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Expansion of Waist Circumference in Medical Literature: Potential Clinical Application of a Body Shape Index

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Abstract

Background: Body mass index (BMI) has become the main indicator of obesity. Due to the limitations of BMI in identifying individuals with obesity-related morbidities, risk assessment has broadened to include other biometric measures, especially waist circumference (WC). Here, we present a brief survey of the increasing medical application of WC and related measures, including waist hip ratio (WHR) and waist height ratio (WHtR), with the goal of motivating the new Body Shape Index (ABSI), which adjusts WC for BMI, and providing guidance for the application of ABSI in medical research.

Methods and findings: We searched Medline for mentions of obesity, BMI, WC, and related measures including ABSI. We find that BMI has become an almost universally used indicator for obesity since the early 1990s, but WC is increasingly employed as a supplementary indicator. We show that whereas fixed WC cutoffs are strongly correlated with BMI thresholds, ABSI values are distributed nearly equally across BMI categories, so that ABSI may be a better candidate for providing a biometric measure of wide clinical applicability that supplements BMI in assessing obesity and body composition. There is nascent interest in ABSI, and several publications have applied the measure. However, most do not appear to have adjusted for gender and age, both of which significantly impact ABSI.

Conclusions: Various simple measures of obesity and body dimensions have been increasingly utilized in recent years. ABSI holds potential to improve clinical assessment beyond the measures now commonly used. Comparisons of anthropometric indices should employ consistent methodology, including adjustment for known covariates such as age and sex.

Keywords: Waist circumference; Body shape index; Obesity

Introduction

Obesity has historically been a sign of good health, except at the greatest excess [1]. The modern era has reversed this notion, with obesity classified as a disease in 2013 by the American Medical Association. It has however long been recognized that the harms of obesity are relative and most related to abdominal fat, while lower-body fat may actually not be harmful [2].

Body mass index (BMI), defined as weight divided by the square of height, was developed to allow assessment of weight independent of height. Other measures have also been considered in an attempt to better capture risk for all-cause mortality as well as obesity-related morbidities, which include such conditions as hypertension, atherosclerotic vascular disease, diabetes, some cancers, and the recently defined "locomotive syndrome" [3]. Thus, BMI has come to be augmented by other simple biometrics, primarily waist circumference (WC) and various derivatives of WC such as waist-hip ratio (WHR) and waist-height ratio (WHtR). In an attempt to further the utility of measuring WC, we have proposed a Body Shape Index (ABSI) that is independent of BMI, derived from the National Health and Nutrition Examination Survey (NHANES) 1999-2004 mortality data to better quantify the risk associated with abdominal obesity (as indicated by a wide waist relative to height and body mass index) [4]. A national survey with longer follow-up, the British Health and Lifestyle Survey (HALS), confirmed the predictive power of ABSI for mortality [5]. This predictive power may be in part due to the association of high ABSI with visceral adiposity and reduced lean mass [6].

In this short article, we seek to quantify the increasing medical interest in WC and in related indicators of abdominal obesity and motivate consideration of ABSI as a derived measure of the body shape complementary to BMI. First, we assess the volume of references in the medical literature to BMI, WC, and related indicators over recent decades. Then, we compare ABSI with WC for applicability across BMI levels. Finally, we examine recent research publications for instances in which, in conjunction with other measures, ABSI could potentially inform clinical decisions, and discuss some guidelines for effectively employing ABSI in conjunction with BMI and other biometric indicators.

Methods

PubMed Medline searches were conducted in January 2014 for the yearly number of total citations related to human biology since 1966. The yearly number of citations including each of the phrases "obesity", "body mass index", "waist circumference", "hip circumference", "waist to hip ratio", "waist to height ratio", "body shape index" were also tallied. The total number of articles indexed increased steadily from 1966 to 2011, with a growth rate of 4% per year. (2012 and 2013 had slightly fewer articles than 2011, presumably because indexing for recent years was still incomplete.) We normalized the frequency of each search term for this increase by dividing the number of articles mentioning the term by the total number of articles indexed each year.

Measurements of WC and BMI from over 14,000 individuals representing the USA non-pregnant adult population were accessed

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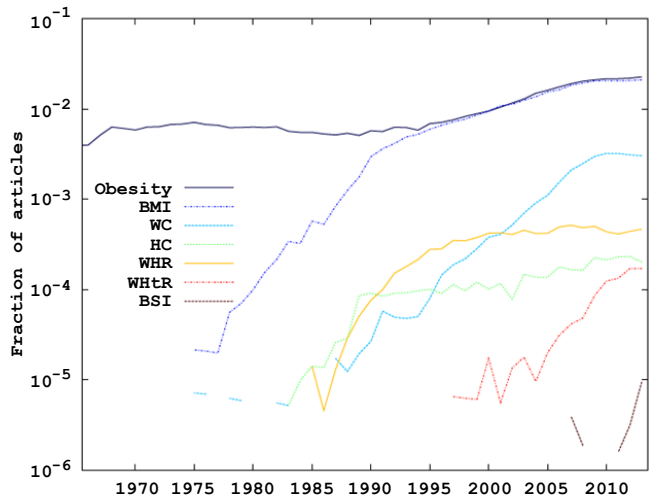

Figure 1: Fraction of Medline articles with each of the selected search terms, 1966-2013. BMI=Body Mass Index; WC=Waist Circumference; HC=Hip Circumference; WHR=Waist Hip Ratio; WHtR=Waist Height Ratio; BSI=Body Shape Index.

