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Original article

Association of obesity with risk of coronary heart disease: findings from the National Health and Nutrition Examination Survey, 1999–2006

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Abstract

Background: Obesity is a well-known risk factor for the development of coronary heart disease (CHD). The aim of the present study was to examine the differences in the 10-year CHD risk with increasing severity of obesity in men and women participating in the latest National Health and Nutrition Examination Survey.

Methods: Data from a representative sample of 12,500 U.S. participants in the National Health and Nutrition Examination Survey from 1999 to 2006 were reviewed. The Framingham risk score was calculated for men and women according to a body mass index (BMI) of <25.0, 25.0–29.9, 30.0–34.9, and ≥ 35.0 kg/m^2.

Results: The prevalence of those with hypertension increased with an increasing BMI, from 24% for a BMI <25.0 kg/m^2 to 54% for a BMI of ≥ 35.0 kg/m^2. The prevalence of an abnormal total cholesterol level (>200 mg/dL) increased from 40% for a BMI <25.0 kg/m^2 to 48% for a BMI of ≥ 35.0 kg/m^2. The 10-year CHD risk for men increased from 3.1% for a BMI <25.0 kg/m^2 to a peak of 5.6% for a BMI of 30.0–34.9 kg/m^2. The 10-year CHD risk for women increased from .8% for a BMI <25.0 kg/m^2 to a peak of 1.5% for a BMI of ≥ 35.0 kg/m^2. Both diabetes and hypertension were independent risk factors for an increasing CHD risk.

Conclusions: The 10-year CHD risk, calculated using the Framingham risk score, substantially increased with an increasing BMI. An important implication from our findings is the need to implement surgical and medical approaches to weight reduction to reduce the effect of morbidity and mortality from CHD on the U.S. healthcare system. (Surg Obes Relat Dis 2010;6:465–469.)

Keywords: Obesity; Hypertension; Framingham risk score; Coronary heart disease

The prevalence of obesity has been increasing in the United States and has reached epidemic proportions. Recent data from the National Health and Nutrition Examination Survey (NHANES) in 2003–2004 indicated that of adults aged 20–39 years, 28.5% were obese and 36.8% of adults aged 40–59 years and 31.0% of those aged ≥60 years were obese, defined as a body mass index (BMI) of ≥30.0 [1]. Excess weight has been shown to be associated with an increased prevalence of type 2 diabetes, gastroesophageal reflux, hypertension, dyslipidemia, and certain cancers [2,3]. Obesity has also been associated with an increased risk of mortality, particularly from cardiovascular disease [4]. Risk prediction for coronary heart disease (CHD) is often performed using data from the Framingham Heart study, which examined patient age, total cholesterol concentration, high-density lipoprotein cholesterol concentration, smoking status, and systolic blood pressure [5]. Previous studies have shown an association between obesity and the Framingham risk score [6–10]. However, this as-

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sociation has not been studied using representative nationwide data. The aim of the present study was to examine the differences in the 10-year risk of CHD with increasing BMI in a large cohort of U.S. individuals participating in the 1999–2006 NHANES.

Methods

Study population

The NHANES was conducted by the National Center for Health Statistics, a part of the Centers for Disease Control and Prevention. The NHANES provides cross-sectional data on the health and nutrition of the U.S. population. The survey has been used to examine a nationally representative complex, multistage probability sample of about 5000 U.S. civilians each year, located within 15 counties across the United States. The NHANES consists of an extensive health information interview, a complete physical examination, and extensive laboratory testing. The physical examinations were performed in a mobile examination center. Data from the 4 latest NHANESs were merged for the present analysis (1999–2000, 2001–2002, 2003–2004, and 2005–2006).

The extracted data files included demographic information, systolic blood pressure measurements, medical disease history, smoking history, and laboratory measures (total cholesterol and high-density lipoprotein cholesterol levels) obtained from the NHANES Website and combined to create a single data set. The participants' height and weight were measured using standardized protocols. Current smoking was measured by the survey question "Do you now smoke cigarettes?" Respondents who answered "everyday" or "some days" were defined as current smokers; those who answered "not at all" were defined as current nonsmokers.

