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<td><strong>Author(s)</strong></td>
<td>Ong, KL; Tso, AWK; Lam, KSL; Cherny, SS; Sham, PC; Cheung, BMY</td>
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<tr>
<td><strong>Citation</strong></td>
<td>The 5th International Symposium on Healthy Aging: Is Aging a Disease?, Hong Kong, 6-7 March, 2010. In Diabetes Care, 2010, v. 33 n. 8, p. 1856-1858</td>
</tr>
<tr>
<td><strong>Issued Date</strong></td>
<td>2010</td>
</tr>
<tr>
<td><strong>URL</strong></td>
<td><a href="http://hdl.handle.net/10722/126404">http://hdl.handle.net/10722/126404</a></td>
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Using Glycosylated Hemoglobin to Define the Metabolic Syndrome in United States Adults

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**OBJECTIVE** — To compare the use of GHb and fasting plasma glucose (FPG) to define the metabolic syndrome (MetS).

**RESEARCH DESIGN AND METHODS** — Data from the U.S. National Health and Nutrition Examination Survey 1999–2006 were used. MetS was defined using the consensus criteria in 2009. Raised blood glucose was defined as either FPG ≥100 mg/dl (5.6 mmol/l) or GHb ≥5.7%.

**RESULTS** — In 2003–2006, there was 91.3% agreement between GHb and FPG when either was used to define MetS. The agreement was good irrespective of age, sex, race/ethnicity, BMI, and diabetes status (≥87.4%). Similar results were found in 1999–2002. Among subjects without diabetes, only the use of GHb alone, but not FPG, resulted in significant association with cardiovascular diseases (odds ratio 1.45, P = 0.005).

**CONCLUSIONS** — Using GHb instead of FPG to define MetS is feasible. It also identifies individuals with increased cardiovascular risk.

**Diabetes Care** 33:1856–1858, 2010

The metabolic syndrome (MetS) describes the clustering of closely related cardiovascular risk factors (1). The definition of MetS, proposed in 2001 by the National Cholesterol Education Program (NCEP) Expert Panel (2), was later modified in accordance with the revised definition of impaired fasting glucose from the American Diabetes Association (ADA) in 2004 (1,3). Recently, a unified definition of MetS was proposed jointly by several organizations (4). In 2009, the ADA proposed the use of GHb in the definition of diabetes and impaired fasting glucose (5). For confirmation, we used the cross-sectional data from NHANES 1999–2002. All participants gave informed consent, and the study received approval from the Centers for Disease Control and Prevention Institutional Review Board.

MetS was defined using the consensus criteria in 2009 (4). Under this definition, a person has MetS if he or she meets three or more of the following criteria: 1) central obesity, defined using ethnic-specific cut points of waist circumference, 2) triglycerides ≥150 mg/dl (1.7 mmol/l), 3) HDL cholesterol <40 mg/dl (1.0 mmol/l) in men and <50 mg/dl (1.3 mmol/l) in women, 4) blood pressure ≥130/85 mmHg or on antihypertensive medication, or 5) raised blood glucose, defined as FPG ≥100 mg/dl (5.6 mmol/l) or on antidiabetic medication. For non-Hispanic whites and blacks, and people of other races and mixed races, the cut points were ≥90 cm in men and ≥80 cm in women. In a separate analysis, MetS was defined using the NCEP criteria, which were the same as the consensus criteria in 2009 (4), except that central obesity was defined as waist circumference ≥102 cm in men and ≥88 cm in women (1,3). The uses of GHb ≥5.7% or FPG ≥100 mg/dl in the definition of the glycemic component of MetS were compared. Agreement between two definitions was defined as the percentage of participants who were classified the same under both definitions (7,8).

The laboratory methods have been described in detail elsewhere (6,8–11). Data on GHb and FPG were adjusted so that measurements across survey periods could be combined (6). History of cardiovascular diseases was obtained from self-reported questionnaires. Statistical analysis was performed using the complex samples function of SPSS version 15.0 (SPSS, Chicago, IL). Fasting sampling weights were used in all analyses to adjust for oversampling and nonresponse bias and to approximate the distribution to the U.S. population in the year 2000.

