is usually smaller, with lower BMI and WC than many other ethnic groups, the prevalence of chronic diseases in this population has doubled over the last decade (6). In a Japanese study, WHtR was positively correlated with coronary risk factors with age adjustment among both men and women (57). Hsieh et al. stated that 98% of men and women were identified as abdominally obese by using the WHtR threshold of 0.5, while only 45% of Japanese men were considered abdominally obese when using WC with the WHO boundary values (57). Another Asian Indian study showed that both sexes had substantially lower BMI, WC, WHT, and body surface area relative to U.S. populations; however, the mean WHtR was significantly higher (58). Height is one of the most important characteristics and possible influences on one's body composition or fat distribution. With the same WC, a shorter person could possibly contain higher amounts of intra-abdominal fat than a taller person. Therefore, it may be necessary to use the ratio between body weight and height for evaluating one's abdominal obesity status.

Due to the importance of an individual's height, WHtR may also be an effective indicator of obesity and health risks among children and adolescents. When using WHtR to evaluate abdominal obesity prevalence, there was a significant increase among U.S. children and adolescents between 1988-1994 and 1999-2004 (59). A recent Chinese study showed that high blood pressure is directly associated with increased WHtR in children and adolescents (60). Another Mexican adolescents study also demonstrated that WHtR is a better predictive and screening tool than WC or BMI, because 69% of obese adolescents were diagnosed with high risk metabolic syndrome (61).

The National Health and Nutrition Examination Survey

The NHANES program is a nationally representative survey that aims to assess the health and nutritional status among children, adults, and seniors living in the United States. The program began in the early 1960s, with data being continuously collected beginning in 1999. The ongoing NHANES survey releases datasets every two years. Approximately 5,000 subjects are surveyed each year with Mexican Americans, African Americans, and seniors being oversampled since 1999 (62). Sample weights of all of the subjects are calculated thus allowing for accurate representation of the entire U.S. population (62). Recognizing that the Non-Hispanic Asian population has been increasing dramatically in the U.S., NHANES oversampled and separately identified this group for the first time as an individual ethnic group in the 2011-2014 cycles.

The NHANES survey includes home interviews and physical examinations at the mobile examination center (MEC). The MEC consists of three sets of four laboratory-equipped trailers which travel to 15 locations throughout the country each year (62). The home interviews include a questionnaire that gathers demographic, socioeconomic, dietary, and health related information. The physical examinations include body measurements, dietary intake, and laboratory tests (62). By collecting these measurements of data, the NHANES program can estimate the prevalence of chronic diseases among the U.S. population.

REFERENCES

1. Colby SL, Ortman JM. Projections of the size and composition of the U.S. population: 2014 to 2060.U.S. Census Bureau. Available from https://www.census.gov/content/dam/Census/library/publications/2015/demo/p25-1143.pdf. Accessed 26 June 2016

2. Aday LA. At risk in America: the health and health care needs of vulnerable populations in the United States. John Wiley & Sons; 2002. 399 p.

3. Evans DL, Price JL. 2000 Profiles of General Demographic Characteristics. U.S. Department of Commerce. Available from: http://www2.census.gov/census_2000/datasets/demographic_profile/0_National_Summary/2khus.pdf. Accessed 26 June 2016.

4. American Immigration Council. Asians in America: A Demographic Overview. Available from: http://www.immigrationpolicy.org/just-facts/asians-america-demographic-overview. Accessed 26 June 2016.

5. World Health Organization. Diabetes Fact Sheet. Available from: http://www.who.int/mediacentre/factsheets/fs312/en. Accessed 26 June 2016.

6. McNeely MJ, Boyko EJ. Type 2 diabetes prevalence in Asian Americans results of a national health survey. Diabetes Care. 2004 Jan 1;27(1):66–9.

7. Lee JWR, Brancati FL. Trends in the prevalence of type 2 diabetes in Asians versus Whites results from the United States National Health Interview Survey, 1997–2008. Diabetes Care. 2011 Feb 1;34(2):353–7.

8. PopKin BM, Udry JR. Adolescent obesity increases significantly in second and third generation U.S. immigrants. American Society for Nutritional Sciences. 1997 Sep 5;534(21):244-251.

9. WHO Expert Consultation. Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. The Lancet. 2004 Jan 10;363(9403):157–63.

10. Carr MC, Brunzell JD. Abdominal obesity and dyslipidemia in the metabolic syndrome: importance of type 2 diabetes and familial combined hyperlipidemia in coronary artery disease risk. J Clin Endocrinol Metab. 2004 Jun 1;89(6):2601–7.

11. Hu FB. Obesity and mortality: watch your waist, not just your weight. Arch Intern Med. 2007 May 14;167(9):875–6.

12. Deurenberg-Yap M, Schmidt G, et al. The paradox of low body mass index and high body fat percentage among Chinese, Malays and Indians in Singapore. Int J Obes Relat Metab Disord J Int Assoc Study Obes. 2000 Aug;24(8):1011–7.

13. Lim U, Ernst T, et al. Asian women have greater abdominal and visceral adiposity than Caucasian women with similar body mass index. Nutr Diabetes. 2011 May;1(5):e6.

14. World Health Organization. Diabetes Mellitus. Available from: http://www.who.int/mediacentre/factsheets/fs138/en/. Accessed 26 June 2016.

