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Waist-To-Hip Ratio vs. Body Mass Index as a Predictor of Total Mortality for People with Normal Weight and Central Obesity

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Abstract

Background: Obesity has become one of the greatest health risks in the U.S. Obesity is one of the largest causes of mortality in the country leading to the development of cardiovascular disease, liver disease, and endocrine disorders, to name a few. For decades, the gold standard in predicting a person's likelihood of developing complications secondary to obesity has been their body mass index (BMI). While BMI succeeds in identifying many who are at risk for developing the complications listed above, there are some individuals who may not receive the proper treatment and preventative measures because they have a normal BMI and excess abdominal adipose tissue. This has lead researchers to investigate whether waist-to-hip ratio or BMI is a better predictor of total mortality in people who have a visceral fat distribution.

Methods: An exhaustive search of the following databases was performed using MEDLINE (Ovid), Google Scholar, and Web of Science using the key terms: normal weight central obesity, healthy, abdominal obesity, and mortality. Articles which evaluated only human participants and written in the English language were reviewed for quality using the GRADE criteria.

Results: Searches of published research returned a total of 104 articles, of which three matched the search inclusion criteria and were read in their entirety. Two of these articles were evaluated using the GRADE guidelines. One study was a stratified multistage probability design using NHANES III data while the other study was a prospective cohort study using data from the Dutch EPIC-MORGEN study.

Conclusion: Studies suggest that while BMI serves as a useful screening tool, it does not sufficiently identify all individuals who may be at risk for developing complications and mortality secondary to obesity. Waist-to-hip ratio may more accurately identify individuals who are at a higher risk of developing obesity related health complications. Some studies have even shown an inverse relationship between BMI and mortality.

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Biography

David Smith is a native of Hawaii where he was born, but has spent the majority of his life in Utah where he graduated from Brigham Young University with a BS in Business Management with an emphasis in Finance. His interests in medicine include surgery, trauma, and urgent care.

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Keywords: *BMI, Body mass index, waist-to-hip ratio, WHR, central obesity, normal weight, normal BMI, visceral fat, abdominal obesity, total mortality, metabolically healthy*

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List of Abbreviations

WHR……………………………………………………………………....…Waist-to-hip ratio
BMI………………………………………………………………………Body mass index
MHAO…………………………………………....…Metabolically healthy abdominally obese
MHNAO……………………………..…………….Metabolically healthy nonabdominal obese
MUNAO……………………...…………………Metabolically unhealthy nonabdominal obese
MUAO……………………………………………Metabolically unhealthy abdominally obese
WC……………………………………………………………………....Waist circumference

Waist-To-Hip Ratio vs. Body Mass Index as a Predictor of Total Mortality for People with Normal Weight and Central Obesity

BACKGROUND

According to the Centers for Disease Control and Prevention, obesity accounts for about 10 percent of the national medical budget costing the country about $150 billion each year. It is estimated that 33 percent of adults and 17 percent of children are obese.[1] These numbers would undoubtedly be much larger if they included individuals with abdominal obesity, but a normal body mass index (BMI). Obesity rates in the U.S. have increased drastically over the last several decades reaching epidemic levels. The reasons for this phenomenon are multifaceted and cross cultural and socioeconomic barriers. Some of the reasons for the rise in obesity include changes to the average American's diet with the prevalence of processed foods and fast food eating establishments, reduced activity levels, and technological advances that make physical activity less appealing.

Regardless of the reasons behind an individual's obesity, it is clear that improvements need to be made concerning the identification and treatment of individuals at risk for the avoidable complications and deaths which result from being obese. For decades the medical profession has used BMI as a screening tool to identify who is at risk for developing complications secondary to long-term obesity. BMI is obtained by taking a person's weight in kilograms and dividing it by their height in meters squared. For example, a person weighing 68 kg with a height of 1.65 m would have a BMI of 24.98.[2] The individual in the example above would be categorized as being a normal or healthy weight (see Table 1). The use of BMI is so prevalent in the medical field because it is an inexpensive and easy screening tool that can be done at any visit. While BMI is an estimate that does not directly measure a person's actual body fat, the CDC states that it has moderate correlation to other tools which more directly measure adipose tissue.[2]

