Relationship Between Obesity and Obesity-Related Morbidities Weakens With Aging

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Background. A weak relationship exists between obesity and mortality risk in older populations, however, the influence of age on the relationship between obesity and morbidity is unclear. The objective of this study was to determine the influence of age on the relationship between obesity and cardiovascular disease, type 2 diabetes, dyslipidemia, and hypertension.

Methods. Data from the Third National Health and Nutrition Examination Survey (1988–1994) were used. Individuals were classified into specific age (young: 18–40; middle: 40–65; old: 65–75; and very old: ≥75 years) and body mass index (BMI; 18.5–24.9, >25–29.9, ≥30 kg/m²) categories. Cardiovascular disease, type 2 diabetes, dyslipidemia, and hypertension were categorized using measured metabolic risk factors, physician diagnosis, or medication use.

Results. Age modified the relationship between BMI and cardiovascular disease (Age × BMI interaction, p = .049), dyslipidemia (Age × BMI interaction, p = .035 for men, p < .001 for women), and hypertension (Age × BMI interaction, p = .023) in women but not in men (p = .167). However, age did not modify the relationship between BMI and type 2 diabetes (Age × BMI interaction, p = .177). BMI was strongly associated with increased relative risk of cardiovascular disease, dyslipidemia, type 2 diabetes, and hypertension in the young and middle aged, however, the association between BMI and these metabolic conditions were much more attenuated with increasing age.

Conclusion. A stronger association between obesity and prevalent metabolic conditions exists in young and middle-aged populations than in old and very old populations. Longitudinal studies are needed to verify these findings and to confirm the benefits of weight loss on health across the life span.

Key Words: Aging—Obesity—Morbidity—Body mass index.

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The risk of obesity increases with age (1–3). It is well established that obesity is associated with increased risks for cardiovascular disease (CVD), type 2 diabetes (T2D), dyslipidemia, hypertension, and mortality (4). It is important to identify whether the relationship between obesity and morbidity is consistent across the life span.

Evidence suggests that a weak relationship exists between obesity and mortality in older populations (5–8). This may be because excess weight in the elderly populations might actually serve as a protective buffer against mortality (8–11). Additionally, older individuals are at an increased risk for morbidity and mortality (12) that is unrelated to obesity. Together, these factors may weaken the association between body mass index (BMI) and mortality risk. However, literature pertaining to the influence of age on the association between BMI and morbidity is not as clear (12,13). Much research suggests that there is a strong, positive relationship between obesity and the prevalence of some metabolic conditions (14,15). Some literature suggests that the association between obesity and metabolic risk may become weaker or stronger with age depending on the risk factor in question (16,17).

The influence of age on the relationship between BMI and different metabolic conditions has rarely been examined. This may have important clinical implications for refining weight management recommendations for different age populations. Therefore, the purpose of this study was to investigate the influence of age on the relationship between obesity and CVD, T2D, dyslipidemia, and hypertension among a sample of U.S. men and women.

Methods

Participants

Data from the Third National Health and Nutrition Examination Survey were used. Third National Health and Nutrition Examination Survey is a nationally representative
cross-sectional survey of the United States conducted between 1988 and 1994 by the National Center for Health Statistics of the Centers for Disease Control and Prevention. Data were collected on 33,994 individuals aged 2 months and older using a multistage probability cluster design. The participants were selected in four stages: primary sampling units (ie, counties), segments (ie, blocks), households, and individuals. Geographical locations that had higher proportions of young children, older persons (aged 65 and older), black persons, and Mexican Americans were oversampled to increase the reliability and precision of estimates of health status indicators for these population subgroups (18). Further details of the study design and procedure are reported elsewhere (18,19). Participants were excluded if they were less than 18 years of age (n = 9,540), had a BMI of less than 18.5 kg/m² (n = 3,933), or had missing information for age (n = 4,827) or BMI (n = 18,689) leaving 9,414 individuals (4,399 men and 5,015 women) for the current data analysis. We certify that all applicable institutional and governmental regulations concerning the ethical use of human volunteers were followed during this research. All participants provided informed consent before participating in the examination and the study protocol was approved by the National Center for Health Statistics.