15. National Diabetes Statistics Report, 2014. National Center for Chronic Disease Prevention and Health Promotion. Available from:

http://www.cdc.gov/diabetes/pubs/statsreport14/national-diabetes-report-web.pdf. Accessed 26 June 2016.

16. The International Expert Committee, Nathan DM. International Expert Committee report on the role of the A1C assay in the diagnosis of diabetes. Available from: http://care.diabetesjournals.org/content/32/7/1327.long. Accessed 26 June 2016.

17. National Health and Nutrition Examination Survey 2011 - 2012: Diabetes Data Documentation, Codebook, and Frequencies. Available from: https://wwwn.cdc.gov/Nchs/Nhanes/2011-2012/DIQ_G.htm. Accessed 26 June 2016.

18. Thorpe LE, Upadhyay UD, et al. Prevalence and control of diabetes and impaired fasting glucose in New York City. Diabetes Care. 2009 Jan 1;32(1):57–62.

19. Fujimoto WY, Boyko EJ, et al. Risk factors for type 2 diabetes: lessons learned from Japanese Americans in Seattle. J Diabetes Investig. 2012 Jun 1;3(3):212–24.

20. World Health Organization. Obesity: situation and trends. Available from: http://www.who.int/gho/ncd/risk_factors/obesity_text/en/. Accessed 26 June 2016.

21. Flegal KM, Carroll MD. Prevalence of obesity and trends in the distribution of body mass index among U.S. adults, 1999-2010. JAMA. 2012 Feb 1;307(5):491–7.

22. National Institute of Diabetes and Digestive and Kidney Disease. Overweight and Obesity Statistics. Available from: http://www.niddk.nih.gov/health-information/health-statistics/Pages/overweight-obesity-statistics.aspx. Accessed 26 June 2016.

23. Nam S. Obesity and Asian Americans in the United States: systematic literature review. Osong Public Health Res Perspect. 2013 Aug;4(4):187–93.

24. Lauderdale DS. Rathouz PJ. Body mass index in a US national sample of Asian Americans: effects of nativity, years since immigration and socioeconomic status. International Journal of Obesity. 2000 Sep; 24(9): 1188-1194.

25. Office of Disease Prevention and Health Promotion. Physical Activity Guidelines. Available from: http://health.gov/paguidelines/. Accessed 26 June 2016.

26. Centers for Disease Control and Prevention. Facts about Physical Activity. Available from: http://www.cdc.gov/physicalactivity/data/facts.htm. Accessed 26 June 2016.

27. Office of Disease Prevention and Health Promotion. Nutrition, Physical Activity, and Obesity. Healthy People 2020. Available from: https://www.healthypeople.gov/2020/leading-health-indicators/2020-lhi-topics/Nutrition-Physical-Activity-and-Obesity/data. Accessed 26 June 2016.

28. Office of Disease Prevention and Health Promotion. Key Recommendations: Components of Healthy Eating Patterns. Available from: http://health.gov/dietaryguidelines/2015/guidelines/chapter-1/key-recommendations/. Accessed 26 June 2016.

29. Centers for Disease Control and Prevention. Caloric intake from fast food among adults: United States, 2007-2010. Available from: http://www.cdc.gov/nchs/data/databriefs/db114.htm. Accessed 26 June 2016.

30. Cho J, Juon H-S. Assessing overweight and obesity risk among Korean Americans in California using World Health Organization body mass index criteria for Asians. Prev Chronic Dis. 2006 Jul; 3(3); A79.

31. Center for Disease Control and Prevention. About Adult BMI. Available from: http://www.cdc.gov/healthyweight/assessing/bmi/adult_bmi/index.html. Accessed 26 June 2016.

32. World Health Organization. Global Database on Body Mass Index Classification. Available from: http://apps.who.int/bmi/index.jsp?introPage=intro_3.html. Accessed 26 June 2016.

33. Hsu WC, Araneta MRG. About Adult BMI. Available from: http://www.cdc.gov/healthyweight/assessing/bmi/adult_bmi/index.html

34. American Heart Association. Extreme obesity, and what you can do. Available from: http://www.heart.org/HEARTORG/HealthyLiving/WeightManagement/Obesity/Extreme-Obesity-And-What-You-Can-Do_UCM_457018_Article.jsp#.VzpCrb6WLo4. Accessed 26 June 2016.

35. Hsu WC, Araneta MRG, et al. BMI cut points to identify at-risk Asian Americans for type 2 diabetes screening. Diabetes Care. 2015 Jan 1;38(1):150–8.

36. American Diabetes Association. American Diabetes Association Releases Position Statement on New BMI Screening Cut Points for Diabetes in Asian Americans. Available from: http://www.diabetes.org/newsroom/press-releases/2014/american-diabetes-association-releases-position-statement-on-new-bmi-screening-cut-points-for-diabetes-in-asian-americans.html. Accessed 26 June 2016.

37. Li C, Ford ES, et al. Increasing trends in waist circumference and abdominal obesity among U.S. adults. Obesity. 2007 Jan 1;15(1):216–216.

38. Ford ES, Maynard LM, et al. Trends in mean waist circumference and abdominal obesity among US adults, 1999-2012. JAMA. 2014 Sep 17;312(11):1151–3.

39. Howel D. Trends in the prevalence of abdominal obesity and overweight in English adults (1993-2008). Obes Silver Spring Md. 2012 Aug;20(8):1750–2.