The participants were considered to have hypertension if their mean systolic blood pressure, measured at the mobile examination center, was >140 mm Hg or the mean diastolic blood pressure was >90 mm Hg (from ≤4 blood pressure readings, of which all but the first were averaged for the final reading), if they had been told by their doctor that they had high blood pressure or hypertension, or if they were taking antihypertensive medication. Diabetes mellitus was defined to include those who had been told by their doctor that they had diabetes, who had a fasting plasma glucose concentration of ≥125 mg/dL, had a hemoglobin A1c level of ≥6.0%, or used antidiabetic medication, such as insulin or oral hypoglycemic agents.

Endpoints

Risk assessment for determining the 10-year risk of developing CHD was performed by calculating the Framingham risk score as reported by the Third Report of the National Cholesterol Education Program Expert Panel on the Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adults Treatment Panel III) [5]. The risk factors included in the calculation of the risk score were age, gender, smoking history, systolic blood pressure, total cholesterol level, high-density lipoprotein cholesterol level, and treatment of hypertension. The 10-year risk of CHD was calculated for both men and women throughout the range of BMI classes. The BMI was calculated as the weight in kilograms divided by the square of the height in meters and categorized as <25.0, 25.0–29.9, 30.0–34.9, and ≥35.0 kg/m^2.

Statistical analysis

All statistical analyses were conducted using the Statistical Analysis Systems, version 9.1 (SAS Institute, Cary, NC). Because of the NHANES' complex probability sampling of the U.S. population, the sample weights, stratification, and clustering of the sampling design were incorporated into all SAS survey procedures to ensure the correct estimation of standard errors, 95% confidence intervals, and *P* values. An 8-year sample weight was created according to the NHANES analytic guidelines for the combined 1999–2006 data by assigning one half the 4-year weight for 1999–2002 if a participant was included in 1999–2002 and assigning one fourth of the 2-year weight for those included in 2003–2006 [10]. The stratification and clustering variables were used in all analyses.

Two-sample *t* tests were used to examine the differences in the mean Framingham CHD risk percentage between those with and without diabetes and those with and without hypertension stratified by the BMI category. Similar analyses were used to examine the differences in the mean Framingham CHD risk percentage across age groups. Statistical significance was set at $P < .05$.

Results

Table 1 lists the demographics of the study population from 1999 to 2006 according to the BMI. Of the participants, 4185 had a BMI of <25.0 kg/m^2, 4301 had a BMI of 25.0–29.9 kg/m^2, 2366 had a BMI of 30.0–34.9 kg/m^2, and 1648 had a BMI of ≥35.0 kg/m^2. The percentage of smokers within each BMI class is also listed in Table 1. The prevalence of hypertension was lowest for the BMI <25.0-kg/m^2 group (24%) and greatest for the BMI ≥35.0-kg/m^2 group (54%). The prevalence of an abnormal total cholesterol level of >200 mg/dL was lowest for those with a BMI <25.0 kg/m^2 (40%) and had increased to 48% for those with a BMI of ≥35.0 kg/m^2.

The prevalence estimates of the 10-year CHD risk among adult men and women according to the BMI are listed in Table 2. The 10-year CHD risk was 3.1% ± 0.2% for men with a BMI <25.0 kg/m^2 and was greatest for the men with a BMI of 30.0–34.9 kg/m^2 at 5.6 ± 0.3% ($P < .01$). The 10-year CHD risk was .8% ± 0.1% for women with a BMI <25.0 kg/m^2 and was greatest for women with a BMI of ≥35.0 kg/m^2 at 1.5% ± .1%

Table 1
NHANES population characteristics stratified by body mass index, 1999–2006

