Persistent Increase of Prevalence of Metabolic Syndrome Among US adults: NHANES III to NHANES 1999-2006

Running title: Increase of Metabolic Syndrome in US adults

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Objective- To compare the prevalence in metabolic syndrome (MetSyn) between 1988-1994 and 1999-2006 among US adults of different race or ethnicity.

Research Design and Methods- Analysis of data on 6423 adult men and non-pregnant women aged >=20 years from Third National Health and Nutrition Examination Survey (NHANES-III) and 6962 participants from the combined NHANES 1999-2006 were done. The revised National Cholesterol Education Program/ Adult Treatment Panel-III definition was used to calculate MetSyn.

Results- Both the unadjusted prevalence (27.9 +/-1.1% to 34.1 +/-0.8%, P <0.001) and age-adjusted prevalence (29.2 +/-1.0% to 34.2 +/-0.7, P <0.001) increased from NHANES-III to NHANES 1999-2006, respectively. Although MetSyn prevalence was highest in Mexican Americans, significant increases in prevalence occurred among non-Hispanic Whites and non-Hispanic Blacks, especially among younger women.

Conclusions- The persistent increase of MetSyn among US adults is a serious public health concern as it raises the likelihood of increased prevalence of type-2 diabetes.

The metabolic syndrome (MetSyn) is a constellation of metabolic abnormalities and is associated with increased risk of developing diabetes (1), cardiovascular disease (2) and higher mortality from all causes (3). Among the few studies using nationally representative samples on MetSyn (4-9), Ford et al (9) estimated an increasing trend of MetSyn prevalence by comparing the Third National Health and Nutrition Examination Survey (NHANES-III) and NHANES 1999-2000 data. However, due to the smaller sample size of NHANES 1999-2000, the change in MetSyn prevalence for various subpopulations was not estimated, which is necessary to track age and ethnicity specific trends. Therefore, the objective of this study is to compare the prevalence of MetSyn between NHANES-III and NHANES 1999-2006 among US adults of different races or ethnicity.

RESEARCH DESIGN AND METHODS

We identified the cases of MetSyn using the revised American Heart Association/ National Cholesterol Education Program/ Adult Treatment Panel-III definition (10), including medication uses for appropriate MetSyn criteria. Data for this study was obtained from public-use data sets of the NHANES-III, 1988-1994 (data release 11#1A), and four continuous NHANES data releases: 1999-2000, 2001-2002, 2003-2004, and 2005-2006. Details of survey and laboratory procedure of NHANES are published elsewhere (11-13). Data from NHANES 1999-2006 were combined for this study to produce estimates of MetSyn for demographic subpopulations (e.g. sex-age-race/ethnicity) with greater statistical reliability. As the data on fasting triglycerides and fasting glucose were required to identify MetSyn and those measurements were done on a subsample population, the sample weights for the subsample were used in this study.

The appropriate sample weights for combined NHANES 1999-2006 were constructed using National Center for Health Statistics.
guidelines (14). To maintain the consistency of blood pressure data between the two surveys, the procedure described by Ford et al. (10) was followed. The continuous NHANES measured fasting glucose and serum triglycerides from blood samples drawn in the morning; therefore, only participants who attended a morning examination session for NHANES-III were included in this analysis. Otherwise, the sample includes men and non-pregnant women aged ≥ 20 years who fasted for at least 8 hours. The number of participants in the final analysis was 6423 for NHANES-III and 6962 for NHANES 1999-2006. Statistical analyses to calculate prevalence were performed using the survey procedures in SAS software version 9.1 (SAS Institute Inc., Cary, NC). The statistical significance of the change in MetSyn prevalence between the two surveys was examined by t-test, where the square root of the sum of the squared standard errors was utilized to calculate the pooled standard error of the difference in the mean.

