Use of Waist Circumference to Assess Health Risk

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Abstract

The increasing prevalence of overweight and obesity in American society and worldwide has contributed to the increased incidence and severity of several diseases, as well as to premature mortality. The most commonly used method for classifying an individual as overweight or obese is the determination of body mass index (BMI), which is based upon body weight and height. BMI is a useful measure for assessing weight-related health risk, but has limitations that sometimes lead to misclassification of individuals. Waist circumference measurements are proposed to be a better indicator of health risk than BMI alone, particularly when used in combination with BMI. The advantage of waist circumference is that is provides an estimate of abdominal fat, which poses a disproportionate health burden relative to fat stored in other parts of the body. There is increasing evidence that waist circumference measures can enhance the prediction of adverse health consequences and early mortality, and that its use in clinical practice is warranted. However, the relationship between waist circumference, morbidity and mortality appears to vary between populations differing in age, sex and race, and this area requires further investigation.

Introduction

Obesity is a worldwide epidemic characterized by excess adipose tissue that contributes to numerous chronic diseases and early mortality.[1,2] Obesity affects an estimated 300 million people worldwide and has a profound, negative impact on health and quality of life among adults, adolescents, and even children in the United States and other industrialized countries. The attention that this epidemic receives both nationally and internationally is justifiable based upon obesity's detrimental impact on health, the enormous economic burden it imposes, and its increasing prevalence. In the United States, it is estimated that approximately 64.5% of adults can be classified as overweight or obese.[3]

Abdominal obesity signifies excess adipose tissue located in the abdomen, and is believed to contribute disproportionately to ill health. The adverse health consequences associated with abdominal obesity, as well as obesity in general, are vast,[4] and include cardiovascular disease,[5,6] stroke, type 2 diabetes mellitus,[7] hypertension, dyslipidemia, liver diseases, gallbladder disease, osteoarthritis,[10,11] respiratory problems such as asthma[12] and sleep apnea,[13] as well as cancers

of the breast, endometrium, prostate, and colon.[8,9] Furthermore, aerobic capacity and the ability to perform physical activities may be hindered by obesity,[14,15] and activities of daily living may be difficult to perform. In addition to this increased morbidity, approximately 325,000 deaths in the United States each year among nonsmokers are attributable to obesity.[16]

Defining Health Risk Based Upon Body Mass Index & Waist Circumference

The most commonly used method today for classifying an individual as overweight or obese is based upon body mass index (BMI), a value that is determined by dividing body weight (in kilograms) by the square of height (in meters). The World Health Organization defines overweight among adults as a BMI $\geq$25.0 kg/m^2, and obesity as a BMI $\geq$30.0 kg/m^2, regardless of sex.[17] The use of BMI has gained international acceptance because of the associations between BMI and adiposity,[18] BMI and disease risk,[4] and BMI and mortality.[19] The major limitation of BMI, however, is that it does not differentiate between weight that is fat and weight that comprises lean body mass. Furthermore, BMI does not provide information about fat distribution, and therefore does not identify abdominal obesity. Due to these limitations, an older adult who has experienced the common loss of muscle tissue with aging may have a BMI value in the healthy range despite muscle wasting and excess abdominal fat. In addition, some athletes are misclassified as overweight using BMI because of the relative density of lean body mass. These limitations necessitate the use of another measure to estimate health risk associated with increased body fat.

The measurement of waist circumference (WC) is a second tool recommended in the Clinical Guidelines on the Identification, Evaluation and Treatment of Obesity[20] to assess weight-related health risk. Waist circumference serves as a useful and potentially better indicator of health risk than BMI, because higher abdominal girth generally represents fat as opposed to muscle tissue. Several anatomical sites have been recommended for the measurement of WC, including the midpoint between the lowest rib and the iliac crest,[17] the level of the iliac crest,[21] and the narrowest waist.[22] WC is a relatively simple and valid measure that may be used independently,[23] but preferably in addition to BMI[24] to more accurately determine health risk.

