Body Weight and Mortality Among Men and Women in China

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THE PREVALENCE OF OBESITY IS increasing to epidemic proportions at an alarming rate around the world.1,2 It is estimated that more than 1 billion adults worldwide are overweight (body mass index [BMI, calculated as weight in kilograms divided by the square of height in meters] of 25.0-29.9) and more than 300 million adults worldwide are obese (BMI ≥ 30.0).1 The prevalence of obesity and overweight has increased dramatically in economically developed countries as well as in developing countries, such as Asian populations.3,4 Observational epidemiological studies have documented that obesity is a strong and independent risk factor for diabetes mellitus, coronary heart disease, stroke, and some types of cancer.5,6 However, the association between body weight and all-cause mortality is more controversial: a direct association or a J-shaped or U-shaped relationship have been reported in recent studies.9,10 Most of these studies have been conducted in Western populations in which only a small proportion of the study participants have had a low BMI. In addition, lifestyle or medical interventions for weight loss are common in Western populations, which might confound any association between body weight and mortality. Furthermore, self-reported body weight and height were used among many previous studies.

Context The effect of underweight and obesity on mortality has not been well characterized in Asian populations.

Objective To examine the relationship between body mass index (BMI) and mortality in Chinese adults.

Design, Setting, and Participants A prospective cohort study in a nationally representative sample of 169,871 Chinese men and women aged 40 years or older. Data on body weight and covariables were obtained at a baseline examination in 1991 using a standard protocol. Follow-up evaluation was conducted in 1999-2000, with a response rate of 93.4% (n = 158,666).

Main Outcome Measures Body mass index and all-cause mortality.

Results After excluding those participants with missing body weight or height values, 154,736 adults were included in the analysis. After adjustment for age, sex, cigarette smoking, alcohol consumption, physical activity, education, geographic region (north vs south), and urbanization (urban vs rural), a U-shaped association between BMI and all-cause mortality was observed (P < .001). Using those participants with a BMI of 24.0 to 24.9 as the reference group, the relative risks of all-cause mortality across categories of BMI were 1.65 (95% confidence interval [CI], 1.54-1.77) for BMI less than 18.5, 1.31 (95% CI, 1.22-1.41) for BMI 18.5 to 19.9, 1.20 (95% CI, 1.11-1.29) for BMI 20.0 to 20.9, 1.12 (95% CI, 1.04-1.21) for BMI 21.0 to 21.9, 1.11 (95% CI, 1.03-1.20) for BMI 22.0 to 22.9, 1.09 (95% CI, 1.01-1.19) for BMI 23.0 to 23.9, 1.00 (95% CI, 0.92-1.08) for BMI 24.0 to 24.9 as the reference group, the relative risks of all-cause mortality across categories of BMI were 1.65 (95% CI, 1.54-1.77) for BMI less than 18.5, 1.31 (95% CI, 1.22-1.41) for BMI 18.5 to 19.9, 1.20 (95% CI, 1.11-1.29) for BMI 20.0 to 20.9, 1.12 (95% CI, 1.04-1.21) for BMI 21.0 to 21.9, 1.11 (95% CI, 1.03-1.20) for BMI 22.0 to 22.9, 1.09 (95% CI, 1.01-1.19) for BMI 23.0 to 23.9, 1.00 (95% CI, 0.92-1.08) for BMI 24.0 to 24.9 as the reference group, the relative risks of all-cause mortality across categories of BMI were 1.65 (95% CI, 1.54-1.77) for BMI less than 18.5, 1.31 (95% CI, 1.22-1.41) for BMI 18.5 to 19.9, 1.20 (95% CI, 1.11-1.29) for BMI 20.0 to 20.9, 1.12 (95% CI, 1.04-1.21) for BMI 21.0 to 21.9, 1.11 (95% CI, 1.03-1.20) for BMI 22.0 to 22.9, 1.09 (95% CI, 1.01-1.19) for BMI 23.0 to 23.9, 1.00 (95% CI, 0.92-1.08) for BMI 24.0 to 24.9 as the reference group, the relative risks of all-cause mortality across categories of BMI were 1.65 (95% CI, 1.54-1.77) for BMI less than 18.5, 1.31 (95% CI, 1.22-1.41) for BMI 18.5 to 19.9, 1.20 (95% CI, 1.11-1.29) for BMI 20.0 to 20.9, 1.12 (95% CI, 1.04-1.21) for BMI 21.0 to 21.9, 1.11 (95% CI, 1.03-1.20) for BMI 22.0 to 22.9, 1.09 (95% CI, 1.01-1.19) for BMI 23.0 to 23.9, 1.00 (95% CI, 0.92-1.08) for BMI 24.0 to 24.9 as the reference group, the relative risks of all-cause mortality across categories of BMI were 1.65 (95% CI, 1.54-1.77) for BMI less than 18.5, 1.31 (95% CI, 1.22-1.41) for BMI 18.5 to 19.9, 1.20 (95% CI, 1.11-1.29) for BMI 20.0 to 20.9, 1.12 (95% CI, 1.04-1.21) for BMI 21.0 to 21.9, 1.11 (95% CI, 1.03-1.20) for BMI 22.0 to 22.9, 1.09 (95% CI, 1.01-1.19) for BMI 23.0 to 23.9, 1.00 (95% CI, 0.92-1.08) for BMI 24.0 to 24.9 as the reference group, the relative risks of all-cause mortality across categories of BMI were 1.65 (95% CI, 1.54-1.77) for BMI less than 18.5, 1.31 (95% CI, 1.22-1.41) for BMI 18.5 to 19.9, 1.20 (95% CI, 1.11-1.29) for BMI 20.0 to 20.9, 1.12 (95% CI, 1.04-1.21) for BMI 21.0 to 21.9, 1.11 (95% CI, 1.03-1.20) for BMI 22.0 to 22.9, 1.09 (95% CI, 1.01-1.19) for BMI 23.0 to 23.9, 1.00 (95% CI, 0.92-1.08)