Characteristic	BMI category (kg/m^2)			
	<25.0 (n = 4185)	25.0–29.9 (n = 4301)	30.0–34.9 (n = 2366)	≥35.0 (n = 1648)
Mean age (yr)	41.3 ± .3	45.4 ± .3	45.7 ± .5	45.0 ± .4
Gender				
Male	1917 (46)	2337 (54)	1071 (45)	531 (32)
Female	2268 (54)	1964 (46)	1295 (55)	1117 (68)
Current smoking	1250 (30)	918 (21)	496 (21)	298 (18)
SBP (mm Hg)				
<140	3603 (86)	3423 (80)	1832 (77)	1264 (77)
≥140	534 (13)	796 (19)	478 (20)	359 (22)
Hypertension	1011 (24)	1568 (36)	1065 (45)	891 (54)
Total cholesterol (mg/dL)				
<200	2529 (60)	2010 (47)	1149 (49)	862 (52)
≥200	1656 (40)	2291 (53)	1217 (51)	786 (48)
HDL cholesterol (mg/dL)				
<40	752 (18)	1080 (25)	737 (31)	518 (31)
≥40	3433 (82)	3221 (75)	1629 (69)	1130 (69)
Diabetes	281 (7)	529 (12)	426 (18)	436 (26)

NHANES = National Health and Nutrition Examination Survey; BMI = body mass index; SBP = systolic blood pressure; HDL = high-density lipoprotein.

Data presented as mean ± standard deviation or numbers, with percentages in parentheses.

(P <.01). The Framingham CHD risk increased substantially for both men and women with hypertension or diabetes (Figs. 1 and 2). The association between an increasing BMI and increasing risk of CHD persisted even when stratified by age (Table 3).

Discussion

The major finding of the present study was the clear association between obesity and cardiovascular risk in a large, representative sample of the U.S. population. In our cross-sectional survey of U.S. men and women, the lowest 10-year CHD risk was for those with a BMI <25.0 kg/m^2. The 10-year CHD risk increased throughout the range of BMI classes for both men and women. Using a BMI of <25.0 kg/m^2 as the reference category, men and women with a BMI of ≥35.0 kg/m^2 had an almost twofold increased risk of CHD. The greatest 10-year CHD risk was for men with a BMI >30.0 kg/m^2. The 10-year CHD risk also increased substantially for those with hypertension or diabetes.

Multiple studies have shown that weight reduction, by either medical management or bariatric surgery, substantially reduces the risk of CHD. One of the largest trials of intentional weight loss in patients with diabetes was the Look AHEAD trial [11]. The Look AHEAD (Action for Health in Diabetes) study was a multicenter, randomized, controlled trial of 5145 patients with type 2 diabetes and BMI >25 kg/m^2, who were randomized to undergo intensive lifestyle intervention compared with diabetes support and education (control group). The participants randomized to the lifestyle intervention lost an average of 8.6% of their initial weight compared with .7% in the control group. A greater proportion of the patients in the lifestyle intervention group were able to reduce their diabetes, hypertension, and lipid-lowering medicine. Blood pressure, triglycerides, mean hemoglobin A1c, and high-density lipoprotein cholesterol improved significantly more in the lifestyle intervention group than in the control group [11]. In a surgical cohort, Kligman et al. [12] reported on 101 patients who had undergone laparoscopic gastric bypass and found that the overall 10-year CHD risk decreased from 6.7% to 3.2%,

Table 2
Predicted 10-year coronary heart disease risk stratified by BMI category and gender

Gender	BMI <25.0 (kg/m^2)		BMI 25.0–29.9 (kg/m^2)		BMI 30.0–34.9 (kg/m^2)		BMI ≥35.0 (kg/m^2)	
	n	Mean ± SE	n	Mean ± SE	n	Mean ± SE	n	Mean ± SE
Male	1917	3.1 ± 0.2	2337	5.2 ± 0.2*	1071	5.6 ± 0.3*	531	5.5 ± 0.5*
Female	2268	0.8 ± 0.1	1964	1.3 ± 0.1*	1295	1.2 ± 0.1*	1117	1.5 ± 0.1*

BMI = body mass index; SE = standard error.

* P <.01 compared with BMI <25.0 kg/m^2, 2-sample t test.

