Relation of Abdominal Height to Cardiovascular Risk Factors in Young Adults

The Bogalusa Heart Study

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Obesity and fat patterns are important predictors of coronary heart disease risk. The relations of abdominal height (sagittal diameter) and various obesity measures to coronary heart disease risk factors were examined in a community-based sample of 409 Blacks and 1,011 Whites aged 20–38 years in Bogalusa, Louisiana (1995–1996). Obesity measures used included weight, waist circumference, waist:hip ratio, waist:height ratio, abdominal height, triceps and subscapular skinfold thicknesses, body mass index, and conicity index. Abdominal height was highly correlated with other obesity measures, especially waist circumference (0.937–0.944, \( p < 0.001 \)), and was least correlated with height. In multivariate analysis, abdominal height was an independent predictor of levels of total cholesterol, triglycerides, very low density lipoprotein cholesterol, low density lipoprotein cholesterol, high density lipoprotein cholesterol, glucose, and insulin and of systolic and diastolic blood pressures (\( p < 0.05 \) to \( p < 0.001 \)), with total \( R^2 \) values ranging from 0.13 to 0.52. Abdominal height contributed more to the prediction of blood pressure than did other measures of central obesity. In canonical analysis, abdominal height was correlated more strongly with the coronary disease risk factor variables as a group than were other obesity measures. These results suggest that abdominal height adds another dimension to measures of obesity in that it may help to assess a component of visceral fat that other measures miss. Am J Epidemiol 2000;151:885–91.

MATERIALS AND METHODS

Population

The Bogalusa Heart Study is a long term epidemiologic study of cardiovascular risk factors from birth through age 38 years in a biracial population (65 percent White and 35 percent Black) in Bogalusa, Louisiana (15, 16). During 1995–1996, 1,420 subjects aged 20–38 years were examined as part of the post-high school cohort study. The study population was 71 percent White and 61 percent female.

General examinations and anthropometry

Trained examiners collected all data under rigid protocols (15). Subjects were instructed to fast for 12 hours before venipuncture, and compliance was assessed by interview on the morning of the screening. Screening consisted of venipuncture followed by replicate measurements of abdominal height, height, weight, triceps and subscapular skinfold thicknesses, and waist and hip circumferences. Replicate measures were conducted by the same examiner, and the average of the measurements was used. Abdominal height, defined as the thickness of the abdomen at waist level, was measured with a portable sliding-
beam abdominal caliper while the subject lay supine on an examining table (Holtain-Kahn Abdominal Caliper; Holtain Ltd., Dyfed, Wales). With the base of the caliper placed under the subject's back, the caliper's sliding beam was brought down to a point midway between the iliac crests. The subject was asked to inhale and exhale naturally; the sliding beam was then moved so that it slightly touched the subject's abdomen without compression. In the supine position, the body's visceral fat projects the abdomen in a sagittal direction, and gravity moves the subcutaneous fat to the sides (17).

Replicate systolic and diastolic (fourth and fifth Korotkoff phases) blood pressure levels were measured. The fifth phase measurement was used in this analysis. The average of six readings, three each taken by two trained observers, was used for analysis.

**Laboratory analyses**

Serum total cholesterol and triglyceride levels were measured by enzymatic procedures in an Abbott VP Analyzer (Abbott Laboratories, North Chicago, Illinois) (18, 19). Lipoprotein cholesterol levels were measured by a combination of heparin-calcium precipitation and agar-agarose gel electrophoresis (20). Measurements of total cholesterol, triglycerides, and high density lipoprotein cholesterol in the Bogalusa Heart Study are being continuously monitored through a surveillance program of the Centers for Disease Control and Prevention (Atlanta, Georgia).

Plasma glucose level was measured as part of a multiple chemistry profile (SMA 20) by a glucose oxidase method; plasma immunoreactive insulin level was measured using a radioimmunoassay procedure, with the Phadebas insulin kit (Pharmacia Diagnostics, Piscataway, New Jersey).

**Statistical analyses**

All analyses were conducted using SAS software (21). Descriptive statistics for measured variables were calculated for each race-sex group. The log-transformed values of the triglyceride and insulin measures were used in all but the descriptive statistics. Analysis of variance was used to test for differences and interactions between race-sex groups. Pearson correlations were used to examine the associations between abdominal height and other measures of obesity, as well as the associations between measures of central obesity (waist circumference, conicity index, waist:hip ratio, and waist:height ratio) and the cardiovascular risk factor variables. Fisher's Z transformation and the z test were used to test for differences between correlations.

