BODY MASS INDEX AND WAIST CIRCUMFERENCE PREDICTORS OF CARDIOVASCULAR RISK IN AFRICAN AMERICANS

Vernessa R. Clark, PhD; Byron Greenberg, PhD; Toni S. Harris, PhD; Bernice L. Carson, PhD

INTRODUCTION

Obesity is a well documented risk factor for cardiovascular disease, yet there is no consensus on the best method of assessment. Body mass index (BMI), a measure of body fat based on height and weight, is the traditional method of measuring obesity and has been associated with the onset of cardiovascular disease. However, a major weakness of BMI is that it does not distinguish between muscle and fat which leads to misclassification of certain people. Researchers found that BMI is useful in predicting cardiovascular disease in individuals with a BMI $\geq 35$, who have more fatty tissue and less muscle, and are more vulnerable to cardiovascular disease. For example, Clark et al examined the effects of body mass on cardiovascular reactivity in African American college students. They found that obese men had increased reactivity to the racial stressor.

Another well documented method of assessing obesity is the measurement of abdominal fat. Waist circumference is considered a risk factor for cardiovascular disease because the abdomen tends to have more visceral fat than subcutaneous fat. Visceral fat in the abdomen produces the hormone adiponectin which leads to a reduction in the body’s response to insulin resulting in insulin resistance. Brenner et al investigated whether waist circumference or BMI is a better predictor of blood lipid concentrations. Waist circumference was significantly related to triglycerides, total cholesterol and high density lipoproteins after adjusting for BMI and covariates among men and women. After the authors adjusted for waist circumference and covariates, BMI was not significantly associated with the two serum lipid measures. In addition, waist circumference demonstrated better predictability of triglycerides, total cholesterol and high density lipoproteins among all sex and subgroups except among East Asian women. The authors concluded that waist circumference is a stronger predictor of cardiometabolic health when compared with BMI among young adults, especially among men.

Other researchers have reported that BMI and waist circumference together, is the best predictor of the future onset of cardiovascular illnesses. For example, Sarno et al studied the effects of BMI and waist circumference on the occurrence of arterial hypertension. The authors found that the combination of BMI and waist circumference increased the prevalence for arterial hypertension. Likewise, Janssen et al investigated the ability of BMI and waist circumference to predict abdominal fat in a sample of healthy White men and women. The investigators found that BMI and waist circumference combined accounted for additional visceral abdominal fat and is a better predictor of metabolic risk than BMI or waist circumference alone.

While the debate over the best measure of obesity continues, few studies have examined the efficacy of BMI and waist circumference to predict cardiovascular illness in African Americans. To this end, the purpose of our study was to determine which measure of obesity would be associated with heart rate, stroke volume, cardiac output and systolic and diastolic blood pressure hyperactivity in African Americans. The following hypotheses were proposed: 1) BMI alone would be significantly associated with cardiovas-
The purpose of our study was to determine which measure of obesity would be associated with heart rate, stroke volume, cardiac output and systolic and diastolic blood pressure hyperactivity in African Americans.

Cardiovascular Activity
A Cardiovascular Profiling System by Hypertension Diagnostic, Inc. was used to noninvasively obtain body mass index, heart rate, stroke volume (volume of blood pumped by the heart with each beat), cardiac output (volume of blood pumped by the heart each minute) and blood pressure. A blood pressure cuff was placed on the left upper arm and an arterial pulsewave sensor was placed on the right wrist overlying the radial artery.

Body Mass Index
Body mass index was measured by using self-reported body weight and height. Body mass index was classified into three categories based on the guidelines of the Department of Health and Human Services. The categories are: normal weight (BMI of 18.5–24.9 kg/m\(^2\)); overweight (BMI of 25–29.9 kg/m\(^2\)); and obese (BMI of ≥30 kg/m\(^2\)).

Waist Circumference
Waist circumference was measured at the level of the umbilicus with a standard tape measure. For men, a waist circumference <94 cm was classified as normal risk of cardiovascular disease, a waist circumference of 94 cm–101 cm was classified as an increased risk of cardiovascular disease and a waist circumference of ≥102 cm was classified as a substantial risk for cardiovascular disease. For women, a waist circumference <80 cm was classified as normal risk of cardiovascular disease, a waist circumference of 80 cm–87 cm was classified as an increased risk of cardiovascular disease and a waist circumference of ≥88 cm was classified as a substantial risk for cardiovascular disease.

