

Trends in Cardiovascular Health Metrics in Obese Adults: National Health and Nutrition Examination Survey (NHANES), 1988–2014

Fangjian Guo, MD, PhD; W. Timothy Garvey, MD

Background—No study has quantified trends in the prevalence of cardiovascular disease risk factors and cardiovascular health metrics among obese people in the United States in recent years.

Methods and Results—We examined the secular changes in cardiovascular health metrics and key cardiovascular disease risk factors among obese adults (aged ≥ 20 years) in the United States. We included 18 626 obese adults (body mass index ≥ 30) from the National Health and Nutrition Examination Survey (NHANES) III and NHANES 1999–2014. Among those obese adults, there were decreases in mean systolic blood pressure, diastolic blood pressure, and total cholesterol levels and increases in mean high-density lipoprotein cholesterol levels and mean hemoglobin A1c levels. Prevalence of blood pressure health and lipid health remained stable during the period 1988–2014, whereas prevalence of blood glucose health decreased significantly during this period. Prevalence of freedom from cardiovascular disease risk factors remained stable at $\approx 15\%$ among the adult obese population during the period 1988–2014, whereas prevalence of presence of all 3 risk factors increased from 16.4% to 22.4% during this period, commensurate with a decline in those with 1 to 2 risk factors (from 69.6% to 62.4%).

Conclusions—During the past 3 decades, blood pressure health and blood lipid health remained stable or improved, whereas blood glucose health deteriorated among adult obese population. This resulted in an overall decrease in cardiovascular health status among obese adults and greater risk of type 2 diabetes mellitus. The data argue for interventions targeted to those obese persons who are metabolically unhealthy to stem rising rates of diabetes mellitus. (*J Am Heart Assoc.* 2016;5:e003619 doi: 10.1161/JAHA.116.003619)

Key Words: blood pressure • glucose • lipids • obesity • risk factor

Obesity is associated with elevated risk of morbidity and mortality¹ and has become an epidemic both in the United States and worldwide.^{2,3} Obese persons who are free from cardiovascular disease (CVD) risk factors, such as hypertension, dyslipidemia, and hyperglycemia, are relatively insulin sensitive.^{4–9} Epidemiological data indicate low risk of progression to diabetes mellitus and CVD outcomes among such people compared with obese persons with risk factors^{10–14} but increased risk of diabetes mellitus compared with healthy lean persons. These people experience low rates

of incident diabetes mellitus and CVD, and their CVD risks are substantially reduced in comparison with either lean or obese persons who have the metabolic syndrome.^{10–12}

Prevalence of obesity in the United States has leveled off in recent years.^{2,15} It was reported that during the period 1960–2000, except for diabetes mellitus, prevalence of CVD risk factors declined in obese people in the United States¹⁶; however, no study has quantified trends in the prevalence of individual CVD risk factors together with cardiovascular health status among obese people in the United States in recent

From the Department of Obstetrics & Gynecology, and Center for Interdisciplinary Research in Women's Health, The University of Texas Medical Branch, Galveston, TX (F.G.); Department of Nutrition Sciences, University of Alabama at Birmingham, AL (W.T.G.); Birmingham Veterans Affairs Medical Center, Birmingham, AL (W.T.G.).

Accompanying Tables S1 through S8 are available at <http://jaha.ahajournals.org/content/5/7/e003619/DC1/embed/inline-supplementarymaterial-1.pdf>

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Correspondence to: Fangjian Guo, MD, PhD, Department of Obstetrics & Gynecology, Center for Interdisciplinary Research in Women's Health, The University of Texas Medical Branch, 301 University Blvd, Galveston, TX 77555-0587. E-mails: guofangjian@gmail.com, faguo@utmb.edu and W. Timothy Garvey, MD, Department of Nutrition Sciences, Webb 232, University of Alabama at Birmingham, 1675 University Blvd, Birmingham, AL 35233. E-mail: garveyt@uab.edu

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years. Using nationally representative data from National Health and Nutrition Examination Survey (NHANES) 1988–2014, we examined secular changes in cardiovascular health and CVD risk factors among obese adults (aged ≥ 20 years) during the past 3 decades in the United States.

Methods

National Health and Nutrition Examination Survey

NHANES is a serial cross-sectional study involving nationally representative samples of the civilian noninstitutionalized US population. NHANES III was conducted during the period 1988–1994, and the continuous NHANES study has been conducted since 1999 with data released in 2-year cycles. The survey is conducted by National Center for Health Statistics (NCHS) using a complex, stratified, multistage probability cluster design.¹⁷ The NCHS ethics review board approved all NHANES protocols before data collection, and all adult participants provided written informed consent.¹⁷ The participant response rate has consistently been $\approx 75\%$ for interviews and $\approx 70\%$ for examinations at mobile examination centers among adults (aged ≥ 20 years). This study was exempt from full board review by the institutional review boards at the University of Texas Medical Branch and the University of Alabama at Birmingham.

Race and ethnicity were self-reported and classified as non-Hispanic white, non-Hispanic black, Mexican American, other Hispanic, and other. Standardized blood pressures were obtained by sphygmomanometer,¹⁸ and mean blood pressures from the last 3 measurements were used in this study. Blood lipids were measured enzymatically; hemoglobin A1c (HbA1c) was measured by high-performance liquid chromatography. Detailed specimen collection and processing instructions are described in the NHANES Laboratory Procedures Manual.¹⁹ Obesity was defined according to body mass index (BMI; in kg/m^2) status (BMI ≥ 30).

Cardiovascular Health Metrics

Cardiovascular health metrics included blood pressure, blood glucose, and lipid profile based on criteria modified from the American Heart Association (AHA)²⁰ and the National Cholesterol Education Program Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III)²¹ and the American College of Cardiology and AHA guidelines expert panel.²² Abnormal blood pressure status included systolic blood pressure ≥ 130 mm Hg, diastolic blood pressure ≥ 85 mm Hg, or use of antihypertensive medication; blood glucose status included HbA1c $\geq 5.7\%$ or use of antidiabetic medication; and blood lipids status included total cholesterol ≥ 240 mg/dL, high-density

lipoprotein (HDL) cholesterol < 40 mg/dL in men and < 50 mg/dL in women, or use of lipid-lowering medications. Participants with blood pressure health, blood glucose health, and blood lipid health were free from the above corresponding risk factors, according to these metrics. We also assessed trends in overall cardiovascular health status (presence of all 3 risk factors, presence of 1 or 2 risk factors, and freedom from all 3 risk factors). Ideal cardiovascular health was defined by the strict definition of the AHA: Blood pressure measured as untreated systolic < 120 mm Hg and diastolic < 80 , blood glucose measured as untreated HbA1c $< 5.7\%$, and blood lipids measured as untreated total cholesterol < 200 mg/dL and HDL ≥ 60 mg/dL.²⁰

Statistical Analysis

Data from NHANES 1988–2014 were used to determine secular trends in the prevalence of each CVD risk factors and cardiovascular health status in the United States during the past 3 decades. All analyses using NHANES data took into account differential probabilities of selection and the complex sample design and nonresponse and noncoverage by using sample weights and SAS (SAS Institute) survey analysis procedures, following NHANES analytic and reporting guidelines.^{23,24} Standard errors were calculated using Taylor series linearization. Age-adjusted values²⁵ were adjusted by the direct method to the year 2010 census population using the age groups 20 to 39, 40 to 59, and ≥ 60 years. Regression models were used to assess linear trends in the prevalence of healthy obese persons among obese adults during the period 1988–2014. Statistical analyses were carried out with SAS for Windows version 9.4 (SAS Institute). A 2-sided $P < 0.05$ was determined to be statistically significant.