To determine the contribution of abdominal height to the variance of cardiovascular risk factor variables, we developed linear multivariate prediction models using PROC GLM in SAS. Variables were forced into the model. Models were developed for each cardiovascular risk factor with serum total cholesterol, fasting serum triglycerides, fasting very low density lipoprotein cholesterol, low density lipoprotein cholesterol, high density lipoprotein cholesterol, systolic and diastolic blood pressure, plasma glucose, and insulin each used as a dependent variable. Partial $R^2$'s were calculated for the contribution of the central obesity variables as a unit and the contribution of abdominal height. The full models included race, sex, age, abdominal height, body mass index, conicity index, waist:hip ratio, waist:height ratio, waist circumference, triceps and subscapular skinfold thicknesses, and weight as the independent variables. In addition to the full model, two reduced models were used. The reduced model for estimating the partial $R^2$'s for abdominal height included all variables but abdominal height. The reduced model for estimating the partial $R^2$'s for the central obesity measures included all variables but the central obesity measures. The partial $R^2$ values are equal to the increase in $R^2$ from the reduced model to the full model relative to the proportion of variance unexplained by the reduced model.

Canonical correlation analysis, a multivariate technique, was used to examine the relations between the obesity measures and each of three sets of risk variables: lipoprotein variables, blood pressure variables, and glucose and insulin levels. This procedure allows the simultaneous examination of predictor and criterion (outcome) variables (22). The analysis produces a "canonical variable" expressed as a correlation. With canonical analysis, it is also possible to examine the correlation of each of the variables within the group (predictor variables, such as the obesity measures) to the grouped criterion variables (outcome variables, such as the lipoprotein variables). The hypothesis that the canonical correlations are zero in the population is tested. Only the correlations with the first significant canonical variable were examined.

**RESULTS**

As table 1 shows, Blacks had a higher body weight, body mass index, abdominal height, subscapular skinfold thickness, and hip circumference than did Whites ($p < 0.05$). Females, overall, were slightly younger and shorter than males and had a higher triceps skinfold thickness than males ($p < 0.05$). There were no race or sex interactions with the obesity measures.

Pearson correlations between abdominal height and other obesity measures are shown in figure 1 for the
TABLE 1. Mean ages and levels of obesity measures, by race and sex: Bogalusa Heart Study, 1995–1996*

<table>
<thead>
<tr>
<th></th>
<th>White males (n = 398)</th>
<th>Black males (n = 152)</th>
<th>White females (n = 613)</th>
<th>Black females (n = 257)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)†</td>
<td>30.2 (5.0)§</td>
<td>30.0 (5.4)</td>
<td>29.5 (5.0)</td>
<td>28.8 (5.2)</td>
</tr>
<tr>
<td>Height (cm)†</td>
<td>177.1 (6.5)</td>
<td>176.1 (6.4)</td>
<td>163.1 (6.4)</td>
<td>162.9 (6.9)</td>
</tr>
<tr>
<td>Weight (kg)§</td>
<td>86.9 (17.3)</td>
<td>86.7 (24.1)</td>
<td>69.6 (18.5)</td>
<td>81.2 (24.2)</td>
</tr>
<tr>
<td>Triceps skinfold (mm)†</td>
<td>18.3 (9.8)</td>
<td>15.6 (12.0)</td>
<td>27.7 (10.6)</td>
<td>30.2 (13.3)</td>
</tr>
<tr>
<td>Subscapular skinfold (mm)§</td>
<td>21.5 (10.7)</td>
<td>21.2 (14.0)</td>
<td>24.3 (12.4)</td>
<td>30.1 (13.9)</td>
</tr>
<tr>
<td>Waist circumference (cm)</td>
<td>94.2 (14.2)</td>
<td>90.4 (17.9)</td>
<td>80.4 (14.8)</td>
<td>89.5 (17.9)</td>
</tr>
<tr>
<td>Hip circumference (cm)§</td>
<td>105.7 (10.1)</td>
<td>105.7 (14.0)</td>
<td>104.4 (13.4)</td>
<td>111.6 (15.4)</td>
</tr>
<tr>
<td>Abdominal height (cm)§</td>
<td>21.7 (3.5)</td>
<td>22.0 (4.5)</td>
<td>19.5 (3.9)</td>
<td>22.8 (4.5)</td>
</tr>
<tr>
<td>Body mass indexH,§</td>
<td>27.7 (5.3)</td>
<td>27.9 (7.4)</td>
<td>26.2 (6.8)</td>
<td>30.5 (8.6)</td>
</tr>
<tr>
<td>Waist:hip ratio</td>
<td>0.89 (0.08)</td>
<td>0.85 (0.07)</td>
<td>0.77 (0.06)</td>
<td>0.80 (0.07)</td>
</tr>
<tr>
<td>Waist:height ratio</td>
<td>0.53 (0.08)</td>
<td>0.51 (0.10)</td>
<td>0.49 (0.09)</td>
<td>0.55 (0.11)</td>
</tr>
<tr>
<td>Conicity index</td>
<td>1.23 (0.10)</td>
<td>1.19 (0.09)</td>
<td>1.13 (0.08)</td>
<td>1.17 (0.09)</td>
</tr>
</tbody>
</table>