40. Du T, Sun X, et al. Increasing trends in central obesity among Chinese adults with normal body mass index, 1993–2009. BMC Public Health. 2013;13:327.

41. Ruma D. The waist circumference measurement: a simple method for assessing the abdominal obesity. J Clin Diagn Res JCDR. 2012 Nov;6(9):1510–3.

42. Balkau B, Deanfield JE, et al. International Day for the Evaluation of Abdominal Obesity (IDEA). Circulation. 2007 Oct 23;116(17):1942–51.

43. International Diabetes Federation. The IDF Consensus Worldwide Definition of Metabolic Syndrome. Available from https://www.idf.org/webdata/docs/IDF_Meta_def_final.pdf. Accessed 26 June 2016.

44. Grundy SM, Cleeman JI. Diagnosis and management of the metabolic syndrome: an American Heart Association. National Heart, Lung, and Blood Institute Scientific Statement. Circulation. 2005;112:2735-52.

45. Vazquez G, Duval S, et al. Comparison of body mass index, waist circumference, and waist/hip ratio in predicting incident diabetes: A Meta-Analysis. Epidemiol Rev. 2007 Jan 1;29(1):115–28.

46. Zamboni M, Turcato E, et al. Sagittal abdominal diameter as a practical predictor of visceral fat. Int J Obes Relat Metab Disord J Int Assoc Study Obes. 1998 Jul;22(7):655–60.

47. Petersson H, Daryani A. Sagittal abdominal diameter as a marker of inflammation and insulin resistance among immigrant women from the Middle East and native Swedish women: a cross-sectional study. Cardiovasc Diabetol. 2007;6:10.

48. Koning L de, Merchant AT, et al. Waist circumference and waist-to-hip ratio as predictors of cardiovascular events: meta-regression analysis of prospective studies. Eur Heart J. 2007 Apr 1;28(7):850–6.

49. Koning L de, Merchant AT, et al. Waist circumference and waist-to-hip ratio as predictors of cardiovascular events: meta-regression analysis of prospective studies. Eur Heart J. 2007 Apr 1;28(7):850–6.

50. Seidell JC, Pérusse L, et al. Waist and hip circumferences have independent and opposite effects on cardiovascular disease risk factors: the Quebec Family Study. Am J Clin Nutr. 2001 Sep 1;74(3):315–21.

51. Hsieh SD, Yoshinaga H. Waist/height ratio as a simple and useful predictor of coronary heart disease risk factors in women. Intern Med Tokyo Jpn. 1995 Dec;34(12):1147–52.

52. Lee CMY, Huxley RR, et al. Indices of abdominal obesity are better discriminators of cardiovascular risk factors than BMI: a meta-analysis. J Clin Epidemiol. 2008 Jul;61(7):646–53.

53. Savva SC, Lamnisos D. Predicting cardiometabolic risk: waist-to-height ratio or BMI. A meta-analysis. Diabetes Metab Syndr Obes Targets Ther. 2013 Oct 24;6:403–19.

54. Browning LM, Hsieh SD. A systematic review of waist-to-height ratio as a screening tool for the prediction of cardiovascular disease and diabetes: 0.5 could be a suitable global boundary value. Nutrition Research Reviews. 2008 Oct 23;247-269.

55. Kodama S, Horikawa C, et al. Comparisons of strength of association with future type 2 diabetes risk among anthropometric obesity indicators, including waist-to-height ratio: a meta-analysis. American Journal of Epidemiology. 2012 Nov; 1093-1099.

56. Bohr A, Laurson K. A novel cutoff for the waist-to-height ratio predicting metabolic syndrome in young American adults. BMC Public Health. 2016; 16:295.

57. Hsieh SD, Yoshinaga H. Waist-to-height ratio, a simple and practical index for assessing central fat distribution and metabolic risk in Japanese men and women. International Journal of Obesity 2003; 27, 610-616.

58. Bajaj HS, Pereira MA, et al. Comparison of relative waist circumferences between Asian Indian and US adults. Journal of Obesity. 2014 Feb; 98, 294-304.

59. Li C, Ford ES, et al. Recent Trends in waist circumference and waist-to-height ratio among US children and adolescents. Pediatrics Nov 2006, 118 (5) e1390-e1398.

60. Hu YH, Reilly KH, et al. Increase in body mass index, waist circumference and waist-to-height ratio is associated with high blood pressure in children and adolescents in China. J Int Med Res. 2011;39(1):23-32.

61. Rodea-Montero ER, Evia-Viscarra ML, et al. Waist-to-Height Ratio Is a Better Anthropometric Index than Waist Circumference and BMI in Predicting Metabolic Syndrome among Obese Mexican Adolescents. International Journal of Endocrinology. 2014;2014:195407.

62. National Health and Nutrition Examination Survey. About the National Health and Nutrition Examination Survey. Available from: http://www.cdc.gov/nchs/nhanes/about_nhanes.htm. Accessed 26 June 2016.

Chapter II

THE WAIST TO HEIGHT RATIO IS A BETTER ANTHROPOMETRIC INDEX OF ABDOMINAL OBESITY AND ITS ASSOCIATION WITH THE PREVALENCE OF DIABETES AMONG ASIAN AMERICANS

Abstract

Background

There is limited information about diabetes prevalence among Asian Americans. Risk factors for diabetes include abdominal obesity and can be assessed by measuring waist circumference (WC) or waist-to-height-ratio (WHtR). The purpose of this study was to compare the prevalence of diabetes among Asians with non-Asians in the U.S. and compare WC and WHtR as predictors of diabetes.

