Obesity, metabolic syndrome and BMI-metabolic-risk sub-phenotypes: A study of an adult Nigerian population

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Obesity and the metabolic syndrome are health care challenges of not only the industrialized nations but also of the developing countries. BMI-metabolic-risk sub-phenotypes separate obesity from its metabolic consequences. These indices have not been duly studied in Nigeria. One hundred and ninety nine adult Nigerians (52.3% females) were studied. Obesity and metabolic syndrome were defined using World Health Organization and US National Cholesterol Education Program Adult Treatment Panel III criteria, respectively. The presence or absence of the metabolic syndrome within the 3 BMI groups (normal, overweight and obese) was used to define 6 BMI-metabolic-risk sub-phenotypes. The results show that 12.1% (13.7% for males and 10.6% for females) of the population were obese. Metabolic syndrome was found in 30.8% (males 34.7%; females 26.9%) of the population. In the obese and overweight subjects, 33.3% and 40.9% respectively were metabolically healthy while 37.6% of the normal weight subjects were metabolically obese. BMI-metabolic-risk sub-phenotypes were found at the rates of 4%-34.2% in the entire population. The results are compared to figures from other studies, and discussed in the light of their implications for a country like Nigeria that is still battling with communicable diseases. Lifestyle modifications that encourage physical exertion and appropriate nutrition are advocated.

Key words: BMI-metabolic-risk sub-phenotypes, metabolic syndrome, obesity

INTRODUCTION

Obesity has become a growing health problem globally, but more importantly in the developing countries where chronic diseases battle with communicable diseases for an often meager healthcare budget (Reddy, 2002; Kengne et al., 2005). It confers risk of morbidity and mortality from type 2 diabetes and atherosclerotic cardiovascular disease (CVD) and other chronic diseases (Flegal et al., 2005; Meigs et al., 2006). The measurement of BMI as a universal criterion of overweight (BMI≥25, but <30) and obesity (BMI≥30) has been recommended by the World Health Organization (WHO, 2000).

Visceral fat accumulation which often accompanies obesity, leads to a cascade of metabolic disturbances, often referred to as the metabolic syndromes (Mokdad et al., 2003; Carr and Brunzell, 2004). The US National Cholesterol Education Program (NCEP) Adult Treatment Panel 3 (ATP III) defines the metabolic syndrome as a cluster of three or more of the following (1) abdominal obesity (waist circumference >102 cm in men and >88 cm in women) (2) concentration of triglycerides ≥150 mg/dl (3) concentration of HDL-cholesterol < 40 mg/dl in men and <50 mg/dl in women (4) blood pressure ≥130/85 mmHg and fasting glucose ≥110 mg/dl (NCEP, 2001). Other definitions of the syndrome, with slight variations are also available (Ford, 2005a). The etiology of the metabolic syndrome is still largely unknown, but it is thought to represent a complex interaction among genetic, metabolic and environmental factors (Groop, 2000; Lidfeldt et al., 2003). Though BMI is known to be related to the metabolic syndrome, the relationship may not always be a dose-response relationship (Meigs et al., 2006).

Sub-phenotypes of obesity, that appear to separate obesity from its apparent metabolic consequences have been described. The metabolically obese normal-weight
Participants were randomly approached and the study explained to 199 subjects (95 males and 104 females) participated in the study. Subjects

MATERIALS AND METHODS

Subjects

Adults (22-84 years old) living in Umuahia were studied. A total of 199 subjects (95 males and 104 females) participated in the study. Participants were randomly approached and the study explained to them individually. Those who orally consented to participation and who had no overt signs of ill-health or who were not pregnant (for women) were allowed to participate in the study. The ethics committee of the Federal Medical Centre Umuahia and the board of the Department of Biochemistry, Michael Okpara University of Agriculture, Umudike, both in Abia state, Nigeria, approved the study and its design.

