Misclassification of Cardiometabolic Health when using Body Mass Index Categories in NHANES 2005-2012

A. Janet Tomiyama, PhD;[1] Jeffrey M. Hunger, MA;[2] Jolene Nguyen-Cuu, BS[1]; Christine Wells, PhD[1]

[1]University of California, Los Angeles; [2]University of California, Santa Barbara

Correspondence concerning this article should be addressed to A. Janet Tomiyama, UCLA Department of Psychology, 5625 Franz Hall, Los Angeles, CA 90095. Phone: 310-206-6875, Fax: 310-206-5895 E-mail: tomiyama@psych.ucla.edu.

The authors have no conflicts of interest to disclose. AJT was supported by the Hellman Fellows fund. The Hellman Fellows Fund had no further role in the design of the study; in the collection, analysis and interpretation of the data; in writing the report; and in deciding to submit the paper for publication. AJT and JMH conceived the study. AJT obtained funding. CW analyzed the data. AJT, JMH, JNC, and CW interpreted the analyses and drafted the manuscript.

Word Count: 1558

Abstract

The United States (US) Equal Employment Opportunity Commission has proposed rules allowing employers to penalize employees up to 30% of health insurance costs if they fail to meet "health" criteria such as reaching a specified Body Mass Index (BMI). Our objective was to examine cardiometabolic health misclassifications given standard BMI categories. Participants (N = 40,420) were individuals aged 18+ in the nationally representative 2005-2012 National Health and Nutrition Examination Survey (NHANES). Using blood pressure, triglyceride, cholesterol, glucose, insulin resistance, and C-reactive protein data, population frequencies/percentages of metabolically healthy versus unhealthy individuals were stratified by BMI. Nearly half of overweight individuals, 29% of obese individuals, and even 16% of obesity type II/III individuals were metabolically healthy. Moreover, over 30% of normal weight individuals were cardiometabolically unhealthy. There was no significant race x BMI interaction, but there was a significant gender x BMI interaction, $F(4,64) = 3.812$, $p = .008$. Using BMI categories as the main indicator of health, an estimated 74,936,678 US adults are misclassified as cardiometabolically unhealthy or cardiometabolically healthy. Policymakers should consider the unintended consequences of relying solely on BMI, and researchers should seek to improve diagnostic tools related to weight and cardiometabolic health. (195/200 words)

Introduction

Recently proposed rules by the Equal Employment Opportunity Commission (EEOC) allow employers to penalize an employee up to 30% of the cost of their health insurance if they fail to meet specific "health" criteria such as reaching a specified (lower) Body Mass Index (BMI). Such a policy is based on the fact that overweight and obesity are associated with poor health conditions including diabetes, cardiovascular disease, hypertension, and some cancers.[1,2] This kind of policy carries with it the major assumption that higher BMI individuals must uniformly face poor health. Yet, the relationship between BMI and health is complex, and focusing on between-BMI category variation in morbidity and mortality obscures substantial within-category variability in cardiometabolic health.[3] Here, we test this assumption using the most recent nationally representative data available. We document the prevalence and demographic distribution of cardiometabolic health, highlighting the considerable number of individuals whose health status is misclassified when BMI categories are used as a proxy for actual health.

Misclassifying individual health on the basis of high BMI has numerous potential consequences. Not only do these types of punitive policies exacerbate the well-established economic consequences of being heavy,[4] but they are also perceived as stigmatizing by heavier individuals,[5] which can have a host of negative mental and physical health consequences.[6] Furthermore, individuals with an overweight or obese BMI are often instructed by their physicians to lose weight. If these individuals are otherwise healthy, however, intentional weight loss may actually *increase* risk for mortality.[7] The assumption underlying a policy like the EEOC's also has potential consequences for lower BMI individuals. If these individuals are classified as healthy solely based on their BMI, they may not engage in proper preventive care or diagnoses may be delayed.