Conclusions Our results indicate that both underweight and obesity were associated with increased mortality in the Chinese adult population. Furthermore, our findings support the use of a single common recommendation for defining overweight and obesity among all racial and ethnic groups.

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Asian populations have higher amounts of body fat and prevalence of cardiovascular disease risk factors at lower levels of BMI compared with their counterparts in Western populations.\textsuperscript{16-20} Based on these findings, the World Health Organization (WHO), the International Association for the Study of Obesity, and the International Obesity Task Force have suggested lower BMI cutoffs for overweight (23.0-24.9) and obesity (\geq 25.0) in Asian populations, labeling these recommendations as provisional and calling for validation in clinical and epidemiological studies.\textsuperscript{21}

In a large prospective cohort study, we examined the relationship between BMI and mortality from all causes and from specific causes in a nationally representative sample of the Chinese adult population. We also assessed whether the present data support the lower BMI cutoffs for defining overweight and obesity in the Asian populations.

\textbf{METHODS}

\textbf{Study Population}

In the 1991 China National Hypertension Survey, a multistage random cluster sampling design was used to select a representative sample of the general Chinese population aged 15 years or older from all 30 provinces in mainland China.\textsuperscript{22} In 1999, investigators from each province were invited to participate in the China National Hypertension Survey Epidemiology Follow-up study. Of the 30 provinces, 13 were not included in the follow-up study because study participants’ contact information was not available. However, the sampling process was conducted independently within each province in the 1991 China National Hypertension Survey and the 17 provinces that were included in the follow-up study were evenly distributed in different geographic regions representing various economic developing statuses in China. Overall, 83,533 men and 86,338 women who were aged 40 years or older at their baseline examination were eligible to participate in the follow-up study. From this population, a total of 158,666 study participants (93.4\%) (or their proxies) were identified and interviewed as part of the follow-up study. After excluding those participants with missing body weight or height values, data from 154,736 study participants were used in our analysis.

\textbf{Baseline Examination}

Baseline data were collected at a single clinic visit by specially trained physicians and nurses using standardized methods with stringent levels of quality control.\textsuperscript{22} Data on demographic characteristics, medical history, and lifestyle risk factors were obtained using a standard questionnaire administered by trained staff. Work-related physical activity was assessed because leisure-time physical activity was uncommon. High school education was defined as high school education or higher. Cigarette smokers were defined as having smoked at least 1 cigarette per day for 1 year or more. The amount and type of alcohol consumed during the past year was collected. Alcohol consumption was defined as drinking alcohol at least 12 times during the last year. Three blood pressure readings were obtained after the study participant had been seated quietly for 5 minutes. Hypertension was defined as a mean systolic blood pressure of at least 140 mm Hg, a diastolic blood pressure of at least 90 mm Hg, and/or use of antihypertensive medication. Body weight and height were measured in light indoor clothing without shoes, using a standard protocol. Height was measured with the participant standing on a firm, level surface at a right angle to the vertical board of the height measurement device. A height board mounted at a 90° angle to a calibrated vertical height bar was used. Body mass index was then calculated as weight in kilograms divided by height in square meters.