RESULTS
The age-adjusted prevalence of four of the five metabolic abnormalities of MetSyn increased significantly between the surveys for women: abdominal obesity 46.0+/−1.4% to 58.0+/−1.1%, P<0.001; hypertriglyceridemia 24.7+/−1.2% to 27.6+/−0.8%, P=0.042; high blood pressure (HBP) 27.8+/−0.9% to 36.6+/−0.8%, P<0.001; high fasting glucose 24.2+/−1.2% to 29.2+/−1.0%, P=0.002. However, for men, age-adjusted prevalence significantly increased in abdominal obesity (30.4+/−1.6% to 41.1+/−1.1%, P<0.001) and HBP (32.0+/−0.8% to 40.0+/−0.7%, P<0.001) only. The age-adjusted prevalence of low HDL-cholesterol significantly decreased in both gender (men: 36.4+/−1.7% to 27.6+/−1.0%, P<0.001; women: 39.6+/−1.4% to 33.8+/−1.1%, P=0.001) between the surveys.

Both age-adjusted and age-specific prevalence of MetSyn for NHANES 1999-2006 were significantly higher than for NHANES-III (Table 1). The unadjusted (P=0.012) and age-adjusted (P=0.046) prevalence increased significantly between the two surveys for men, however, there was no significant change in any of the three age-groups. For women, both unadjusted and age-adjusted (P<0.001) prevalence increased significantly between the two surveys, with a significant increase noted in all three age-groups. Among non-Hispanic White (NHW), both men and women showed significant increases in unadjusted (men: P=0.010, women: P=0.001) and age-adjusted (men: P=0.048, women: P=0.007) prevalence of MetSyn. However, when classified by age groups, only women age 20-39 showed significant increase (P=0.010). Prevalence of MetSyn did not change significantly among Non-Hispanic Black (NHB) men (P>0.050) between the two surveys, but NHB women age 20-39 showed a significant increase in prevalence (P=0.036). The age-adjusted prevalence of MetSyn in NHANES 1999-2006 was highest among Mexican Americans (men: 36.6+/−1.9%, women: 42.6+/−1.7%) with little change in this group from NHANES-III. Using the unadjusted prevalence rates from combined sample population of NHANES 1999-2006 we estimated that about 32.4 million men and 35.3 million women in US had MetSyn. Among US adults with MetSyn, about 50.6 million were NHW, about 6.3 million were NHB, and about 4.6 million were Mexican Americans.

The age-adjusted prevalence of US adults reporting diabetes (other than pregnancy related) or having a fasting blood glucose ≥126mg/dL significantly increased in both gender (men: 8.1+/−0.6% to 10.5+/−0.6%, P=0.005; women: 5.8+/−0.6% to 8.5+/−0.5%, P=0.001) between the two surveys. The age-
The adjusted prevalence of MetSyn among US men without diabetes did not change significantly (27.6 +/- 1.4% to 30.6 +/- 1.1%, \( P=0.08 \)), however, the prevalence significantly increased for women without diabetes (24.0 +/- 1.2% to 29.4 +/- 1.0%, \( P=0.001 \)), including women age 20-39 (10.0 +/- 1.6% to 15.8 +/- 1.2%, \( P=0.003 \)) and age 40-59 (25.8 +/- 2.4% to 31.6 +/- 1.7%, \( P=0.049 \)).

**CONCLUSIONS**
Ford et al. estimated that ~50 million US adults had MetSyn in 1990 and ~64 million in 2000 (9), representing a 28% increase in prevalence. From the combined NHANES 1999-2006 data, we estimated ~68 million US adults had MetSyn, or a further increase of 6%. The prevalence of MetSyn in US adults in 1999-2006 was 34.1 +/- 0.8% (after age adjustment 34.2 +/- 0.7%) which is a significant increase from 1988-1994, and more so in women (28.4%) than men (16.8%). Further, in both NHW and NHB, the prevalence of MetSyn significantly increased in women, particularly younger women (age 20-39). The increased prevalence of MetSyn was primarily due to increases in abdominal obesity and HBP.

