Midlife Body Mass Index and Hospitalization and Mortality in Older Age

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Context Abundant evidence links overweight and obesity with impaired health. However, controversies persist as to whether overweight and obesity have additional impact on cardiovascular outcomes independent of their strong associations with established coronary risk factors, eg, high blood pressure and high cholesterol level.

Objective To assess the relation of midlife body mass index with morbidity and mortality outcomes in older age among individuals without and with other major risk factors at baseline.

Design Chicago Heart Association Detection Project in Industry study, a prospective study with baseline (1967-1973) cardiovascular risk classified as low risk (blood pressure ≤120/≤80 mm Hg, serum total cholesterol level <200 mg/dL [5.2 mmol/L], and not currently smoking); moderate risk (nonsmoking and systolic blood pressure 121-139 mm Hg, diastolic blood pressure 81-89 mm Hg, and/or total cholesterol level 200-239 mg/dL [5.2-6.2 mmol/L]); or having any 1, any 2, or all 3 of the following risk factors: blood pressure ≥140/90 mm Hg, total cholesterol level ≥240 mg/dL (6.2 mmol/L), and current cigarette smoking. Body mass index was classified as normal weight (18.5-24.9), overweight (25.0-29.9), or obese (≥30). Mean follow-up was 32 years.

Setting and Participants Participants were 17,643 men and women aged 31 through 64 years, recruited from Chicago-area companies or organizations and free of coronary heart disease (CHD), diabetes, or major electrocardiographic abnormalities at baseline.

Main Outcome Measures Hospitalization and mortality from CHD, cardiovascular disease, or diabetes, beginning at age 65 years.

Results In multivariable analyses that included adjustment for systolic blood pressure and total cholesterol level, the odds ratio (95% confidence interval) for CHD death for obese participants compared with those of normal weight in the same risk category was 1.43 (0.33-6.25) for low risk and 2.07 (1.29-3.31) for moderate risk; for CHD hospitalization, the corresponding results were 4.25 (1.57-11.5) for low risk and 2.04 (1.29-3.24) for moderate risk. Results were similar for other risk groups and for cardiovascular disease, but stronger for diabetes (eg, low risk: 11.0 [2.21-54.5] for mortality and 7.84 [3.95-15.6] for hospitalization).

Conclusion For individuals with no cardiovascular risk factors as well as for those with 1 or more risk factors, those who are obese in middle age have a higher risk of hospitalization and mortality from CHD, cardiovascular disease, and diabetes in older age than those who are normal weight.

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in the absence or presence of other major risk factors.

In this study, we examined the relationship of body mass index (BMI) earlier in life with morbidity and mortality outcomes in older age, ie, 65 years and older. Most adults, including obese persons, survive to age 65 years, and older persons disproportionately bear the burden of morbidity and mortality. The exceptionally long follow-up of the Chicago Heart Association Detection Project in Industry (CHA) study offers a rare opportunity to assess the long-term relationship between midlife BMI and health outcomes in older age, for which limited data exist. The large cohort size permits stratification of all participants into 5 baseline risk categories to examine the risk associated with obesity within risk strata, to our knowledge an analysis that has not been reported before.

METHODS

Baseline Examination and Mortality Follow-up

Between 1967 and 1973, the CHA study recruited 39,522 participants from 84 Chicago-area companies and organizations. Details of the study design and methods have been described.7 Two 4-person research teams trained in standardized methods of data collection performed all measurements. Height and weight were measured with participants wearing light indoor clothing; BMI was calculated as weight in kilograms divided by the square of height in meters. Blood pressure was measured as a single supine reading using a standard mercury sphygmomanometer. Nonfasting serum total cholesterol levels were measured by the Levine-Zak method.7 No lipid fractions were measured. Resting electrocardiograms were coded according to the criteria of the National Cooperative Pooling Project.8 Information on demographics, smoking, medical history, and medication use was collected by questionnaire. According to self-reported, investigator-defined racial/ethnic groups (white, black, Hispanic, Asian or Oriental, and others), the majority of study participants were white (87%). Vital status was ascertained through 2002 for more than 99% of the cohort with local procedures, Social Security Administration records, and the National Death Index. The mean follow-up was 32 years.