Results

Characteristics

The characteristics of participants from NHANES are provided in Table 1 for each of the sequential cross-sectional surveys from 1988 to 2014. The study population over this time frame was composed of 18 626 obese adults. By way of illustration, the characteristics of obese participants from the most recent NHANES study, from 2011 to 2014, included a mean age of 47.2 years, mean systolic blood pressure of 124.4 mm Hg and diastolic blood pressure of 72.5 mm Hg, mean HbA1c of 5.9%, mean HDL cholesterol of 47.4 mg/dL, mean total cholesterol of 193.7 mg/dL, mean BMI of 36.0, and mean waist circumference of 114.8 cm. In examining trends in BMI and waist circumference in the analyses of participants with obesity, mean BMI was observed to significantly increase from 34.7 in 1988–1992 to 36.0 in 2011–2014 (Table 2), and

Table 1. The Characteristics of Participants From NHANES 1988–2014 (N=18 626)

Participants	1988–1992	1999–2002	2003–2006	2007–2010	2011–2014
All	4297 (100)	2854 (100)	3185 (100)	4334 (100)	3956 (100.0)
Aged 20–39 y	1505 (37.5)	939 (34.8)	1084 (33.6)	1309 (34.1)	1240 (32.3)
Aged 40–59 y	1468 (39.3)	980 (42.1)	1083 (44.7)	1522 (40.2)	1468 (41.3)
Aged ≥60 y	1324 (23.2)	935 (23.1)	1018 (21.8)	1503 (25.7)	1248 (26.4)
Men	1603 (41.7)	1134 (42.6)	1367 (46.1)	1938 (46.6)	1695 (45.4)
Women	2694 (58.3)	1720 (57.4)	1818 (53.9)	2396 (53.4)	2261 (54.6)
Non-Hispanic white	1492 (72.1)	1262 (69.1)	1472 (69.5)	1888 (66.4)	1541 (63.8)
Non-Hispanic black	1434 (14.9)	673 (13.8)	877 (15.3)	1027 (15.3)	1184 (15.0)
Mexican American	1224 (6.2)	709 (7.3)	662 (8.2)	846 (9.7)	576 (10.6)
Other	147 (6.8)	210 (9.8)	174 (6.9)	573 (8.7)	655 (10.6)
Age, y	47.3 (47.0–47.6)	47.0 (46.7–47.3)	47.1 (46.8–47.3)	47.4 (47.2–47.6)	47.2 (46.9–47.4)
Mean SBP, mm Hg	126.1 (125.2–127.0)	126.6 (125.5–127.7)	125.7 (124.7–126.7)	123.2 (122.4–123.9)	124.4 (123.6–125.2)
Mean DBP, mm Hg	76.6 (76.0–77.2)	74.4 (73.4–75.3)	72.5 (71.9–73.0)	71.5 (70.6–72.4)	72.5 (71.9–73.1)
HbA1c (%)	5.7 (5.6–5.8)	5.7 (5.7–5.7)	5.7 (5.6–5.7)	5.8 (5.8–5.9)	5.9 (5.8–5.9)
HDL, mg/dL	45.4 (44.7–46.2)	46.0 (45.2–46.8)	48.7 (48.0–49.3)	46.4 (45.7–47.0)	47.4 (46.8–48.1)
TC, mg/dL	214.5 (212.7–216.3)	206.7 (204.6–208.7)	201.8 (200.0–203.5)	196.9 (195.1–198.7)	193.7 (192.3–195.1)
BMI, kg/m ²	34.7 (34.4–35.1)	35.5 (35.2–35.8)	35.6 (35.3–35.8)	35.7 (35.5–35.9)	36.0 (35.7–36.3)
WC, cm	110.1 (109.5–110.7)	112.4 (111.6–113.1)	113.3 (112.7–114.0)	114.0 (113.4–114.7)	114.8 (114.1–115.4)
On antihypertensive drugs (%)	23.2 (21.1–25.4)	27.1 (24.9–29.2)	30.3 (28.4–32.2)	33.2 (31.6–34.8)	32.1 (30.3–33.9)
On antidiabetic drugs (%)	8.0 (6.8–9.3)	9.4 (8.4–10.5)	7.8 (6.4–9.1)	9.7 (8.6–10.8)	14.3 (12.8–15.7)
On lipid-lowering drugs (%)	3.9 (3.0–4.8)	11.5 (10.3–12.7)	17.9 (16.4–19.4)	21.0 (19.7–22.4)	22.0 (19.8–24.2)

Data are shown as n (weighted %), mean (95% CI), or proportion (95% CI). BMI indicates body mass index; HbA1c, hemoglobin A1c; HDL, high-density lipoprotein cholesterol; DBP, diastolic blood pressure; NHANES, National Health and Nutrition Examination Survey; SBP, systolic blood pressure; TC, total cholesterol; WC, waist circumference.

waist circumference increased from 110.1 to 114.8 cm (Table 3).

Blood Pressure Health

Mean systolic blood pressure decreased from 126.1 mm Hg in 1988–1992 to 124.4 mm Hg in 2011–2014 (P for trend <0.001). The decrease was observed in all age groups, for both sexes, and in all racial and ethnic groups except for young adults (Table S1). Mean diastolic blood pressure also decreased from 76.6 to 72.5 mm Hg over the period 1988–2014 (Table S2). Prevalence of blood pressure health was stable during the 1988–2014 period and characterized just below 50% of the population (Table 4). In 2011–2014, 44.1% of men and 51.5% of women were below the threshold for the blood pressure risk factor. Prevalence of blood pressure health decreased as a function of age; $>70\%$ of young adults (aged 20–39 years) exhibited healthy blood pressure metrics, whereas only 20.4% of older adults (aged ≥ 60 years) did. Non-Hispanic black participants had the lowest prevalence of blood pressure health, whereas Mexican American participants had the highest

prevalence. For the prevalence of ideal blood pressure health (untreated systolic blood pressure <120 mm Hg and diastolic <80), we observed similar patterns, and the prevalence was stable, slightly above 30% (Table S3).

Blood Glucose Health

Mean HbA1c increased from 5.7% in 1988–1992 to 5.9% in 2011–2014 (P for trend <0.001). All age, sex, and racial and ethnic groups showed increases except non-Hispanic black participants (Table S4). Prevalence of blood glucose health declined from 67.0% to 56.2% during the period 1988–2010 ($P<0.001$) but leveled off at $\approx 57\%$ during 2011–2014 (Table 5). In 2011–2014, men and women had similar prevalence of ideal glucose health (57.4% versus 57.1%), and the prevalence declined by age ($P<0.001$); non-Hispanic white participants had the highest prevalence, at 62.6%, whereas non-Hispanic black participants had the lowest prevalence, at 44.2%.

An increase in the prevalence of diabetes mellitus (self-reported or HbA1c $\geq 6.5\%$) contributed to declining rates of

Table 2. Secular Trends in BMI in Obese Adults During NHANES 1988–2014 (n=18 626)

Participants	1988–1992 (n=4297)	1999–2002 (n=2854)	2003–2006 (n=3185)	2007–2010 (n=4334)	2011–2014 (n=3956)	P Value*
All	34.7 (34.4–35.1)	35.5 (35.2–35.8)	35.6 (35.3–35.8)	35.7 (35.5–35.9)	36.0 (35.7–36.3)	<0.001
Aged 20–39 y	35.1 (34.6–35.6)	35.8 (35.4–36.3)	35.7 (35.4–36.1)	36.0 (35.6–36.5)	36.5 (36.0–36.9)	<0.001
Aged 40–59 y	34.9 (34.4–35.4)	35.8 (35.3–36.4)	35.9 (35.4–36.4)	35.8 (35.6–36.1)	36.0 (35.6–36.4)	0.055
Aged ≥60 y	34.0 (33.8–34.3)	34.6 (34.3–35.0)	34.8 (34.5–35.2)	35.1 (34.8–35.4)	35.3 (34.8–35.9)	<0.001
Men	33.9 (33.4–34.4)	34.7 (34.3–35.2)	34.7 (34.4–34.9)	34.9 (34.7–35.1)	35.1 (34.6–35.6)	0.021
Women	35.4 (34.9–35.8)	36.1 (35.8–36.5)	36.3 (35.9–36.7)	36.5 (36.3–36.8)	36.8 (36.4–37.1)	<0.001
Non-Hispanic white	34.7 (34.3–35.1)	35.4 (35.1–35.7)	35.4 (35.1–35.8)	35.6 (35.3–35.9)	36.0 (35.5–36.5)	<0.001
Non-Hispanic black	35.8 (35.4–36.1)	36.9 (36.3–37.4)	36.8 (36.5–37.1)	37.1 (36.6–37.6)	37.1 (36.7–37.6)	0.004
Mexican American	34.3 (34.0–34.6)	34.9 (34.4–35.3)	35.0 (34.6–35.3)	35.0 (34.6–35.4)	35.4 (35.1–35.7)	0.002

BMI indicates body mass index; NHANES, National Health and Nutrition Examination Survey.

Data are shown as mean (95% CI). BMI is shown in kg/m².

*P value for trends, adjusted for age group, sex, and race/ethnicity, as appropriate.

blood glucose health. Diabetes prevalence increased from 11.3% to 19.0% during the 1988–2014 period (Table S5). The prevalence increased with aging. A significant increase was observed in all age groups, for both sexes, and in all racial and ethnic groups except for young adults (aged 20–39 years).

Blood Lipid Health

Mean blood total cholesterol in obese adults decreased markedly by 20.8 mg/dL, from 214.5 mg/dL in the period 1988–1992 to 193.7 mg/dL in 2011–2014 ($P<0.001$). All subgroups experienced substantial decrements in mean total cholesterol during 1988–2014 (Table S6). In contrast, mean HDL cholesterol increased from 45.4 to 47.4 mg/dL during 1988–2014 ($P<0.001$ for trend) (Table S7). Prevalence of

blood lipid health status changed little during the period 1988–2014 (Table 6). In 2011–2014, men had higher prevalence of lipids health than women (38.0% versus 31.7%), and the non-Hispanic black group was the racial/ethnic group with the highest prevalence of lipids health (33.7%). In all constituencies, the prevalence of lipids health declined as a function of age; however, the prevalence of ideal blood cholesterol health (untreated total cholesterol <200 mg/dL and HDL ≥60 mg/dL) increased from 1988 to 2006 (3.3–5.2%) and then leveled off during 2007–2014 (Table S8).