\textbf{Follow-up Data Collection}

The follow-up examination, which was conducted between 1999 and 2000, included tracking study participants or their proxies to a current address, performing in-depth interviews to ascertain disease status and vital information, and obtaining hospital records and death certificates. All deaths reported during the in-person interview were verified by obtaining death certificates from the local public health department or police department. If death occurred during a hospitalization, the participant’s hospital records, including medical history, physical examination findings, laboratory test results, autopsy reports, and discharge diagnosis, were abstracted by trained staff using a standard form. In addition, photocopies of selected sections of the participant’s inpatient record, discharge summary, electrocardiogram, and pathology reports were obtained. An end point assessment committee within each province reviewed and confirmed (or rejected) the hospital discharge diagnosis and cause of death based on the abstracted information using preestablished criteria.

A study-wide end point assessment committee at the Chinese Academy of Medical Sciences in Beijing, China, reviewed all death records and determined the final underlying cause of death. Two committee members independently verified the cause of death and discrepancies were adjudicated by discussion involving additional committee members. All members of the local and study-wide end point assessment committees were blinded to the study participant’s baseline risk factor information. Causes of death were coded according to the \textit{International Classification of Diseases, Ninth Revision}. This study was approved by the Tulane University Health Sciences Center Institutional Review Board and the Cardiovascular Institute and Fu Wai Hospital Ethics Committee. Written informed consent was obtained from all study participants at their follow-up visit.

\textbf{Statistical Analysis}

Study participants were grouped according to 10 categories of BMI, as measured at the baseline examination (<18.5, 18.5-19.9, 20.0-20.9, 21.0-22.9, 23.0-23.9, 24.0-24.9, 25.0-26.9, 27.0-28.9, 29.0-29.9, \geq 30.0).

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hyperc 1.64 (95% CI, 1.49-1.80) and hypertension were more prevalent among heavier participants.

During a mean follow-up of 8.3 years (1 113 162 person-years), 17 687 deaths were documented. There was a statistically significant U-shaped association between BMI and age-standardized all-cause mortality ($P<$0.001), with the lowest mortality among study participants with a BMI of 24.0 to 24.9 in men and 25.0 to 26.9 in women (TABLE 2). This U-shaped association between BMI and all-cause mortality remained after multivariate adjustment for important risk factors, including age, sex, cigarette smoking, alcohol consumption, physical activity, education, geographic region (north vs south), and urbanization (urban vs rural). Hypertension was not adjusted for in the primary analyses because it is an intermediate factor in the causal path between BMI and mortality. However, the results were similar after adjustment for hypertension in sensitivity analyses. Multivariate-adjusted relative risk (RR) was calculated using study participants with a BMI of 24.0 to 24.9 as the reference group because this group had the lowest mortality. The presence of a linear or U-shaped (quadratic term) association was tested using the median of BMI in each category as a continuous variable in the Cox proportional hazards regression models. $P$ values for the quadratic term from the Cox proportional hazards regression models reported were based on all linear terms were not statistically significant (all $P$ > 0.05). Subgroup analyses by age (<65 or $\geq$65 years) or baseline health status (present prevalent cardiovascular disease, stroke, cancer, end-stage renal disease, chronic obstructive pulmonary disease, cigarette smoking, or heavy alcohol drinking [consumption of $\geq$3 drinks per day]) were conducted. Methods to estimate variances that take into account sample clustering were used in Cox proportional hazards regression models.

Statistical analyses were conducted using SAS statistical software version 9.1 (SAS Institute Inc, Cary, NC).

## RESULTS

Baseline characteristics of the study participants are presented according to 10 categories of BMI in TABLE 1. Body mass index was inversely related to age. Male sex, cigarette smoking, and alcohol consumption were more common among leaner study participants, and physical inactivity, a high school education (high school or higher education), and hypertension were more prevalent among heavier participants.