There has been some speculation within the medical community that not all fat deposits are created equal. Screening for total mortality using BMI alone fails to capture a portion of the population who may have a normal BMI but are at risk for developing complications of obesity because of their visceral fat deposits. The American Heart Association along with the American College of Cardiology and The Obesity Society recommend using BMI and waist circumference (WC) to screen for patients who need to lose weight (see Figure 1). They recommend identifying patients with a BMI over 25.0 kg/m^2 (overweight) who may be at risk for cardiovascular disease, and patients with a BMI over 30.0 kg/m^2 (obese) who may be at risk for mortality. In addition to calculating BMI, these guidelines recommend measuring WC for individuals who are overweight or obese according to BMI. These guidelines make the assumption that an individual with a normal BMI (<25 kg/m^2) is not at risk for any type of obesity-related sequelae. Practitioners following these guidelines may fail to adequately screen patients who may be at risk for developing cardiovascular disease or other complications of obesity because their BMI measurements do not take into consideration the distribution of adipose tissue concentrated to the abdomen.

The World Health Organization defines abdominal obesity as having a waist-to-hip ratio (WHR) $\geq$0.90 for men and a WHR $\geq$ 0.85 for women.[3] A large cohort study by Berentzen et al[4] looked at the changes in WC compared to changes in BMI and found that changes in BMI were inversely associated with mortality while changes in WC were positively associated with mortality. This study showed that the hazard ratio for the change in BMI was 0.91 per kg/m^2 while the hazard ratio for the change in WC was 1.09 per 5 cm for the combined sexes. When combining the two measurements the hazard ratio increased to 1.15 for an increase in WC with a concurrent drop in BMI. Conversely the hazard ratio dropped to 1.02 in participants with an increase in both WC and BMI.[4]

To many, these findings are counterintuitive and appear to contradict what the general population has been led to believe concerning BMI and its usefulness as a screening tool for morbidity and mortality. Knowing this, it is important that early and accurate screening be used to help patients avoid unnecessary complications of their obesity. The importance of this issue has led many researchers to ask whether WHR or BMI is a better predictor of total mortality for people with normal weight and central obesity.

METHODS

An exhaustive search of available literature was performed using MEDLINE (Ovid), Google Scholar, and Web of Science. The searches were carried out using the following keywords: normal weight central obesity, healthy, abdominal obesity, and mortality. Eligibility criteria included research conducted on individuals with a normal BMI (<25.0) who have central obesity in comparison with individuals who have a normal BMI with no central obesity and individuals with an increased BMI (>25) with no central obesity.

The articles which met the inclusion criteria that were completed using humans or human tissue and written in the English language comprised the pool of available studies. The chosen studies were then evaluated for quality using the Grading of Recommendations, Assessment, Development and Evaluation (GRADE) criteria (see Table 1).[5]

RESULTS

The search resulted in a total of 104 articles which were reviewed for appropriateness. Of the above articles, three were included for consideration and read in their entirety. Upon application of the inclusion criteria stated previously, two articles remained.[6,7]

Sahakyan et al

The Sahakyan et al study[6] is a stratified multistage probability design study of the Third National Health and Nutrition Examination Survey (NHANES III) which included 15 184 adults aged 18 to 90 years who had available WHRs, a BMI greater than 18.5 kg/m^2, and no history of cancer other than skin cancer. This study evaluated the hazard ratios of individuals with various BMIs and WHRs using Cox proportional hazard models. Study participants were compared to a model of various BMIs and WHRs combinations to establish appropriate total mortality hazard ratios. A BMI of 22.0 kg/m^2 represented an individual with a normal BMI, a BMI of 27.5 kg/m^2 represented a classification of overweight, and a BMI of 33 kg/m^2 indicated that someone was obese. For men, a WHR of 0.89 indicated they were not centrally obese while a WHR of 1.0 indicated central obesity. For women, a WHR of 0.80 indicated non-centrally obese and a WHR 0.92 was the model for central obesity (see Tables 3 & 4).[6]