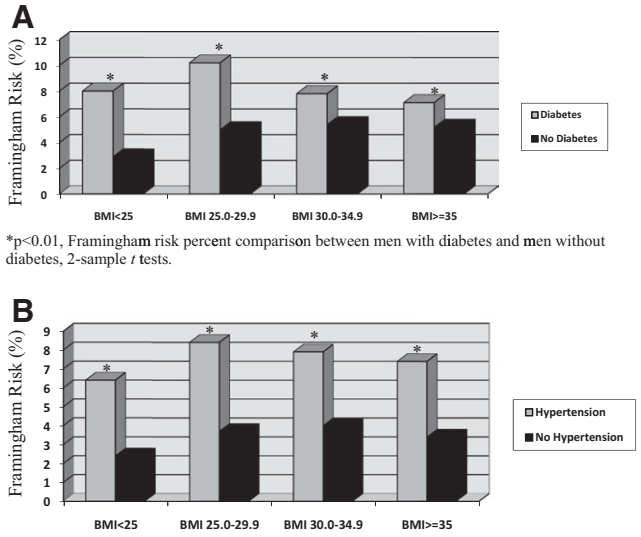

Fig. 1. (A) Predicted 10-year CHD risk for men according to BMI and diabetes status, NHANES 1999–2006. (B) Predicted 10-year CHD risk for men according to BMI and hypertension status, NHANES 1999–2006.

representing a relative risk reduction of 52%. Torquati et al. [13] reported on 500 patients who had undergone gastric bypass and found that the average 10-year absolute risk of cardiac events decreased from 5.4% at baseline to 2.7% at 1 year after surgery. Finally, Vogel et al. [14] reported on 109 patients who had undergone laparoscopic gastric bypass and found that the predicted 10-year CHD risk at baseline and at a mean follow-up of 17 months was 6% and 4%, respectively. These data suggest that substantial weight loss from either medical weight control or bariatric surgery is important to decrease future rates of cardiovascular-related death in the morbidly obese. Furthermore, several recent studies have shown improved survival rates for morbidly obese individuals who underwent bariatric surgery compared with control individuals without surgical intervention [15–17]. Adams et al. [16] reported on a retrospective cohort study of comparing 7925 morbidly obese patients who had undergone bariatric surgery and 7925 severely obese control subjects. They found that the cause-specific mortality rate in the surgical group decreased by 56% for coronary artery disease during a mean follow-up of 7.1 years [16]. In a landmark report published in 2007 comparing 2010 severely obese patients who had undergone bariatric surgery compared with 2037 control subjects, Sjostrom et al. [17] reported that bariatric surgery for severe obesity was associated with long-term weight loss and decreased overall mortality. Although the current indications for bariatric surgery include patients with a BMI >35 kg/m^2 with associated co-morbidities or a BMI of ≥ 40 kg/m^2, the findings from the present study suggest that even those with a BMI of 30.0–34.9 kg/m^2 have a greater risk of the development of CHD and could benefit from medical or surgical treatment of obesity. In addition to the currently available obesity treatments, the prevention of obesity is a key public heath initiative in an attempt to reduce the incidence of obesity and CHD risk. Currently, Head Start is the largest federally funded early childhood obesity education program in the United States. In a survey of 1583 Head Start programs, Whitaker et al. [18] reported that most Head Start programs are doing more to support healthy eating and gross motor activity than required by federal requirement standards.

Our results have shown a clear association between obesity and the Framingham cardiovascular risk score, using a large nationwide database. However, notable limitations are present in the use and interpretation of these observational data. The NHANES is a series of cross-sectional analyses of the U.S. population. Therefore, longitudinal data across study years were not provided, and no temporal analyses could be conducted. As with all survey data, inherent limitations are present in the collection methods, which can lead to sampling error, measurement error, and reporting bias. These inaccuracies will bias toward the null hypothesis of no association. Most importantly, no causative inferences can be made from the observed associations (i.e., obesity and related co-morbidities cannot be said to cause cardiovascular events on the basis of these data). Finally, the Framingham risk score is a widely accepted, yet imprecise, measurement of cardiovascular risk. The Framingham risk score is calculated from patient-related factors, such as age, gender, hypertensive status, and cholesterol level. Because both obesity and the Framingham risk score are known to be associated with these same variables, a formal risk adjustment could not be performed. The data from the present study has been presented in tables, stratified by these vari-