Given these potential consequences of misclassification, the goal of this study is to quantify the extent to which individual cardiometabolic health is mischaracterized when using established BMI categories. To do so, we draw on the most recently available nationally representative prevalence data on cardiometabolic health drawn from the 2005-2012 National Health and Nutrition Examination Survey (NHANES). We use the stringent definition of metabolic health described in Wildman et al.,[3] which relies on the greatest number of criteria across multiple systems (blood pressure, triglyceride, cholesterol, glucose, insulin resistance, and C-reactive protein), and was used with earlier data from NHANES.

Methods

NHANES provides data on the health and nutritional status of adults in the U.S. through interviews and physical examinations. Sampling for NHANES is representative of the noninstitutionalized civilian U.S. population and consists of ~5,000 persons each year. The present analyses are based on NHANES participants 18 and older from 2005-2012 who completed the interview, examination, and/or lab components of NHANES. N for analyses ranged from 12,351 (HOMA) to 39,303 (demographics).

Age, gender, race/ethnicity, and pregnancy were self-reported.[8] For the present analyses, race was categorized as follows: Mexican American, Non-Hispanic white, Non-Hispanic black, and other. Use of antihypertensive, lipid-lowering, and antidiabetic medications was also self-reported.[8]

Height was measured to the nearest 0.1 centimeter by a stadiometer, and weight was measured in kilograms by a digital weight scale with participants wearing a standard examination gown.[8] BMI values were calculated from measured height and weight values using the standard equation: weight(kg)/height(m)^2. Waist circumference was measured to the nearest 0.1 centimeter at the end of participants' normal expiration.[8]

Because a standardized definition of metabolic health has yet to be established, the present analyses used the definition outlined by Wildman and colleagues,[3] which uses the greatest number of criteria among existing definition options. This defines metabolic health as 0-1 of the following metabolic abnormalities: [1] systolic/diastolic blood pressure ≥130/85 mmHg or antihypertensive medication use, [2] fasting triglyceride level ≥150 mg/dL (1.69 mmol/L), [3] HDL-C level <40 mg/dL (1.04 mmol/L) in men or <50 mg/dL (1.29 mmol/L) in women or lipid-lowering medication use, [4] fasting glucose level ≥100 mg/dL (5.55 mmol/L) or antidiabetic medication use, [5] HOMA-IR >5.13, and [6] hsCRP level >0.1 mg/L (0.95 nmol/L).

Three consecutive blood pressure readings were averaged.[8] Due to high prevalence of extremely low implausible diastolic blood pressure measurements, all diastolic blood pressure <35mmHg were excluded in the present analyses. Triglycerides were determined by timed-endpoint.[8] Glucose was determined by oxygen rate. HDL-C was measured enzymatically through traditional precipitation methods.[8] Insulin was measured using two-site enzyme immunoassay. CRP was quantified by latex-enhanced nephelometry.[8]

Statistical analyses

Data from the 2005-2006, 2007-2008, 2009-2010 and 2011-2012 data collection cycles were appended and the sampling weights modified as directed in NHANES documentation. All analyses were done on the non-pregnant subpopulation of the data. Female respondents who had a positive lab pregnancy test or self-reported as pregnant were excluded. Listwise deletion of missing data was done for all analyses.

Means/percentages were calculated for the overall population as well as 5 BMI categories: underweight, normal weight, overweight, obesity, and obesity types II/III (combined due to low *n*). Logistic regressions controlling for age (top-coded at 80 years) were conducted using healthy versus not healthy as the outcome variable. Gender, and BMI category were used as predictors.

Analyses were conducted using SAS 9.4 (SAS Institute, Cary, North Carolina) and SUDAAN 11.0.1 (Research Triangle Institute, Research Triangle Park, North Carolina). The sampling weight was adjusted for the multiple years following the method suggested in NHANES documentation.[9] This revised sampling weight, clustering, and stratification were incorporated into all analyses as recommended in NHANES documentation.[10]

Results

Table 1 displays descriptive statistics. Table 2 presents population frequencies and percentages of healthy versus unhealthy metabolic status, stratified by BMI category. Although the relative percentage of healthy versus unhealthy individuals decreased in obesity, as expected, fully 19,761,047 obese U.S. adults were classified as metabolically healthy. Supplementary Figure 1 displays the age-adjusted predicted population frequencies and percentages of healthy versus unhealthy stratified by BMI, further stratified by gender and race, respectively.