Instruments and Measures

Blood pressure was measured on a single visit, using sphygmomanometry and appropriate cuff sizes, with the subject in a sitting position, and having rested for at least 10 minutes. Three separate readings were taken per subject, after two minutes intervals and the average of the second and third readings recorded. Systolic blood pressure (SBP) and diastolic blood pressure (DBP) were taken at the 1st and 5th Korotkoff sounds respectively. The same trained personnel took all blood pressure measurements. Weights and heights of participants were taken, with participants dressed in light clothing, and BMI calculated as the weight (kg) divided by the square of the subjects' height (m).

Self-reported age at the last birthday was recorded per participant. Based on their ages, and taking into consideration that age (≥45 years for men, and ≥55 years for women) is one of the risk factors for coronary artery disease (CAD) listed by NCEP (NCEP, 2001), we grouped subjects into age ranges as follows: 22-44 years, 45-54 years, 55-64 years and ≥65 years.

Fasting blood samples (4 ml) was drawn from each participant, and a drop used to measure the concentration of fasting blood glucose by the glucose oxidase method (Washako and Rice, 1961). The rest was allowed to stand at ambient temperature until clotting took place, and the serum separated by centrifugation for 5 minutes at 1000 x g. From the serum, total cholesterol, HDL-Cholesterol and triglycerides were measured by enzymatic colorimetric methods (Allain et al., 1974; Lopes-Virella et al., 1977; Tietz, 1990). LDL-Cholesterol was measured by difference (Friedwald et al., 1972).

Definitions

We defined normal weight as BMI>18.5 but <25, overweight as BMI between 25 and 29.9, and obese as BMI≥30 (WHO, 1995). We defined metabolic syndrome according to the NCEP ATP III definition (NCEP, 2001) but used BMI cut-offs recommended by Schneider et al (2007) (BMI ≥ 25.5 for males and BMI ≥ 25.8 for females) in place of waist circumference as a measure of obesity. The characteristics (clinical and anthropometric) of the studied population within the 6 BMI-metabolic-risk sub-phenotypes are presented in Table 1. A total of 54.8% (49.5% for males and 59.6% for females) had a normal BMI, while 12.1% (13.7% for males and 10.6% for females) were obese (Figure 1). More males, compared to females, had metabolic syndrome (Figure 2). In both sexes, the proportion of population with metabolic syndrome increased with increasing age. For males, it increased more than 5-folds from age 22-44 years (9.7%) to age ≥ 65 (50.0%), while for females, it increased more than 2-folds from age 22-44 years (18.2%) to age ≥ 65 (41.7%).

Figure 3 shows that as much as 37.6% (36.2% for males and 38.7% for females) who had a normal weight were metabolically obese. This however represents 20.6% (17.9% for males and 23.1% for females) of the entire population (Figure 4). Again Figure 3 shows that 33.3% (23.1% for males and 45.5% for females) who were obese actually had a healthy metabolic profile. However, this represents only 4.0% (3.2% for males and 4.8% for females) of the entire population. Females clearly had better metabolic profiles than males. The characteristics of the population within the 6 BMI-metabolic-risk sub-phenotypes are presented in Table 2.
Table 1. Characteristics of the population, stratified by age and gender