Body mass index	Disease risk relative to normal BMI and WC	
	Below-reference WC	Above-reference WC
Underweight <18.5		
Normal 18.5-24.9		
Overweight 25-29.9	Increased	High
Obesity I 30-34.9	High	Very High
Obesity II 35-39.9	Very high	
Extreme obesity 40+	Extremely high	

Table 1: Current categorization of obesity and associated disease risk based on BMI and WC as given by the National Institutes of Health and the World Health Organization (Table 2 of [21]; Table 5.1 of [22]). The WC reference values used are 102 cm for men and 88 cm for women. Abbreviation key: BMI, body mass index; WC, waist circumference.

BMI Category	% above WC cutoff	% above ABSI mean
Underweight <18.5	0.3	54
Normal 18.5-24.9	7	47
Overweight 25-29.9	50	51
Obesity I 30-34.9	93	51
Obesity II 35-39.9	99.8	51
Extreme obesity 40+	100	45

Table 2: Percentage of population above WC and ABSI reference values for each BMI class. The WC reference values are 102 cm for men and 88 cm for women. The ABSI reference is taken to be the age and sex specific population mean (i.e. z score=0). The WC and ABSI distributions by BMI category were derived from NHANES 1999-2004 (see text). Abbreviation key: ABSI, a body shape index; BMI, body mass index; WC, waist circumference.

from the National Health and Examination Survey (NHANES) 1999-2004 as previously described [4].

We reviewed abstracts of 2170 citations for WC from 2013. Selected papers were further reviewed in full text form. Several of these are summarized below.

Results

Obesity is a longstanding, though escalating, medical concern, with the share of the medical literature mentioning it rising from 0.4% in the 1960s to 1% around 2000 and over 2% now. The use of BMI as the main quantitative measure of obesity is relatively recent. The ratio of "BMI" to "obesity" mentions was below 10% until the mid-1980s, but rose quickly through the late 1970s and 1980s before leveling off. Since 2000, obesity and BMI have had very nearly equal numbers of citations each year, demonstrating the extent to which the two have become synonymous.

WC began gaining prominence later than BMI, in the 1990s. Out of 4,398,721 total citations for 1990-1999, 645 (0.01%) were indexed WC, compared to the 10,725,295 total citations 2000-2013 of which 15,921 (0.15%) were indexed WC (odds ratio (OR) 10.1; 95% confidence interval: 9.4-11.0). Hip circumference (HC) and WHR have a few citations going back to the mid-1980s, and grew rapidly in the 1990s before leveling off at under 3% the popularity of obesity and BMI. WC first overtook HC in 1996 – still just 2% of BMI's number of citations – and only reached 10% of the BMI citations in 2007. WHtR was essentially introduced in 1996 [7] and increased rapidly in usage over the period 2005-2012, although still just under 1% of the popularity of BMI. Figure 1 illustrates the annual volume of citations indexed by each of the search terms, normalized for total citations.

A search conducted for "body shape index" (BSI) yielded 7 citations. Two of these predated publication of ABSI and represented two separate pediatric indexes [8,9]. The remaining studies evaluated ABSI [4] and are discussed below.

Further, we found that current cutoffs for large waist circumference (Table 1) are only of relevance for the "overweight" BMI category. For BMI under 25 kg m^{-2} over 90% of adults are under the cutoff, while for BMI over 30 kg m^{-2} over 90% are above the cutoff (Table 2), limiting the usefulness of such a cutoff as a predictor of mortality or morbidity hazard across the adult population [20]. By contrast, high ABSI values, indicating elevated mortality hazard [4], are uniformly distributed over the entire range of BMI (Table 2). Out of reports published after 2012 related to WC, we selected several for which ABSI would possibly be informative:

1. In 2007, the Japanese Orthopaedic Association "proposed the concept of the locomotive syndrome", encompassing disorders which affect walking ability [3]. A motivational pamphlet for people at risk of this syndrome is available in English (https://locomo-joa.jp/en/index.pdf). Recently, Muramoto et al. [10] found that compared to BMI and WHR, waist circumference was most associated with structural and functional lower-body symptoms in elderly females. We propose evaluation of ABSI as a possibly more powerful parameter to assess risk of locomotive syndrome.
2. Gingras et al. [11] proposed to improve postpartum diabetes testing in women with prior gestational diabetes by combining threshold criteria for Hgb A1C and WC, finding an OR of 4.4. We suggest that use of ABSI thresholds in lieu of WC could improve on the 34% sensitivity found for detection of type 2 diabetes.
3. Park et al. [12] studied the 2009 Korea National Health and Nutrition Examination Survey, which includes DXA scan body composition measurements of appendicular muscle mass. They determined that sarcopenia (defined by appendicular muscle mass/body weight t score < −2.0) increased the risk for metabolic syndrome in subjects with both normal and high WC. However, sarcopenia was not a significant predictor in men with high WC. We suggest that ABSI should be considered for identifying risk from sarcopenia among the men with high WC.