Waist circumference generally correlates well with BMI (r = 0.84-0.88),[25] but has two advantages. First, WC provides an estimate of abdominal fat,[24,26] which is more strongly associated with health risk than fat stored in other regions of the body.[27] The World Health Organization defines sex-specific waist circumference values that signify increased health risk (≥80 cm for women, ≥94 cm for men) and substantially increased health risk (≥88 cm for women, ≥102 cm for men).[17] Similarly, the National Cholesterol Education Program defines abdominal obesity using waist circumference criteria of >88 cm (women) and >102 cm (men).[28] Therefore, WC measurements are helpful in identifying whether an older adult with a healthy body weight has excess abdominal fat that may pose a health threat. Likewise, WC measurements in athletes provide a simple assessment of whether high BMI values reflect excess abdominal adipose tissue in addition to increased muscle mass.[29] A second advantage of WC is that this measurement requires a tape measure only, which is a portable and clinically feasible tool.

Waist Circumference as an Indicator of Abdominal Fat

Excess abdominal fat is an important contributor to several metabolic risk factors and adverse health consequences. Abdominal fat can be subdivided into abdominal subcutaneous adipose tissue and visceral adipose tissue, the latter being more of a health risk than the former. Although sophisticated body composition assessment techniques such as computed tomography, magnetic resonance imaging, or dual-energy x-ray absorptiometry are necessary to differentiate between subcutaneous and visceral fat stores, waist circumference serves as a simple, available, and inexpensive surrogate that has been shown to correlate with visceral adipose tissue.[24,26,30,31]

Waist circumference frequently is expressed relative to hip circumference as the waist-to-hip ratio (WHR), which provides an indication of adipose tissue distribution. A high WHR represents abdominal obesity, also referred to as central or upper-body obesity. Currently, high WHR values are defined as >0.85 in women and >1.0 in men,[17] whereas WHR values exceeding 0.80 in women and 0.95 in men were used previously to signify increased health risk. The limitation of WHR, however, is that an individual with enlarged waist and hip girths can have a 'healthy' WHR despite the presence of excess abdominal adipose tissue. Therefore, waist circumference alone

may be a better indicator of both visceral fat and metabolic risk factors than is WHR,[26] and has gained favor as the preferred method for assessing abdominal adiposity. Waist circumference also may be expressed relative to height as the waist-to-height ratio, an index that reflects abdominal fat[32] and may have better predictive ability than WHR for health risk.[33,34]

Associations Between Waist Circumference and Health Risk

Waist circumference and similar measures of abdominal obesity correlate well with numerous metabolic risk factors,[35-37] as well as coronary heart disease,[38] cardiovascular events,[39] the metabolic syndrome,[40-42] and type 2 diabetes.[43] The link between waist circumference and metabolic risk factors is supported by extensive evidence from cross-sectional and observational studies. Using the World Health Organization waist circumference criteria, high WC values were associated with increasing frequency of cardiovascular disease risk factors among a population sample of 4,881 women and men 20-59 years of age in the Netherlands.[44] Among 2,698 women in this sample, the odds ratio of having at least one cardiovascular risk factor was 1.6 in those with WC values between 80-88 cm, and 2.6 in those with WC >88 cm. More dramatic results were observed for the 2,183 men, in whom the excess risks attributable to a large waist girth were 2.2 (WC 94-102 cm) and 4.6 (WC >102 cm) times greater than those with WC values in the healthy range. Consistent with these findings, results from the Baltimore Longitudinal Study of Aging revealed that WC was highly correlated with 10 risk factors for coronary artery disease among 1,941 men and women.[25] In the Bogalusa Heart Study of 518 young women and men, WC was a risk factor associated with increased carotid artery intima-media thickness, an indicator of atherosclerosis.[45] Among 768 middle-aged men from the Olivetti Heart Study, WC was the strongest predictor of blood pressure, and also was related to heart rate, insulin concentrations, and insulin sensitivity.[42] Even among adolescents, higher waist circumferences were associated with increased risk for coronary heart disease based upon low density lipoprotein (LDL) subclass properties and other lipid parameters.[46]