This study had a mean follow-up period of 14.3 years, during which time there were 3222 deaths, 1404 from cardiovascular disease. In a comparison of various mixtures of BMI and body fat distribution, it was found that men with a normal BMI and central obesity (Row 2 Column 2 in Table 3) have a higher total risk of mortality than any other combination of BMI and adipose tissue distribution. The study found that men with a BMI less than 25 kg/m^2 who had visceral fat deposits had an 87 percent higher mortality risk than their peers with similar BMIs but no abdominal adiposity. Further comparison of the figures seen on Table 3 show that a centrally-obese male with a normal BMI has twice the risk of mortality than a male who is overweight according to BMI but is not centrally obese. For women with a normal BMI and central obesity, total mortality risk was 48 percent higher than a woman with a similar BMI but no excessive visceral fat deposits (see Table 4).[6]

Expected mortality rates during a 10 year period are markedly higher than those observed over a 5 year course. “The effect of central obesity on 5- and 10-year survival across all age groups is pronounced. The rank-ordering pattern of expected survival, both within age groups and overall, consistently favors men with less central obesity. The same general pattern is seen in women.” The authors note that the mortality risks associated with an individual having notable visceral fat deposits for a prolonged period of time additionally call into question the current guidelines of screening for individuals who should lose weight (see Figure 1).[6]

van der A et al

This prospective cohort study[7] followed 22 654 Dutch individuals aged 20-59 for an average of 13.4 years and examined the mortality risk of individuals classified as metabolically healthy abdominal obese (MHAO) in comparison to the reference group of individuals who were metabolically healthy non-abdominal obese (MHNAO). The study also compared the risks of MHAO individuals to those who were metabolically unhealthy non-abdominal obese (MUNAO) and metabolically unhealthy abdominal obese (MUAO) individuals. A study participant’s classification of metabolic health were based on the presence the following metabolic risk factors: waist circumference (≥102 cm in men, ≥88 cm in women); hypertension (SBP ≥130 and/or DBP 85 mmHg and/or use of antihypertensive medication); dyslipidemia was defined as total cholesterol ≥6.5 mmol L^{-1}, and/or HDL-C <1.03 mmol L^{-1} (men) or <1.29 mmol L^{-1} (women), and/or use of cholesterol-lowering medication; and hyperglycemia was defined as nonfasting plasma glucose ≥7.8 mmol L^{-1} and/or self-reported diabetes. Using the MHNAO group as reference, the study designers calculated hazard ratios through Cox proportional regression analysis.[7]

The study found that nearly 23 percent of the study participants were abdominally obese with 20 percent of those individuals being metabolically healthy. During the study's 13.4 year follow up, 838 individuals passed away. When compared to MHNAO, the total mortality hazard ratio of MHAO participants was 1.43 (95% CI: 1.00-2.04). The study also found that the total mortality risk for MHAO individuals was of the same magnitude of MUNAO individuals (MUNAO to MHNAO HR 1.31).[7] The comparison of MUAO to MHAO reveals a hazard ratio of 1.12 showing that, while MUAO individuals have a higher total mortality risk, the difference is not very significant. As seen in the study cited above, the "data suggests that it may take at least a decade before metabolic changes arise as a result of obesity" showing that men who had abdominal obesity for longer than 10 years had a twofold increase in the occurrence of elevated triglycerides and metabolic syndrome.[7]

Analysis of the four phenotypes listed earlier showed that, when defined by waist circumference, abdominally obese adults were less likely to be metabolically healthy when compared to BMI-defined obesity measures. Comparison of the MHAO and MUAO groups revealed that while the MHAO group was less obese, there were no significant differences in the presence of preexisting myocardial infarction, stroke, cancer, past surgeries, or persistent back problems. Both groups showed an increased risk in total mortality when compared to the MHNAO individuals. The researchers suggest that the MHAO group may just be a transitional stage on the way to becoming metabolically unhealthy.[7]

DISCUSSION

Obesity has reached epidemic status here in the U.S. and abroad. When solely categorized by BMI (see Table 1), the problem appears massive and results in unnecessary drains on the economy, productivity, and healthcare resources.[1] If the negative externalities of the obesity problem were to include complications experienced by individuals of normal weight with central obesity as measured by WHR according to the World Health Organization[3] (≥0.90 for men and ≥ 0.85 for women), the figures would be staggering. Whether or not the official measure of obesity should be amended to include those who are of normal weight with central obesity, it is clear that more needs to be done to identify those who are at an elevated risk of morbidity and mortality secondary to obesity.