The study protocol has received periodic institutional review board approval, and a waiver as described by the Health Insurance Portability and Accountability Act was granted by the institutional review board prior to commencement of the present project. Appropriate administrative and physical safeguards were established to protect confidentiality of the data and to prevent unauthorized use or access.

Morbidity Follow-up

Morbidity data were derived from Medicare fee-for-service claims data obtained from the Centers for Medicare and Medicaid Services for surviving participants who were 65 years or older and thus eligible for Medicare benefits during the period from 1984, the first year Medicare data were available for public use, through 2002. Medicare data for each participant were cross-referenced by Social Security number, sex, name, and birth date. Records include—for each medical service billed to Medicare—date of service, primary discharge diagnosis, and up to 9 other diagnoses coded according to the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM).

Main Outcome Measures

One main outcome measure based on Medicare data was hospitalization for CHD, CVD, and diabetes—the leading causes of morbidity and disability among older adults.9 Hospitalization for CHD or CVD was defined as any primary diagnosis with ICD-9-CM codes 410-414 or 390-459, respectively, in inpatient claims from 1984-2002. Due to small numbers of primary diagnoses of diabetes in inpatient care, we defined “diabetes listed on Medicare records” as any inpatient or any 2 or more outpatient (provided by hospitals, not physicians) diagnoses from 1984-2002 with ICD-9-CM code 250. Since 1 occurrence of diabetes in ambulatory care claims (eg, outpatient services) may indicate diagnostic tests rather than diagnosis of diabetes, 2 or more mentions of the diagnoses in ambulatory care claims were used to establish a diagnosis of diabetes.10

The other main outcome measure was older-age mortality, defined as risk of dying after age 65 years among those who survived to 65 years. We investigated this outcome, as opposed to premature mortality, to focus on health outcomes in older age. Deaths from CHD were defined as underlying cause of death as listed on the death certificate, ascertained from the time cohort participants reached age 65 years to year 2002, using the International Classification of Diseases, Eighth Revision (ICD-8) codes 410-414 for deaths occurring prior to 1995, ICD-9 codes 410-414 (1995-1998), or International Classification of Diseases, 10th Revision (ICD-10) codes 102-125 (1999-2002). The corresponding codes for underlying CVD deaths were 390-459 for ICD-8 and ICD-9 and 100-199 for ICD-10. Diabetes listed on death certificates was defined as “any mention” in multiple causes of death with ICD-8 or ICD-9 code of 250 and ICD-10 codes of E10-E14. Diabetes as underlying cause of death was not investigated due to the small number of deaths (n=89).

Study Cohorts

Participants with CHD (self-report or positive electrocardiographic findings of myocardial infarction), diabetes (self-reported physician diagnosis), major electrocardiographic abnormality, or underweight (BMI <18.5) at baseline were excluded to eliminate the influence of these preexisting conditions on health outcomes later in life. To increase the likelihood that participants would have used services provided by Medicare, those with less than 2 years of Medicare eligibility were also excluded. Of 24,347 participants aged 31 years (the youngest age to have ≥2 years of Medicare data) to 64 years at baseline, 422 had missing data and 3465
had preexisting conditions. A total of 2427 persons died before age 65 years or prior to 1984 and thus did not have any Medicare data available. Another 390 persons died before age 67 years or 1986 and thus had less than 2 years of Medicare data. Therefore, the cohort with hospitalization data (1984-2002) included 17 643 participants (43.1% women).

The cohort to examine older-age mortality included all participants not underweight and free of CHD, diabetes, and major electrocardiographic abnormalities at baseline who survived to age 65 years (n=18 270; baseline mean age, 47.4 years, with an average follow-up of 11.9 years after age 65).