### Table 1. Baseline Characteristics of Study Participants According to Body Mass Index

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>&lt;18.5</th>
<th>18.5-19.9</th>
<th>20.0-20.9</th>
<th>21.0-21.9</th>
<th>22.0-22.9</th>
<th>23.0-23.9</th>
<th>24.0-24.9</th>
<th>25.0-26.9</th>
<th>27.0-29.9</th>
<th>$\geq$30.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of participants</td>
<td>17 998</td>
<td>20 742</td>
<td>17 128</td>
<td>17 429</td>
<td>16 658</td>
<td>14 745</td>
<td>13 233</td>
<td>18 466</td>
<td>13 227</td>
<td>5110</td>
</tr>
<tr>
<td>BMI, mean (SD)</td>
<td>21.9 (1.1)</td>
<td>22.0 (1.2)</td>
<td>22.1 (1.3)</td>
<td>22.2 (1.4)</td>
<td>22.3 (1.5)</td>
<td>22.4 (1.6)</td>
<td>22.5 (1.7)</td>
<td>22.6 (1.8)</td>
<td>22.7 (1.9)</td>
<td>22.8 (2.0)</td>
</tr>
<tr>
<td>Age, mean (SD)</td>
<td>56.4 (10.5)</td>
<td>54.7 (10.5)</td>
<td>54.7 (10.5)</td>
<td>54.7 (10.5)</td>
<td>54.7 (10.5)</td>
<td>54.7 (10.5)</td>
<td>54.7 (10.5)</td>
<td>54.7 (10.5)</td>
<td>54.7 (10.5)</td>
<td>54.7 (10.5)</td>
</tr>
<tr>
<td>Sex, %</td>
<td>51.2 (50.6)</td>
<td>48.8 (51.0)</td>
<td>48.8 (51.0)</td>
<td>48.8 (51.0)</td>
<td>48.8 (51.0)</td>
<td>48.8 (51.0)</td>
<td>48.8 (51.0)</td>
<td>48.8 (51.0)</td>
<td>48.8 (51.0)</td>
<td>48.8 (51.0)</td>
</tr>
<tr>
<td>Cigarette smokers, %</td>
<td>7874 (43.8)</td>
<td>9166 (44.4)</td>
<td>7315 (42.9)</td>
<td>6909 (39.9)</td>
<td>6296 (38.0)</td>
<td>5232 (35.7)</td>
<td>4477 (33.8)</td>
<td>3883 (29.5)</td>
<td>2390 (46.8)</td>
<td></td>
</tr>
<tr>
<td>Alcohol consumption, %</td>
<td>3094 (17.2)</td>
<td>4483 (21.7)</td>
<td>3859 (22.7)</td>
<td>3790 (21.9)</td>
<td>3479 (21.0)</td>
<td>2992 (20.4)</td>
<td>2531 (19.2)</td>
<td>2388 (19.0)</td>
<td>2226 (16.9)</td>
<td></td>
</tr>
<tr>
<td>Physical inactivity, %</td>
<td>5983 (33.2)</td>
<td>5861 (28.3)</td>
<td>5197 (30.3)</td>
<td>5738 (32.9)</td>
<td>6165 (40.9)</td>
<td>5594 (42.0)</td>
<td>8242 (44.6)</td>
<td>6001 (45.4)</td>
<td>2390 (46.8)</td>
<td></td>
</tr>
<tr>
<td>High school education, %</td>
<td>2096 (11.7)</td>
<td>3105 (15.1)</td>
<td>3135 (18.5)</td>
<td>3843 (22.3)</td>
<td>4356 (26.5)</td>
<td>4321 (29.7)</td>
<td>4178 (22.2)</td>
<td>6309 (34.7)</td>
<td>4173 (31.8)</td>
<td>1364 (26.8)</td>
</tr>
</tbody>
</table>

*Body mass index was calculated as weight in kilograms divided by the square of height in meters. Cigarette smoking was defined as smoking at least 1 cigarette per day for 1 year or more. Alcohol consumption was defined as drinking alcohol at least 12 times during the last year. Physical activity was assessed based on participants’ work-related activity only. High school education was defined as high school education or higher. Hypertension was defined as a mean systolic blood pressure of at least 140 mm Hg, a diastolic blood pressure of at least 90 mm Hg, and/or use of antihypertensive medication.