RESULTS
Multiple regression analyses were used to determine the association of BMI and waist circumference with each cardiovascular measure. Multiple regression analyses were also used to examine the association of BMI and waist circumference with the cardiovascular measures collapsed across periods. In addition, a correlation analysis was used to examine the relationship among BMI, waist circumference and cardiovascular reactivity to the emotional arousing stimulus. Means and standard deviations for all study variables are in Table 1. The SPSS statistical package (version 17) was used for the statistical analysis.

BMI and Cardiovascular Reactivity
Our first hypothesis suggested that BMI alone would be significantly associated with cardiovascular reactivity. This hypothesis was supported by the data. Body mass index was significantly associated with systolic blood pressure, during the pre-stressor, \( R^2 = .121, F (1, 101) = 13.9, P < .001 \); stressor, \( R^2 = .215, F (1, 99) = 19.09, P < .001 \); and recovery periods, \( R^2 = .111, F (1, 98) = 12.18, P < .05 \). Body mass index also was significantly associated with stroke volume during the pre-stressor,
Table 1. Means and standard deviations for all study variables

<table>
<thead>
<tr>
<th></th>
<th>Means</th>
<th>Standard Deviations</th>
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<tbody>
<tr>
<td>BMI (kg/m²)</td>
<td>26.56</td>
<td>6.64</td>
</tr>
<tr>
<td>Waist Circumference (cm)</td>
<td>86.50</td>
<td>16.46</td>
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<tr>
<td>Heart rate (bpm)</td>
<td>72.50</td>
<td>10.34</td>
</tr>
<tr>
<td>Stroke volume (mL)</td>
<td>78.34</td>
<td>15.08</td>
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<tr>
<td>Cardiac output (L/mm)</td>
<td>5.68</td>
<td>.83</td>
</tr>
<tr>
<td>Systolic blood pressure (mm Hg)</td>
<td>115.87</td>
<td>10.60</td>
</tr>
<tr>
<td>Diastolic blood pressure (mm Hg)</td>
<td>63.42</td>
<td>7.62</td>
</tr>
</tbody>
</table>

*Collapsed across periods. N = 105.

\[ R^2 = .234, F(1, 102) = 31.09, P < .001; \]
\[ R^2 = .215, F(1, 99) = 27.18, P < .001; \]
\[ R^2 = .216, F(1, 98) = 27.07, P < .001. \]

Lastly, BMI was significantly associated with cardiac output during the pre-stressor, \( R^2 = .562, F(1, 102) = 131.03, P < .001; \)
\( R^2 = .569, F(1, 99) = 130.65, P < .001; \)
\( R^2 = .580, F(1, 98) = 135.37, P < .001 \)
as well as diastolic blood pressure during the pre-stressor period, \( R^2 = .045, F(1, 102) = 4.81, P < .05; \)
and the recovery period, \( R^2 = .043, F(1, 99) = 4.40, P < .05. \)

In addition, the multiple regression analysis revealed BMI was significantly associated with cardiovascular reactivity collapsed across groups. BMI was significantly associated with systolic blood pressure, \( R^2 = .129, F(1, 102) = 15.17, P < .001; \)
stroke volume, \( R^2 = .24, F(1, 102) = 2.42, P < .001; \)
and cardiac output, \( R^2 = .58, F(1, 102) = 140.01, P < .001. \)
These findings indicate that participants with higher BMIs also had higher levels of systolic and diastolic blood pressure, and greater stroke volume and cardiac output. See Table 2 for BMI regression values.