Presence of All 3 CVD Risk Factors

Table 7 shows the trends in prevalence of the presence of all 3 risk factors among obese adults. Prevalence increased by 37% from 16.4% to 22.4% during the period 1988–2014. An

Table 3. Secular Trends in Waist Circumference in Obese Adults During NHANES 1988–2014 (n=17 661)

Participants	1988–1992 (n=4015)	1999–2002 (n=2783)	2003–2006 (n=3037)	2007–2010 (n=4087)	2011–2014 (n=3739)	P Value*
All	110.1 (109.5–110.7)	112.4 (111.6–113.1)	113.3 (112.7–114.0)	114.0 (113.4–114.7)	114.8 (114.1–115.4)	<0.001
Aged 20–39 y	108.1 (107.1–109.1)	111.0 (110.1–112.0)	111.7 (110.8–112.6)	112.4 (111.3–113.5)	113.9 (112.8–115.0)	<0.001
Aged 40–59 y	111.1 (110.3–112.0)	113.0 (111.9–114.1)	113.9 (112.8–114.9)	114.7 (113.8–115.5)	114.9 (113.9–115.9)	<0.001
Aged ≥60 y	111.4 (110.6–112.1)	113.3 (112.5–114.1)	114.9 (114.3–115.5)	115.5 (114.6–116.3)	115.7 (114.7–116.7)	<0.001
Men	113.2 (112.2–114.2)	116.5 (115.3–117.6)	116.4 (115.7–117.1)	116.3 (115.5–117.1)	117.1 (116.0–118.2)	0.008
Women	107.9 (107.1–108.6)	109.3 (108.5–110.2)	110.8 (110.0–111.6)	112.1 (111.2–112.9)	112.8 (112.2–113.5)	<0.001
Non-Hispanic white	110.6 (109.7–111.5)	112.9 (112.0–113.8)	114.1 (113.3–114.8)	114.9 (114.2–115.6)	115.7 (114.8–116.6)	<0.001
Non-Hispanic black	110.1 (109.3–110.8)	112.0 (110.9–113.2)	112.8 (112.0–113.5)	113.7 (112.5–114.9)	114.6 (113.7–115.6)	<0.001
Mexican American	108.3 (107.7–108.9)	109.5 (108.4–110.7)	110.3 (109.0–111.5)	111.1 (110.2–112.1)	112.6 (111.5–113.8)	<0.001

NHANES indicates National Health and Nutrition Examination Survey.

Data are shown as mean (95% CI). Waist circumference is shown in centimeters.

*P value for trends, adjusted for age group, sex, and race/ethnicity when appropriate.

Table 4. Secular Trends in Blood Pressure Health in Obese Adults During NHANES 1988–2014 (N=18 626)

Participants	1988–1992 (n=4297)	1999–2002 (n=2854)	2003–2006 (n=3185)	2007–2010 (n=4334)	2011–2014 (n=3956)	P Value*
All	49.8 (47.5–52.2)	48.4 (45.7–51.0)	49.2 (47.1–51.2)	49.4 (47.3–51.5)	48.1 (45.9–50.3)	0.71
Aged 20–39 y	70.8 (66.4–75.3)	73.0 (68.1–77.8)	76.7 (73.0–80.3)	74.4 (71.1–77.6)	72.0 (68.7–75.3)	0.96
Aged 40–59 y	44.1 (39.8–48.3)	43.9 (41.0–46.8)	43.2 (39.5–46.9)	44.4 (41.5–47.3)	43.4 (39.8–47.0)	0.86
Aged ≥60 y	27.9 (24.4–31.4)	19.3 (14.7–23.9)	18.2 (15.8–20.7)	20.6 (17.9–23.2)	20.4 (17.0–23.9)	0.64
Men	44.6 (39.6–49.6)	45.2 (40.9–49.4)	45.3 (42.4–48.1)	45.7 (42.4–48.9)	44.1 (40.8–47.4)	0.62
Women	53.6 (51.2–56.0)	50.7 (48.2–53.2)	52.7 (50.1–55.2)	52.8 (50.7–54.9)	51.5 (48.6–54.3)	0.98
Non-Hispanic white	49.2 (46.1–52.4)	48.9 (45.5–52.3)	49.8 (47.0–52.6)	49.4 (46.1–52.7)	48.1 (45.0–51.2)	0.75
Non-Hispanic black	42.8 (40.3–45.2)	41.0 (37.7–44.3)	41.6 (38.5–44.6)	40.7 (37.5–43.9)	39.7 (37.1–42.2)	0.42
Mexican American	57.8 (54.0–61.5)	55.2 (51.7–58.6)	55.9 (51.0–60.7)	54.9 (51.7–58.1)	54.4 (50.9–58.0)	0.91

NHANES indicates National Health and Nutrition Examination Survey. Data are shown as prevalence percentage (95% CI). Blood pressure health: untreated systolic <130 mm Hg and diastolic <85 mm Hg. Prevalence was age-adjusted by the direct method to the year 2010 census population using age groups 20–39, 40–59, and ≥60 years. *P value for trends, adjusted for age group, sex, and race/ethnicity, as appropriate.

increase was noted in all ages, sexes, and racial/ethnic subgroups. The increase occurred in parallel with a decline in the prevalence of healthy blood glucose, which is the predominant explanation accounting for the rise in the prevalence of presence of all 3 risk factors.

Presence of 1 to 2 CVD Risk Factors

Table 8 shows the trends in the prevalence of presence of 1 to 2 risk factors among obese adults. The prevalence decreased significantly from 69.6% to 62.4% during the 1988–2014 period. Only young adults (aged 20–39 years) and non-Hispanic black participants did not see a decrease trend in prevalence over this time frame.

Freedom From CVD Risk Factors

As can be seen in Table 9, the prevalence of participants free from all 3 CVD risk factors remained stable at ≈15% among the general adult obese population and in all sex and racial/ethnic subgroups during the period 1988–2014. The prevalence remained highest in participants aged 20 to 39 years and declined progressively in the subgroups aged 40 to 59 and ≥60 years. Very few adult obese participants met the criteria for ideal cardiovascular health, and the prevalence of ideal cardiovascular health remained stable at ≈2% during the 1988–2014 period (Table 10).

We summarized the trends in cardiovascular health status in obese adults during NHANES 1988–2014 in Figure.

Table 5. Secular Trends in Blood Glucose Health in Obese Adults During NHANES 1988–2014 (N=18 626)

Participants	1988–1992 (n=4297)	1999–2002 (n=2854)	2003–2006 (n=3185)	2007–2010 (n=4334)	2011–2014 (n=3956)	P Value*
All	67.0 (64.2–69.9)	68.4 (66.2–70.7)	66.7 (65.0–68.5)	56.2 (54.2–58.1)	57.3 (54.7–59.9)	<0.001
Aged 20–39 y	84.4 (80.5–88.4)	87.3 (84.9–89.8)	85.7 (83.3–88.1)	78.6 (76.4–80.9)	77.4 (74.2–80.7)	<0.001
Aged 40–59 y	63.5 (59.3–67.8)	64.7 (60.2–69.2)	63.8 (60.5–67.2)	50.8 (47.4–54.1)	54.6 (50.5–58.8)	<0.001
Aged ≥60 y	47.0 (43.5–50.5)	46.6 (42.4–50.9)	43.6 (40.1–47.1)	31.7 (28.0–35.5)	32.1 (28.1–36.1)	<0.001
Men	66.0 (61.5–70.6)	67.4 (63.8–71.0)	67.4 (64.6–70.1)	55.0 (52.5–57.4)	57.4 (53.9–61.0)	<0.001
Women	67.7 (65.2–70.3)	69.3 (66.7–71.9)	66.3 (63.8–68.7)	57.2 (54.2–60.2)	57.1 (54.7–59.5)	<0.001
Non-Hispanic white	71.9 (68.4–75.5)	71.6 (68.4–74.9)	71.2 (69.3–73.1)	60.6 (58.3–62.9)	62.6 (59.1–66.1)	<0.001
Non-Hispanic black	48.7 (45.4–52.0)	56.2 (53.5–59.0)	56.1 (53.0–59.2)	46.1 (41.7–50.4)	44.2 (40.9–47.6)	<0.001
Mexican American	57.6 (53.5–61.7)	64.5 (60.5–68.4)	55.8 (51.5–60.0)	49.6 (44.5–54.7)	50.4 (47.4–53.4)	<0.001

NHANES indicates National Health and Nutrition Examination Survey. Data are shown as prevalence percentage (95% CI). Blood glucose health: untreated hemoglobin A1c <5.7%. Prevalence was age-adjusted by the direct method to the year 2010 census population using age groups 20–39, 40–59, and ≥60 years. *P value for trends, adjusted for age group, sex, and race/ethnicity, as appropriate.