**Risk and Body Mass Index Categories**

Using current guidelines on blood pressure and serum total cholesterol level\(^{11,12}\) applied to baseline cardiovascular risk factors, low cardiovascular risk was defined as systolic blood pressure (SBP) of 120 mm Hg or less, diastolic blood pressure (DBP) of 80 mm Hg or less, no treatment for hypertension, serum total cholesterol level less than 200 mg/dL (5.2 mmol/L), no treatment for hypercholesterolemia, and not currently smoking cigarettes. Participants not at low risk were classified into 4 mutually exclusive groups. Moderate risk was defined as not currently smoking cigarettes and not taking antihypertensive or lipid-lowering medication but having 1 or more of the following: SBP between 121 and 139 mm Hg, DBP between 81 and 89 mm Hg, or serum total cholesterol level between 200 and 239 mg/dL (5.2-6.2 mmol/L). The following risk factors were used to define intermediate risk (1 risk factor), elevated risk (2 risk factors), or highest risk (3 risk factors): (1) SBP of 140 mm Hg or greater, DBP of 90 mm Hg or greater, or taking antihypertensive medication; (2) serum total cholesterol level of 240 mg/dL (6.2 mmol/L) or greater or taking lipid-lowering medication; and (3) currently smoking cigarettes. Each risk category was further stratified into 3

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**Table 1. Baseline Characteristics of Study Participants Aged 31-64 Years, by Risk and Body Mass Index (BMI) Category—Chicago Heart Association Detection Project in Industry Study, 1967-1973**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Low Risk</th>
<th>Moderate Risk</th>
<th>Highest Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Normal</td>
<td>Overweight</td>
<td>Obese</td>
</tr>
<tr>
<td>Participants, No. (%)</td>
<td>693 (3.8)</td>
<td>433 (2.5)</td>
<td>61 (0.4)</td>
</tr>
<tr>
<td>Age, mean (SD), y</td>
<td>43.7 (7.1)</td>
<td>43.8 (7.5)</td>
<td>44.5 (6.6)</td>
</tr>
<tr>
<td>Women, No. (%)</td>
<td>433 (62.5)</td>
<td>150 (34.6)</td>
<td>24 (39.3)</td>
</tr>
<tr>
<td>Age, mean (SD), y</td>
<td>43.7 (7.1)</td>
<td>43.8 (7.5)</td>
<td>44.5 (6.6)</td>
</tr>
<tr>
<td>BMI, mean (SD)</td>
<td>22.4 (1.7)</td>
<td>26.9 (1.3)</td>
<td>32.2 (2.1)</td>
</tr>
<tr>
<td>BMI, mean (SD)</td>
<td>22.4 (1.7)</td>
<td>26.9 (1.3)</td>
<td>32.2 (2.1)</td>
</tr>
<tr>
<td>Smoking, No. (%)</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>BMI, mean (SD)</td>
<td>22.4 (1.7)</td>
<td>26.9 (1.3)</td>
<td>32.2 (2.1)</td>
</tr>
<tr>
<td>Blood pressure, mean (SD), mm Hg</td>
<td>114.6 (6.2)</td>
<td>116.5 (5.7)</td>
<td>117.7 (4.5)</td>
</tr>
<tr>
<td>Systolic</td>
<td>70.8 (7.0)</td>
<td>71.7 (7.3)</td>
<td>73.5 (6.5)</td>
</tr>
<tr>
<td>Diastolic</td>
<td>22.9 (1.7)</td>
<td>26.9 (1.3)</td>
<td>32.2 (2.1)</td>
</tr>
<tr>
<td>Blood pressure, mean (SD), mm Hg</td>
<td>1909 (59.7)</td>
<td>999 (28.8)</td>
<td>467 (37.8)</td>
</tr>
<tr>
<td>Systolic</td>
<td>3010 (94.2)</td>
<td>3285 (93.9)</td>
<td>1159 (93.9)</td>
</tr>
<tr>
<td>Diastolic</td>
<td>22.4 (1.7)</td>
<td>26.9 (1.3)</td>
<td>32.2 (2.1)</td>
</tr>
<tr>
<td>Total cholesterol, mean (SD), mg/dL</td>
<td>173.7 (18.3)</td>
<td>178.2 (16.3)</td>
<td>178.9 (14.7)</td>
</tr>
</tbody>
</table>