## Acknowledgments

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## References

weight (BMI <18.5), and 1.34 (95% CI, 1.15-1.55) and 1.24 (95% CI, 1.08-1.43) for obesity (BMI ≥30.0), in men and women, respectively.

The U-shaped association between BMI and all-cause mortality was also present when the WHO/National Heart, Lung, and Blood Institute criteria were used. For example, the multivariate-adjusted RRs for participants with a BMI of less than 18.5, 18.5 to 29.9, and 30.0 or more were 1.41 (95% CI, 1.35-1.46), 0.93 (95% CI, 0.89-0.97), and 1.13 (95% CI, 1.04-1.23), respectively, compared with those participants with a BMI of 18.5 to 24.9.

The age-standardized all-cause mortality rate for the 10 categories of BMI was 1583.7, 1238.5, 1042.6, 1022.2, 947.2, 945.2, 830.6, 843.0, 965.3, and 1127.4 per 100 000 person-years, respectively, for participants aged 65 years or older. The corresponding age-standardized all-cause mortality rate for all-cause mortality across BMI categories was 1.53 (95% CI, 1.41-1.67) for BMI less than 18.5, 1.26 (95% CI, 1.16-1.37) for BMI 18.5 to 19.9, 1.20 (95% CI, 1.10-1.31) for BMI 20.0 to 20.9, 1.10 (95% CI, 1.01-1.21) for BMI 21.0 to 21.9, 1.11 (95% CI, 1.01-1.21) for BMI 22.0 to 22.9, 1.09 (95% CI, 0.99-1.20) for BMI 23.0 to 23.9, 1.04 (95% CI, 0.95-1.14) for BMI 24.0 to 24.9, and 1.00 (95% CI, 0.87-1.10) for BMI 25.0 to 26.9.