Table 6. Secular Trends in Blood Lipid Health in Obese Adults During NHANES 1988–2014 (N=18 626)

Participants	1988–1992 (n=4297)	1999–2002 (n=2854)	2003–2006 (n=3185)	2007–2010 (n=4334)	2011–2014 (n=3956)	P Value*
All	29.8 (27.2–32.4)	30.8 (28.4–33.2)	37.1 (34.8–39.4)	31.2 (29.2–33.2)	34.6 (32.1–37.1)	0.19
Aged 20–39 y	32.9 (28.0–37.7)	33.2 (30.3–36.1)	44.4 (40.5–48.2)	36.0 (32.8–39.2)	41.0 (36.8–45.2)	0.04
Aged 40–59 y	28.1 (24.3–32.0)	29.8 (25.4–34.1)	33.8 (30.1–37.5)	29.7 (26.0–33.3)	33.6 (29.6–37.6)	0.31
Aged ≥60 y	27.9 (23.6–32.2)	28.8 (25.5–32.2)	31.3 (28.3–34.4)	26.6 (23.8–29.4)	26.7 (23.1–30.4)	0.18
Men	35.0 (30.6–39.3)	32.2 (29.4–35.1)	39.1 (36.2–42.0)	33.3 (30.8–35.8)	38.0 (34.7–41.3)	0.17
Women	26.3 (23.6–29.0)	29.9 (26.5–33.3)	35.4 (31.9–38.9)	29.4 (26.7–32.1)	31.7 (28.8–34.5)	0.46
Non-Hispanic white	27.9 (24.3–31.4)	27.9 (24.8–31.0)	35.5 (32.6–38.3)	29.2 (26.6–31.9)	33.3 (29.9–36.7)	0.11
Non-Hispanic black	35.8 (33.1–38.6)	39.8 (35.4–44.3)	46.9 (43.9–49.9)	37.7 (34.8–40.6)	39.6 (36.4–42.7)	0.67
Mexican American	30.3 (26.4–34.2)	34.1 (30.2–37.9)	36.5 (31.7–41.4)	32.5 (29.3–35.6)	33.7 (30.1–37.2)	0.79

NHANES indicates National Health and Nutrition Examination Survey. Data are shown as prevalence percentage (95% CI). Blood lipid health: untreated total cholesterol <240 mg/dL and high-density lipoprotein cholesterol ≥40 mg/dL in men and ≥50 in women. Prevalence was age-adjusted by the direct method to the year 2010 census population using age groups 20–39, 40–59, and ≥60 years. *P value for trends, adjusted for age group, sex, and race/ethnicity, as appropriate.

Prevalence of freedom from all 3 CVD risk factors remained stable at ≈15% during 1988–2014, whereas prevalence of the presence of all 3 risk factors was greatly increased during this period. In addition, prevalence of ideal cardiovascular health remained very low at <2% over the period 1988–2014.

Discussion

Using data from NHANES III and NHANES 1999–2014, we assessed the secular trends in the prevalence of CVD risk factors and in cardiovascular health status in an adult

obese population in the United States over the past 3 decades. Among 18 626 obese adults from NHANES 1988–2014, mean systolic blood pressure, diastolic blood pressure, total cholesterol, and HDL cholesterol levels all showed improvement. In contrast, mean HbA1c levels increased during this period. Healthy status was ascribed to each factor based on accepted risk thresholds. During the period 1988–2014, the prevalence of participants meeting criteria for blood pressure health and blood cholesterol health remained stable, whereas the prevalence of blood glucose health decreased significantly. Prevalence of freedom from all 3 CVD risk factors remained stable at

Table 7. Secular Trends in Prevalence of the Presence of All 3 Cardiovascular Risk Factors in Obese Adults During NHANES 1988–2014 (N=18 626)

Participants	1988–1992 (n=4297)	1999–2002 (n=2854)	2003–2006 (n=3185)	2007–2010 (n=4334)	2011–2014 (n=3956)	P Value*
All	16.4 (14.8–17.9)	16.7 (15.0–18.3)	17.1 (15.7–18.5)	22.4 (21.2–23.6)	22.4 (20.8–24.0)	<0.001
Aged 20–39 y	4.5 (2.9–6.0)	4.7 (2.8–6.6)	4.2 (3.0–5.5)	6.0 (4.3–7.6)	6.0 (4.5–7.4)	0.013
Aged 40–59 y	18.7 (15.9–21.4)	16.7 (14.1–19.3)	17.2 (15.1–19.3)	24.4 (22.3–26.5)	22.9 (19.8–25.9)	<0.001
Aged ≥60 y	30.2 (27.7–32.7)	34.0 (30.9–37.1)	35.7 (31.7–39.6)	43.2 (39.7–46.7)	45.5 (41.8–49.3)	<0.001
Men	15.4 (12.8–18.1)	15.4 (12.5–18.3)	17.2 (15.4–18.9)	23.1 (21.4–24.8)	22.1 (20.0–24.2)	<0.001
Women	16.8 (15.2–18.5)	17.5 (15.5–19.4)	17.0 (15.2–18.8)	21.8 (19.7–23.9)	22.7 (20.7–24.7)	<0.001
Non-Hispanic white	15.3 (13.4–17.2)	15.3 (13.2–17.5)	15.8 (14.0–17.5)	21.5 (19.7–23.4)	20.6 (18.6–22.6)	<0.001
Non-Hispanic black	24.6 (22.3–26.9)	23.5 (20.8–26.2)	20.5 (18.0–22.9)	26.7 (23.3–30.2)	28.0 (25.2–30.8)	0.003
Mexican American	16.3 (13.3–19.3)	16.2 (13.4–19.0)	18.4 (15.1–21.6)	23.2 (21.2–25.3)	23.0 (20.3–25.7)	0.002

NHANES indicates National Health and Nutrition Examination Survey. Data are shown as prevalence percentage (95% CI). Participants with the presence of all 3 cardiovascular risk factors: (1) blood pressure: systolic blood pressure ≥130 mm Hg, diastolic blood pressure ≥85 mm Hg, or on antihypertensive medication; (2) blood glucose: hemoglobin A1c ≥5.7% or on antidiabetic medication; (3) blood lipids: total cholesterol ≥240 mg/dL, high-density lipoprotein cholesterol <40 mg/dL in men and <50 mg/dL in women, or on lipid-lowering medications. Prevalence was age-adjusted by the direct method to the year 2010 census population using age groups 20–39, 40–59, and ≥60 years. *P value for trends, adjusted for age group, sex, and race/ethnicity, as appropriate.

Table 8. Secular Trends in the Prevalence of 1 to 2 Cardiovascular Disease Risk Factors in Obese Adults During NHANES 1988–2014 (N=18 626)

Participants	1988–1992 (n=4297)	1999–2002 (n=2854)	2003–2006 (n=3185)	2007–2010 (n=4334)	2011–2014 (n=3956)	P Value*
All	69.6 (67.9–71.3)	69.3 (67.5–71.1)	65.5 (63.5–67.6)	64.2 (62.8–65.6)	62.4 (60.2–64.6)	<0.001
Aged 20–39 y	73.9 (70.2–77.7)	71.4 (68.2–74.6)	64.5 (60.9–68.0)	69.9 (66.7–73.1)	68.4 (64.4–72.5)	0.37
Aged 40–59 y	69.8 (66.4–73.2)	71.5 (68.1–74.8)	70.5 (67.0–73.9)	65.9 (63.1–68.7)	65.5 (62.3–68.7)	0.002
Aged ≥60 y	63.1 (59.5–66.7)	63.0 (60.0–66.0)	59.7 (55.8–63.6)	53.4 (50.0–56.9)	49.0 (45.0–53.1)	<0.001
Men	70.4 (67.4–73.3)	71.0 (67.9–74.1)	65.8 (63.0–68.6)	64.3 (62.1–66.5)	62.6 (59.8–65.4)	<0.001
Women	69.3 (66.4–72.1)	68.2 (65.7–70.7)	65.3 (61.8–68.7)	64.1 (62.2–66.0)	62.3 (59.9–64.7)	<0.001
Non-Hispanic white	70.7 (68.7–72.7)	71.7 (69.3–74.1)	66.5 (63.5–69.4)	65.0 (63.0–67.0)	64.2 (60.6–67.8)	<0.001
Non-Hispanic black	63.6 (61.2–65.9)	61.6 (57.4–65.9)	62.7 (58.5–66.9)	61.5 (57.7–65.3)	59.4 (56.1–62.6)	0.27
Mexican American	71.4 (68.1–74.7)	68.1 (64.6–71.6)	66.1 (62.4–69.8)	62.8 (60.3–65.3)	61.5 (57.6–65.4)	0.017

NHANES indicates National Health and Nutrition Examination Survey. Data are shown as prevalence percentage (95% CI). Cardiovascular risk factors: (1) blood pressure: systolic blood pressure ≥130 mm Hg, diastolic blood pressure ≥85 mm Hg, or on antihypertensive medication; (2) blood glucose: hemoglobin A1c ≥5.7% or on antidiabetic medication; (3) blood lipids: total cholesterol ≥240 mg/dL, high-density lipoprotein cholesterol <40 mg/dL in men and <50 mg/dL in women, or on lipid-lowering medications. Prevalence was age-adjusted by the direct method to the year 2010 census population using age groups 20–39, 40–59, and ≥60 years. *P value for trends, adjusted for age group, sex, and race/ethnicity, as appropriate.