No significant race x BMI interaction emerged, $F(12,64) = 1.62$, $p = 0.11$). There was a significant gender x BMI interaction, $F(4,64) = 3.81$, $p = .008$, further qualified by examining specific meaningful combinations of gender and BMI. Pairwise comparisons within BMI-by-gender groups using Sidak correction for multiple comparisons indicated normal weight females had greater odds of being metabolically healthy than normal weight men (OR = 1.41, $p < .001$), as did women with type II/III obesity compared to men with type II/III obesity (OR = 2.05, p =

.034). However, obese women were no more likely to be metabolically healthy than obese men (OR = 1.13, p = .909).

Discussion

Overweight and obesity have long been considered uniformly detrimental to health, and recently proposed rules by the EEOC would codify this into policy. Yet focusing on BMI ignores overweight and obese individuals who are cardiometabolically healthy – nearly half of overweight individuals, approximately 29% of obese individuals, and approximately 16% of obesity type II and III individuals. For these individuals, having a healthcare provider prescribe weight loss could be a misuse of time, patient effort, and resources. Focusing on BMI as a proxy for health may also contribute to and exacerbate weight stigmatization, an issue that is particularly concerning given healthcare providers evince high levels of anti-fat bias.[11,12] Moreover, this focus ignores the many individuals whose BMI is considered "normal" yet are cardiometabolically *unhealthy* – 30% of this population. When healthcare providers deem these individuals as "healthy" merely because they are not overweight or obese, critical diagnoses could be delayed or missed altogether. Overall, we found that using BMI as the main indicator of cardiometabolic health misclassifies an estimated 74,936,678 individuals.

These results clearly indicate that health policies such as those proposed by the EEOC should not rely on BMI. Not only are such policies discriminatory, but they run the risk of overlooking more effective approaches. A recent component analysis suggests that the most effective health interventions are those that emphasize health behaviors, foster improved self-concept (e.g., a sense of self-efficacy) and provide practical skills (e.g., stress management); targeting weight and weight loss was found to be unnecessary to improve health.[13] We recognize, however, that BMI may be seen as a quick, convenient, and inexpensive marker of health in the clinical setting. Yet excessive focus on weight is likely to have detrimental consequences for the health and wellbeing of heavier individuals[14] and thus should not be the principal outcome in health promotion efforts.[15]

Although obtaining blood markers is more time intensive, invasive, and costly, doing so can foster more accurate diagnosis and improved patient care. If lab markers are absolutely unobtainable, potential solutions are to instead use markers that researchers argue are a more accurate marker of health than BMI, such as physical activity and cardiorespiratory fitness,[16–18] waist circumference,[19] or body fat percentage,[16] or their combination. Regardless of the ultimate solution, the need for improved diagnostic tools related to cardiometabolic health is clear.

We contend that blood pressure, triglyceride, cholesterol, glucose, insulin resistance, and C-reactive protein data are more accurate measures of health than BMI. However, this multi-system definition of cardiometabolic health should be confirmed using mortality data from longitudinal studies.[e.g.20]

In sum, a large proportion of US adults are misclassified as cardiometabolically unhealthy according to BMI categories, indicating that the EEOC and other entities should not rely on BMI when formulating health policy. Moreover, a clinical focus guided by weight and BMI may be misdirected. Future research should study overweight and obese individuals who are cardiometabolically healthy to understand how individuals can be healthy, no matter their BMI.

Supplementary information is available at the International Journal of Obesity's website.

References

1. Catenacci VA, Hill JO, Wyatt HR. The Obesity Epidemic. *Clin Chest Med*. 2009;30:415-444. doi:10.1016/j.ccm.2009.05.001.

2. Guh DP, Zhang W, Bansback N, Amarsi Z, Birmingham CL, Anis AH. The incidence of co-morbidities related to obesity and overweight: a systematic review and meta-analysis. *BMC Public Health*. 2009;9(1):88. doi:10.1186/1471-2458-9-88.