### Table 2. Age-Standardized All-Cause Mortality and Multivariate-Adjusted Relative Risk According to Body Mass Index

<table>
<thead>
<tr>
<th>Body Mass Index</th>
<th>Total</th>
<th>&lt;18.5</th>
<th>18.5-19.9</th>
<th>20.0-20.9</th>
<th>21.0-21.9</th>
<th>22.0-22.9</th>
<th>23.0-23.9</th>
<th>24.0-24.9</th>
<th>25.0-26.9</th>
<th>27.0-29.9</th>
<th>≥30.0</th>
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</thead>
<tbody>
<tr>
<td>No. of deaths</td>
<td>3881</td>
<td>2826</td>
<td>1955</td>
<td>1686</td>
<td>1575</td>
<td>1298</td>
<td>1083</td>
<td>1508</td>
<td>1277</td>
<td>598</td>
<td></td>
</tr>
<tr>
<td>Person-years of follow-up</td>
<td>122262</td>
<td>149294</td>
<td>124395</td>
<td>126797</td>
<td>121131</td>
<td>107185</td>
<td>96489</td>
<td>134185</td>
<td>95525</td>
<td>36099</td>
<td></td>
</tr>
<tr>
<td>Age-standardized rate, per 100 000 person-years</td>
<td>1888.0</td>
<td>1499.4</td>
<td>1354.4</td>
<td>1242.8</td>
<td>1209.1</td>
<td>1141.8</td>
<td>1037.3</td>
<td>1037.9</td>
<td>1164.4</td>
<td>1301.3</td>
<td></td>
</tr>
<tr>
<td>RR (95% CI)†</td>
<td>1.65 (1.54-1.77)</td>
<td>1.31 (1.22-1.41)</td>
<td>1.20 (1.11-1.29)</td>
<td>1.12 (1.04-1.21)</td>
<td>1.11 (1.03-1.20)</td>
<td>1.09 (1.01-1.19)</td>
<td>1.00</td>
<td>1.00 (0.92-1.08)</td>
<td>1.15 (1.06-1.24)</td>
<td>1.29 (1.16-1.42)</td>
<td></td>
</tr>
<tr>
<td>Men</td>
<td>2037</td>
<td>1751</td>
<td>1189</td>
<td>999</td>
<td>815</td>
<td>767</td>
<td>614</td>
<td>863</td>
<td>677</td>
<td>235</td>
<td></td>
</tr>
<tr>
<td>Person-years of follow-up</td>
<td>54565</td>
<td>78213</td>
<td>66692</td>
<td>66191</td>
<td>61138</td>
<td>53612</td>
<td>46838</td>
<td>65080</td>
<td>39560</td>
<td>10945</td>
<td></td>
</tr>
<tr>
<td>Age-standardized rate, per 100 000 person-years</td>
<td>2168.3</td>
<td>1694.1</td>
<td>1488.4</td>
<td>1345.4</td>
<td>1306.2</td>
<td>1234.7</td>
<td>1116.3</td>
<td>1127.2</td>
<td>1353.8</td>
<td>1422.8</td>
<td></td>
</tr>
<tr>
<td>RR (95% CI)†</td>
<td>1.64 (1.49-1.80)</td>
<td>1.32 (1.20-1.45)</td>
<td>1.17 (1.06-1.30)</td>
<td>1.10 (0.99-1.22)</td>
<td>1.10 (0.99-1.22)</td>
<td>1.09 (0.98-1.21)</td>
<td>1.00</td>
<td>1.01 (0.91-1.13)</td>
<td>1.22 (1.10-1.37)</td>
<td>1.34 (1.15-1.55)</td>
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<tr>
<td>Women</td>
<td>1844</td>
<td>1075</td>
<td>766</td>
<td>687</td>
<td>660</td>
<td>531</td>
<td>469</td>
<td>645</td>
<td>600</td>
<td>363</td>
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<tr>
<td>Person-years of follow-up</td>
<td>67687</td>
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<td>57703</td>
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<td>49651</td>
<td>69106</td>
<td>55765</td>
<td>25154</td>
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<tr>
<td>Age-standardized rate, per 100 000 person-years</td>
<td>1648.3</td>
<td>1233.8</td>
<td>1142.6</td>
<td>1089.3</td>
<td>1073.9</td>
<td>1018.6</td>
<td>958.8</td>
<td>919.2</td>
<td>1016.8</td>
<td>1270.5</td>
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</tr>
<tr>
<td>RR (95% CI)†</td>
<td>1.65 (1.49-1.84)</td>
<td>1.27 (1.14-1.42)</td>
<td>1.21 (1.08-1.36)</td>
<td>1.14 (1.01-1.28)</td>
<td>1.12 (1.00-1.26)</td>
<td>1.10 (0.97-1.24)</td>
<td>1.00</td>
<td>0.98 (0.87-1.10)</td>
<td>1.07 (0.94-1.24)</td>
<td>1.24 (1.08-1.43)</td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: CI, confidence interval; RR, relative risk.

*Body mass index was calculated as weight in kilograms divided by the square of height in meters. All P values for quadratic term were <.001.

†Multivariate-adjusted RR was calculated using study participants with a body mass index of 24.0 to 24.9 as the reference group, adjusted for age, sex, cigarette smoking, alcohol consumption, physical activity, education, geographic region (north vs south), and urbanization (urban vs rural), and stratified by sampling clusters.

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During follow-up, 8079 deaths from cardiovascular disease, 3929 deaths from cancer, and 5679 deaths from other causes were documented. The age-standardized mortality rate from cardiovascular disease across BMI categories was 765.3, 617.0, 578.4, 536.6, 549.8, 535.8, 526.5, 517.9, and 658.0 per 100 000 person-years, respectively. The corresponding age-standardized mortality rate from cancer across BMI categories was 384.3, 347.2, 303.4, 267.5, 277.1, 256.7, 245.7, 229.2, 266.7, and 248.2 per 100 000 person-years, respectively, and from other causes was 738.5, 535.3, 473.3, 438.8, 382.2, 349.3, 294.8, 282.2, 279.8, and 395.1 per 100 000 person-years, respectively. There was a statistically significant U-shaped association between BMI and mortality from cardiovascular disease, cancer, and other causes after adjustment for important risk factors (Table 3). The relationship between BMI and cause-specific mortality was consistent among men and women.