An increase in MetSyn prevalence is expected to be followed by an increase in diabetes prevalence, though of a lesser magnitude. Between the two surveys, there was a 4.3% increase in age-adjusted prevalence of MetSyn among adults without diabetes and a 2.6% increase in diabetes. As we continue to see an increase in MetSyn, especially in certain ethnic groups and younger women, we will see a concomitant increase in diabetes and its co-morbidities and associated medical costs.

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Table 1- Age-specific (unadjusted) and age-adjusted (Adjusted) prevalence of the metabolic syndrome among US adults aged >= 20 years: NHANES-III and NHANES 1999-2006.

|                  | NHANES-III | NHANES 1999-2006 | Absolute change | Relative change |
|------------------|------------|-------------------|-----------------|-----------------|
|                  | n   | % (SE)          | n   | % (SE) | change | % change | P     |
| Total            |     |                 |     |        |        |          |       |
| Unadjusted       | 6423 | 27.9 (1.1)      | 6962 | 34.1 (0.8) | 6.3 | 22.6     | <0.001 |
| Adjusted         | 6423 | 29.2 (1.0)      | 6962 | 34.2 (0.7) | 5.0 | 17.0     | <0.001 |
| Men              |     |                 |     |        |        |          |       |
| Unadjusted       | 3059 | 29.3 (1.6)      | 3582 | 34.2 (1.1) | 4.9 | 16.8     | 0.012  |
| Adjusted         | 3059 | 31.4 (1.4)      | 3582 | 34.9 (1.0) | 3.5 | 11.2     | 0.046  |
| 20-39            | 1217 | 15.7 (2.1)      | 1229 | 20.2 (1.4) | 4.4 | 28.1     | 0.080  |
| 40-59            | 839  | 36.3 (2.3)      | 1114 | 41.2 (1.7) | 5.0 | 13.7     | 0.083  |
| 60+              | 1003 | 50.3 (2.3)      | 1239 | 49.9 (2.0) | -0.4 | -0.8    | 0.899  |
| Women            |     |                 |     |        |        |          |       |
| Unadjusted       | 3364 | 26.5 (1.4)      | 3380 | 34.1 (1.10 | 7.5  | 28.4     | <0.001 |
| Adjusted         | 3364 | 27.1 (1.2)      | 3380 | 33.3 (1.0) | 6.2  | 22.8     | <0.001 |
| 20-39            | 1447 | 10.7 (1.7)      | 1061 | 16.7 (1.2) | 6.0  | 55.5     | 0.003  |
| 40-59            | 943  | 30.2 (2.3)      | 1113 | 36.3 (1.7) | 6.2  | 20.4     | 0.033  |
| 60+              | 974  | 50.2 (2.2)      | 1206 | 56.8 (1.9) | 6.6  | 13.1     | 0.022  |
| NH-White*        |     |                 |     |        |        |          |       |
| Men              |     |                 |     |        |        |          |       |
| Unadjusted       | 1284 | 30.8 (2.0)      | 1881 | 37.0 (1.3) | 6.3  | 20.3     | 0.010  |
| Adjusted         | 1284 | 32.1 (1.9)      | 1881 | 36.5 (1.2) | 4.4  | 13.8     | 0.048  |
| 20-39            | 337  | 16.6 (2.8)      | 523  | 22.3 (2.0) | 5.8  | 35.0     | 0.090  |
| 40-59            | 361  | 37.1 (3.0)      | 618  | 42.2 (2.0) | 5.1  | 13.7     | 0.164  |
| 60+              | 586  | 50.4 (2.5)      | 740  | 51.4 (2.4) | 1.0  | 2.1      | 0.762  |
| Women            |     |                 |     |        |        |          |       |
| Unadjusted       | 1462 | 26.5 (1.6)      | 1725 | 33.3 (1.4) | 6.8  | 25.6     | 0.001  |
| Adjusted         | 1462 | 26.2 (1.4)      | 1725 | 31.4 (1.3) | 5.2  | 20.0     | 0.007  |
| 20-39            | 446  | 9.1 (1.9)       | 483  | 16.0 (1.8) | 6.8  | 74.5     | 0.010  |
| 40-59            | 411  | 29.4 (2.7)      | 543  | 33.0 (2.2) | 3.7  | 12.6     | 0.292  |
| 60+              | 605  | 50.2 (2.5)      | 699  | 55.2 (2.1) | 5.0  | 9.9      | 0.121  |
| NH-Black*        |     |                 |     |        |        |          |       |
| Men              |     |                 |     |        |        |          |       |