* Tests of differences with the obesity measures were adjusted for age.
† Sex difference: p < 0.05.
§ Numbers in parentheses, standard deviation.
H Weight (kg)/height (m)².
§ Race difference: p < 0.05.

All correlations except height were highly significant (p < 0.001). Waist circumference was the strongest correlate of abdominal height in every race-sex grouping. Correlations ranged from 0.937 for White males to 0.944 for White females. The next highest correlations were noted for body mass index and waist:height ratio. Correlations for body mass index ranged from 0.91 in White males to 0.94 in Black females. For waist:height ratio, correlations ranged from 0.92 in White males to 0.93 in White...
females. Height showed the weakest relation with abdominal height in every grouping, with correlations ranging from 0.05 in White females to 0.16 in Black females. The correlation between height and abdominal height was significant for Black females ($p < 0.05$) but not for the other race-sex groups ($p > 0.05$).

Pearson correlations between the circumference measures of central obesity (abdominal height, waist circumference, conicity index, waist:hip ratio, and waist:height ratio) and cardiovascular risk factor variables for the overall samples are presented in figure 2. These variables were chosen because they are measures of central obesity. The measures correlated significantly with serum total cholesterol, triglycerides, very low density lipoprotein cholesterol, low density lipoprotein cholesterol, high density lipoprotein cholesterol (inverse association), plasma glucose and insulin levels, and systolic and diastolic blood pressures ($p < 0.0001$). Correlations were highest with insulin; both abdominal height and waist:height ratio showed higher correlations than the other measures ($p < 0.001$) and were not found to be significantly different ($p > 0.05$). Waist:hip ratio was least correlated with insulin level ($p < 0.001$) and significantly less correlated than the other measures of central obesity ($p < 0.05$). With respect to high density lipoprotein cholesterol, abdominal height showed weaker correlations than waist circumference and waist:hip ratio ($p < 0.05$). With very low density lipoprotein cholesterol, abdominal height was significantly less correlated than waist:hip ratio ($p < 0.05$). Abdominal height also showed a lower correlation ($p < 0.05$) than conicity index with triglyceride level.

The correlations with insulin were further explored for each race-sex group (data not shown). The correlations for abdominal height, waist:height ratio, and waist circumference were similar and were not found to be significantly different ($p > 0.05$) for the different groups. However, abdominal height, waist:height ratio, and waist circumference showed higher correlations than waist:hip ratio in all race-sex groups ($p < 0.05$). Conicity index showed a significantly smaller correlation ($p < 0.01$) than abdominal height, waist circumference, and waist:height ratio with insulin in White males, White females, and Black females.

In a multivariate analysis which included waist circumference, triceps and subscapular skinfold thick-

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**FIGURE 2.** Relation of central obesity measures (abdominal height, waist circumference, conicity index, waist:hip ratio, and waist:height ratio) to cardiovascular risk factor variables: Bogalusa Heart Study, 1995–1996. *Comparison of correlations with abdominal height—triglycerides (TG): abdominal height was lower than conicity index ($p < 0.05$); very low density lipoprotein cholesterol (VLDL-C): abdominal height was lower than waist:hip ratio ($p < 0.05$); high density lipoprotein cholesterol (HDL-C): abdominal height was lower than waist circumference and waist:hip ratio ($p < 0.05$); insulin: abdominal height was greater than all other measures ($p < 0.05$) except waist:height ratio ($p > 0.05$); all other differences: $p > 0.055$. TC, total cholesterol; LDL-C, low density lipoprotein cholesterol; Sys. BP, systolic blood pressure; Dias. BP, diastolic blood pressure.
The results of the canonical analysis of obesity measures, serum lipoprotein variables, blood pressure, and plasma glucose and insulin levels are presented in Table 3 by race and sex. All canonical correlations were significant ($p < 0.001$). Obesity measures (predictor variables) as a whole correlated most strongly with the canonical variable for glucose and insulin combined (criterion variables) when compared with the canonical variables for lipoproteins and blood pressure. The canonical correlations for the obesity measures and glucose and insulin grouped together ranged from 0.68 for White males to 0.75 for White females. Among the obesity measures, abdominal height showed stronger relations with the canonical variables for lipoproteins, blood pressure, and glucose and insulin levels than nearly all of the other obesity measures. These trends were similar for each race-sex group.