*SI conversion factor: To convert total cholesterol values to mmol/L, multiply by 0.0259.
*Participants were classified into risk categories with exclusion of persons with coronary heart disease, diabetes, major electrocardiographic abnormality, or underweight (BMI <18.5) at baseline; see “Methods” section for definitions of risk and BMI categories.
*P<.01 for comparisons with persons of normal weight in the same risk category (not presented for the BMI row because BMI was used to define the categories).
*P<.001 for comparisons with persons of normal weight in the same risk category (not presented for the BMI row because BMI was used to define the categories).
*P<.05 for comparisons with persons of normal weight in the same risk category (not presented for the BMI row because BMI was used to define the categories).
(Calculated as weight in kilograms divided by the square of height in meters.)
Statistical Methods

Baseline characteristics were computed across the 15 risk-BMI groups, and comparisons were made within each risk category between normal-weight individuals and the other 2 BMI groups separately by F tests (for continuous variables) or χ² tests (for binary variables). Age-adjusted CHD, CVD, and diabetes death rates per 1000 persons were estimated, as well as incidence rates per 1000 persons for hospitalizations for CHD, CVD, or diabetes. Since the times of exact onset for the binary outcomes of hospitalization were not known, logistic regression (not Cox regression) was used to calculate multivariable-adjusted odds ratios and 95% confidence intervals for each outcome by risk and BMI category. Logistic regression was also used to test differences between normal-weight participants and overweight or obese participants within each risk category. All models were adjusted for sex, race (indicator for blacks), baseline age, education (years), and minor electrocardiographic abnormality. In addition, SBP and serum total cholesterol level were included as continuous variables because of the aim to assess the independent effect of BMI beyond that of other major risk factors. Smoking (or number of cigarettes per day) was not included because it had little or no variation within risk categories (all participants in the low-risk and moderate-risk groups were nonsmokers, and all persons with highest risk were current smokers; for the other 2 risk groups, the variation was small). Cox proportional hazards regression was used to estimate relative risks of mortality by risk and BMI stratum. Separate analyses by sex or smoking status were performed to examine whether patterns differed for men and women or smokers and nonsmokers. Furthermore, multivariable logistic and Cox regression models were performed for the full cohort (not stratified by risk and BMI category) as an additional approach to evaluate the significance of BMI with control for other risk factors. All analyses were performed using SAS version 9.1 (SAS Institute Inc, Cary, NC); P<.05 was used to determine statistical significance.

RESULTS

Of 17 643 participants with at least 2 full years of Medicare exposure, 1187 (6.7%) were at low risk, and only 693 (3.9%) were at both low risk and normal weight at baseline (1967-1973) (TABLE 1). By definition, differences in mean BMI across the weight groups within each risk category were substantial. Except for the low-risk group, overweight and obese individuals had significantly higher levels of blood pressure than did normal-weight persons in the same risk category. Overweight and obese persons were less likely to smoke. In general, differences in cholesterol levels between the weight groups were small.

<table>
<thead>
<tr>
<th>Risk Category</th>
<th>No. at Risk</th>
<th>No. of Events</th>
<th>Odds Ratio</th>
<th>95% CI</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Risk</td>
<td>693</td>
<td>15</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate Risk</td>
<td>1477</td>
<td>14</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intermediate Risk</td>
<td>1284</td>
<td>25</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elevated Risk</td>
<td>1752</td>
<td>166</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Highest Risk</td>
<td>2194</td>
<td>129</td>
<td>100</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Risk adjusted for race (indicator for blacks), sex, baseline age, education (years), minor electrocardiographic abnormality, systolic blood pressure, and serum total cholesterol level. Reference group was the low-risk normal-weight group. Rate/1000 persons indicates age-adjusted death (or incidence) rate per 1000 persons. See “Methods” section for definitions of outcomes and of baseline risk and body mass index categories. Error bars indicate 95% confidence intervals.
Multivariable-adjusted risk of mortality and hospitalization from CHD in older age by risk and BMI category is presented in Figure 1. Being in a higher-risk group was associated with elevated risk of dying from CHD in a graded fashion. Within each risk stratum, the risk was higher for overweight and obese persons than for those of normal weight (Figure 1A). This pattern was true for both absolute risks (age-adjusted death rates per 1000 persons) and relative risks (hazard ratios). For CHD hospitalization, the relative impact of obesity appeared to be stronger for lower-risk than for higher-risk categories (Figure 1B).

