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ORIGINAL PAPER

Do Anthropometric Indices Accurately Reflect Directly Measured Body Composition in Men and Women With Chronic Heart Failure?

How well anthropometric indices such as body mass index (BMI), waist circumference, waist-stature ratio, and waist index correlate with direct measures of body composition (lean body mass, body fat) in men and women with chronic heart failure (CHF) has not been reported. Body composition was assessed by dual-energy x-ray absorptiometry in 140 patients with CHF. Age-adjusted Pearson correlations between each index and measures of body composition for men and women were calculated. Diagnostic accuracy of detecting obesity or high central fat was also examined. In men, all of the anthropometric indices except waist index were just as strongly correlated with lean body mass (correlation coefficients varied between 0.56 for waist-stature ratio to 0.74 for BMI) as with percentage of body fat (correlation coefficients varied between 0.72 for BMI to 0.79 for waist circumference). In women, all 4 anthropometric measures were unable to significantly differentiate between body fat and lean body mass. The positive likelihood ratios for the detection of obesity varied between 2.26 for waist circumference and 3.42 for BMI, waist-stature ratio, and waist index. Anthropometric indices do not accurately reflect body composition in patients with CHF, especially in women. When accurate assessment of body composition is required, direct measurements should be obtained.
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Obesity as categorized by body mass index (BMI) is paradoxically associated with better survival rates in patients with chronic heart failure (CHF),[1] a relationship that has been termed the obesity paradox.[2] The validity of the obesity paradox has been questioned, in part because BMI is a surrogate measure of body fat and may not accurately reflect adipose tissue stores. We previously reported similar correlations between BMI and lean body mass vs BMI and percent body fat in patients with heart failure and that the use of BMI misclassified body fat status in 41% of cases.[3] The purpose of this study was to further explore the relationship between various anthropometric indices and body composition by examining the sex-specific diagnostic accuracy of BMI, waist circumference (WC), waist index (WI), and waist-stature ratio (WSR) to detect obesity in patients with CHF.

Methods

A cross-sectional study was conducted with 140 consecutive adult patients with systolic and/or diastolic CHF recruited from the University of Alberta Heart Function Clinic between June 2008 and July 2009. This analysis represents a predefined secondary objective of a larger study.[3] Total body fat was assessed by dual energy x-ray absorptiometry (DEXA) performed with a Hologic Series Delphi-A Fan Beam X-ray Bone Densitometer (version 12.4; Hologic Inc, Bedford, MA) after it was determined that patients did not have fluid overload. WC was determined as the average of 2 measurements taken at the umbilicus. Other anthropometric indices were calculated as follows: BMI = body mass in kg divided by height in meters squared, WSR = WC in cm divided by height in meters and WI = WC in cm divided by height in meters cubed.

The DEXA-ascertained percent body fat measurement was used to classify each patient into normal, overweight, or obese categories using the reference ranges developed by Gallagher and colleagues.[4] A BMI $\geq$30 kg/m^2 was used to define obesity for both men and women.[5] The cutoffs for high WC were defined as $\geq$102 cm for men or $\geq$88 cm for women,[6] $\geq$60.5 cm/m for men and $\geq$61.5 cm/m for women[7] for high WSR, and $\geq$25.3 cm/m^3 for

Table I. Partial Pearson Correlation Coefficients[a] Between Anthropometric Indices and Percent Total Body Fat vs Absolute LBM

			P Value[b]
	BMI-BF%	BMI-LBM	
Men (n=103)	0.72, $P<.0001$	0.74, $P<.0001$	.8
Women (n=37)	0.54, $P<.0001$	0.72, $P<.0001$	.2
Overall (n=140)	0.67, $P<.0001$	0.72, $P<.0001$	.4
	WC-BF%	WC-LBM	
Men (n=103)	0.79, $P<.0001$	0.68, $P<.0001$	.09
Women (n=37)	0.54, $P=.001$	0.70, $P<.0001$	.3
Overall (n=140)	0.72, $P<.0001$	0.68, $P<.0001$	.5
	WI-BF%	WI-LBM	
Men (n=103)	0.67, $P<.0001$	0.25, $P=.01$	<.0001
Women (n=37)	0.48, $P<.0001$	0.20, $P=.3$	.2
Overall (n=140)	0.60, $P<.0001$	0.23, $P=.008$	.0001
	WSR-BF%	WSR-LBM	
Men (n=103)	0.79, $P<.0001$	0.56, $P<.0001$	.005
Women (n=37)	0.56, $P<.0001$	0.57, $P<.0001$	.9
Overall (n=140)	0.73, $P<.0001$	0.55, $P<.0001$	.01

Abbreviations: BF%, body fat percent; BMI, body mass index; LBM, lean body mass; WC, waist circumference; WI, waist index; WSR, waist-stature ratio. [a]Adjusted for age. [b]Comparing LBM and BF% correlations.

women and $\geq$20.3 cm/m^3 for men[8] for high WI.