**DISCUSSION**

Although sophisticated and expensive imaging techniques such as computerized axial tomography (CAT) and magnetic resonance imaging are accurate measures of abdominal fat deposition, inexpensive and readily available methods are needed for epidemiologic studies. Understanding simplified methods is important, since central obesity may be associated with increased cardiovascular risk even in the presence of slight overweight or normal weight (23). In this study, abdominal height was found to correlate highly with several of the obesity measures. It contributed significantly (up to 3 percent of the variation) to the prediction of each of the modeled cardiovascular risk factors, suggesting that abdominal height is an additional parameter of risk. Abdominal height contributed the most to the prediction of fasting triglyceride and insulin levels and was important in predicting blood pressure outcomes when other measures of central obesity were not. Canonical correlation analysis
showed that abdominal height was generally more highly correlated with the canonical variables and was therefore a slightly better predictor of serum lipoprotein levels, blood pressure, and plasma glucose and insulin levels than the other obesity measures were.

Abdominal height has been shown to be highly correlated with visceral adipose tissue (24–26). Van der Kooy et al. (25) reported that abdominal height may better assess changes in visceral fat measured by magnetic resonance imaging than waist circumference and waist:hip ratio. Kvist et al. (26), on the basis of CAT scan measurements, suggested that visceral adipose tissue be predicted from abdominal height rather than from measurements of other areas of the body. Additionally, waist circumference and abdominal height were shown to be related to the metabolic and blood pressure variables more than waist:hip ratio (12). The multivariate analysis of the present study suggested that the independent association of abdominal height with cardiovascular risk factors may be due to its ability to measure a component of visceral obesity that the other indirect obesity measures miss.

Assessment of central obesity may contribute to the evaluation of an individual’s risk for coronary heart disease (2, 3, 6). Kannel et al. (27) reported that total risk for cardiovascular events increased with the degree of central obesity, although they did not find that one measure of central obesity was better than the others in predicting coronary disease. Various measures of central obesity are often used in epidemiologic studies. Waist circumference, either by itself or in relation to hip circumference or height, assesses abdominal fat and has been found to be highly correlated with cardiovascular risk factors. It is interesting that abdominal obesity measured by waist:height ratio was found to be a better predictor of coronary disease risk factors than waist:hip ratio (28). This ratio was also shown to be a strong predictor of abdominal obesity (29). Another measure used to assess abdominal adiposity is the conicity index (30). This is a standardized index suggested to measure the circumference of the body as it departs from a cylindrical shape, and it indicates the proportion of total body fat that may be found in the midsection of the body. However, questions have arisen as to whether abdominal girth should be used in the formula at all (31). Kahn (31) suggests that abdominal height would be preferable.

It has been reported that neither waist girth nor abdominal height alone is sufficient to distinguish coronary disease outcomes in a case-control study (13). However, the ratio of abdominal height to midthigh girth was associated more highly with coronary disease outcomes than was waist:hip ratio in that study. Pouliet et al. (12) showed that abdominal height measured by CAT scan and waist circumference are better than waist:hip ratio in assessing central visceral obesity. However, they did not measure abdominal height manually and compare it with measurements derived from CAT scans. The present study shows that manually measured abdominal height significantly contributes to the prediction of cardiovascular risk factor levels after adjustment for other central obesity measures, including waist:hip ratio and waist circumference (table 2).

In summary, abdominal height adds another dimension to central obesity measurement. It contributes to the prediction of cardiovascular risk factor levels similarly to other measures of obesity but may help to assess a component of visceral fat deposition that the other measures miss. The preciseness needed for measurement of body fatness and the availability of instrumentation beyond that used for weight, height, waist, and skinfold measurements should determine the practicality of measurements used.

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REFERENCES