**COMMENT**

A U-shaped association between BMI and age-standardized all-cause mortality has been observed in several prospective cohort studies conducted in Western populations.13,14,24 The study by Allison et al24 examined data from 6 prospective cohort studies conducted in US populations. A U-shaped association between BMI and all-cause mortality was observed among all cohorts, with the lowest mortality for persons with a BMI between 23.0 to 23.9 and 26.0 to 26.9. In the Cancer Prevention Study II,13 a prospective study of mortality among 1184 657 men and women in the United States, a U-shaped association between BMI and all-cause mortality was documented for all subgroups, according to smoking status and the presence of a history of disease. The lowest all-cause mortality was found among study participants with a BMI between 22.0 to 23.4 and 26.5 to 27.9. In our large population-based, prospective cohort study, the lowest rates of all-cause mortality were found at a BMI of 24.0 to 24.9 in Chinese men and 25.0 to 26.9 in Chinese women. The study participants who were underweight (BMI <18.5) or who had low normal weight (BMI of 18.5-22.9) had a significantly
increased all-cause mortality rate compared with participants with a BMI of 24.0 to 24.9 in both men and women. In addition, a BMI of more than 27.0 in men and more than 30.0 in women was associated with increased all-cause mortality.

The unique features of our study include its large sample size and the relatively high proportion of participants who were underweight or who had low normal weight (BMI <23.0). We documented 11,923 deaths during 643,878 person-years of follow-up among study participants with a BMI of less than 23.0. As such, we are able to examine the relationship between low body weight and mortality with great precision and statistical power. Another advantage of our cohort was that it used a nationally representative sample of the general Chinese adult population. Our study also used stringent quality control procedures at the baseline examination and in assessing study outcomes during follow-up. Unlike other large cohort studies,9,13 body weight and height were measured in our study using a standard protocol. A high follow-up rate was achieved in our study. A major limitation was that body weight changes over time were not measured. Therefore, we were not able to evalu-

Table 3. Age-Standardized Mortality and Multivariate-Adjusted Relative Risk for Cardiovascular Disease, Cancer, and Other Causes According to Body Mass Index*

<table>
<thead>
<tr>
<th>Body Mass Index</th>
<th>Cardiovascular Disease†</th>
<th>Cancer†</th>
<th>Other Causes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RR (95% CI)‡</td>
<td>RR (95% CI)†‡</td>
<td>RR (95% CI)‡</td>
</tr>
<tr>
<td>Men</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;18.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age-standardized rate, per 100,000 person-years</td>
<td>875.9</td>
<td>698.8</td>
<td>596.1</td>
</tr>
<tr>
<td>RR (95% CI)‡</td>
<td></td>
<td>1.45 (1.26-1.66)</td>
<td>1.18 (1.03-1.35)</td>
</tr>
<tr>
<td>18.5-19.9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age-standardized rate, per 100,000 person-years</td>
<td>671.6</td>
<td>508.0</td>
<td>541.7</td>
</tr>
<tr>
<td>RR (95% CI)†‡</td>
<td></td>
<td>1.48 (1.27-1.72)</td>
<td>1.14 (0.97-1.34)</td>
</tr>
<tr>
<td>20.0-20.9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age-standardized rate, per 100,000 person-years</td>
<td>478.0</td>
<td>495.7</td>
<td>421.7</td>
</tr>
<tr>
<td>RR (95% CI)‡</td>
<td></td>
<td>1.49 (1.23-1.81)</td>
<td>1.40 (1.16-1.68)</td>
</tr>
<tr>
<td>21.0-21.9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age-standardized rate, per 100,000 person-years</td>
<td>305.3</td>
<td>233.8</td>
<td>165.9</td>
</tr>
<tr>
<td>RR (95% CI)‡</td>
<td></td>
<td>1.56 (1.24-1.97)</td>
<td>1.27 (1.00-1.62)</td>
</tr>
<tr>
<td>22.0-22.9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age-standardized rate, per 100,000 person-years</td>
<td>814.3</td>
<td>549.7</td>
<td>480.5</td>
</tr>
<tr>
<td>RR (95% CI)‡</td>
<td></td>
<td>2.12 (1.77-2.55)</td>
<td>1.55 (1.28-1.87)</td>
</tr>
<tr>
<td>23.0-23.9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age-standardized rate, per 100,000 person-years</td>
<td>671.4</td>
<td>492.0</td>
<td>436.4</td>
</tr>
<tr>
<td>RR (95% CI)‡</td>
<td></td>
<td>2.00 (1.66-2.42)</td>
<td>1.50 (1.23-1.83)</td>
</tr>
</tbody>
</table>

Abbreviations: CI, confidence interval; RR, relative risk.