Methods

Data from the National Health and Nutrition Examination Survey (NHANES) 2011-14 was analyzed using SAS 9.2. There were 8,615 adult non-pregnant non-Asians and 1,224 Asians included in this study. The prevalence of diabetes was established using a hemoglobin A1c concentration of > 6.5% or use of insulin or hypoglycemic medication.

Results

Despite a lower prevalence of obesity among Asians compared to non-Asians (12% vs 38%, $p < .001$), Asians had a higher age-adjusted prevalence of diabetes (16% vs 11%, $p < .001$), particularly among normal (10% vs 3%) and overweight Asians (20% vs 8%). The prevalence of abdominal obesity assessed using WC was greater in non-Asians than Asians overall (58% vs 25%, $p < .001$) and among those with a normal body mass index (11% vs 5%, $p < .001$). In contrast, the abdominal obesity prevalence assessed using WHtR produced higher rates in both non-Asians and Asians overall (79% vs 65%, $p < .001$), but a higher prevalence in Asians than non-Asians with normal BMI (51% vs 44%, $p < .001$). Among Asians with a normal body mass index, abdominal obesity

assessed using WC accounted for just 12% of those with diabetes whereas using WHtR accounted for 93% of those with diabetes. Similarly, among non-Asians, abdominal obesity assessed with WC accounted for 34% of normal weight diabetics while WHtR accounted for 73% of diabetics.

Conclusion

This study is the first to confirm the greater prevalence of diabetes with laboratory measurements among US Asians in a nationally representative survey. In addition, the results of this study show that abdominal obesity when assessed with WHtR but not WC explains the greater prevalence of DM among Asians, particularly in those with a normal BMI.

Introduction

Over the last few decades, the population of Asian Americans has grown rapidly in the United States. According to U.S. Census Bureau, the population of this ethnic group is projected to reach 34.4 million and increase from 5.1% to 8.2% of total U.S. population by 2060 (1,2). Studies have shown that Asian Americans have a higher chance to develop diabetes than Caucasians despite a lower prevalence of obesity and a genetic differences in body composition could be the possible reason (3). Asians have been reported to be usually shorter and have a larger waist circumference when compared to Caucasians at a similar body mass index (BMI) (4). The National Center for Health Statistics (NCHS) stated that about one quarter of Asian American adults had hypertension and approximately 10% of them had abnormally high blood cholesterol levels in 2011-2012 (5). However, there is limited information about the prevalence of

diabetes in Asian Americans based on laboratory results. In order to determine the prevalence of chronic diseases among Asian Americans, the National Health and Nutrition Examination Survey (NHANES) released non-Hispanic Asian data beginning in 2011. The NHANES survey is conducted by NCHS; the datasets collected by this program not only included questionnaires but also laboratory tests that allow for analysis of the prevalence of major diseases in different ethnic groups.

Diabetes mellitus is the sixth leading cause of death in the United States with approximately 18 million Americans diagnosed with this disease (6). According to a report from the New York City Health and Nutrition Examination Survey (NYCHNES) 2004, Asian Americans had the highest risk of diabetes and impaired fasting glucose compared with non-Asian groups (7). Abdominal obesity is one of the risk factors for diabetes. Ford et al. using NHANES data from 1999-2012, showed that the prevalence of abdominal obesity was increasing within each ethnic group (8). Even though clinical research has not determined the mechanisms of how visceral fat impacts diabetes, studies have indicated that abdominal obesity is highly associated with diabetes in all body mass index (BMI) categories (9). It has been suggested that Asian Americans have larger amount of intra-abdominal fat compared to Non-Asians (9) and this might be the explanation for the higher rate of diabetes among Asian Americans than other ethnic groups. Diabetes is beginning to be screened for in Asian Americans who are not typically classified as overweight or obese with a few studies using BMI < 23 kg/m2 as normal weight and 23-27.5 kg/m2 as overweight categories in this population (10,11). This has led to the World Health Organization (WHO) debate over whether or not BMI

cutoff points should be lower for Asians since more Asians were diagnosed with diabetes at a lower BMI range (12).

Although BMI is an indicator total body fat mass, it does not strongly predict body fat distribution. Waist circumference (WC) is the common assessment for abdominal obesity, but its accuracy as a risk factor for diabetes may be affected by the height of each individual. In contrast, waist-to-height ratio (WHtR), which was first proposed in the mid-1990s (13), might be a better predictor of abdominal obesity and used as a screening tool for diabetes, because it takes the differences in height into account. Additionally, a recent meta-analysis indicated that WHtR has a similar or even superior association as WC for predicting diabetes (13); therefore, more research comparing these two assessments as predictors of diabetes is needed.

The purpose of this study was to establish the prevalence of diabetes using laboratory values among Asian Americans compared with Non-Asians as well as to evaluate whether WHtR is a better predictor of diabetes than WC among Asian Americans by using NHANES data from 2011-2014. We hypothesize that Asian Americans have a higher prevalence of diabetes at a lower BMI range and that WHtR is a better predictor of diabetes than WC.