Current guidelines for identification of patients who are at an elevated risk of morbidity and mortality and need to lose weight only capture a portion of the total population at risk (see Figure 1). The Berentzen et al study[4] postulates that peripheral subcutaneous fat deposits which are more likely to lead to a person being categorized as overweight or obese according to BMI may actually be beneficial as seen in the inverse relationship noted between BMI and mortality. Individuals with peripheral subcutaneous fat distribution, specifically around the hips and thighs, appear to be less likely to suffer from metabolic syndrome and other inflammatory processes which are more strongly correlated to visceral fat deposits.

Both studies used Cox hazard statistical analysis to make the data comparable across varying body types and measures of adiposity. And while the above studies had serious limitations (see Table 2), these were not significant enough to detract from the combined findings which more strongly correlate cardiovascular and total mortality to abdominal obesity than to obesity as measured by BMI alone. The cursory review of results returned in the initial search of published literature appears to show a growing consensus that visceral adiposity is a better predictor of an individual's total mortality. The articles chosen for this review focused on persons with a normal BMI who have abdominal obesity and the research shows that individuals with this phenotype are at an increased risk when compared to those who do not have abdominal obesity, regardless of their BMI.

The Sahakyan et al study[6] was found to have several strengths including length of follow up. The long follow up revealed that there is an increase in mortality when 5- and 10-year expected mortality rates are compared. In addition to length of follow up the study's other main strength was the large sample size which included a population that is representative of the U.S. population in regards to race, culture, age, and socioeconomic status.

This study[6] also contained several limitations. Among those limitations were the self-reporting of comorbidities which is prone to error; however, underreporting of comorbidities is likely to lessen the correlation between WHR and mortality. The NHANES III study also measured WC differently than the method recommended by the WHO[3] which may make comparisons to other studies difficult or impossible. And finally, the study used WHR ratio as a measure of visceral obesity. While this method is more accurate than BMI at identifying abdominal adiposity, use of imaging such as computed tomography would more accurately differentiate between visceral and subcutaneous fat.

The van der A et al study[7] also had several strengths. The study's 13.4 year average follow up revealed similar trends of worsening outcomes the longer an individual is centrally obese. Comparable to the Sahakyan et al study, this study's large sample size proved to be a valuable strength. Researchers had access to wide-ranging information on participants' lifestyle, diet, activity levels, medical history, etc. While a large sample size increases the study's validity and applicability, the study participants were all from the Dutch population and the relatively narrow age range of adults between 20 and 59 years of age also limits how the data maybe be put to practical use. The study may also have misclassified some participants with hyperglycemia and hyperlipidemia as a result of non-fasting blood levels being collected rather than fasting blood levels. Metabolically unhealthy individuals may been underreported as a result of not measuring triglyceride and insulin levels as well as any inflammatory markers. Finally, this study also measured WC instead of computed tomography to estimate visceral obesity. While many studies have found that the correlation between the two is strongly positive, WC fails to accurately differentiate between what the researchers call "metabolically active visceral fat and the less metabolically active subcutaneous fat."[7]

More research needs to be done to address the limitations of these studies and to discover the physiologic mechanisms shown in studies where BMI is inversely related to mortality, as well as the precise mechanisms that make abdominal obesity so damaging. While some have speculated that having central obesity for longer than 10 years triggers the activation of multiple inflammatory processes which then results in the development of metabolic syndrome and cardiovascular disease, not enough is known about these metabolic pathways to confirm this hypothesis.

CONCLUSION

Studies have shown that screening all patients with WHRs appears to be a better and more precise way of identifying risk of total mortality when compared to calculating BMI. Current guidelines do not adequately identify those who have an elevated risk of mortality secondary to obesity, and further studies are recommended to address the limitations mentioned above and to establish the best way to screen at risk individuals. Given that it is not feasible or safe for every person to undergo repeated computed tomography scans to screen for the presence of visceral fat deposits, it is reasonable to continue to use WHRs as an easy and reliable means of assessing a person's abdominal obesity.