4. The important issue of appropriate criteria for bariatric surgery has been addressed by a prediction rule for 10-year mortality among individuals who qualify for surgery by current BMI thresholds [13]. BMI in fact did not improve mortality prediction. It is possible that simple anthropomorphic measures would re-enter the model with use of ABSI instead of BMI (shape rather than size). ABSI could also be considered for identifying high risk individuals who may benefit more from emerging molecular therapies for improving adiposity profiles [14].

5. Most work on ABSI has so far dealt only with adults. Childhood obesity is however of great current interest. A childhood adiposity index has been created based on 13 measures, including WC [15]. We would question, however, the extent to which body shape is represented, as the authors report a correlation of the obesity index with BMI of 0.81. ABSI may offer greater independence from BMI.

6. Indicators for monitoring healthy growth in children include age and sex specific z scores for anthropometric quantities such as height, weight, BMI, head circumference, midupper arm circumference, and triceps and subcapsular skinfold thickness, presented in the easy-to-interpret form of z-score or percentile charts and online cal- culators for each quantity [16, 17, 18]. Changes in body shape as measured by WC relative to height and weight may provide additional insight, for example in assessing growth hormone treatment in children with Prader-Willi Syndrome [19]. We propose that a pediatric ABSI chart in conjunction with the usual height and weight charts may prove informative in monitoring growth.

Discussion

Literature search shows that medical authors have increasingly made reference to waist circumference over the last decade. WC has also been appearing more frequently in conjunction with both BMI and obesity (data not shown). Correspondingly, official definitions of obesity by BMI category now also include cut off points for elevated WC, as in Table 1. Those with elevated WC are deemed at increased risk versus those with normal or low WC. However, as our tabulation of data from NHANES 1999-2004 shows, WC is above the cut point in almost all adults with a BMI > 30 and below the cut point in almost all with BMI < 25 (Table 2). Therefore, the WC cut points that have been used have limited value for the assessment of relative abdominal obesity at low or elevated BMI. ABSI-based cut points appear to be more applicable across BMI categories (Table 2).

Our preliminary bibliometric survey illustrates how different measures of obesity and cardiometabolic risk have gained popularity at different times over the past few decades, although BMI certainly remains the main measure of obesity used. These changing associations may reflect increasing realization of the importance of abdominal obesity. For quantifying abdominal obesity, WC has the advantage of being a simple anthropomorphic measure requiring only a measuring tape. The heightened interest in WC is understandable in light of the limited availability and high cost of more complex biochemical, genetic or imaging technology. Because ABSI uses the basic inputs of WC, height, and weight, it can contribute to this trend by improving the assessment of risk related to obesity and body composition that is not captured by BMI.

Since publication of our initial paper [4], several authors have sought to apply ABSI. Applications have included prediction of cardiovascular mortality, mortality in hemodialysis patients, new onset of diabetes mellitus and blood pressure in adolescents [23-26]. Most of these studies do not appear to have transformed ABSI to age and sex specific z scores as previously advocated [4]. It is also curious that one population survey found ABSI higher for women, contrary to the expectation of higher waist circumference in men [27]. Supporting Information Table 1 of [4] can be used to generate z scores for gender and age categories. Alternatively, scores can be computed at http://www-ce.ccny.cuny.edu/nir/sw/absi-calculator.html

Correction for age is particularly relevant since mean ABSI increases from the youngest to the oldest adults by about two standard deviations of young adult ABSI. In comparison, for both BMI and WC the age-associated change was only about one standard deviation (Figure 1 of [4]). This strong variation with age of ABSI could be explored for creating a biological age indicator, similar to what was suggested using WC and HC [28].

We further point out that without careful attention to standardization of predictor variables, comparison between odds ratios may not reflect the comparative performance between closely competing models. Using an information index, we have shown that despite small differences in the odds ratios, total mortality is considerably better predicted by ABSI then by BMI, WC, WHtR, or WHR [5].

Given these suggested methodological guidelines, ABSI could be a useful tool for population or individual risk assessment. If ABSI does prove its worth in future studies, we may expect to see it increase in usage in the medical literature over a period of several years to decades, similar to the bibliometric trends seen for WHtR and WC.

Conclusions

ABSI has been shown to be a readily computed dynamic gender and age sensitive indicator of mortality risk across BMI categories. The broad range of studies discussing WC in recent medical literature suggests potential uses of ABSI for making clinical decisions and for correlation with lifestyle and with other risk factors and health outcomes.

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