3. Wildman RP, Muntner P, Reynolds K, et al. The obese without cardiometabolic risk factor clustering and the normal weight with cardiometabolic risk factor clustering: prevalence and correlates of 2 phenotypes among the US population (NHANES 1999-2004). *Arch Intern Med*. 2008;168(15):1617-24. doi:10.1001/archinte.168.15.1617.

4. Cawley J. The Impact of Obesity on Wages. *J Hum Resour*. 2004;XXXIX(2):451-474. doi:10.3368/jhr.XXXIX.2.451.

5. Tannenbaum D, Valasek CJ, Knowles ED, Ditto PH. Incentivizing wellness in the workplace: sticks (not carrots) send stigmatizing signals. *Psychol Sci*. 2013;24(8):1512-22. doi:10.1177/0956797612474471.

6. Hunger, J.M., Major, B., Blodorn, A., & Miller C. Weighed down by stigma: How weight-based social identity threat influences weight gain and health. *Soc Psychol Personal Compass*. 2015;9:255-268. doi:10.1111/spc3.12172.

7. Harrington M, Gibson S, Cottrell RC. A review and meta-analysis of the effect of weight loss on all-cause mortality risk. *Nutr Res Rev*. 2009;22(1):93-108. doi:10.1017/S0954422409990035.

8. National Health and Nutrition Examination Survey: Questionnaires, Datasets, and Related Documentation. Available at: http://www.cdc.gov/nchs/nhanes/nhanes_questionnaires.htm.

9. Task 2: When and How to Construct Weights When Combining Survey Cycles. Available at: http://www.cdc.gov/nchs/tutorials/nhanes/SurveyDesign/Weighting/Task2.htm.

10. National Health and Nutrition Examination Survey: Analytic guidelines, 1999–2010. Available at: http://www.cdc.gov/nchs/data/series/sr_02/sr02_161.pdf.

11. Tomiyama AJ, Finch LE, Belsky ACI, et al. Weight bias in 2001 versus 2013: contradictory attitudes among obesity researchers and health professionals. *Obesity (Silver Spring)*. 2015;23(1):46-53. doi:10.1002/oby.20910.

12. Phelan SM, Burgess DJ, Yeazel MW, Hellerstedt WL, Griffin JM, van Ryn M. Impact of weight bias and stigma on quality of care and outcomes for patients with obesity. *Obes Rev*. 2015;16(4):319-26. doi:10.1111/obr.12266.

13. Friedemann Smith C, Heneghan C, Ward A. Moving Focus from Weight to Health. What Are the Components Used in Interventions to Improve Cardiovascular Health in Children? *PLoS One*. 2015;10(8):e0135115. doi:10.1371/journal.pone.0135115.

14. Hunger JM, Tomiyama AJ. A call to shift the public health focus away from weight. *Am J Public Health*. 2015;105(11):e3-e3. doi:10.2105/AJPH.2015.302845.

15. Ross R, Blair S, de Lannoy L, Després J-P, Lavie CJ. Changing the endpoints for determining effective obesity management. *Prog Cardiovasc Dis*. 2015;57(4):330-6. doi:10.1016/j.pcad.2014.10.002.

16. Ortega FB, Lee D-C, Katzmarzyk PT, et al. The intriguing metabolically healthy but obese phenotype: cardiovascular prognosis and role of fitness. *Eur Heart J*. 2013;34(5):389-97. doi:10.1093/eurheartj/ehs174.

17. Barry VW, Baruth M, Beets MW, Durstine JL, Liu J, Blair SN. Fitness vs. fatness on all-cause mortality: a meta-analysis. *Prog Cardiovasc Dis*. 2014;56(4):382-90. doi:10.1016/j.pcad.2013.09.002.

18. Lavie CJ, De Schutter A, Milani R V. Healthy obese versus unhealthy lean: the obesity paradox. *Nat Rev Endocrinol*. 2015;11(1):55-62. doi:10.1038/nrendo.2014.165.

19. Plourde G, Karelis AD. Current issues in the identification and treatment of metabolically healthy but obese individuals. *Nutr Metab Cardiovasc Dis*. 2014;24(5):455-9. doi:10.1016/j.numecd.2013.12.002.