<table>
<thead>
<tr>
<th>Age (Years)</th>
<th>BMI</th>
<th>Chol (mg/dl)</th>
<th>LDL (mg/dl)</th>
<th>TAG (mg/dl)</th>
<th>HDL (mg/dl)</th>
<th>FBG (mg/dl)</th>
<th>SBP (mmHg)</th>
<th>DBP (mmHg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>22-44 years</td>
<td>Total</td>
<td>34.6 ± 6.0</td>
<td>23.7 ± 4.0</td>
<td>180.9 ± 71.0</td>
<td>86.6 ± 65.2</td>
<td>147.4 ± 75.8</td>
<td>66.1 ± 33.6</td>
<td>91.2 ± 47.5</td>
</tr>
<tr>
<td></td>
<td>Males</td>
<td>36.9 ± 5.7</td>
<td>23.6 ± 3.5</td>
<td>190.1 ± 64.9</td>
<td>90.7 ± 63.4</td>
<td>144.3 ± 62.5</td>
<td>71.3 ± 32.0</td>
<td>95.1 ± 46.3</td>
</tr>
<tr>
<td></td>
<td>Females</td>
<td>32.9 ± 5.7</td>
<td>23.8 ± 4.4</td>
<td>174.4 ± 75.1</td>
<td>83.6 ± 67.1</td>
<td>149.5 ± 84.6</td>
<td>62.4 ± 34.6</td>
<td>88.4 ± 48.8</td>
</tr>
<tr>
<td>45-54 years</td>
<td>Total</td>
<td>49.2 ± 2.8</td>
<td>25.0 ± 4.4</td>
<td>236.5 ± 83.0</td>
<td>113.6 ± 81.7</td>
<td>166.7 ± 74.0</td>
<td>88.1 ± 22.1</td>
<td>168.3 ± 98.9</td>
</tr>
<tr>
<td></td>
<td>Males</td>
<td>49.2 ± 3.1</td>
<td>25.3 ± 4.2</td>
<td>219.9 ± 76.8</td>
<td>96.4 ± 82.5</td>
<td>162.3 ± 77.4</td>
<td>91.2 ± 27.7</td>
<td>194.4 ±115.7</td>
</tr>
<tr>
<td></td>
<td>Females</td>
<td>49.2 ± 2.4</td>
<td>24.8 ± 4.6</td>
<td>252.4 ± 87.1</td>
<td>130.1 ± 79.1</td>
<td>171.0 ± 72.0</td>
<td>85.2 ± 14.9</td>
<td>143.3 ± 73.5</td>
</tr>
<tr>
<td>55-64 years</td>
<td>Total</td>
<td>59.9 ± 2.8</td>
<td>25.0 ± 4.4</td>
<td>243.1 ± 89.5</td>
<td>128.2 ± 87.2</td>
<td>171.4 ± 68.1</td>
<td>81.2 ± 31.4</td>
<td>144.4 ± 79.1</td>
</tr>
<tr>
<td></td>
<td>Males</td>
<td>59.7 ± 3.1</td>
<td>25.7 ± 4.2</td>
<td>258.2±101.5</td>
<td>140.1 ± 98.2</td>
<td>175.2 ± 51.7</td>
<td>84.9 ± 30.5</td>
<td>166.6 ± 92.4</td>
</tr>
<tr>
<td></td>
<td>Females</td>
<td>60.2 ± 2.5</td>
<td>24.3 ± 4.6</td>
<td>228.6 ± 75.6</td>
<td>116.8 ± 75.5</td>
<td>167.8 ± 81.7</td>
<td>77.6 ± 32.5</td>
<td>123.1 ± 58.2</td>
</tr>
<tr>
<td>≥ 65 years</td>
<td>Total</td>
<td>68.3 ± 7.1</td>
<td>26.1 ± 3.7</td>
<td>258.0 ± 90.2</td>
<td>127.4 ± 95.4</td>
<td>168.9 ± 68.5</td>
<td>94.4 ± 22.9</td>
<td>144.7 ± 86.2</td>
</tr>
<tr>
<td></td>
<td>Males</td>
<td>69.3 ± 6.0</td>
<td>26.4 ± 3.9</td>
<td>260.0±108.0</td>
<td>131.3 ± 110.1</td>
<td>157.4 ± 75.7</td>
<td>96.6 ± 25.0</td>
<td>169.5 ± 95.7</td>
</tr>
<tr>
<td></td>
<td>Females</td>
<td>66.8 ± 8.6</td>
<td>25.7 ± 3.6</td>
<td>255.1 ± 58.3</td>
<td>121.5 ± 72.0</td>
<td>186.2 ± 54.7</td>
<td>91.2 ± 20.0</td>
<td>107.6 ± 54.2</td>
</tr>
</tbody>
</table>

BMI, Chol, LDL, TAG, HDL, FBG, SBP and DBP represent Body Mass Index, Total Cholesterol, Low density lipoprotein cholesterol, Triacylglycerol, High density lipoprotein cholesterol, Fasting blood glucose, Systolic blood pressure and Diastolic blood pressure respectively.