**RESULTS** — After excluding pregnant women and subjects with missing data in BMI, GHb, and the five components of MetS, there were 3,551 and 3,412 participants aged ≥20 years in NHANES 1999–2002 and 2003–2006, respectively, who had fasted for 8–24 h. As shown in Table 1, in NHANES 2003–2006, the use of GHb alone resulted in a lower percentage of people meeting the glycemic criteria of MetS.
### CONCLUSIONS

The controversy regarding the definition of MetS has been addressed recently in a joint scientific statement (4). GHb reflects the average glucose. The components of MetS are in moderate agreement between GHb and FPG in defining raised blood glucose. The components of MetS are in moderate agreement between GHb and FPG. In defining raised blood glucose, the measurement is not recommended because it has been associated with cardiovascular risk. A subgroup should already be aggressively treated due to high cardiovascular risk, a subgroup treated due to high risk of cardiovascular disease. The use of GHb levels to define MetS is feasible compared with the use of FPG levels in the population and used in the definition of MetS is feasible compared with the use of FPG levels in the population and used in the definition of MetS is feasible. The use of GHb levels to define MetS is feasible compared with the use of FPG levels in the population and used in the definition of MetS is feasible.

### Table 1—Prevalence of MetS based on the consensus criteria in 2009 and its glucose components using different definitions for raised blood glucose

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Non-Hispanic white</th>
<th>Other ethnicities</th>
<th>Non-Hispanic black</th>
<th>Non-Hispanic white</th>
<th>Non-Hispanic black</th>
<th>Female</th>
<th>Male</th>
<th>Sex</th>
<th>Age (years)</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>20–29</td>
<td>12.0</td>
<td>3.2</td>
<td>3.9</td>
<td>27.9</td>
<td>12.0</td>
<td>3.2</td>
<td>3.1</td>
<td>1.1</td>
<td>36.0</td>
<td>12.0</td>
</tr>
<tr>
<td>30–39</td>
<td>13.0</td>
<td>4.3</td>
<td>4.1</td>
<td>25.5</td>
<td>15.2</td>
<td>4.2</td>
<td>4.0</td>
<td>1.1</td>
<td>43.8</td>
<td>13.0</td>
</tr>
<tr>
<td>40–49</td>
<td>13.0</td>
<td>4.3</td>
<td>4.2</td>
<td>20.6</td>
<td>18.5</td>
<td>4.3</td>
<td>4.0</td>
<td>1.1</td>
<td>46.8</td>
<td>13.0</td>
</tr>
<tr>
<td>50–59</td>
<td>12.0</td>
<td>3.2</td>
<td>3.9</td>
<td>27.9</td>
<td>12.0</td>
<td>3.2</td>
<td>3.1</td>
<td>1.1</td>
<td>36.0</td>
<td>12.0</td>
</tr>
<tr>
<td>60–69</td>
<td>13.0</td>
<td>4.3</td>
<td>4.1</td>
<td>25.5</td>
<td>15.2</td>
<td>4.2</td>
<td>4.0</td>
<td>1.1</td>
<td>43.8</td>
<td>13.0</td>
</tr>
<tr>
<td>70+</td>
<td>12.0</td>
<td>3.2</td>
<td>3.9</td>
<td>27.9</td>
<td>12.0</td>
<td>3.2</td>
<td>3.1</td>
<td>1.1</td>
<td>36.0</td>
<td>12.0</td>
</tr>
</tbody>
</table>

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**Table 1**—Prevalence of MetS based on the consensus criteria in 2009 and its glucose components using different definitions for raised blood glucose in NHANES 2003–2006.
data. It remains to be seen if our conclusions are also applicable to Asians, among whom the prevalence of raised blood glucose is likely to be different.

The current cut point of GHb identifies a slightly smaller group of people as having MetS. However, it also identifies subjects at high risk for cardiovascular diseases, even in those without diabetes, when the consensus criteria in 2009 are used to define MetS. Whether GHb results in better risk stratification needs to be investigated in large prospective studies.

Acknowledgments — No potential conflicts of interest relevant to this article were reported.

K.L.O. researched data, contributed to discussion, and wrote the manuscript. A.W.K.T. and K.S.L.L. contributed to discussion and reviewed/edited the manuscript. S.S.C. and P.C.S. contributed to discussion. B.M.Y.C. contributed to discussion, wrote the manuscript, and reviewed/edited the manuscript.

References