In light of the results documented in this review, practitioners may want to give serious consideration to utilizing WHR and BMI in conjunction to screen all patients regardless of BMI in order to more precisely identify those who have an elevated risk of total mortality secondary to obesity. Many electronic medical record programs utilized in clinical practice automatically calculate a patient's BMI based on height and weight measurements collected at each visit. In addition to this calculation, patients should have their WHR's calculated at least annually. These additional measurements are so easily and quickly obtained that it would be feasible to collect them at each office visit. While some may see this as an unnecessary step, the information gleaned from this simple approach may slow the development of many unnecessary health complications and deaths for patients who may not know they are at risk. Using BMI and WHR to screen and educate patients about their health risks will result in significantly fewer dollars spent on the treatment of obesity-related diseases. In addition to the cost savings, patients will be able to increase their lifespans by decreasing their waistbands.

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Tables

Table 1. BMI Weight Status Categories

BMI	Weight Status
Below 18.5 kg/m^2	Underweight
18.5 - 24.9 kg/m^2	Normal or Healthy Weight
25.0 - 29.9 kg/m^2	Overweight
30.0 kg/m^2 and Above	Obese

Table 2: Quality Assessment of Reviewed Articles

Study	Design	Downgrade Criteria					Upgrade Criteria	Quality
		Limitations	Indirectness	Inconsistency	Imprecision	Publication bias		
Sahakyan et al[6]	Stratified multistage probability design	Not serious [a,b]	Not Serious	Not Serious	Not Serious	Unlikely	None	Low
Van Der A et al[7]	Cohort	Serious [a,c,d]	Not Serious	Not Serious	Not Serious	Unlikely	None	Very low

[a] WC instead of CT for abdominal obesity
[b] Self-reporting of comorbidities
[c] Limited geography and ages for sample
[d] Collection of non-fasting blood samples

Table 3. Hazard Ratios for Total Mortality for Men

1. BMI: 22 kg/m² WHR: 0.89 	2 vs. 1 1.87 (1.53–2.29)	3 vs. 1 0.84 (0.64–1.09)	4 vs. 1 1.53 (1.27–1.86)	5 vs. 1 0.77 (0.46–1.30)	6 vs. 1 1.38 (1.07–178)
1 vs. 2 0.53 (0.44–0.65)	2. BMI: 22 kg/m² WHR: 1.0 	3 vs. 2 0.45 (0.30–0.66)	4 vs. 2 0.82 (0.69–0.97)	5 vs. 2 0.41 (0.22–0.77)	6 vs. 2 0.74 (0.55–0.99)
1 vs. 3 1.20 (0.91–1.57)	2 vs. 3 2.24 (1.52–3.32)	3. BMI: 27.5 kg/m² WHR: 0.89 	4 vs. 3 1.84 (1.39–2.42)	5 vs. 3 0.93 (0.72–1.20)	6 vs. 3 1.65 (1.34–2.04)
1 vs. 4 0.65 (0.54–0.79)	2 vs. 4 1.22 (1.03–1.45)	3 vs. 4 0.54 (0.41–0.72)	4. BMI: 27.5 kg/m² WHR: 1.0 	5 vs. 4 0.50 (0.30–0.84)	6 vs. 4 0.90 (0.79–1.03)
1 vs. 5 1.29 (0.77–2.18)	2 vs. 5 2.42 (1.30–4.53)	3 vs. 5 1.08 (0.84–1.40)	4 vs. 5 1.98 (1.20–3.29)	5. BMI: 33 kg/m² WHR: 0.89 	6 vs. 5 1.79 (1.18–2.70)
1 vs. 6 0.72 (0.56–0.94)	2 vs. 6 1.36 (1.01–1.82)	3 vs. 6 0.60 (0.49–0.75)	4 vs. 6 1.11 (0.97–1.26)	5 vs. 6 0.56 (0.37–0.85)	5. BMI: 33 kg/m² WHR: 1.0 

The group of interest versus the referent are shown in the cells above. For example, to compare a normal-weight centrally obese man (profile 2: BMI = 22 kg/m²; WHR = 1.0) with an overweight but not centrally obese person (profile 4: BMI = 27.5 kg/m²; WHR = 1.0), the cell in row 4, column 2 would be referenced (denoted as 2 vs. 4: HR = 1.22 [95% CI, 1.03 to 1.45]). To interpret the HRs, select an intersection of 2 anthropometric profiles of interest. The HRs and 95% CIs were estimated by statistical models presented in **Appendix Tables 1** and **2** (available at www.annals.org). Courtesy of the Mayo Clinic. BMI = body mass index; HR = hazard ratio; WHR = waist-to-hip ratio.