Survey and Anthropometric Assessment Methods
Age, sex, education (≤secondary, secondary, >postsecondary), ethnicity (non-Hispanic white or other), smoking status (never smoked, former smoker, current smoker), physical activity (exercise frequency <5 or ≥5 times per week), physician-diagnosed morbidity (stroke, heart attack, congestive heart failure, T2D, and hypertension), and medications prescribed for metabolic conditions were assessed by questionnaire. BMI was calculated using technician-measured height and weight.

Morbidity Parameters
Metabolic conditions were defined using metabolic risk factors, physician diagnosis, or medication use. CVD was defined as a physician diagnosis of stroke, heart attack, congestive heart failure, or use of antianginal or coronary vasodilators. T2D was defined as a physician diagnosis of T2D, fasting plasma glucose of greater than or equal to 7 mmol/L, or use of blood glucose regulator medications. Hypertension was defined as a physician diagnosis of hypertension, systolic blood pressure of greater than or equal to 140 mm Hg or diastolic blood pressure of greater than or equal to 90 mm Hg, or use of antihypertensive medication. Dyslipidemia was defined as triglycerides greater than or equal to 2.06 mmol/L, total cholesterol greater than or equal to 6 mmol/L, high-density lipoprotein cholesterol less than 1.04 mmol/L for men, and less than 1.29 mmol/L for women, or use of dyslipidemia medication. Individuals were categorized by age (years; young [18–39], middle [40–64], old [65–74], and very old [≥75]) and standard BMI categories (kg/m²; normal weight [≥18.5–24.9], overweight [≥25–29.9], and obese [≥30]).

Statistical Analysis
Differences in participant characteristics by age group and sex were assessed using analysis of variance for the continuous variables and chi-square tests for the categorical variables. PROC GENMOD with Log Link function was used to calculate the prevalent risks (PR) between each age- and BMI-specific category with the main dichotomous outcome variables of CVD, T2D, dyslipidemia, and hypertension. Middle-aged, normal weight was used as the reference group. To determine if sex or age influenced the relationship between BMI and each metabolic condition, interaction terms were incorporated into the PROC GENMOD Logit function. Analyses with sex or age interactions effects of less than 0.1 were stratified by sex. The multivariate analyses were adjusted for smoking status, ethnicity, education, and physical activity. All statistical analyses were performed using SAS v9.3. Statistical significance was set at α < 0.05.

RESULTS
Participant characteristics stratified by age category and sex are presented in Table 1. In men and women, mean BMI increased across the young, middle, and old age groups (p < .05) and decreased in the very old age group (p < .05). The prevalence of metabolic conditions increased across age categories (p < .001).

There was no sex difference in the relationship between BMI and the PR of CVD (Sex × BMI interaction, p = .143; Figure 1A), therefore, the analyses were conducted collapsed across sex. Age modified the relationship between BMI and CVD (Age × BMI interaction, p = .049) such that an increase in BMI was associated with an increase in the PR of CVD for the young and middle-aged categories but not for the old or very old.

There was no sex difference in the relationship between BMI and the PR of T2D (Sex × BMI interaction, p = .983), therefore, the analyses were computed collapsed across sex (Figure 1B). Age did not influence the relationship between BMI and T2D (Age × BMI interaction, p = .177). An increase in BMI was associated with a similar increase in the PR associated with T2D in all age categories.

There was a sex difference in the relationship between BMI and the risk of dyslipidemia (Sex × BMI interaction, p < .001), therefore, the analyses were stratified by sex (Figure 2A and B). Age modified the relationship between BMI and dyslipidemia for both men (Age × BMI interaction, p = .35) and women (Age × BMI interaction, p < .001). In both men and women, BMI was associated...
with an increased PR of dyslipidemia in the young and middle-aged categories, however, no association was observed in the old or very old.