For the broader outcome of CVD (including CHD) mortality and hospitalization, results were similar to those for CHD alone (Figure 2). Overweight and obese persons had higher risks of having a CVD-related death (Figure 2A) or hospitalization (Figure 2B) than did individuals of normal weight with similar baseline risk profile. The relationship held true for both outcomes and all 5 risk categories, especially for obesity.

Compared with CHD and CVD, the impact of overweight and obesity on diabetes was stronger and statistically significant for almost all risk categories (Figure 3). Despite the small numbers with diabetes listed on death certificates in some subgroups (Figure 3A), results were generally consistent with diabetes diagnoses listed on Medicare hospitalization records (Figure 3B).

In the 3 figures herein, the 14 odds ratios shown in each panel were from a single regression model with comparison to a single reference group. To provide direct comparisons of overweight and obesity with normal weight for each risk category, 5 separate regression models for the 5 risk categories were conducted for each outcome, with normal weight in the corresponding risk category as the reference group in each model (Table 2). Within each baseline risk category, overweight was associated with higher risk of morbidity and mortality in older age, albeit nonsignificantly in some cases. The elevated risk of obesity was significant and consistent for all outcomes and most risk categories.

In sex-specific analyses, the fundamental relationships between midlife BMI category within each risk group and morbidity and mortality outcomes in older age were substantively similar for both men and women, although in most cases, measures of relative risk (odds ratio or hazard ratio) were larger for women than for men of the same risk and BMI category (results not shown). However, because numbers were smaller, risk estimates were less stable and are not presented herein (data available from authors on request). In separate analyses by smoking status (eg, 6424 current smokers and 11 219 nonsmokers for the hospitalization cohort), results were generally consistent for both smokers and nonsmokers (data available from authors on request).
In an alternative approach, baseline BMI was entered as a continuous variable in multivariable models for the entire cohort, with adjustment for actual baseline blood pressure, serum total cholesterol level, and smoking; BMI was highly predictive (P<.001) of all outcomes (hospitalization and mortality). For example, odds ratios (95% confidence intervals) of experiencing a CHD hospitalization associated with 1-SD higher BMI were 1.16 (1.10-1.22) per 4-point difference in BMI, 1.26 (1.19-1.32) per 38-mg/dL (1.0-3.0 mmol/L) difference in serum total cholesterol level, and 1.07 (1.01-1.13) per 19-mm Hg difference in SBP. For CVD hospitalization and diabetes listed on Medicare records, odds ratios (95% confidence intervals) were 1.20 (1.16-1.25) and 1.79 (1.71-1.87), respectively, per 4-point difference in BMI.

**COMMENT**

In this predominantly white cohort who survived to age 65 years and older, persons who were overweight, and particularly those who were obese earlier in life (aged 31-64 years), had significantly higher risks of hospitalization and mortality in older age compared with persons of normal weight with similar other cardiovascular risk factors at baseline. Elevated risk was present for individuals both with and without other major cardiovascular risk factors (smoking, high blood pressure, and/or serum total cholesterol level) in young adulthood and middle age. In general, relationships were qualitatively consistent for both sexes for both hospitalization for and mortality from CHD, CVD, and diabetes in older age.

The escalating pandemic of overweight and obesity presents a major public health challenge. Among US adults aged 20 through 74 years, the prevalence of obesity increased from 15% in the 1970s to 31% in 2000. This dramatic increase affected both sexes and persons of all ages and racial/ethnic and socioeconomic backgrounds, such that the BMI distribution for the entire population shifted toward the heavier end. Abundant evidence from cross-sectional and prospective population-based and clinical studies has linked excess weight with higher risk of hypertension, dyslipidemia, the metabolic syndrome, CHD, stroke, diabetes, musculoskeletal disorders, and some cancers. Consequently, overweight and obesity in adulthood are also associated with large reductions in life expectancy similar in magnitude to those associated with smoking, and overweight resulting from adverse diet and physical inactivity may soon overtake smoking as the “actual” leading cause of death. A recent controversial article even concluded that the effect of obesity potentially may bring a decline in life expectancy in the United States in the 21st century.