Methods

This epidemiological cross-sectional study included a total sample size of 10,354 subjects who were non-pregnant and over the age of 20 years old from the NHANES 2011-2014 datasets. There were 1,301 Non-Hispanic Asians and 9,053 Non-Asians, which were selected as the comparison group instead of selecting another specific

ethnic/racial group. The NHANES program is a nationally representative survey that aims to assess the health and nutritional status among non-institutionalized children, adults, and seniors living in the United States. The program began in the early 1960s and with data being continuously collected beginning in 1999. The continuous NHANES survey releases datasets every two years. Approximately 5,000 subjects are surveyed each year with Mexican Americans, African Americans, and seniors being oversampled since 1999 (15). Sample weights of all of the subjects are calculated thus allowing for accurate representation of the entire U.S. population (15). Recognizing that the Non-Hispanic Asian population has been increasing dramatically in the U.S., NHANES oversampled and separately identified this group for the first time as an individual ethnicity group in the 2011-2014 cycles.

The NHANES survey includes home interviews and physical examinations at the mobile examination center (MEC). The MEC consists of four connected laboratory-equipped trailers which travel to 15 locations throughout the country every two years (15). The home interviews include a questionnaire gathering demographic, socioeconomic, dietary, and health related information. The physical examinations include body measurements, dietary intake, and laboratory tests (15). Through collecting these data, the NHANES program can estimate the prevalence of chronic diseases among the U.S. population.

Diabetes was classified in this study if the subject's hemoglobin A1c (HbA1c) level was above 6.5% or if he/she reported to be using insulin or oral hypoglycemic medications. Since HbA1c measurements do not require a fasted blood sample, it was used as the diagnostic test for diabetes instead of fasting blood glucose because it allowed

for a far greater number of subjects to be included in the study. In addition, elevated levels of HbA1c may be a more sensitive indicator of the early development of insulin resistance or prediabetes than a fasting blood glucose concentration. Standing height was measured using a stadiometer with a fixed vertical backboard and an adjustable head piece. WC was measured using an anthropometric tape at the level of the iliac crest, while WHtR was calculated by using WC dividing by body height. Abdominal obesity using WC was defined as greater than 102 cm in males and 88 cm in females (15). Abdominal obesity using WHtR was defined when it exceeded 0.5 (16).

Data were weighted, thus our sample population can be representative of the actual U.S. population. Statistical analysis software (SAS 9.2) was used for the descriptive and inferential statistics. Results are presented as mean +/- standard error. Statistical significance was established if the p-value <0.05. The Chi-square analysis procedures were used to determine if significant differences existed in the prevalence of diabetes, obesity, and abdominal obesity assessed by WC and WHtR between Asians and non-Asians. The t-test procedures were used to determine if significant differences existed among the continuous variables, such as WC and WHtR between Asians and non-Asians.

Results

Table 1 describes demographic characteristics for U.S. Asians and non-Asians included in this study. There were some expected differences between the two groups: Asian subjects generally were of shorter stature, younger, had a lower mean BMI, and had a lower mean body weight than non-Asians. The mean WC of non-Asians (99.7 cm)

Table 1. Characteristics of 10,354 subjects ≥ 20 years of age by race and ethnicity, NHANES 2011-2014

	Non-Asians	US Asians	p-value
N	9,053	1,301	
Age (years)*	47.8±0.4	44.9±0.8	0.0005
Height (cm)*	168.9±0.2	163.2±0.3	<.0001
Weight (kg)*	83.4±0.3	65.9±0.4	<.0001
BMI (kg/m^2)*	29.2±0.1	24.6±0.2	<.0001
Waist Circumference (cm)*	99.7±0.3	87.7±0.4	<.0001
Waist-to-height Ratio (WHtR)*	0.54±0.0003	0.59±0.0002	<.0001
Normal Weight (%)**	28±0.8	59±1.4	<.0001
Overweight (%)**	34±0.7	29±1.4	<.0001
Obese (%)**	38±0.8	12±0.8	<.0001

*Values expressed as weighted means ± SE, P-values for mean differences across ethnic groups
** % prevalence; normal weight defined as BMI< $25 kg/m^2$; overweight defined as BMI 25-29 kg/m^2; and obese defined as BMI ≥ 30 kg/m^2.

was much higher than that of Asians (87.7 cm); however, the mean WHtR was higher in Asians than non-Asians (0.59 vs. 0.54, respectively $p < 0.0001$).

Table 2 describes the actual total prevalence of diabetes (14%) and the rates of diabetes in each BMI category in Asians and non-Asians. The age-adjusted prevalence of diabetes (adjusted to match the age distribution of non-Asians) among Asians was 16% while the percentage of diabetes in non-Asians was 11%, ($p < 0.0001$). Among normal weight subjects, the prevalence of diabetes was substantially greater in Asians than in non-Asians (10% vs 3%, $p < 0.0001$). Similarly, among overweight individuals, the prevalence of diabetes was substantially greater in Asians than in non-Asians (20% vs 8%, $p < 0.0001$). In obese category (BMI $\geq$ 30kg/m2), diabetes was also more prevalent in U.S. Asians than non-Asians (24% vs 20%, $p < 0.0001$).