20. Must A, Phillips SM, Naumova EN. Occurrence and timing of childhood overweight and mortality: findings from the Third Harvard Growth Study. *J Pediatr*. 2012;160(5):743-50. doi:10.1016/j.jpeds.2011.10.037.

Table 1. Descriptive statistics of study sample, stratified by metabolic health status and BMI.

Demographic and Behavioral Characteristics	Overall	Metabolically Healthy					Metabolically Abnormal				
		Underweight	Normal	Overweight	Obese type 1	Obese type 2 and 3	Underweight	Normal	Overweight	Obese type 1	Obese type 2 and 3
Prevalence, % (population frequency)	98.70 (221813615)	3.07 (3187756)	44.80 (46578422)	33.13 (34444523)	17.01 (17682754)	2.00 (2078293)	0.87 (1004707)	18.03 (20731008)	33.23 (38215006)	38.31 (44051013)	9.56 (10997304)
Age, y	46.19 (0.34)	34.53 (1.04)	37.65 (0.46)	41.26 (0.36)	39.88 (0.48)	38.30 (1.30)	56.01 (1.83)	54.95 (0.59)	53.73 (0.41)	51.07 (0.35)	47.76 (0.63)
Men, %	48.94 (0.31)	1.83 (0.30)	40.06 (1.12)	39.58 (0.87)	17.50 (0.76)	1.03 (0.17)	0.68 (0.12)	16.35 (0.63)	37.84 (0.68)	38.20 (0.86)	6.93 (0.47)
Race/ethnicity, %											
White	68.71 (1.72)	3.15 (0.35)	46.05 (1.17)	33.34 (1.01)	15.87 (0.82)	1.59 (0.21)	0.96 (0.15)	18.56 (0.63)	33.84 (0.74)	37.87 (0.60)	8.78 (0.48)
Black	11.54 (0.93)	3.24 (0.33)	36.47 (1.21)	30.25 (1.08)	24.90 (1.36)	5.14 (0.47)	0.85 (0.16)	14.19 (0.70)	26.95 (0.80)	41.59 (1.00)	16.41 (0.71)
Mexican-American	8.18 (0.83)	1.53 (0.33)	35.29 (1.93)	39.22 (1.38)	21.49 (1.44)	2.47 (0.55)	0.33 (0.11)	11.65 (0.75)	36.38 (1.26)	43.40 (1.14)	8.24 (0.69)
Other	11.57 (0.78)	3.46 (0.61)	51.22 (1.60)	30.46 (1.31)	13.58 (1.18)	1.28 (0.33)	0.76 (0.20)	23.95 (1.74)	34.21 (1.52)	33.38 (1.90)	7.70 (0.97)
SBP, mm Hg	121.69 (0.26)	107.02 (0.78)	112.57 (0.29)	114.85 (0.28)	116.08 (0.32)	115.92 (1.48)	137.58 (2.80)	130.95 (0.59)	128.58 (0.40)	127.27 (0.32)	128.76 (0.86)
DBP, mm Hg	70.73 (0.24)	65.87 (0.78)	67.37 (0.31)	69.02 (0.29)	70.62 (0.38)	70.44 (0.83)	74.30 (1.37)	71.79 (0.44)	72.61 (0.32)	73.18 (0.39)	73.70 (0.55)
Elevated blood pressure (SBP130 mmHg and/or DBP 85 mm Hg and/or medication use), %	39.43 (0.67)	1.52 (0.47)	39.83 (2.52)	36.04 (2.39)	20.07 (1.93)	2.53 (0.99)	1.06 (0.14)	18.11 (0.58)	32.40 (0.76)	38.02 (0.66)	10.42 (0.45)
HDL-C, mg/dL	52.92 (0.23)	65.40 (1.14)	61.62 (0.26)	55.29 (0.42)	51.70 (0.42)	52.32 (0.88)	64.41 (2.27)	55.76 (0.76)	49.22 (0.35)	45.41 (0.24)	45.08 (0.48)
HDL-C < 40 mg/dL for men or < 50 mg/dL	30.30 (0.63)	1.48 (0.43)	29.58 (1.78)	38.34 (2.02)	27.27 (1.91)	3.33 (0.66)	0.39 (0.09)	12.94 (0.67)	30.05 (0.97)	44.37 (0.83)	12.25 (0.53)