Only fasting blood glucose concentration, SBP and DBP were significantly (p<0.05) higher in the 3 BMI groups with metabolic syndrome (metabolically obese phenotypes) compared to their respective BMI groups without metabolic syndrome. BMI, HDL-Cholesterol concentration and LDL-Cholesterol concentration were similar (p>0.05) in subjects with and without metabolic syndrome, within the same BMI group. Triglycerides concentration was significantly (p<0.05) lower in the MHNW group compared to that of MONW group, while the other groups had similar (p>0.05) values of triglycerides. Total cholesterol concentration was similar (p=0.05) between those with and without metabolic syndrome in all BMI groups except the obese group where MHO individuals had significantly (p<0.05) lower values of this attribute compared to those of MOO subjects. Age of subjects was similar (p>0.05) only in the 2 overweight groups studied.

**DISCUSSION**

In this study, we sought to describe the prevalence and characteristics of obesity, metabolic syndrome and BMI-metabolic-risk sub-phenotypes. We found that more than half of the studied population had normal weight BMI while about 45% had undesirable BMI. More males were obese and overweight, compared to the females. These figures agree with a recent study in another part of Nigeria (Ejike et al., 2009) that found obesity in 12.7% of the studied population, and also reported a higher prevalence of obesity in males, compared to that in females. The Nigeria demographic and health survey, 2003
Prevalence of BMI-metabolic-risk sub-phenotypes in the entire population.

(NPC and ORC Marco, 2004) however reported only 15% and 5% overweight and obesity respectively among Nigerian women. BMI is an acceptable measure of nutritional status in adults.

Obesity is largely due to excessive energy intake without a commensurate expenditure rate. The modernization of cultures in Nigeria, and in sub-Saharan Africa, the improving standards of living and less need for physical exertion due to the availability of energy sparing devices, all of which characterize the modern environment, promote behaviors that predispose individuals to obesity (Amoah, 2003). The role of physical exertion in the development of obesity is even made clearer by comparing our BMI data (23.7 ± 4.0 in the youngest age-range and 26.1 ± 3.7 in the oldest age-range) to those of Glew et al. (2003) who studied a nomadic Fulani population of Nigeria, subsisting on high saturated fat diets, and yet had a BMI of 20.0 ± 2.2 for men and 20.2 ± 3.0 for women. Though our data show a higher prevalence of obesity in males than in females, the mean BMI of both sexes within the age groups were significantly different (p>0.05). Though BMI is associated with mortality and morbidity, it is important to note that it is excessive body fat that is associated with these health risks, and BMI does not measure fat mass or fat percentage (WHO, 1995).

We found the metabolic syndrome in 30.7% of the population. For the males, the disorder increased 5-folds in prevalence from the low risk for CAD group (22-44 years) to the high risk for CAD group (≥45 years) while for the females the increase in the prevalence of the disorder from the low risk for CAD group (22-54 years) to the high risk for CAD group (≥55 years) was 2-folds. There are, at present, at least 4 different definitions of the metabolic syndrome (NCEP, 2001; Alberti and Zimmet, 1998; Balkau and Charles, 1999; IDF, 2008) and more may still come up. This makes comparison between figures slightly difficult, especially across races and cultures. However, the similarities in all the definitions outweigh the differences (Ford, 2005a). We used the NCEP ATP III definition (NCEP, 2001) and our figure is slightly higher than the 27.8% reported in the Framingham Offspring Study (FOS) (Meigs et al., 2006), but lower than the 34.5% reported in the US National Health and Nutrition Evaluation System (NHANES) (Ford et al., 2002).
Table 2. Characteristics of the population, stratified by the presence or absence of the metabolic syndrome, within the three BMI categories