Table 4. Hazard Ratios for Total Mortality for Women

1. BMI: 22 kg/m² WHR: 0.80 	2 vs. 1 1.48 (1.35–1.62)	3 vs. 1 1.06 (0.99–1. 13)	4 vs. 1 1.56 (1.38–1.77)	5 vs. 1 1.12 (0.99–1.27)	6 vs. 1 1.65 (1.39–1.97)
1 vs. 2 0.68 (0.62–0.74)	2. BMI: 22 kg/m² WHR: 0.92 	3 vs. 2 0.72 (0.65–0.79)	4 vs. 2 1.06 (0.99–1.13)	5 vs. 2 0.76 (0.66–0.87)	6 vs. 2 1.12 (0.99–1.27)
1 vs. 3 0.95 (0.89–1.01)	2 vs. 3 1.40 (1.27–1.54)	3. BMI: 27.5 kg/m² WHR: 0.80 	4 vs. 3 1.48 (1.35–1.62)	5 vs. 3 1.06 (0.99–1.13)	6 vs. 3 1.56 (1.38–1.77)
1 vs. 4 0.64 (0.56–0.72)	2 vs. 4 0.95 (0.89–1.01)	3 vs. 4 0.68 (0.62–0.74)	4. BMI: 27.5 kg/m² WHR: 0.92 	5 vs. 4 0.72 (0.65–0.79)	6 vs. 4 1.06 (0.99–1.13)
1 vs. 5 0.89 (0.79–1.01)	2 vs. 5 1.32 (1.15–1.51)	3 vs. 5 0.95 (0.89–1.01)	4 vs. 5 1.40 (1.27–1.54)	5. BMI: 33 kg/m² WHR: 0.80 	6 vs. 5 1.48 (1.35–1.62)
1 vs. 6 0.60 (0.51–0.72)	2 vs. 6 0.89 (0.79–1.01)	3 vs. 6 0.64 (0.56–0.72)	4 vs. 6 0.95 (0.89–1.01)	5 vs. 6 0.68 (0.62–0.74)	6. BMI: 33 kg/m² WHR: 0.92 

The group of interest versus the referent are shown in the cells above. To interpret the HRs, select an intersection of 2 anthropometric profiles of interest. The HRs and 95% CIs were estimated by statistical models presented in **Appendix Tables 1** and **2** (available at www.annals.org). Courtesy of the Mayo Clinic. BMI = body mass index; HR = hazard ratio; WHR = waist-to-hip ratio.

Figure I. AHA/ACC/TOS Screening Guidelines

(http://circ.ahajournals.org/content/129/25_suppl_2/S102/T4.expansion.html)

Recommendations

Identifying Patients Who Need to Lose Weight (BMI and Waist Circumference)

1a. Measure height and weight and calculate BMI at annual visits or more frequently

1b. Use the current cutpoints for overweight (BMI 25.0 - 29.9 kg/m2) and obesity (BMI >/= 30.0 kg/m2) to identify adults who may be at elevated risk of CVD and the current cutpoints for obesity (BMI >/= 30.0 kg/m2) to identify adults who may be at elevated risk of mortality from all causes.

1c. Advise overweight and obese adults that the greater the BMI, the greater the risk of CVD, type 2 diabetes, and all-cause mortality.

1d. Measure waist circumference at annual visits or more frequently in overweight and obese adults.

Advise adults that the greater the waist circumference, the greater the risk of CVD, type 2 diabetes, and all-cause mortality. The cutpoints currently in common use (from either NIH/NHLBI or WHO/IDF) may continue to be used to identify patients who may be at increased risk until further evidence becomes available.