Most previous research did not directly address the issue of whether BMI...
had an independent impact on cardiovascular outcomes apart from its associations with established risk factors such as blood pressure, serum total cholesterol level, and diabetes. In regression analyses that adjusted both for BMI and for obesity-related risk factors, results on the relationship of BMI with risk of CHD and CVD mortality have been inconsistent, with many outcomes showing significantly positive associations, and its unique contribution to risk assessment can be difficult to quantify.5 Data from the CHA cohort have recently demonstrated that in shorter-term follow-up, no consistent relationships between BMI and mortality from CVD emerged for young, middle-aged, or older men and women; however, with exclusion of early deaths and longer follow-up, BMI was significantly and directly related to CVD mortality for 7 of 8 age-sex subgroups, with adjustment for blood pressure, serum total cholesterol level, diabetes, and smoking.3

In light of these previous findings on the long-term impacts of obesity earlier in life,3 we investigated the long-term relationship between midlife BMI and morbidity conditions in older age. The main outcome measures were hospitalization for and mortality from CHD, CVD, and diabetes—common chronic diseases and leading causes of morbidity and disability among older adults.9 These outcomes are important to investigate in an era of population aging marked by an unprecedented large number of older adults resulting from the baby boomer generation and dramatic improvements in life expectancy for the entire population.26 The results were generally consistent for both hospitalization and mortality. The additional impact on these outcomes of BMI beyond traditional major risk factors assessed at baseline was present for all 3 disease categories and was especially strong for diabetes (as expected, since obesity is the most important risk factor for diabetes1).

The large size of the CHA cohort and the long-term follow-up, together with baseline measurement of the major risk factors at ages 31 through 64 years, allowed us to examine the differential impact in older age of normal weight, overweight, and obesity according to 5 risk levels defined by blood pressure, cholesterol level, and smoking. Individuals with favorable levels of blood pressure and serum total cholesterol without medication use and not currently smoking cigarettes (ie, low risk) earlier in life have markedly lower CHD, CVD, and all-cause mortality.27 lower medical costs,28 and higher health-related quality of life29 than do those with adverse risk factor profiles. Prior research on low-risk status did not include BMI in the risk definition.27,28 The present study shows that among participants surviving to age 65 years and older (the majority of the cohort), having a normal BMI in young adulthood and middle age confers significant health benefits at all levels of traditional risk factors.

### Table 2. Comparisons of Midlife Overweight and Obesity With Normal Weight Within Each Risk Category, With Regard to Risk of Hospitalization and Mortality From Coronary Heart Disease, Cardiovascular Disease, and Diabetes in Older Age*  

<table>
<thead>
<tr>
<th>Risk and BMI Category†</th>
<th>Coronary Heart Disease</th>
<th>Cardiovascular Disease</th>
<th>Diabetes Listed on</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mortality, HR (95% CI)</td>
<td>Mortality, HR (95% CI)</td>
<td>Death Certificates, OR (95% CI)</td>
</tr>
<tr>
<td>Low risk</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal weight</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Overweight</td>
<td>1.30 (0.63-2.69)</td>
<td>1.33 (0.63-2.79)</td>
<td>1.16 (0.70-1.91)</td>
</tr>
<tr>
<td>Obese</td>
<td>1.43 (0.33-6.25)</td>
<td>4.25 (1.57-11.5)</td>
<td>1.29 (0.46-3.62)</td>
</tr>
<tr>
<td>Moderate risk</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal weight</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Overweight</td>
<td>1.10 (0.77-1.56)</td>
<td>1.81 (1.33-2.47)</td>
<td>1.20 (0.93-1.54)</td>
</tr>
<tr>
<td>Obese</td>
<td>2.07 (1.29-3.31)</td>
<td>2.04 (1.29-3.24)</td>
<td>1.81 (1.25-2.61)</td>
</tr>
<tr>
<td>Intermediate risk</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal weight</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Overweight</td>
<td>1.05 (0.87-1.24)</td>
<td>1.25 (1.04-1.49)</td>
<td>0.98 (0.86-1.12)</td>
</tr>
<tr>
<td>Obese</td>
<td>1.56 (1.27-1.92)</td>
<td>1.38 (1.10-1.74)</td>
<td>1.42 (1.22-1.67)</td>
</tr>
<tr>
<td>Elevated risk</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal weight</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Overweight</td>
<td>1.07 (0.88-1.29)</td>
<td>1.44 (1.16-1.77)</td>
<td>1.03 (0.89-1.19)</td>
</tr>
<tr>
<td>Obese</td>
<td>1.28 (1.02-1.61)</td>
<td>1.27 (0.97-1.66)</td>
<td>1.28 (1.07-1.53)</td>
</tr>
<tr>
<td>Highest risk</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal weight</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Overweight</td>
<td>1.13 (0.74-1.72)</td>
<td>1.49 (0.94-2.37)</td>
<td>0.96 (0.69-1.32)</td>
</tr>
<tr>
<td>Obese</td>
<td>1.67 (1.01-2.75)</td>
<td>1.07 (0.57-2.00)</td>
<td>1.46 (0.99-2.16)</td>
</tr>
</tbody>
</table>