<table>
<thead>
<tr>
<th></th>
<th>BMI &lt; 25</th>
<th></th>
<th>BMI 25-29.9</th>
<th></th>
<th>BMI ≥ 30</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No MetS</td>
<td>Yes MetS</td>
<td>No MetS</td>
<td>Yes MetS</td>
<td>No MetS</td>
<td>Yes MetS</td>
</tr>
<tr>
<td></td>
<td>MHNW</td>
<td>MONW</td>
<td>MHOW</td>
<td>MOOW</td>
<td>MHO</td>
<td>MOO</td>
</tr>
<tr>
<td>Age (Years)</td>
<td>46.2 ± 13.8</td>
<td>*55.3 ± 9.3</td>
<td>0.024</td>
<td>47.3 ± 12.6</td>
<td>53.4 ± 9.3</td>
<td>0.065</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>21.5 ± 2.1</td>
<td>22.0 ± 2.1</td>
<td>0.368</td>
<td>27.1 ± 1.4</td>
<td>22.0 ± 2.1</td>
<td>0.325</td>
</tr>
<tr>
<td>Chol (mg/dl)</td>
<td>208.9 ± 72.1</td>
<td>252.2 ± 66.5</td>
<td>0.098</td>
<td>214.8 ± 105.7</td>
<td>252.2 ± 66.5</td>
<td>0.091</td>
</tr>
<tr>
<td>LDL (mg/dl)</td>
<td>100.8 ± 66.4</td>
<td>143.0 ± 81.9</td>
<td>0.083</td>
<td>143.0 ± 81.9</td>
<td>143.0 ± 81.9</td>
<td>0.135</td>
</tr>
<tr>
<td>TAG (mg/dl)</td>
<td>162.0 ± 73.1</td>
<td>*222.4 ± 66.3</td>
<td>0.006</td>
<td>143.2 ± 68.3</td>
<td>222.4 ± 66.3</td>
<td>0.215</td>
</tr>
<tr>
<td>HDL (mg/dl)</td>
<td>75.9 ± 30.0</td>
<td>64.7 ± 18.9</td>
<td>0.224</td>
<td>78.0 ± 27.0</td>
<td>64.7 ± 18.9</td>
<td>0.897</td>
</tr>
<tr>
<td>FBG (mg/dl)</td>
<td>110.2 ± 64.5</td>
<td>*173.4 ± 103.0</td>
<td>0.006</td>
<td>108.3 ± 74.4</td>
<td>*173.4 ± 103.0</td>
<td>0.001</td>
</tr>
<tr>
<td>SBP (mmHg)</td>
<td>116.5 ± 14.4</td>
<td>*160.2 ± 28.6</td>
<td>&lt;0.001</td>
<td>122.5 ± 21.1</td>
<td>*160.2 ± 28.6</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>DBP (mmHg)</td>
<td>75.3 ± 9.8</td>
<td>*89.8 ± 21.7</td>
<td>&lt;0.001</td>
<td>76.0 ± 11.4</td>
<td>*89.8 ± 21.7</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

MetS, MHNW, MONW, MHOW, MOOW, MHO and MOO represent Metabolic syndrome, Metabolically Healthy Normal Weight, Metabolically Obese Normal Weight, Metabolically Healthy Overweight, Metabolically Healthy Overweight, Metabolically Healthy Obese and Metabolically Obese Obese. BMI, Chol, LDL, TAG, HDL, FBG, SBP and DBP represent Body Mass Index, Total Cholesterol, Low density lipoprotein cholesterol, Triacylglycerol, High density lipoprotein cholesterol, Fasting blood glucose, Systolic blood pressure and Diastolic blood pressure respectively. * indicates significant mean difference compared to the corresponding metabolically healthy group.