*Body mass index was calculated as weight in kilograms divided by the square of height in meters. All P values for quadratic term were <.001.
†Cardiovascular disease (International Classification of Diseases, Ninth Revision) included acute rheumatic fever (codes 390-392), chronic rheumatic heart disease (codes 393-398), hypertensive disease (codes 401-405), ischemic heart disease (codes 410-414), diseases of pulmonary circulation (codes 415-417), other forms of heart disease (codes 418-429), and cerebrovascular disease (codes 430-438). Cancer included all types of malignant neoplasm (codes 140-208).
‡Multivariate-adjusted RR was calculated using study participants with a body mass index of 24.0 to 24.9 as the reference group, adjusted for age, sex, cigarette smoking, alcohol consumption, physical activity, education, geographic region (north vs south), and urbanization (urban vs rural), and stratified by sampling clusters.

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Body weight and mortality in China

Age has been proposed as an effect modifier for the relationship between body weight and all-cause mortality in several epidemiological studies. However, few studies have had adequate sample size to analyze the effect of a low BMI on all-cause mortality across age groups. Our study indicated that the U-shaped association between BMI and all-cause mortality was consistently present for study participants aged 40 to 64 years and 65 years or older. Our study does not support the theory that a high mortality rate among elderly persons with a low body weight accounts for the U-shaped association between BMI and all-cause mortality.

In a sensitivity analysis, we excluded individuals who had prevalent cardiovascular disease, stroke, cancer, end-stage renal disease, or chronic obstructive pulmonary disease at the baseline examination, or deaths that occurred during the first 3 years of follow-up. Furthermore, we excluded cigarette smokers and heavy alcohol drinkers in the sensitivity analysis because cigarette smoking and heavy alcohol consumption have been shown to be related to both low body weight and high mortality. These exclusions and the long duration of follow-up would be expected to minimize the potential bias caused by the presence of clinical or subclinical disease at the baseline examination and by illness-related weight loss.

The WHO, the International Association for the Study of Obesity, and the International Obesity Task Force have recommended lower BMI cutpoints for defining overweight and obesity in Asian populations. Few prospective cohort studies have examined the association between body weight and mortality from all causes in Asian populations. Yuan et al found a U-shaped relationship between BMI and all-cause mortality among lifelong nonsmokers in a cohort of 18,244 Chinese men aged 45 to 64 years in Shanghai, China. Compared with nonsmokers with a BMI of 21.0 to 23.4, the RR for men with a BMI of less than 18.5 and 1.48 for men with a BMI of 26.0 or more after adjustment for age, education, and alcohol consumption. The study by Zhou reported a meta-analysis of four prospective cohorts with a total of 76,227 Chinese adults. A U-shaped association between BMI and all-cause mortality was identified, even after exclusion of those participants who died during the first 3 years of follow-up and exclusion of cigarette smokers. Age-adjusted all-cause mortality was lowest in persons with a BMI of 24.0 to 27.9 and higher in persons with a BMI of less than 18.5 or 28.0 or more. Our study findings are consistent with these previous studies and do not support the use of a lower cutoff for obesity in the Chinese population.

In conclusion, our study indicates that both obesity and underweight are associated with increased mortality from all causes in the Chinese adult population. The relationship between BMI and all-cause mortality and mortality from cardiovascular disease, cancer, and other causes was consistent among men and women, those persons who were middle-aged or older, never smokers, and persons who did not have a chronic illness at baseline and who did not die during the first 3 years of follow-up. Our findings are also consistent with observations from Western populations that have identified the lowest all-cause mortality in persons with a BMI between 23.0 and 27.0. This internal and external consistency for the association between BMI and mortality upholds the use of a single common recommendation for defining overweight and obesity among all racial and ethnic groups.

Author Contributions: Drs Gu and He had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. Drs Gu and He contributed equally to this work.

Study concept and design: Gu, He, Wu, J. Chen, Whelton.

Acquisition of data: Gu, He, Duan, Wu, Huang, Whelton.

Analysis and interpretation of data: Gu, He, Reynolds, J. Chen, C.-S. Chen, Whelton.

Drafting of the manuscript: He.