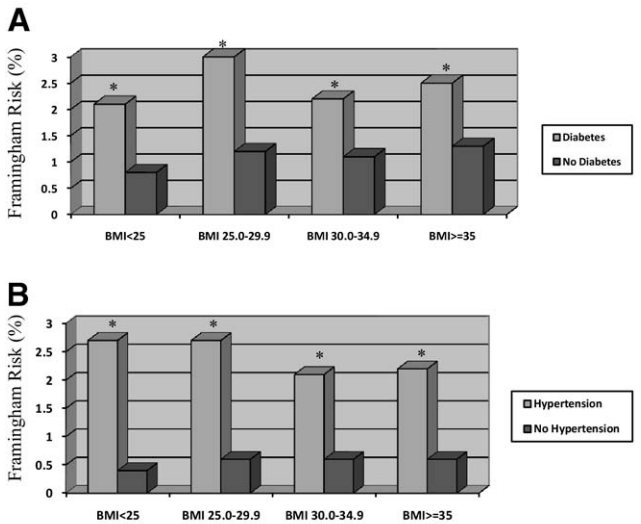

Fig. 2. (A) Predicted 10-year CHD risk for women according to BMI and diabetes status, NHANES 1999–2006. (B) Predicted 10-year CHD risk for women according to BMI and hypertension status, NHANES 1999–2006.

Table 3
Predicted 10-year CHD risk for men and women stratified by age, NHANES 1999–2006

BMI (kg/m^2)	Mean CHD risk (%)		
	Age 20–40 yr	Age 40–55 yr	Age ≥55 yr
Men			
<25.0	0.6 ± .1 (n = 910)	3.5 ± .3 (n = 449)	10.1 ± .6 (n = 558)
25.0–29.9	1.8 ± .1* (n = 780)	5.2 ± .3* (n = 707)	12.6 ± .4* (n = 850)
30.0–34.9	1.2 ± .1* (n = 345)	5.5 ± .5* (n = 329)	12.4 ± .8* (n = 397)
≥35.0	1.3 ± .3* (n = 183)	5.4 ± .7* (172)	13.1 ± 1.0* (n = 176)
Women			
<25.0	.1 ± .01 (n = 1141)	.6 ± .04 (n = 520)	3.0 ± .3 (n = 607)
25.0–29.9	.2 ± .03† (n = 785)	.9 ± .1† (n = 500)	3.1 ± .3 (n = 679)
30.0–34.9	.1 ± .02 (n = 489)	.8 ± .1† (n = 358)	3.1 ± .3 (n = 448)
≥35.0	.3 ± .1† (n = 423)	1.1 ± .2† (n = 331)	3.5 ± .3† (n = 363)

CHD = coronary heart disease; other abbreviations as in Table 1.
Data presented as mean ± standard error.
* $P < .05$ compared with BMI <25.0 kg/m^2 within corresponding age group, 2-sample t test.
† $P < .05$ compared with BMI <25.0 kg/m^2 within corresponding age group, 2-sample t test.

ables, to emphasize their relative effect on the Framingham risk score and obesity status.

Conclusions

Our findings have demonstrated an association between an increasing BMI and an increase in the 10-year risk of CHD, with the strongest association found for men. Our findings were consistent across all age groups. Because the 10-year risk of CHD increased substantially even for those with a BMI of 30.0–34.9 kg/m^2, these data, which were determined from an 8-year period (1999–2006), suggest that the optimal weight class should be within the normal range with a BMI of <25.0 kg/m^2. An important implication from the present study was that surgical and medical programs for weight reduction and preventive approaches to obesity should be given the greatest priority to reduce the prevalence of cardiovascular disease in the United States.

Disclosures

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