Menopause is associated with increased risks for cardiovascular disease among women, and waist circumference has been shown to correlate with known cardiovascular risk factors. Among

323 healthy postmenopausal women between 59 and 84 years of age, a high WC (>88 cm) was strongly associated with hyperinsulinemia and hypertriglyceridemia, and was more sensitive than BMI as a predictor of these risk factors.[47] Among postmenopausal Chinese women in the Kinmen Women-Health Investigation, WC was shown to be an independent predictor of insulin resistance and other metabolic risk factors, whereas BMI was not.[48] Waist-to-hip circumference ratio also has been associated with health risk, and was inversely correlated with HDL_2 cholesterol, a protective factor against cardiovascular disease, among healthy postmenopausal women and men 60 to 70 years of age.[49]

In addition to its relationship with disease risk factors, waist circumference also serves as a correlate of disease incidence and prevalence in prospective and cross-sectional studies, respectively. In the Atherosclerosis Risk in Communities (ARIC) study, a multicenter prospective study of 14,040 black and white adults followed for an average of 6.2 years, the relative risks for coronary heart disease among men and women were 1.51 and 2.53, respectively, in the highest quartiles for waist circumference.[50] In the prospective Kuopio Ischaemic Heart Disease Risk Factor Study of 1,346 Finnish males, high waist circumference was an independent risk factor for coronary events during 10.6 years of follow-up, and was more strongly associated with coronary heart disease than was BMI.[39] Likewise, WC was shown to be associated more closely with cardiovascular disease risk than was BMI among 9,019 white participants in the third National Health and Nutrition Examination Survey (NHANES III).[51] In another cross-sectional study involving 569 men aged 18-69, coronary artery disease (determined by angiography) was more prevalent among men with both a high WC ($\geq$90 cm) and hypertriglyceridemia, with odds ratios between 5.4 and 8.5, depending upon the absence or presence of impaired fasting glucose.[38]

The risk for stroke also is increased among older men with a high waist circumference, as shown in a prospective cohort study of 2,278 men and women in Sweden who were in their 70s at baseline and were followed for 15 years.[52] Men with WC $\geq$99 cm had a relative risk of stroke of 1.65; this relationship was not observed in women, however.[52] High WC (>88 cm in women, >102 cm in men) significantly increases the risk of developing type 2 diabetes and hypertension, as demonstrated in 1,968 white and Mexican American adults participating in an eight-year

follow-up of the San Antonio Heart Study.[40] Furthermore, increasing WC values were associated with a greater number of metabolic disorders (i.e., dyslipidemia, hypertension, type 2 diabetes) within an individual. In the Women's Health Initiative, a prospective study of more than 85,000 women aged 50 to 79 years at baseline, WC was associated with breast cancer risk among women who had never used hormone replacement therapy.[53] Interestingly, health care costs for a sample of 424 adults were found to be significantly greater among those in the highest quartile for WC (i.e., >103.5 cm), whereas the relationship between BMI and medical costs was not nearly as strong.[54]

Associations Between Waist Circumference and Mortality

There is a great deal of evidence that obesity decreases length of life,[55] and there is a growing body of literature suggesting that high waist circumference also correlates with mortality. The relationship between WC and premature death is variable, however, with differences observed across different gender, age, and racial groups. Among 5,686 women aged 20 to 69 followed for 13 years in the Canada Fitness Survey, waist circumference was linearly related to all-cause mortality.[56] BMI and body fat also showed linear associations with mortality, but the addition of WC to BMI did not enhance the prediction of mortality. In the Iowa Women's Health Study, a five-year, prospective cohort study of 41,837 predominantly white women aged 55 to 69 years at baseline, waist-to-hip ratio was strongly associated with mortality in a linear manner, with women in the highest WHR quintile having a relative risk of death of 2.19 relative to those in the lowest WHR quintile.[57] WC and BMI showed weaker, J-shaped relationships with mortality. In the Charleston Heart Study, which included 312 white and 243 black females, abdominal circumference (measured at the umbilicus) was predictive of all-cause mortality and coronary heart disease mortality among white, but not black women.[58]