≈15% among the adult obese population during the 1988–2014 period. Prevalence of the presence of all 3 risk factors was greatly increased by 37%, from 16.4% to 22.4% during this period; commensurately, prevalence of the presence of 1 to 2 risk factors declined significantly from 69.6% to 62.4% during the 1988–2014 period. Finally, a definition of ideal cardiovascular health was applied; however, prevalence rates of ideal cardiovascular health remained very low, at <2% over the period 1988–2014. Prevalence of ideal blood lipid health improved from 1988

to 2006 and then leveled off during the 2007–2014 period but remained extremely low (<5%).

Cardiometabolic Health in People With Obesity

Obese participants who are free from cardiometabolic disease risk factors are termed “metabolically healthy obese.”^{9,26} The existence of the metabolically healthy obese condition has been controversial^{27–30}; however, we have recently added some clarification to this issue by pointing out that

Table 9. Secular Trends in Prevalence of Freedom From Cardiovascular Disease Risk Factors in Obese Adults During NHANES 1988–2014 (N=18 626)

Participants	1988–1992 (n=4297)	1999–2002 (n=2854)	2003–2006 (n=3185)	2007–2010 (n=4334)	2011–2014 (n=3956)	P Value*
All	14.0 (12.1–15.9)	14.1 (12.7–15.4)	17.3 (15.7–19.0)	13.4 (12.1–14.7)	15.2 (13.3–17.0)	0.93
Aged 20–39 y	21.6 (17.7–25.5)	24.0 (21.3–26.6)	31.3 (27.6–35.0)	24.1 (21.0–27.2)	25.6 (21.9–29.3)	0.79
Aged 40–59 y	11.6 (8.4–14.7)	11.9 (9.4–14.3)	12.3 (9.8–14.8)	9.7 (8.0–11.4)	11.6 (9.0–14.3)	0.66
Aged ≥60 y	6.7 (4.2–9.3)	3.0 (1.4–4.6)	4.6 (2.9–6.3)	3.4 (2.3–4.5)	5.4 (3.7–7.1)	0.41
Men	14.2 (10.9–17.5)	13.6 (11.3–15.9)	17.0 (14.6–19.5)	12.6 (10.9–14.3)	15.3 (12.3–18.2)	0.98
Women	13.9 (11.2–16.6)	14.4 (12.6–16.2)	17.7 (14.9–20.5)	14.1 (12.3–16.0)	15.1 (13.3–16.8)	0.91
Non-Hispanic white	14.0 (11.5–16.6)	13.0 (11.2–14.8)	17.8 (15.5–20.1)	13.5 (11.6–15.4)	15.2 (12.1–18.2)	0.64
Non-Hispanic black	11.8 (9.8–13.8)	14.8 (12.2–17.5)	16.8 (13.7–19.9)	11.8 (9.8–13.8)	12.7 (10.8–14.6)	0.11
Mexican American	12.3 (9.8–14.8)	15.7 (13.2–18.3)	15.5 (11.8–19.2)	14.0 (11.2–16.8)	15.5 (12.9–18.1)	0.63

NHANES indicates National Health and Nutrition Examination Survey. Data are shown as prevalence percentage (95% CI). Participants who were free from cardiovascular disease risk factors did not cross the threshold for any of the 3 risk factors (exhibit normal values for all 3 risk factors): (1) blood pressure, untreated systolic <130 mm Hg and diastolic <85; (2) blood glucose, untreated fasting <100 mg/dL or hemoglobin A1c <5.7%; (3) blood lipids, untreated total cholesterol <240 mg/dL and high-density lipoprotein cholesterol ≥40 mg/dL in men and ≥50 in women). *P value for trends, adjusted for age group, sex, and race/ethnicity, as appropriate.

Table 10. Secular Trends in Prevalence of Ideal Cardiovascular Health in Obese Adults During NHANES 1988–2014 (N=18 626)

Participants	1988–1992 (n=4297)	1999–2002 (n=2854)	2003–2006 (n=3185)	2007–2010 (n=4334)	2011–2014 (n=3956)	P Value*
All	1.8 (0.9–2.6)	1.7 (1.3–2.2)	1.6 (1.1–2.0)	1.7 (1.2–2.2)	1.7 (1.4–2.1)	0.62
Aged 20–39 y	3.3 (1.1–5.6)	3.0 (1.7–4.4)	3.7 (2.6–4.8)	2.8 (1.7–3.8)	2.7 (2.0–3.3)	0.43
Aged 40–59 y	1.2 (0.4–1.9)	1.2 (0.5–1.9)	0.3 (0.0–0.6)	1.7 (0.9–2.6)	1.7 (0.8–2.7)	0.057
Aged ≥60 y	0.4 (0.0–1.0)	0.7 (0.0–1.6)	0.4 (0.0–0.8)	0.2 (0.0–0.5)	0.4 (0.0–0.8)	0.53
Men	0.3 (0.0–0.6)	0.1 (0.0–0.4)	0.4 (0.0–0.8)	0.3 (0.0–0.6)	0.6 (0.0–1.2)	0.27
Women	2.8 (1.4–4.2)	2.9 (2.1–3.8)	2.6 (1.9–3.3)	3.0 (2.2–3.8)	2.7 (2.2–3.3)	0.98
Non-Hispanic white	1.9 (0.6–3.2)	1.1 (0.5–1.7)	1.4 (0.9–1.9)	1.5 (0.9–2.0)	1.6 (1.0–2.2)	0.55
Non-Hispanic black	2.3 (1.5–3.2)	1.7 (0.9–2.5)	2.3 (1.3–3.2)	2.1 (1.0–3.2)	1.9 (1.1–2.6)	0.95
Mexican American	1.1 (0.4–1.7)	1.5 (0.7–2.4)	1.4 (0.2–2.6)	2.2 (0.9–3.6)	2.8 (1.5–4.1)	0.03

NHANES indicates National Health and Nutrition Examination Survey.

Data are shown as prevalence percentage (95% CI). Participants meeting ideal cardiovascular health had normal values for all 3 factors: (1) blood pressure, untreated systolic <120 mm Hg and diastolic <80; (2) blood glucose, untreated fasting <100 mg/dL or hemoglobin A1c <5.7%; (3) blood lipids, untreated total cholesterol <200 mg/dL and high-density lipoprotein cholesterol ≥60 mg/dL.

*P value for trends, adjusted for age group, sex, and race/ethnicity, as appropriate.

conclusions rest heavily on the definition of metabolically healthy obese.³¹ We^{4,5,10} and others^{12–14} have shown that 1 or 2 metabolic syndrome traits confer increased risk of diabetes mellitus and CVD outcomes and that such persons are relatively insulin resistant. The problem with many reports minimizing the importance of the metabolically healthy obese

condition is the inclusion of participants with 1 or 2 risk factors among metabolically healthy participants. When “metabolically healthy” is defined as the absence of all metabolic syndrome risk factors, there is minimal or no contribution of BMI to CVD events or mortality, and cumulative rates of diabetes mellitus remain quite low regardless of