Abbreviations: BMI, body mass index; CI, confidence interval; HR, hazard ratio; OR, odds ratio.

*Adjusted for race (indicator for blacks), sex, baseline age, education (years), minor electrocardiographic abnormality, systolic blood pressure, and serum total cholesterol level.
†See “Methods” section for definitions of outcomes and of baseline risk and BMI categories.
Low risk is uncommon in the general population. In our cohort (1967-1973), the prevalence of low risk based on the traditional risk factors was 6.7%; with additional inclusion of normal weight (BMI 18.5-24.9), it decreased to only 3.9%. We found a lower risk of morbidity in older age for persons of normal weight, not only among low-risk and moderate-risk individuals who did not currently smoke or who have high blood pressure or cholesterol levels at baseline, but also among individuals with higher levels of traditional risk factors. A clear graded association between baseline risk status and disease outcomes was also observed across the 5 risk categories. The dose-response relationship of risk categories and the fact that elevated BMI has additional effects in each risk category have significant public health implications.

A limitation of this study is the use of Medicare data for ascertainment of morbidity outcomes. Medicare data are designed for administrative use, and they are not available before 1984, for most adults younger than 65 years, or for the small proportion of health maintenance organization or Veterans Administration enrollees. However, Medicare data are frequently used in epidemiologic and health services research, and the validity of defining disease outcomes on the basis of Medicare claims has been demonstrated. Enrollment of Medicare-eligible individuals in health maintenance organization–style plans in Illinois was 4% in 1994, 7% in 1997, and 6% in 2002. Only a very small proportion (less than 2%) of our cohort had received care through the Veterans Administration.

Other than the Medicare records, no other interim comorbidity data are available in this data set. Nevertheless, the consistency between results on mortality and morbidity adds credibility to our findings. Our results should be interpreted with caution, as numbers for some of the 15 risk and BMI subgroups were small. Another limitation is the lack of repeated risk factor measurements over time. The influence of midlife BMI on older-age morbidities could be partially mediated through its effects on the eventual occurrence of hypertension, hypercholesterolemia, and diabetes later in life.

Nonetheless, our results underscore the importance of including BMI earlier in life in comprehensive risk assessment. Lastly, some other important lifestyle factors, such as diet and exercise, were not assessed at baseline. The influence of these 2 characteristics is, however, indirectly reflected in the 3 diet-dependent major risk factors, ie, blood pressure, total cholesterol level, and BMI.

Clinical trials have demonstrated the effectiveness of lifestyle (diet and exercise) modifications in risk factor reduction and health promotion at the individual level. At the population level, small downward shifts in the distribution of BMI levels could have tremendous societal impact on public health. Convincing evidence from our findings and other studies provides strong support for population-wide, multifaceted, primary prevention starting at young age of all major risk factors, including overweight and obesity, as a key element for the national effort to continue the progress already achieved toward ending the epidemic of CHD and CVD. The success of smoking cessation campaigns and national blood pressure and cholesterol programs can be used as models to combat and reverse the worsening obesity epidemic. The real challenge is to apply the extensive knowledge already gained in the practice of medical care and public health for the benefit of individuals and society.

Author Contributions: Dr Yan had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

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References


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