The product-moment correlations revealed that similar to the regressions, BMI was significantly correlated with systolic blood pressure during the pre-stressor period, \( r = .348, P < .001; \)
and the recovery period, \( r = .332, P < .05; \)
diastolic blood pressure during the pre-stressor, \( r = .212, P < .05; \)
and stressor periods, \( r = .206, P < .05; \)
(see Table 4 for all significant correlations). Body mass index was also significantly correlated with stroke volume during the pre-stressor, \( r = .483, P < .05; \)
and the recovery period, \( r = .465, P < .05. \)
Lastly, BMI was significantly correlated with cardiac output during the pre-stressor period, \( r = .750, P < .001; \)
and the recovery period, \( r = .754, P < .001. \)

Waist Circumference and Cardiovascular Reactivity

Our second hypothesis stated that waist circumference alone would be significantly associated with cardiovascular reactivity. In support of the hypothesis, a separate regression analysis revealed that when waist circumference was entered into the regression equation alone, it was significantly associated with systolic blood pressure during the pre-stressor, \( R^2 = .085, F(1, 100) = 9.33, P < .05; \)
and the recovery periods, \( R^2 = .059, F(1, 97) = 6.12, P < .05. \)
Waist circumference also was significantly associated with stroke volume during the pre-stressor, \( R^2 = .383, F(1, 101) = 17.3, P < .001; \)
and the recovery periods, \( R^2 = .136, F(1, 97) = 15.33, P < .001. \)
Lastly, waist circumference was significantly associated with cardiac output during the pre-stressor, \( R^2 = .437, F(1, 101) = 78.4, P < .001; \)
and the recovery periods, \( R^2 = .386, F(1, 98) = 61.7, P < .001; \)
and the recovery periods, \( R^2 = .382, F(1, 97) = 59.8, P < .001. \)
In addition, the multiple regression analysis revealed that waist circumference was significantly associated with cardiovascular reactivity collapsed across groups. It was significantly associated with systolic blood pressure, \( R^2 = .09, F(1, 101) = 9.99, P < .05; \)
stroke volume, \( R^2 = .15, F(1, 101) = 17.84, P < .001; \)
and cardiac output, \( R^2 = .406, F(1, 101) = 69.12, P < .001. \)
See Table 3 for waist circumference regression values. Similar to BMI, these findings indicate that participants with higher levels of waist circumference also
had higher levels of systolic blood pressure, and greater blood output.

The product-moment correlation analysis revealed that waist circumference was significantly correlated with systolic blood pressure during the pre-stressor period, \( r = 0.292, P < 0.05 \); stressor period, \( r = 0.367, P < 0.001 \); and recovery period, \( r = 0.244, P < 0.05 \); and stroke volume during the pre-stressor, \( r = 0.383, P < 0.001 \); stressor period, \( r = 0.355, P < 0.001 \); and the recovery period, \( r = 0.369, P < 0.001 \). In addition, waist circumference was significantly correlated with cardiac output during the pre-stressor, \( r = 0.661, P < 0.001 \); stressor period, \( r = 0.622, P < 0.001 \); and the recovery period, \( r = 0.618, P < 0.001 \). Lastly, product-moment correlations analysis revealed that BMI was significantly correlated with waist circumference, \( r = 0.926, P < 0.001 \). See Table 4 for correlation values.

### The Association of BMI and Waist Circumference Combined with Cardiovascular Activity

Our third hypothesis stated that BMI and waist circumference together would be more associated with cardiovascular reactivity and account for more of the variance than the two measures alone. The hypothesis was not supported by the data. Body mass index was significantly associated with systolic blood pressure, during the pre-stressor, \( R^2 = 0.13, F(2,99) = 7.6, P < 0.05 \); stressor, \( R^2 = 0.174, F(2,97) = 10.2, P < 0.001 \); and recovery periods, \( R^2 = 0.20, F(2,97) = 10.2, P < 0.001 \). Body mass index also was significantly associated with stroke volume during the pre-stressor, \( R^2 = 0.23, F(2,100) = 14.9, P < 0.001 \); stressor, \( R^2 = 0.21, F(2,97) = 13.03, P < 0.001 \); and the recovery periods, \( R^2 = 0.212, F(2,96) = 12.9, P < 0.001 \). Lastly, BMI was significantly associated with cardiac output during the pre-stressor, \( R^2 = 0.57, F(2,100) = 66.8, P < 0.05 \); stressor, \( R^2 = 0.57, F(2,97) = 64.9, P < 0.001 \); and recovery periods, \( R^2 = 0.59, F(2,96) = 67.5, P < 0.001 \). These findings show that BMI was positively associated with systolic blood pressure, stroke volume and cardiac output. In addition, the multiple regression analysis revealed BMI was significantly associated with cardiovascular reactivity collapsed across groups. Body mass index was significantly associated with systolic blood pressure, \( R^2 = 0.14, F(2,100) = 8.06, P < 0.05 \); stroke volume, \( R^2 = 0.24, F(2,100) = 15.53, P < 0.001 \); and cardiac output, \( R^2 = 0.58, F(2,100) = 69.86, P < 0.001 \). Unexpectedly, waist circumference did not significantly associate with any of the cardiovascular indices when both BMI and waist circumference were entered into the regression equation. In addition, the association of BMI decreased slightly when waist circumference was entered into the regression equation.