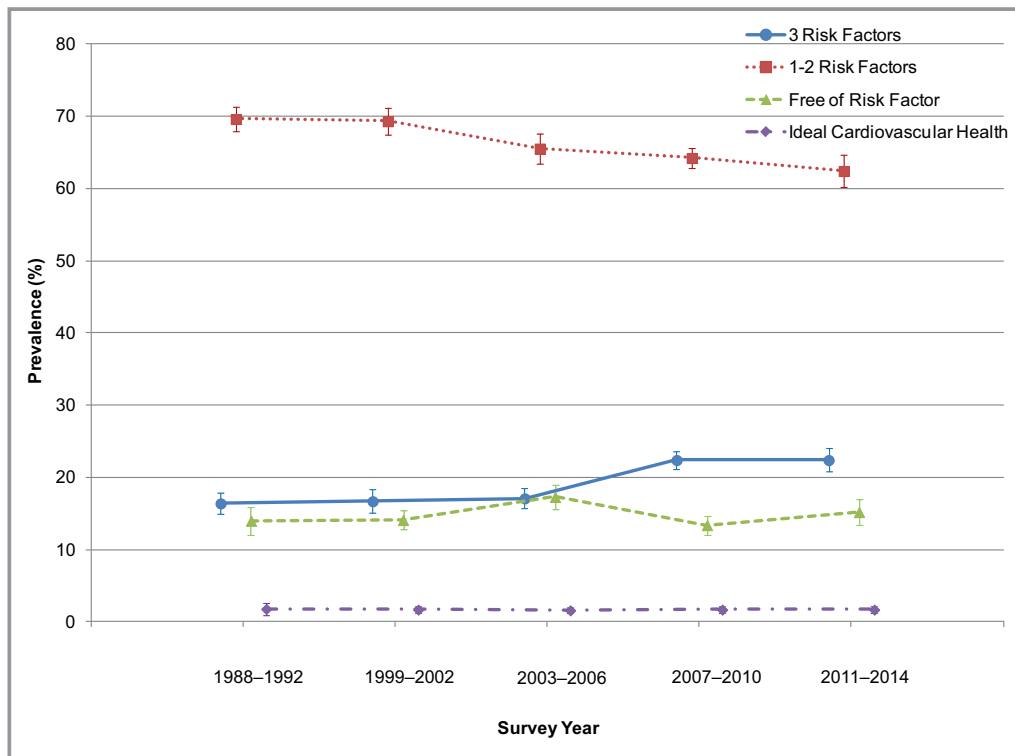


Figure. Secular trends in cardiovascular health status in obese adults in NHANES 1988–2014. Data are plotted as prevalence (95% CI). Prevalence was age-adjusted by the direct method to the year 2010 census population using the age groups 20 to 39, 40 to 59, and ≥60 years. NHANES indicates National Health and Nutrition Examination Survey.

BMI. Obese participants with metabolic syndrome consistently have much greater risks for diabetes mellitus and CVD than their counterparts assigned to the metabolically healthy subgroup.^{12–14} We have also defined a subgroup of patients with suboptimal metabolic health who have 1 or 2 risk factors but who do not meet criteria for metabolic syndrome, and those persons have intermediate risks of incident diabetes mellitus and CVD outcomes.^{10,31} BMI interacts with metabolic status to significantly augment diabetes risks such that progressive increments in BMI augment the risk of diabetes mellitus; however, the impact of BMI on rates of diabetes mellitus is greater among those with metabolic syndrome (ie, metabolically unhealthy obese), less so in those with suboptimal metabolic health, and least in metabolically healthy obese persons. In any event, cardiometabolic risk factors confer much higher risk of diabetes mellitus, CVD, stroke, and mortality than BMI per se.

Our finding that the prevalence of metabolically healthy obese participants who are free from all CVD risk factors has remained relatively stable at $\approx 15\%$ during the past 3 decades in the United States agrees with a large collaborative study in Europe encompassing 163 517 participants (the BioSHaRE-EU Healthy Obese Project). This European study demonstrated that the frequency of metabolically healthy obesity was 7% to 28% in women and 2% to 19% in men in various European countries.³² Although these persons have lower risks of total and CVD mortality and type 2 diabetes mellitus, the proportion of metabolically healthy persons among all obese adults is relatively low. We also observed that the prevalence of ideal cardiovascular health among obese people was extremely low over the past 3 decades, remaining consistently $<2\%$, and that very few adult obese participants met the criteria for ideal blood cholesterol health ($<5\%$). These results are consistent with previously reported very low prevalence of meeting cardiovascular health among the general adult population in the United States.³³ Consistent with a previous report on the prevalence of CVD risk factors in US adults from 1960 to 2000,¹⁶ our results indicated that blood glucose health continued to deteriorate in obese people during the period 1988–2014. Further studies are needed to unravel the underlying causes of this troubling phenomenon. The improvements in mean blood pressure and blood cholesterol may reflect the healthy trends in the US population, including decreases in the proportion of dietary saturated fat; increases in fruits and vegetables and the proportion of polyunsaturated and monounsaturated fats in the diet^{34–37}; decreased smoking^{38–40}; and increased awareness, identification, and pharmacological treatment of high cholesterol and blood pressure levels.^{25,41}

Obese participants with metabolic syndrome are at greater risk of diabetes and CVD outcomes.^{12–14} In our

study, the prevalence of obese people with all 3 CVD risk factors kept increasing over the past 3 decades in the United States. The increasing trend of obese people with all 3 CVD risk factors, commensurate with a decline in those with 1 to 2 risk factors, suggested an overall deterioration in health among people with obesity. In recent years, almost 1 in 4 obese adults had all 3 CVD risk factors. During the period 1988–2010, adults in the United States experienced a significant decrease in diet quality and an increase in the prevalence of sedentary lifestyles.³³ Those changes may partially explain our findings regarding the increasing trend in prevalence of presence of all 3 CVD risk factors in obese adults.

Implications

Although some data point to a leveling off of prevalence rates of obesity in recent years, our data indicate that overall metabolic health is declining among people with obesity in the United States. Furthermore, deteriorating metabolic health can be attributed primarily to worsening glycemic health because mean values of HbA1c have been increasing, whereas mean blood pressure and lipid metrics have been improving. These patterns of worsening metabolic health constitute an increase in risk of type 2 diabetes mellitus and underlie increasing prevalence rates for diabetes mellitus. Without intensive interventions, obese people do not lose sufficient body weight to become lean, regardless of their age³¹; however, moderate weight loss of 10% of body weight is sufficient to dramatically reduce progression to diabetes among high-risk persons.^{42,43} The deteriorated blood glucose health among obese adults in the United States calls for lifestyle interventions (diet and exercise) on a national scale. Community-based public health intervention programs may help increase physical activity and diet quality to alleviate the problem.^{44,45} Obese adults at high risk of diabetes and CVD may require more intense approaches to achieve weight loss using lifestyle interventions alone or in combination with weight loss medications.^{42,43,46,47} A complication-centric approach may be adopted to guide the selection of weight loss therapy options (eg, more aggressive treatment in those obese patients with complications or at higher risk of complications to optimize outcomes, the benefit–risk ratio of the intervention, and the cost-effectiveness of care).^{48,49} In the context of the current data, those obese adults who are metabolically unhealthy or perhaps those with suboptimal metabolic health represent patients who will benefit most from intensive obesity management. As suggested by Yang et al,³³ coordinated efforts aligning CVD prevention and control activities across the public and private sectors in the United States are needed to reduce the burden of CVD among the obese population.⁵⁰

Strengths and Limitations

The main strengths of this study involve the use of sequential surveys over time, consisting of nationally representative data from NHANES. These data from the past 3 decades enabled us to assess the secular trends of prevalence of individual CVD risk factors and overall CVD health status among obese people in a nationally representative sample. Limitations of this study include the sample size, which may not be large enough to permit extensive subgroup analyses of each age, sex, and racial or ethnic group. In addition, we were able to assess only the trends in major racial and ethnic groups (eg, non-Hispanic black, non-Hispanic white, and Mexican American); we could not further differentiate other racial and ethnic groups because of the sample size limit. Furthermore, because the duration of physical activity (in minutes) changed substantially since the 2007–2008 cycle, we did not assess physical activity among obese adults during the 1988–2014 period.

Conclusions

During past 3 decades, blood pressure health and blood lipid health remained stable, whereas blood glucose health deteriorated among adults with obesity. During the period 1988–2014, the prevalence of freedom from all 3 CVD risk factors remained stable at \approx 15% among the adult obese population, whereas prevalence of the presence of all 3 risk factors greatly increased from 16.4% to 22.4%. In 2011–2014, almost 1 in 4 obese people had all 3 risk factors. The increase in the number of obese people with all 3 risk factors was largely the result of worsening glycemic status. The data support continuing efforts to target obese people who are at risk with weight loss therapy to improve cardiometabolic disease health and to prevent progression to diabetes mellitus.

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Disclosures

Dr Garvey is an advisor for Astra Zeneca, Boehringer-Ingelheim, Daiichi-Sankyo, Inc., Eisai, Janssen Pharmaceuticals, LipoScience, Novo Nordisk, Takeda, and VIVUS, Inc.; is a stockholder for Bristol-Myers Squibb Company, Eli Lilly and Company, Isis/Genzyme, Merck, Novartis, and Pfizer, Inc.; and has received research support from Astra Zeneca, Eisai, Lexicon, Merck & Co., Pfizer, Inc., Sanofi, and Weight Watchers International, Inc. Dr Guo has no conflict of interest or financial disclosure to declare.

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Supplemental Material

Table S1. Secular trends in systolic blood pressure in obese adults during NHANES 1988-2014 (N=17,393).