Examination Survey (NHANES) 1999-2002 (Ford, 2005a). The prevalence figure may increase slightly if the International Diabetes Federation (IDF) definition were used, as was the case in the US (Ford, 2005a). The prevalence of the metabolic syndrome in males, but not females, in our study compares with that of Ford (2005a). The prevalence figure from both the FOS and NHANES studies were derived using the NCEP ATP III definition, making comparison with our figures easy. Obesity, elevated blood glucose concentration, hypertension and (to a lesser extent) elevated triglycerides concentration appear to be the major determinants of the metabolic syndrome in our population (see Table 2).

Metabolic syndrome has been shown to be a good surrogate indicator for insulin resistance in predicting the risk and prognosis of cardiovascular diseases (Ford, 2005b; Li et al., 2007) for insulin resistance has been suggested as a possible mechanism for metabolic syndrome (Reaven, 1988). Our data therefore suggests that a large proportion of our population (>30%) are at risk of CVD’s – more than 20% of the women at low risk for CAD (age-wise) fall into this group. These figures also indicate the lifestyle patterns of this population, and calls for urgent public health action since the metabolic syndrome is a potentially modifiable risk state for CVD’s (McKeown et al., 2004).

Our study confirms the high prevalence of different BMI-metabolic-risk sub-phenotypes in Nigeria. Our data is in tandem with a recent study in Nigeria that found that 33% of the obese population was metabolically healthy (Ejike et al., 2009). The slight difference being that 45.5% of the obese females (as against 40.0% in the said study) and 23.1% of obese males (as against 26.5% in the said study) were metabolically healthy. Our figure of 4.0% for MHO phenotype in the entire population is a lot lower than 11-28% reported in other populations (Ferrannini et al., 1997; Bonora et al., 1998; McLaughlin et al., 2004; St. Onge et al., 2004). Methodological differences however make these comparisons difficult.

We found the MONW phenotype in 37.6% of normal weight subjects, and 20.6% of the entire population. Unlike the earlier study in Nigeria (Ejike et al., 2009), more females (38.7%) than males (36.2%) of the normal weight BMI group were metabolically obese. The 37.6% prevalence of MONW within the normal weight BMI group is slightly if the International Diabetes Federation (IDF) definition were used, as was the case in the population, and calls for urgent public health action since the metabolic syndrome is a potentially modifiable risk state for CVD’s (McKeown et al., 2004).
Conclusion

In conclusion, we found obesity in 12.1% of the population, metabolic syndrome in 30.7% of the population and BMI-metabolic-risk sub-phenotypes at prevalence rates of 4.0-34.2% of the population. Lifestyle modifications that emphasize good nutrition and physical exertion to check these trends in a rapidly modernizing society like ours are advocated.

REFERENCES


diseases are actually at high risk, while 40.9% and 33.3% of those who were overweight and obese respectively actually have a healthy metabolic profile and may not be at high risk for chronic diseases.

Caution must be exercised in interpreting these data especially for the MHOW and MHO phenotypes, as the measurement of sub-clinical inflammation, endothelial dysfunction or adiponectin might reveal that they have less than healthy metabolic states (Festa et al., 2000; Kraelis et al., 2005; Meigs et al., 2004). Meigs et al (2006) also suggested that follow-up longer than 7-11 years might be required to be certain that obese subjects without metabolic risk factors are indeed at low risk. Our small sample size also implies limited statistical power to make appropriate inferences. The small sample size was because we studied people in a community that culturally view blood as synonymous with life, and as such resist, often vehemently, to cooperate with researchers that require their blood. Our detailed and standard measures and studying a clearly un-studied population (with respect to the studied metabolic disturbances) are the strengths of this study.
National Cholesterol Education Program (NCEP) (2001). Executive summary of the third report of the National Cholesterol Education Program (NCEP) expert panel on detection, evaluation, and treatment of high blood cholesterol in adults (Adult Treatment Panel III) JAMA 285:2486-2497