After adjustment for sex, BMI was significantly associated with systolic blood pressure during the pre-stressor (\( R^2 = 0.32 \)), stressor (\( R^2 = 0.28 \)), and recovery periods (\( R^2 = 0.18 \)); stroke volume during the pre-stressor (\( R^2 = 0.39 \)), stressor (\( R^2 = 0.33 \)), and recovery periods (\( R^2 = 0.38 \)); and cardiac output during the pre-stressor (\( R^2 = 0.61 \)), stressor (\( R^2 = 0.61 \)), and recovery periods (\( R^2 = 0.63 \)). Although the adjustment augmented the relationship between BMI and cardiovascular reactivity to stress, it did not influence the relationship between waist circumference and cardiovascular activity. See Table 5 for sex associations with cardiovascular activity.
**DISCUSSION**

The first major finding revealed that when BMI was entered into the regression equation alone, it was significantly associated with systolic blood pressure, stroke volume and cardiac output prior to, during and after the stressor. Body mass index also was significantly associated with diastolic blood pressure during the pre-stressor and stressor periods. In addition, BMI correlated with systolic and diastolic blood pressures as well as stroke volume and cardiac output. These positive associations showed that heavier participants had higher systolic blood pressure and their hearts pumped out greater blood volume compared to their thinner counterparts. These results are similar to Javed et al.\(^15\) who found that BMI significantly predicted hypertension in African American elderly women, which indicated that as BMI increased, the risk for hypertension increased.

The second major finding showed that when entered into the regression equation alone, waist circumference was significantly associated with systolic blood pressure, stroke volume and cardiac output. The positive associations of BMI and waist circumference with cardiovascular activity may be attributed to the need of the heart to circulate a greater volume of blood to reach a greater mass of cells with oxygenation and nutrients.\(^16\)

An unexpected finding revealed that waist circumference was significantly associated with cardiovascular reactivity when it was entered into the regression equation alone; however, this relationship was no longer significant after BMI was entered into the equation. This finding indicated that BMI completely mediated the relationship between waist circumference and cardiovascular reactivity. The mediation was enhanced after the adjustment for sex. Similar to the present study, Waldstein et al.\(^17\) found that high density cholesterol, dietary practices and fasting insulin levels attenuated the relationship between waist circumference and systolic and diastolic blood pressure in African Americans. The mediation of waist circumference and cardiovascular reactivity may be attributed to the premise that African Americans have less abdominal adipose tissue than Whites with the same waist circumference.\(^18–21\) To this end, waist circumference thresholds standardized on Whites may not be an accurate predictor of cardiovascular disease in African Americans. These inaccurate thresholds may contribute to the relationship between waist circumference and cardiovascular reactivity being susceptible to mediation by other factors.

A major limitation of the study was that insulin resistance and cholesterol levels were not measured and thus were excluded as mediating variables. Examining insulin resistance and cholesterol levels may help to elucidate the relationship between obesity and cardiovascular disease.

**REFERENCES**


AUTHOR CONTRIBUTIONS
Design and concept of study: Clark
Acquisition of data: Clark
Data analysis and interpretation: Clark, Greenberg, Harris, Carson
Manuscript draft: Clark, Greenberg, Harris, Carson
Statistical expertise: Clark, Greenberg
Administrative: Clark, Harris, Carson
Supervision: Clark