The relationship between WC and mortality is different for men. Among 5,039 men aged 20 to 69 in the Canada Fitness Survey, the relationship between WC and all-cause mortality was curvilinear, and in contrast to the data for women, the addition of WC to BMI did significantly improve the prediction of mortality.[56] Among 1,209 males enrolled in the Kuopio Ischaemic Heart

Disease Risk Factor Study, a prospective cohort study of Finnish men followed for an average of 11.4 years, higher WC was associated with increased all-cause mortality and deaths due to coronary heart disease and cardiovascular disease.[59] In stark contrast to these findings, a three-year prospective study involving 2,032 older (i.e., ≥70 y) Chinese adults revealed that both WC and BMI were inversely related to mortality, whereas WHR showed no relationship with mortality.[60]

Critical Issues

There are several potential explanations for the apparent discrepancies between WC and premature death observed in these studies. Age is one factor, as there is some evidence suggesting that extra adipose tissue stores may be beneficial in old age, and that the optimal BMI range for adults 65 years and older is higher than the range for younger adults.[61-63] This assertion is based in part on the U-shaped relationship commonly observed between body weight and mortality,[63] in which very low and very high body weights appear to contribute to death. Some of the mortality data based upon body weight, however, may be confounded by cigarette smoking or unintentional weight loss due to cancer and other terminal illnesses, which increase mortality among those at the lower end of the weight spectrum.[64,65] A mortality follow-up study of men who participated in the first two National Health and Nutrition Examination Surveys (NHANES I and II) revealed a U-shaped relationship between BMI and mortality, but this relationship was altered when body composition was factored into the model.[66] Indicators of fat mass (i.e., skinfold thicknesses) were positively associated with mortality, whereas an indicator of fat-free mass (i.e. upper-arm circumference) was inversely associated with mortality.[66] These findings highlight the importance of body composition assessment and the potential limitation of using BMI alone for estimating health risk among older adults. Excess body fat appears to have adverse health effects into old age, and a simple method of estimating excess abdominal fat, such as an assessment of waist circumference, may be helpful in assessing mortality risk among older adults.

Factors that may influence the observed relationship between WC and mortality in prospective studies are age at baseline and duration of follow-up. For example, high WC values among young or middle-aged adults may be expected to have different associations with mortality than high WC values among older adults. Furthermore, if the period of follow-up is relatively long, then changes in WC, rather than simply WC at baseline, may have a dramatic impact on the interpretation of the outcomes.

Race and ethnicity also influence the relationship between waist circumference (or BMI) and risk of disease and/or premature death.[33,37] While WC correlates well with metabolic risk factors and adverse health outcomes in various populations, the precise WC and BMI thresholds at which health risks begin to escalate are influenced by race and ethnicity. For example, African Americans have relatively lower mortality risk than Caucasians at the same BMI,[19] which may be explained, at least in part, by the observation that African Americans have less visceral fat than Caucasians for the same degree of adiposity or WHR.[67,68] Asians, on the other hand, have relatively greater health risks than Caucasians or African Americans at the same BMI.[69] Therefore, the World Health Organization, the International Association for the Study of Obesity, and the International Obesity Task Force jointly have established distinct BMI and WC criteria for assessing health risks among Asian populations.[69] These critera[69] are lower than the BMI and WC criteria recommended for Europids in the Clinical Guidelines on the Identification, Evaluation and Treatment of Obesity.[20]

Despite these various factors that influence the observed relationships between waist circumference and morbidity or mortality, there is a great deal of evidence that the measurement of waist circumference is a feasible and valid tool that can significantly enhance the ability to predict adverse health consequences and early mortality. As the measurement of waist circumference becomes more routine in clinical practice and widespread among varying populations, additional data will emerge that may clarify the relationship between waist circumference and the risks for various diseases and premature death among different populations and during different stages of life.

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