| Unadjusted       | 762  | 20.2 (1.2)      | 634  | 22.0 (1.6) | 1.8  | 8.8      | 0.372  |
| Adjusted         | 762  | 23.1 (1.4)      | 634  | 24.9 (1.6) | 1.9  | 8.0      | 0.388  |
| 20-39            | 375  | 13.9 (1.5)      | 261  | 11.9 (2.0) | -2.0 | -14.1    | 0.439  |
| 40-59            | 210  | 24.3 (3.10)     | 192  | 26.6 (3.2) | 2.3  | 9.3      | 0.613  |
| 60+              | 177  | 36.9 (3.3)      | 181  | 44.6 (3.3) | 7.7  | 21.0     | 0.098  |
| Women            |     |                 |     |        |        |          |       |
|                      | Unadjusted | Adjusted | Unadjusted | Adjusted | Unadjusted | Adjusted | Unadjusted | Adjusted | Unadjusted | Adjusted |
|----------------------|------------|----------|------------|----------|------------|----------|------------|----------|------------|----------|
|                      |            |          |            |          |            |          |            |          |            |          |
|                      | 913        | 30.6     | 656        | 36.5     | 268        | 35.6     | 173        | 53.3     |            |          |
|                      | 26.4 (1.7) | (1.7)    | 34.3 (1.7) | (1.6)    | 5.9        | (2.5)    | 5.1        | (2.7)    |            |          |
|                      | 7.9        |          | 30.0       |          | 0.001      |          | 19.3       |          | 0.014      |          |
|                      |            |          |            |          |            |          |            |          |            |          |
| 20-39                | 472        | 12.6     | 244        | 18.9     | 287        | 14.5     | 241        | 15.2     |            |          |
|                      | 12.6 (1.6) | (1.6)    | 18.9 (2.5) |          | 14.5       | (2.9)    | 15.2       | (2.9)    |            |          |
|                      | 6.3        |          | 49.8       |          | 27.1       |          | 124.4      |          |            |          |
|                      | 49.8       |          | 0.036      |          | 0.005      |          | 0.005      |          |            |          |
|                      |            |          |            |          |            |          |            |          |            |          |
| 40-59                | 268        | 35.6     | 230        | 40.7     | 268        | 35.6     | 173        | 53.3     |            |          |
|                      | 35.6 (2.7) | (2.7)    | 40.7 (3.4) | (2.7)    | 35.6       | (3.4)    | 5.1        | (2.7)    |            |          |
|                      | 5.1        |          | 14.2       |          | 23.9       |          | 56.6       |          |            |          |
|                      | 14.2       |          | 0.241      |          | 0.021      |          |            |          |            |          |
|                      |            |          |            |          |            |          |            |          |            |          |
| 60+                  | 173        | 53.3     | 182        | 59.9     | 173        | 53.3     | 173        | 53.3     |            |          |
|                      | 53.3 (4.0) | (4.0)    | 59.9 (2.7) | (2.7)    | 53.3       | (4.0)    | 53.3       | (4.0)    |            |          |
|                      | 6.6        |          | 12.3       |          | 23.9       |          | 56.6       |          |            |          |
|                      | 12.3       |          | 0.180      |          | 0.021      |          |            |          |            |          |

* NH = Non-Hispanic, Mex Amer = Mexican American