Table 2. Prevalence of diabetes by ethnicity and BMI categories

	Non-Asian	US Asian	p-values
Total (%)*	11 ±0.4	14±1.2	0.0495
Normal weight (%)*	3±0.4	10±1.4	< .0001
Overweight (%)*	8±0.4	20±2.3	< .0001
Obese (%)*	20±0.9	24±3.4	00074

*Values stated as weighted prevalence ± SE, P-values for mean differences across ethnic groups. Normal weight defined as BMI < 25 kg/m^2; overweight defined as BMI 25-29 kg/m^2; and obese defined as BMI ≥ 30 kg/m^2.

Despite a higher rate of diabetes in Asian subjects, they had a much lower prevalence of obesity. Table 1 shows the prevalence of BMI weight categories in Asians and non-Asians. The percentage of those classified as overweight was 34% in non-Asians and 29% in Asian subjects. In addition, the prevalence of obesity was 38% in non-Asians, whereas the prevalence was only 12% in Asians. The percentage of normal weight BMI in Asians (59%) was doubled compared to non-Asian group (28%, $p < 0.0001$).

As shown in Table 3, the prevalence of abdominal obesity was very different depending on the method of assessment used. Based on using WC, abdominal obesity prevalence was much higher in non-Asians than Asians (58% vs 25%, $p < 0.0001$). The higher prevalence of abdominal obesity among non-Asians compared to Asians was consistent within each BMI category when using WC. In contrast, the prevalence of abdominal obesity was higher when using WHtR compared to when using WC among both non- Asians compared to Asians (79% vs 65%, $p = 0.016$). Notably, the prevalence of abdominal obesity using WHtR among Asians was greater than non-Asians within the normal weight BMI category (51% vs 44%, $p = 0.022$).

Table 3. Prevalence of abdominal obesity by WC and WHtR

	Non-Asians	US Asians	p-values
Waist Circumference			
Total (%)*	58+1.0	25+1.2	< .0001
Normal weight (%)*	11+0.9	5+0.6	< .0001
Overweight (%)*	55+1.4	41+2.6	< .0001
Obese (%)*	97+0.3	91+2.9	0.0063
Waist-Height Ratio			
Total (%)*	79+0.8	65+2.1	0.016
Normal weight (%)*	44+1.6	51+2.8	0.022
Overweight (%)*	93+0.5	94+1.4	0.773
Obese (%)*	96+0.4	96+1.5	0.897

*Values stated as weighted prevalence + SE, P-values for mean differences across ethnic groups. Normal weight defined as BMI < 25 kg/m2; overweight defined as BMI 25-29 kg/m2; and obese defined as BMI ≥ 30 kg/m2.

To determine the relationship between abdominal obesity and diabetes, the prevalence of diabetes in those with and without abdominal obesity was determined as well (Table 4). Not surprisingly, almost all obese subjects with diabetes were also abdominally obese, regardless of whether WC or WHtR was used. However, the prevalence of diabetes in overweight abdominally obese in non-Asians was 74% and only 52% in Asians when abdominal obesity was assessed using WC ($p < 0.0001$). In contrast, the prevalence of diabetes in both overweight abdominally obese non-Asians and Asian was 96% when abdominal obesity was assessed using WHtR ($p < 0.14$). Notably, only 34% and 12% of normal weight (BMI: 18.5-24.5 kg/m2) subjects with diabetes had abdominal obesity in non-Asians and Asians, respectively, when abdominal obesity was assessed using WC ($p < 0.0001$). In contrast, 73% and 93% of subjects with diabetes within the normal weight category had abdominal obesity in non-Asians and Asians, respectively, when abdominal obesity was assessed using WHtR ($p < 0.0001$). Among normal weight Asians without diabetes, 44% of them had abdominal obesity using WHtR ($p < 0.0001$, data not shown).

Table 4. Prevalence of diabetes by ethnicity, BMI, and abdominal obesity

	Abdominal obese Non-Asian	Abdominal obese US Asian	p-values
Waist Circumference			
Normal weight (%)*	34±7.8	12±3.6	< 0.0001
Overweight (%)*	74±3.1	52±6.7	< 0.0001
Obese (%)*	99±0.1	96±3.5	0.14
Waist-Height Ratio			
Normal weight (%)*	73±6.3	93±2.1	< 0.0001
Overweight (%)*	96±2.0	96±1.9	0.28
Obese (%)*	94±1.3	97±3.0	0.62

*Values stated as weighted prevalence + SE, P-values for mean differences across ethnic groups. Normal weight defined as BMI < 25 kg/m2; overweight defined as BMI 25-29 kg/m2; and obese defined as BMI ≥ 30 kg/m2.

Discussion

This is the first study to show that the age-adjusted prevalence of diabetes determined primarily by laboratory methods in a nationally representative sample of adults was substantially higher in U.S. Asians than non-Asians (16% vs 11%, $p<0.0001$). Thus, the prevalence of diabetes among Asian-Americans after age-adjustment was 45% greater than in non-Asians. In addition, the prevalence of diabetes was notably higher among normal weight and overweight Asians than non-Asians ($p<0.0001$). Using the National Health Interview Survey (NHIS) data from 1997-2008, Lee et al. reported that the age and sex-adjusted self-reported prevalence of diabetes was 40% higher in Asian subjects compared to non-Hispanic White counterparts (17). In addition, another cross-sectional study from the New York City Health and Nutrition Examination Survey (NYC HANES) stated that almost 50% of normal weight Asians had dysglycemia within the normal weight range (18). However, in 2004, McNeely and Boyko reported that the prevalence of diabetes among Asian Americans was lower compared to other ethnic groups (19).