There was a sex difference in the relationship between BMI and the risk of hypertension (Sex × BMI interaction, \( p < .001 \)), therefore, the analyses were stratified by sex (Figure 3A and B). Age modified the relationship between BMI and hypertension for women (Age × BMI interaction, \( p = .023 \)) but not for men (\( p = .167 \)). In both men and women, an increase in BMI was associated with an increase in the PR associated with hypertension in all age categories.

However, in women, the positive association between BMI and hypertension risk diminished with age.

**Discussion**

The findings from this study demonstrate that the association between obesity and health risk changes across the life span. Although a strong, positive association exists between obesity with hypertension and T2D in all age populations, a weaker or no association exists between obesity with CVD and dyslipidemia in the older age groups. This may suggest

**Table 1.** Participant Characteristics of 9,414 Men and Women From the Third National Health and Nutrition Examination Survey in Young, Middle, Old, and Very Old Age Categories

<table>
<thead>
<tr>
<th></th>
<th>Men</th>
<th>Women</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age Group (n)</strong></td>
<td>18–39 y (1,864)</td>
<td>40–64 y (1,420)</td>
</tr>
<tr>
<td><strong>Age (y)</strong></td>
<td>28.3 ± 6.2*†‡</td>
<td>51.8 ± 7.7*†</td>
</tr>
<tr>
<td><strong>BMI (kg/m²)</strong></td>
<td>26.0 ± 5.1*†‡</td>
<td>27.7 ± 4.8*†‡</td>
</tr>
<tr>
<td><strong>Normal weight</strong></td>
<td>888 (47.6%)*†‡</td>
<td>425 (30.0%)*†‡</td>
</tr>
<tr>
<td><strong>Overweight</strong></td>
<td>673 (36.1%)*†‡</td>
<td>614 (43.2%)*†‡</td>
</tr>
<tr>
<td><strong>Obese</strong></td>
<td>303 (16.3%)*†‡</td>
<td>381 (26.8%)*†‡</td>
</tr>
<tr>
<td><strong>Cardiovascular disease</strong>, n (%)</td>
<td>18 (0.97%)*†‡</td>
<td>120 (8.4%)*†‡</td>
</tr>
<tr>
<td><strong>Type 2 diabetes</strong></td>
<td>31 (1.7%)*†‡</td>
<td>177 (12.5%)*†‡</td>
</tr>
<tr>
<td><strong>Dyslipidemia</strong></td>
<td>560 (30.0%)*†‡</td>
<td>655 (46.1%)*†‡</td>
</tr>
<tr>
<td><strong>Hypertension</strong></td>
<td>280 (15.0%)*†‡</td>
<td>608 (42.8%)*†‡</td>
</tr>
</tbody>
</table>

Notes: BMI = body mass index. Values reported are means (M) ± standard deviations (SD) or frequencies (percent).
*Different from middle.
†Different from old.
‡Different from very old.
§Different from young.
that different approaches to managing obesity and health may be needed across the life span.

There are many physiological and body compositional changes that occur as individuals age. Body mass increases across the life span until about age 60 and then tends to decrease (20). This decrease in body mass can be explained by the process of sarcopenia where significant decreases in muscle mass occur in conjunction with smaller increases in fat mass (21). An additional process associated with aging is fat redistribution. Subcutaneous fat that is located away from the truncal region is redistributed to abdominal areas that pose greater metabolic risk as visceral or abdominal adiposity is more strongly linked with many conditions (22, 23). The increases in abdominal adipose tissue are not entirely captured by BMI and may, in part, explain the weakened association between BMI and health risk with age. There are also age-related losses in height that inflates the measured BMI (12, 24–26). However, these age-related changes in BMI should theoretically increase the obesity-related health risk associated with BMI, rather than weaken the association between BMI and morbidity.