for women, %											
Triglycerides, mg/DL	133.35 (1.74)	78.30 (3.61)	83.25 (1.08)	95.72 (1.57)	96.02 (2.35)	83.43 (5.22)	100.10 (7.50)	129.61 (2.78)	168.83 (3.77)	171.96 (4.08)	159.98 (4.83)
Triglycerides, 150 mg/dL, %	27.77 (0.72)	3.30 (2.03)	39.53 (5.19)	47.91 (5.22)	8.75 (2.71)	0.51 (0.49)	0.21 (0.08)	12.90 (0.66)	35.33 (1.11)	41.53 (0.94)	10.02 (0.96)
Glucose, mg/dL	105.24 (0.49)	90.95 (0.84)	91.87 (0.23)	95.10 (0.82)	94.35 (0.41)	92.61 (1.07)	104.24 (3.94)	107.83 (1.04)	109.43 (0.78)	116.13 (0.96)	121.15 (2.10)
Glucose ge 100 mg/dL and/or antidiabetic medication use, %	47.26 (0.90)	2.60 (0.78)	41.37 (3.11)	40.96 (3.24)	14.68 (2.22)	0.40 (0.31)	0.62 (0.14)	15.95 (0.65)	33.40 (0.91)	39.40 (0.78)	10.63 (0.62)
Insulin, U/mL	12.95 (0.18)	5.66 (0.47)	6.44 (0.15)	8.53 (0.16)	11.36 (0.26)	15.50 (1.58)	7.59 (1.88)	8.90 (0.31)	13.45 (0.32)	19.15 (0.37)	28.30 (1.24)
HOMA-IR	3.57 (0.07)	1.28 (0.11)	1.47 (0.03)	1.99 (0.04)	2.66 (0.06)	3.56 (0.35)	1.97 (0.42)	2.44 (0.10)	3.69 (0.12)	5.62 (0.13)	8.67 (0.52)
HOMA-IR > 5.13, %	17.97 (0.59)	---	28.72 (9.95)	25.38 (11.07)	28.65 (9.17)	17.25 (8.45)	0.25 (0.19)	4.66 (0.71)	22.16 (1.27)	52.27 (1.46)	20.66 (1.30)
BMI	28.52 (0.09)	17.62 (0.05)	22.25 (0.03)	27.19 (0.03)	33.16 (0.08)	44.77 (0.36)	17.45 (0.13)	22.78 (0.04)	27.55 (0.03)	33.89 (0.06)	45.59 (0.18)
Waist circumference, cm	97.65 (0.27)	70.07 (0.28)	81.28 (0.17)	94.31 (0.19)	107.13 (0.29)	128.01 (0.68)	72.10 (0.57)	85.83 (0.19)	98.25 (0.13)	111.71 (0.22)	132.08 (0.50)
hsCRP, mg/L	0.04 (0.0008)	0.01 (0.002)	0.02 (0.002)	0.02 (0.002)	0.04 (0.002)	0.09 (0.009)	0.04 (0.008)	0.04 (0.002)	0.04 (0.002)	0.06 (0.002)	0.10 (0.005)
hsCRp > 0.1, mg/L, %	8.97 (0.30)	1.45 (0.61)	29.11 (3.67)	23.30 (3.54)	35.52 (3.55)	10.62 (1.84)	0.37 (0.15)	10.76 (0.88)	20.44 (1.41)	43.67 (1.80)	24.76 (1.88)

Note: Percentages may not add to 100% due to rounding.

Table 2. Estimated population frequency of metabolic status (%), stratified by Body Mass Index Category, of non-pregnant adults

	Underweight	Normal Weight	Overweight	Obese Class I	Obese Class II & III
Metabolic Status					
Healthy	3,187,756 (76.04)	46,578,422 (69.20)	34,444,523 (47.41)	17,682,754 (28.64)	2,078,293 (15.89)
Unhealthy	1,004,707 (23.96)	20,731,008 (30.80)	38,215,006 (52.59)	44,051,013 (71.36)	10,997,304 (84.11)