According to a National Diabetes Statistics report which used 2010-2012 National Health Interview Survey data, the prevalence of diabetes among Asian Americans was 9%, which was higher than Caucasians (7.6%) but lower than Mexican Americans (12.8%) (20). These previous studies tend to show that the prevalence of diabetes is higher among Asian Americans. However, the differences in the prevalence rates for diabetes between this study and others could be caused by numerous factors as described below.

First, our study utilized the most recent datasets released by NHANES 2011-2014, while previous studies used older data and different survey systems. Additionally, NHANES measures actual blood values (% hemoglobin A1c) along with interview responses to diabetic medication use; in contrast, most other national survey data only included responses to interview questionnaires. Self-reported data is not as accurate and is likely to underestimate the true prevalence of diabetes compared to results based on laboratory tests. The criteria of diabetes used in our study were based on elevated HbA1C levels or self-reported use of oral diabetic medications or insulin usage status, which was likely more accurate. Other studies may only use fasting blood glucose levels or simple questions, such as "Have you ever been told by a doctor or health professional that you have diabetes?" (17); therefore, varying methodologies may have led to the different findings.

In our study, the analysis suggests that Asian Americans may have larger amounts of visceral fat when assessed using WHtR, which may have contributed to the higher rate of diabetes. Visceral fat is highly associated with metabolic and obesity-related diseases such as diabetes. One study showed that among women with similar BMIs, Asian women had greater amounts of intra-abdominal and visceral fat than Caucasian women when measured using dual energy X-ray absorptiometry (DXA) (4). In a prospective cohort study in 1980-2000, Shai et al. reported that Asians gained the lowest amounts of weight but the weight gain seemed to be more strongly associated with diabetes compared to other ethnic groups (22). Wang et al. also pointed out that when comparing for height, weight and percent of body fat between Asians and Caucasians in the New York area, Asians were generally of shorter stature, had thicker abdomen skinfolds, and had lower

BMIs (23). The differences of body composition between different ethnic groups could be the possible explanation for the higher prevalence of diabetes among Asian Americans. However, there is no standard diabetes and obesity screening tools for each ethnic group.

Having a normal BMI is generally considered a healthy status; therefore it is possible that normal body weight Asian Americans may be less likely to receive any proper screenings for diabetes and consequently receive care for diabetes much later in life. Even though Asian Americans had a greater rate of diabetes, their prevalence of obesity was far lower when compared to non-Asians. A few studies found that normal weight Asians had higher risk of metabolic diseases than their American counterparts (17,19) and that the current BMI cutoff points as defined by WHO may not accurately reflect the percentage of body fat as well as the health-related issues among Asians. The American Diabetes Association suggested lowering the BMI cutoff points for Asian Americans and they recommended the adoption of 23 kg/m2 or above as the cutoff point for chronic diseases screening (11). Additionally, they pointed out that Asian Americans tend to accumulate fat around the abdomen area, which lead to relatively higher risks for metabolic diseases (11).

BMI and WC have been commonly used as clinical screening tools for metabolic syndrome, cardiovascular disease, and diabetes. However, both methods have imperfect associations with health related issues, particularly among Asian subjects. BMI is generally associated with the overall body fat mass, while WC may identify if someone is at risk of abdominal obesity. However, just as BMI assesses excess body weight relative

to height, WHtR may be a more accurate and sensitive assessment of abdominal obesity than WC, because height is considered along with WC.

Of normal weight Asian Americans who were diagnosed with diabetes, 93% of them had abdominal obesity by using WHtR. Similarly, among normal weight diabetic Non-Asians, about 75% of them had abdominal obesity. In overweight or obese Asian Americans or Non-Asians with diabetes, virtually all of them had abdominal obesity when assessed using WHtR. In contrast, fewer normal and overweight Asian subjects were considered abdominally obese when using WC alone. The strength of this relationship between abdominal obesity and diabetes is much stronger when using WHtR than WC. These results suggest that assessment of abdominal obesity is improved when using WHtR. Therefore, the greater prevalence of diabetes in Asian Americans, particularly in the normal and overweight BMIs is largely explained by the greater prevalence of abdominal obesity as assessed using WHtR assessment.

One of the strengths of this study is the large sample size. NHANES assigns each subject a specific sample weight that allows the sample population to be representative of the actual U.S. population. In addition, assessment of diabetes was made using a laboratory measurement in addition to self-reported use of diabetic medications. However, as a cross-sectional observational study, NHANES data cannot prove a cause and effect relationship between abdominal obesity and diabetes; but other studies have reported a similar association among Asians (3, 4). In addition, WHtR may have a different impact among children and adolescents; therefore, future research could include the use of subjects below 20 years old while studying the association between WHtR, abdominal obesity, and diabetes. Future studies also need to consider other factors, such

as family history and education levels when analyzing the prevalence of diabetes and abdominal obesity among Asian adults.

Conclusion

This study documents that the prevalence of diabetes in Asian Americans is 45% higher than in Non-Asians and this is the first to report this disparity using laboratory measurements of a nationally represented population. The greater prevalence of diabetes in Asians exists despite a far lower prevalence of overweight and obese conditions. Additionally, the prevalence of diabetes is over three times higher in normal weight Asians and two times higher in overweight Asians compared to non-Asians. Our findings suggest that the greater prevalence of diabetes in normal weight Asians is associated with a greater prevalence of abdominal obesity as assessed by WHtR. Therefore, the WHtR could be a better assessment method for assessing abdominal obesity as well as screening diabetes when compared to WC, especially in Asian populations.