	Mean (95% CI)					p value*
	1988-1992 (n=4016)	1999-2002 (n=2696)	2003-2006 (n=2830)	2007-2010 (n=4058)	2011-2014 (n=3793)	
All	126.1 (125.2-127.0)	126.6 (125.5-127.7)	125.7 (124.7-126.7)	123.2 (122.4-123.9)	124.4 (123.6-125.2)	<0.001
20-39 y	117.8 (116.5-119.2)	118.3 (116.5-120.1)	118.8 (117.6-119.9)	118.1 (117.2-119.0)	119.1 (118.2-120.1)	0.6
40-59 y	126.9 (125.4-128.3)	127.0 (125.7-128.3)	126.1 (124.8-127.3)	123.8 (122.6-124.9)	124.7 (123.5-125.9)	<0.001
60+ y	136.9 (135.6-138.2)	138.2 (136.1-140.2)	135.2 (133.4-137.1)	129.5 (128.2-130.8)	131.6 (130.1-133.1)	<0.001
Men	128.3 (127.1-129.6)	127.2 (125.9-128.5)	126.8 (125.6-128.0)	124.7 (123.7-125.8)	126.5 (125.5-127.6)	0.048
Women	124.6 (123.5-125.6)	126.2 (124.9-127.4)	124.6 (123.5-125.8)	121.6 (120.7-122.5)	122.5 (121.4-123.6)	<0.001
non-Hispanic Whites	126.0 (125.0-127.0)	126.1 (124.8-127.4)	125.1 (123.9-126.2)	122.8 (121.8-123.7)	123.8 (122.9-124.6)	<0.001
non-Hispanic Blacks	129.9 (129.1-130.7)	130.8 (129.1-132.4)	129.3 (128.0-130.6)	126.4 (124.7-128.0)	127.8 (126.2-129.4)	0.004
Mexican Americans	125.7 (125.0-126.5)	126.5 (124.8-128.2)	126.3 (124.7-128.0)	124.3 (122.8-125.8)	124.0 (122.6-125.5)	0.047

Systolic blood pressure is showed in the unit of mmHg.

*: p value for trends, adjusted for age group, sex, and race/ethnicity when appropriate.

Table S2. Secular trends in diastolic blood pressure in obese adults during NHANES 1988-2014 (N=17,325).

	Mean (95% CI)					p value*
	1988-1992 (n=4016)	1999-2002 (n=2684)	2003-2006 (n=2814)	2007-2010 (n=4036)	2011-2014 (n=3775)	
All	76.6 (76.0-77.2)	74.4 (73.4-75.3)	72.5 (71.9-73.0)	71.5 (70.6-72.4)	72.5 (71.9-73.1)	<0.001
20-39 y	76.8 (75.9-77.7)	73.0 (71.4-74.6)	71.2 (70.3-72.1)	71.4 (70.3-72.5)	72.3 (71.5-73.1)	0.001
40-59 y	78.9 (78.0-79.9)	77.9 (77.1-78.6)	76.6 (75.8-77.4)	75.2 (74.3-76.1)	75.6 (74.9-76.4)	<0.001
60+ y	72.8 (71.7-74.0)	71.1 (70.0-72.2)	68.2 (67.2-69.3)	66.0 (64.7-67.3)	68.2 (67.3-69.1)	<0.001
Men	79.9 (78.9-80.8)	76.8 (75.6-77.9)	74.0 (73.2-74.9)	73.6 (72.6-74.5)	74.3 (73.5-75.1)	<0.001
Women	74.3 (73.7-75.0)	72.5 (71.6-73.4)	71.0 (70.4-71.7)	69.7 (68.7-70.6)	71.0 (70.3-71.6)	<0.001
non-Hispanic Whites	76.9 (76.1-77.7)	74.3 (73.2-75.4)	72.5 (71.8-73.3)	71.6 (70.6-72.6)	72.9 (72.1-73.7)	<0.001
non-Hispanic Blacks	76.9 (76.0-77.8)	75.0 (73.8-76.2)	73.4 (72.2-74.5)	72.3 (70.9-73.7)	72.6 (71.2-73.9)	<0.001
Mexican Americans	76.0 (75.2-76.9)	74.5 (73.4-75.6)	71.2 (70.4-71.9)	70.6 (69.3-72.0)	71.3 (70.2-72.5)	<0.001

Diastolic blood pressure is showed in the unit of mmHg.

*: p value for trends, adjusted for age group, sex, and race/ethnicity when appropriate.

Table S3. Secular trends in ideal blood pressure health in obese during NHANES 1988-2014 (N=18,626).

	Prevalence (% , 95% CI)					p value*
	1988-1992 (n=4297)	1999-2002 (n=2854)	2003-2006 (n=3185)	2007-2010 (n=4334)	2011-2014 (n=3956)	
All	32.3 (30.1-34.4)	30.6 (28.8-32.5)	33.1 (30.8-35.5)	32.8 (30.4-35.2)	31.7 (29.6-33.8)	0.6
20-39 y	50.1 (45.7-54.5)	50.0 (45.3-54.7)	55.0 (50.8-59.1)	52.2 (48.5-55.9)	51.1 (47.7-54.5)	0.57
40-59 y	26.0 (23.0-29.0)	25.7 (23.2-28.3)	25.0 (21.7-28.2)	27.0 (23.5-30.5)	27.2 (24.1-30.4)	0.35
60+ y	15.7 (13.2-18.3)	9.9 (7.5-12.4)	13.7 (11.4-16.0)	13.3 (11.1-15.5)	10.2 (7.3-13.1)	0.33
Men	24.0 (20.0-28.0)	22.5 (19.2-25.7)	27.5 (24.5-30.6)	25.9 (23.0-28.8)	25.0 (22.0-28.1)	0.59
Women	38.2 (34.9-41.4)	36.7 (34.4-39.0)	38.2 (35.2-41.2)	39.1 (36.6-41.6)	37.5 (34.5-40.5)	0.76
non-Hispanic Whites	31.9 (29.0-34.8)	29.4 (26.7-32.1)	32.4 (29.0-35.8)	32.2 (29.2-35.2)	31.3 (28.6-34.0)	0.43
non-Hispanic Blacks	28.5 (26.1-30.8)	26.5 (23.6-29.5)	30.5 (27.2-33.9)	29.3 (25.9-32.7)	27.3 (24.0-30.7)	0.79
Mexican Americans	38.4 (34.9-41.9)	38.9 (34.4-43.4)	39.2 (34.9-43.6)	36.1 (31.2-41.0)	37.9 (34.1-41.7)	0.73

Ideal blood pressure health: untreated systolic blood pressure <120 mmHg and diastolic <80.

Prevalence was age-adjusted by the direct method to the year 2010 Census population using age groups 20-39 y, 40-59 y, and 60+ y.

*: p value for trends, adjusted for age group, sex, and race/ethnicity when appropriate.

Table S4. Secular trends in HbA1c in obese adults during NHANES 1988-2014 (N=17,773).

	Mean (95% CI)					p value*
	1988-1992 (n=4108)	1999-2002 (n=2741)	2003-2006 (n=3031)	2007-2010 (n=4091)	2011-2014 (n=3802)	
All	5.7 (5.6-5.8)	5.7 (5.7-5.7)	5.7 (5.6-5.7)	5.8 (5.8-5.9)	5.9 (5.8-5.9)	<0.001
20-39 y	5.3 (5.2-5.3)	5.3 (5.3-5.4)	5.4 (5.3-5.4)	5.5 (5.4-5.5)	5.5 (5.4-5.5)	<0.001
40-59 y	5.8 (5.7-6.0)	5.8 (5.7-5.9)	5.8 (5.7-5.8)	6.0 (5.9-6.1)	6.0 (5.9-6.1)	<0.001
60+ y	6.1 (6.0-6.1)	6.1 (6.0-6.2)	6.0 (5.9-6.1)	6.2 (6.1-6.3)	6.2 (6.1-6.3)	0.005
Men	5.7 (5.6-5.8)	5.8 (5.7-5.9)	5.7 (5.7-5.8)	5.9 (5.8-5.9)	5.9 (5.8-6.0)	0.005
Women	5.7 (5.6-5.8)	5.6 (5.6-5.7)	5.7 (5.6-5.7)	5.8 (5.8-5.9)	5.8 (5.8-5.9)	<0.001
non-Hispanic Whites	5.6 (5.5-5.7)	5.6 (5.5-5.7)	5.6 (5.5-5.6)	5.7 (5.7-5.8)	5.8 (5.7-5.8)	<0.001
non-Hispanic Blacks	6.1 (6.0-6.2)	6.0 (5.9-6.1)	6.0 (5.9-6.0)	6.1 (6.0-6.2)	6.1 (6.0-6.1)	0.19
Mexican Americans	5.9 (5.8-6.0)	5.8 (5.7-5.9)	6.0 (5.9-6.2)	6.0 (5.9-6.1)	6.1 (5.9-6.2)	0.004

HbA1c is showed in the unit of %.

*: p value for trends, adjusted for age group, sex, and race/ethnicity when appropriate.

Table S5. Secular trends in prevalence of diabetes in obese adults during NHANES 1988-2014 (N=18,626).