Age-adjusted, sex-specific partial Pearson correlations between percent body fat and each of the anthropometric measures were calculated. For a given anthropometric variable, differences in the correlation coefficients for percent total body fat vs lean body mass were examined using *z* tests after applying Fisher *z* transformation.[9,10] The accuracy of BMI, WC, WSR, and WI in detecting obesity according to the Gallagher classification was examined by calculating sensitivity, specificity, positive and negative predictive values (PPVs and NPVs), and likelihood ratios (LRs).[11] *P* values of <.05 were considered statistically significant.

Results

Full details on our study cohort have been published previously.[3] In brief, the mean age of patients was 63 years, 73.6% were men, 90% were Caucasian, and the prevalence of obesity according to the Gallagher classification system was 41.7% in men and 51.4% in women. In contrast, the prevalence of obesity according to the World Health Organization BMI classification system was 38.8% in men and 32.4% in women. The prevalence of high WC was 55.3% in men and 81.1% in women. WI and WSR had measures of prevalence that most closely approximated the prevalence according to Gallagher body fat categories. The variability in prevalence of obesity or high central measures of adiposity was greater in women compared with men (ranging from 32.4% obesity by BMI and 81.1% with high WC in women vs 38.8% obesity by BMI and 55.3% with high WC in men).

While there was minimal difference in the correlation between BMI and lean body mass or percent body fat in men (0.74 vs 0.72, respectively), BMI in women was better correlated to lean body mass than to percent body fat (0.72 vs 0.52), although this was nonsignificant (Table I). The correlations between anthropometric indices and percent total body fat were consistently lower for women compared with men.

A BMI $\geq$30.0 kg/m^2 had the lowest sensitivity at 61.3% but the highest specificity at 82.1%, corresponding to a +LR of 3.42 and −LR of 0.47, respectively (Table II). High WC had the highest sensitivity (90.3%) but the lowest specificity (60.3%), corresponding to a +LR of 2.26 and −LR of 0.16, respectively. The diagnostic accuracy of a high WI and high WSR fell in between the values for BMI and WC.

Discussion

In patients with CHF, BMI appears to be equivalently correlated to both percent body fat and lean body mass in men and more correlated to lean body mass than to percent body fat in women. BMI underestimates the prevalence of obesity in patients with CHF. A BMI value $\geq$30 kg/m^2 has moderate specificity but poor sensitivity for diagnosing obesity based on body fat percent, and, as a result, may miss many CHF patients with true excess adiposity. In addition, our study found that WC overestimates substantially the prevalence of obesity in the CHF population, especially in women. WC and WSR displayed the highest correlations with percent body fat in men, but neither differentiates well between fat and lean mass in women. Correlations between anthropometric indices and percent total body fat in women were generally poor, indicating that none of the indices studied accurately reflect body fat levels in women with CHF.

Our observation that BMI was most highly correlated with lean body mass in both sexes may provide an explanation for the counterintuitive associations between higher BMI levels and longer survival rates that characterize the obesity paradox. Because heart failure is a catabolic state[12] and the development of cachexia is a marker of more severe disease,[13] lesser degrees of cachexia (and a higher BMI) likely reflect higher amounts of muscle mass and a better prognosis.

We demonstrated sex-specific differences in correlations between anthropometric indices and percent total body fat. This may be related to differences in the distribution of fat between sexes and aging—women tend to have a more peripheral than central fat distribution in early adulthood,[14] yet gain central fat with increasing age.[15] This indicates

Table II. Diagnostic Accuracy of BMI, Waist Circumference, Waist-Stature Ratio, and Waist Index to Detect Obesity in Patients With Heart Failure

Anthropometric Measure	Sensitivity, %	Specificity, %	PPV, %	NPV, %	+LR	−LR
BMI $\geq$30 kg/m^2	61.3	82.1	73.1	72.7	3.42	0.47
Waist circumference $\geq$102 cm in men, $\geq$88 cm in Women	90.3	60.3	64.4	88.7	2.26	0.16
Waist-stature ratio $\geq$60.5 cm/m in men, $\geq$61.5 cm/m in women	77.4	76.9	72.7	81.1	3.35	0.29
Waist index $\geq$25.3 cm/m^3 in women, $\geq$20.3 cm/m^3 in men	69.4	79.5	72.9	76.6	3.39	0.39

Abbreviations: BMI, body mass index; LR, likelihood ratio; NPV, negative predictive value; PPV, positive predictive value.

that direct measurements of adiposity may be especially important in women for accurate diagnosis of obesity.

Limitations

We acknowledge potential limitations inherent in our study. There were a relatively small number of women included in the study, and our analyses may have been underpowered. In addition, there is no consensus on the optimal site to measure WC; however, WC was measured in a subsample of 80 patients at 3 additional sites (the top of the iliac crest, the mid-point between the lowest rib and the top of the iliac crest, and the narrowest part of the waist), and the differences in correlations with DEXA-measured lean body mass, percent total body fat, and central fat were minimal. Finally, the body fat status reference categories developed by Gallagher and colleagues[5] were derived in the general population without CHF.

Conclusions

No anthropometric index performed particularly well in measuring obesity in heart failure. Direct measures of body composition are therefore more accurate and desirable in both the clinical and research setting. DEXA for body composition measurement is ideal; however, near-infrared interactance, which has been validated in the CHF population,[16] may be used when DEXA is unavailable.

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