REFERENCES

1. U.S Department of Commerce. U. S. Census Bureau projections show a slower growing, older, more diverse nation a half century from now. Available from: https://www.census.gov/newsroom/releases/archives/population/cb12-243.html. Accessed 26 June 2016.

2. Sandra LC, Portman JM. Projections of the size and composition of the U.S. population: 2014 to 2016. U.S. Census Bureau. Available from: https://www.census.gov/content/dam/Census/library/publications/2015/demo/p25-1143.pdf. Accessed 26 June 2016.

3. McNeely MJ, Boyko EJ. Type 2 diabetes prevalence in Asian Americans results of a national health survey. Diabetes Care. 2004 Jan 1;27(1):66–9.

4. Lim U, Ernst T, et al. Asian women have greater abdominal and visceral adiposity than Caucasian women with similar body mass index. Nutr Diabetes. 2011 May 9;1(5):e6.

5. Aoki Y, Yoon SS. Hypertension, abnormal cholesterol, and high body mass index among Non-Hispanic Asian adults: United States, 2011-2012. U.S. Department of Health and Human Services. Available from: http://www.cdc.gov/nchs/data/databriefs/db140.pdf. Accessed 26 June 2016.

6. American Diabetes Association. Diabetes basics. Available from: http://www.diabetes.org/diabetes-basics/. Accessed 26 June 2016.

7. Thorpe LE, Upadhyay UD, et al. Prevalence and control of diabetes and impaired fasting glucose in New York City. Diabetes Care. 2009 Jan 1;32(1):57–62.

8. Ford ES, Maynard LM, Li C. Trends in mean waist circumference and abdominal obesity among us adults, 1999-2012. JAMA. 2014 Sep 17;312(11):1151–3.

9. Kodama S, Horikawa C, et al. Comparisons of the strength of associations with future type 2 diabetes risk among anthropometric obesity indicators, including waist-to-height ratio: A Meta-Analysis. Am J Epidemiol. 2012 Dec 1;176(11):959–69.

10. Hsu WC, Araneta MRG. BMI cut points to identify at-risk Asian Americans for type 2 diabetes screening. Diabetes Care. 2015 Jan 1;38(1):150–8.

11. American Diabetes Association. American Diabetes Association releases position statement on new BMI screening cut points for diabetes in Asian Americans. Available from: http://www.diabetes.org/newsroom/press-releases/2014/american-diabetes-association-releases-position-statement-on-new-bmi-screening-cut-points-for-diabetes-in-asian-americans.html. Accessed 26 June 2016.

12. Araneta MRG, Kanaya AM, Fujimoto W. BMI cut points to identify at-risk Asian Americans for type 2 diabetes Screening. Diabetes Care. 2015 Jan 1;38(1):150–8.

13. Ashwell M, Gunn P. Waist-to-height ratio is a better screening tool than waist circumference and BMI for adult cardiometabolic risk factors: systematic review and meta-analysis. Obes Rev. 2012 Mar 1;13(3):275–86.

14. National Health and Nutrition Examination Survey. About the National Health and Nutrition Examination Survey. Available from: http://www.cdc.gov/nchs/nhanes/about_nhanes.htm. Accessed 26 June 2016.

15. The National Heart, Lung, and Blood Institute. Clinical guidelines on the identification, evaluation, and treatment of overweight and obesity in adults. 1998 Sep; 16-25.

16. Browning LM, Hsieh SD. A systematic review of waist-to-height ratio as a screening tool for the prediction of cardiovascular disease and diabetes: 0.5 could be a suitable global boundary value. Nutr Res Rev. 2010 Dec;23(2):247–69.

17. Lee JWR, Brancati FL. Trends in the prevalence of type 2 diabetes in Asians versus Whites results from the United States National Health Interview Survey, 1997–2008. Diabetes Care. 2011 Feb 1;34(2):353–7.

18. Thorpe LE, Upadhyay UD, et al. prevalence and control of diabetes and impaired fasting glucose in New York City. Diabetes Care. 2009 Jan 1;32(1):57–62.

19. McNeely MJ, Boyko EJ. Type 2 diabetes prevalence in Asian Americans results of a national health survey. Diabetes Care. 2004 Jan 1;27(1):66–9.

20. Centers for Disease Control and Prevention. National Diabetes Statistics Report, 2014. Available from: http://www.cdc.gov/diabetes/pubs/statsreport14/national-diabetes-report-web.pdf. Accessed 26 June 2016.

21. Lim U, Ernst T, et al. Asian women have greater abdominal and visceral adiposity than Caucasian women with similar body mass index. Nutr Diabetes. 2011 May 9;1(5):e6.

22. Shai I, Jiang R, et al. Ethnicity, obesity, and risk of type 2 diabetes in women a 20-year follow-up study. Diabetes Care. 2006 Jul 1;29(7):1585–90.

23. Wang J, Thornton JC, et al. Asians have lower body mass index (BMI) but higher percent body fat than do whites: comparisons of anthropometric measurements. Am J Clin Nutr. 1994 Jul;60(1):23–8.