	Prevalence (%; 95% CI)					p value*
	1988-1992 (n=4297)	1999-2002 (n=2854)	2003-2006 (n=3185)	2007-2010 (n=4334)	2011-2014 (n=3956)	
All	11.3 (9.9-12.7)	14.1 (12.7-15.6)	16.5 (14.9-18.1)	19.4 (17.4-21.3)	19.0 (17.5-20.6)	<0.001
20-39 y	3.0 (1.8-4.1)	4.5 (2.9-6.2)	5.8 (3.9-7.7)	5.1 (4.0-6.2)	5.5 (4.1-6.9)	0.23
40-59 y	13.6 (10.5-16.8)	14.5 (12.0-17.0)	16.7 (14.6-18.8)	21.7 (19.0-24.5)	21.6 (17.9-25.3)	<0.001
60+ y	19.9 (17.6-22.3)	27.5 (24.3-30.7)	31.7 (27.8-35.5)	36.5 (31.5-41.5)	34.9 (32.2-37.5)	<0.001
Men	12.1 (9.7-14.5)	16.0 (13.0-19.0)	16.8 (14.8-18.8)	19.8 (17.9-21.7)	19.9 (17.5-22.4)	0.002
Women	10.7 (9.2-12.1)	12.7 (11.2-14.3)	16.3 (14.3-18.4)	19.0 (16.5-21.6)	18.4 (16.8-20.0)	<0.001
non-Hispanic Whites	9.8 (8.1-11.5)	12.1 (10.8-13.4)	14.3 (12.6-16.0)	17.1 (14.7-19.6)	16.9 (15.0-18.8)	<0.001
non-Hispanic Blacks	17.2 (15.2-19.2)	20.3 (17.5-23.2)	21.7 (18.6-24.7)	26.4 (24.0-28.8)	23.4 (20.5-26.4)	0.01
Mexican Americans	16.8 (14.3-19.3)	17.7 (15.3-20.1)	24.1 (20.0-28.2)	23.5 (20.7-26.3)	23.5 (20.6-26.4)	0.04

Diabetes: self-reported of diabetes diagnosed by their doctors or HbA1c $\geq 6.5\%$.

Prevalence was age-adjusted by the direct method to the year 2010 Census population using age groups 20-39 y, 40-59 y, and 60+ y.

*: p value for trends, adjusted for age group, sex, and race/ethnicity when appropriate.

Table S6. Secular trends in total cholesterol in obese adults during NHANES 1988-2014 (N=17,560).

	Mean (95% CI)					p value*
	1988-1992 (n=4064)	1999-2002 (n=2691)	2003-2006 (n=3008)	2007-2010 (n=4053)	2011-2014 (n=3744)	
All	214.5 (212.7-216.3)	206.7 (204.6-208.7)	201.8 (200.0-203.5)	196.9 (195.1-198.7)	193.7 (192.3-195.1)	<0.001
20-39 y	200.7 (197.3-204.1)	196.4 (193.1-199.7)	196.3 (193.1-199.5)	195.5 (192.6-198.3)	189.5 (186.3-192.6)	<0.001
40-59 y	218.4 (215.4-221.3)	212.7 (209.4-216.0)	207.7 (204.4-211.1)	202.3 (199.0-205.7)	201.2 (198.3-204.0)	<0.001
60+ y	228.6 (225.7-231.5)	212.5 (209.3-215.7)	200.7 (196.9-204.5)	190.7 (187.9-193.4)	188.5 (185.3-191.7)	<0.001
Men	210.9 (207.7-214.1)	205.0 (201.5-208.5)	199.9 (197.9-201.9)	194.9 (192.3-197.6)	190.8 (188.0-193.5)	<0.001
Women	216.9 (214.3-219.5)	207.7 (205.5-210.0)	203.1 (200.5-205.8)	198.2 (195.4-201.1)	195.9 (194.2-197.7)	<0.001
non-Hispanic Whites	216.2 (213.9-218.6)	207.8 (205.2-210.4)	203.2 (201.2-205.3)	197.2 (194.9-199.6)	194.5 (192.4-196.7)	<0.001
non-Hispanic Blacks	211.6 (208.9-214.2)	203.7 (199.8-207.5)	197.0 (193.7-200.2)	194.9 (192.0-197.7)	189.2 (186.5-191.9)	<0.001
Mexican Americans	210.7 (207.6-213.7)	202.5 (198.7-206.3)	198.9 (194.3-203.5)	198.9 (196.0-201.9)	193.2 (189.6-196.9)	0.003

Total cholesterol is showed in the unit of mg/dL.

*: p value for trends, adjusted for age group, sex, and race/ethnicity when appropriate.

Table S7. Secular trends in HDL cholesterol in obese adults during NHANES 1988-2014 (N=17,525).

	Mean (95% CI)					p value*
	1988-1992 (n=4029)	1999-2002 (n=2691)	2003-2006 (n=3008)	2007-2010 (n=4053)	2011-2014 (n=3744)	
All	45.4 (44.7-46.2)	46.0 (45.2-46.8)	48.7 (48.0-49.3)	46.4 (45.7-47.0)	47.4 (46.8-48.1)	0.001
20-39 y	44.4 (43.0-45.8)	44.5 (43.6-45.4)	47.1 (46.1-48.1)	44.6 (43.6-45.6)	45.6 (44.6-46.5)	0.15
40-59 y	44.8 (43.6-46.0)	45.5 (44.2-46.8)	48.1 (47.2-49.0)	46.1 (45.2-47.0)	47.5 (46.6-48.3)	0.007
60+ y	47.9 (46.7-49.1)	48.8 (47.9-49.8)	51.7 (50.6-52.8)	49.4 (48.6-50.2)	50.2 (49.2-51.1)	0.033
Men	40.2 (39.1-41.4)	40.6 (39.6-41.5)	43.4 (42.8-44.0)	41.4 (40.8-41.9)	42.6 (41.8-43.4)	0.007
Women	49.3 (48.5-50.1)	50.1 (48.9-51.2)	53.2 (52.1-54.3)	50.8 (50.0-51.7)	51.5 (50.7-52.3)	0.031
non-Hispanic Whites	44.3 (43.4-45.2)	44.9 (43.8-46.0)	47.7 (47.0-48.3)	45.2 (44.6-45.9)	47.0 (46.2-47.8)	0.001
non-Hispanic Blacks	51.1 (50.1-52.2)	51.3 (49.8-52.8)	53.9 (52.7-55.1)	52.0 (50.7-53.3)	51.2 (50.4-52.0)	0.89
Mexican Americans	45.1 (44.3-45.9)	45.4 (44.5-46.3)	47.8 (46.4-49.2)	46.1 (45.2-46.9)	46.4 (45.6-47.2)	0.18

HDL cholesterol is showed in the unit of mg/dL.

*: p value for trends, adjusted for age group, sex, and race/ethnicity when appropriate.

Table S8. Secular trends in ideal blood lipid health in obese adults during NHANES 1988-2014 (N=18,626).

	Prevalence (% , 95% CI)					p value*
	1988-1992 (n=4297)	1999-2002 (n=2854)	2003-2006 (n=3185)	2007-2010 (n=4334)	2011-2014 (n=3956)	
All	3.3 (2.3-4.3)	3.8 (2.9-4.7)	5.2 (4.1-6.3)	4.9 (4.1-5.7)	4.8 (4.0-5.6)	0.022
20-39 y	4.5 (2.3-6.8)	4.2 (2.7-5.7)	6.5 (4.7-8.3)	5.5 (3.8-7.1)	5.0 (3.9-6.0)	0.48
40-59 y	3.0 (1.9-4.0)	4.0 (2.4-5.6)	4.1 (2.6-5.6)	4.4 (3.2-5.6)	5.0 (3.5-6.5)	0.14
60+ y	2.0 (0.9-3.1)	2.9 (1.9-3.9)	5.0 (3.4-6.5)	4.8 (3.8-5.7)	4.5 (3.0-5.9)	0.02
Men	1.5 (0.6-2.3)	0.9 (0.4-1.4)	2.3 (1.4-3.1)	2.0 (1.3-2.7)	2.5 (1.5-3.5)	0.028
Women	4.7 (3.1-6.2)	6.0 (4.5-7.5)	7.7 (6.0-9.4)	7.4 (6.2-8.6)	6.8 (5.5-8.0)	0.16
non-Hispanic Whites	2.6 (1.2-4.0)	2.5 (1.4-3.5)	4.6 (3.1-6.0)	4.1 (3.2-5.0)	4.1 (2.9-5.3)	0.026
non-Hispanic Blacks	6.4 (5.2-7.6)	7.7 (6.0-9.5)	9.0 (7.4-10.6)	8.2 (6.2-10.2)	8.7 (7.2-10.2)	0.12
Mexican Americans	3.1 (2.1-4.2)	3.4 (1.8-5.1)	5.5 (3.3-7.6)	4.7 (3.2-6.2)	5.3 (3.8-6.9)	0.087

Ideal blood lipid health: untreated total cholesterol <200 mg/dL, and HDL ≥60 mg/dL.

Prevalence was age-adjusted by the direct method to the year 2010 Census population using age groups 20-39 y, 40-59 y, and 60+ y.

*: p value for trends, adjusted for age group, sex, and race/ethnicity when appropriate.