Previous research on CVD risk and obesity in older adults suggest that a weak relationship exists between CVD morbidity (12) and mortality (24) and obesity in older adults. In accordance with this study, Stevens and colleagues (8), demonstrated that the relative risk of all-cause and CVD mortality associated with an excess body mass is greater for younger and middle-aged individuals than for older individuals. Nanas and colleagues (27) observe that a similar weakened association with BMI and dyslipidemia, which is a strong risk factor of CVD, may, in part, explain this weakened association with CVD in older populations. A potential hypothesis could be that of a selective survival effect (12) of healthier, older individuals, in that unhealthy individuals with a high BMI may have already died from the ill effects of obesity. There also may be confounding effects associated with diet that may in part explain the weakened to no association observed between obesity and the PR of dyslipidemia in older populations. Older individuals generally have decreased food intake (28), and therefore, may not consume high-fat diets that are strongly associated with obesity and dyslipidemia. Furthermore, overweight and obese individuals are more likely to survive a heart attack than normal weight individuals (29) suggesting another potential explanation for the weak relationship with CVD observed in older populations.

Unlike for dyslipidemia, previous research suggests that obesity (30) and age (31) are strongly associated with an increased risk for hypertension. In this study, we observe that the association between BMI and hypertension is consistent across the life span. Age-related changes such as arterial stiffness and other physiological changes (32) contribute to an increased systolic blood pressure and decreased diastolic blood pressure.

A wealth of evidence clearly demonstrates the link between adiposity and T2D (33, 34). However, literature evaluating this relationship in older individuals is sparse. In a study conducted by Patterson and colleagues (35), the authors report that middle to old aged, obese adults are at an increased risk of T2D with the risk for women being more prominent compared with men. Findings from the Iowa Women’s Study indicate that BMI is a strong independent risk factor for T2D incidence in women aged 55–69 years old (36). We are the first to demonstrate that the risk for prevalent T2D is more consistent across the life span, highlighting the deleterious effects of T2D at every stage of life.

Several limitations warrant mention for this study. Studies have shown that BMI is not an optimal measure determining obesity (9, 24) due to the age-related changes resulting in a decrease in muscle mass with concomitant
increases in fat mass (37) and the redistribution of fat mass to the visceral area. Because this is a cross-sectional study, causation cannot be inferred with these results; therefore, it is uncertain whether age or BMI caused the incidence of the metabolic conditions or whether developing the actual metabolic condition caused the obesity. The diagnosis of the metabolic condition or a traumatic event leading up to the diagnosis could result in unintentional weight loss (12) due to long hospital stays or lifestyle changes. It could be these occurrences that may reflect the weaker association observed with obesity and morbidity in the older populations. It cannot be concluded that an older individual with excess body mass will not develop a metabolic condition. Rather the results just state the PR of metabolic disorders associated with BMI, which are generally lower for older age groups. It cannot be concluded that an older individual with excess body mass will not develop a metabolic condition. Rather the results just state the PR of metabolic disorders associated with BMI, which are generally lower for older age groups. Finally, it is unclear whether similar observations would be observed with subclinical CVD risk factors. The prevalence of individuals with subclinical elevations in CVD is similar to the prevalence of clinically elevated CVD risk factors (38), however, this proportion is similar across the life span (39). Therefore, the results of this study would likely also apply to the PR for subclinical CVD.

In summary, the PR for obesity-related comorbidities are not consistent across the entire life span. Age weakens the relationship between obesity and CVD, dyslipidemia, and hypertension in women but not hypertension in men or T2D. A stronger relationship exists between obesity and morbidity in the young and middle-aged populations than in the old and very old populations. The results of this study increase the understanding of the influence of age on the relationship between obesity and morbidity. However, longitudinal studies are needed to confirm these observations and to clarify the benefits of weight loss on health across the life span.

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**References**


**Figure 3.** Prevalent Risk (PR) of hypertension (A) in men and (B) in women by body mass index (BMI) and age categories. Age groups: white—young = 18–39, light grey—middle = 40–64, black—old = 65–74, and dark grey—very old = 75 and older. BMI groups: ■ = normal weight (NW), ● = overweight (OW), and ▲ = obese (OB). Models are adjusted for physical activity, smoking status, ethnicity, and education. The bars represent 95% confidence intervals. Reference group: middle-aged, normal weight. *p < .05 represents main effect of BMI.


