

# Body Weight and Mortality Among Men and Women in China

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**T**HE PREVALENCE OF OBESITY IS increasing to epidemic proportions at an alarming rate around the world.<sup>1,2</sup> 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  $\geq$ 30.0).<sup>1</sup> The prevalence of obesity and overweight has increased dramatically in economically developed countries as well as in developing countries, such as Asian populations.<sup>3-6</sup> 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.<sup>7,8</sup> 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.<sup>9-14</sup> 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 con-

**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 25.0 to 26.9, 1.15 (95% CI, 1.06-1.24) for BMI 27.0 to 29.9, and 1.29 (95% CI, 1.16-1.42) for BMI 30.0 or more. The U-shaped association existed even after excluding participants who were current or former smokers, heavy alcohol drinkers, or who had prevalent chronic illness at the baseline examination, or who died during the first 3 years of follow-up. A similar association was observed between BMI and mortality from cardiovascular disease, cancer, and other causes.

**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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found any association between body weight and mortality. Furthermore, self-reported body weight and height were used among many previous studies.

Current definitions of overweight and obesity are based on data from Western populations.<sup>15</sup> Several epidemiological studies have suggested that

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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.<sup>16-20</sup> 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 their validation in clinical and epidemiological studies.<sup>21</sup>

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.

## METHODS

### 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.<sup>22</sup> 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.

### 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.<sup>22</sup> 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.

### 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, per-

forming 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 *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.

### 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-

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

Characteristics	Body Mass Index										P Value for Trend
	<18.5	18.5-19.9	20.0-20.9	21.0-21.9	22.0-22.9	23.0-23.9	24.0-24.9	25.0-26.9	27.0-29.9	≥30.0	
No. of participants	17 998	20 742	17 128	17 429	16 658	14 745	13 233	18 466	13 227	5 110	
Age, mean (SD), y	60.5 (11.6)	56.4 (11.1)	55.3 (10.9)	54.8 (10.5)	54.7 (10.5)	54.5 (10.2)	54.7 (10.1)	55.0 (9.9)	55.8 (9.6)	57.5 (9.6)	<.001
Men, No. (%)	8136 (45.2)	10 881 (52.5)	9179 (53.6)	9079 (52.1)	8422 (50.6)	7405 (50.2)	6448 (48.7)	9007 (48.8)	5566 (42.1)	1573 (30.8)	<.001
Cigarette smokers, No. (%)	7874 (43.8)	9166 (44.4)	7315 (42.9)	6909 (39.9)	6296 (38.0)	5232 (35.7)	4447 (33.8)	5999 (32.6)	3883 (29.5)	1267 (24.8)	.005
Alcohol consumption, No. (%)	3094 (17.2)	4483 (21.7)	3859 (22.7)	3790 (21.9)	3479 (21.0)	2992 (20.4)	2531 (19.2)	3488 (19.0)	2226 (16.9)	577 (11.3)	<.001
Physical inactivity, No. (%)	5983 (33.2)	5861 (28.3)	5197 (30.3)	5738 (32.9)	6165 (37.0)	6026 (40.9)	5554 (42.0)	8242 (44.6)	6001 (45.4)	2390 (46.8)	.01
High school education, No. (%)	2096 (11.7)	3105 (15.1)	3135 (18.5)	3843 (22.3)	4356 (26.5)	4321 (29.7)	4178 (32.2)	6309 (34.7)	4173 (31.8)	1364 (26.8)	<.001
Hypertension, No. (%)	3826 (21.3)	4120 (19.9)	3480 (20.3)	3896 (22.4)	4230 (25.4)	4077 (27.7)	4174 (31.5)	7002 (37.9)	6153 (46.5)	2851 (55.8)	<.001
Body weight, mean (SD), kg	42.8 (5.9)	49.0 (5.6)	52.6 (5.9)	55.3 (6.2)	58.1 (6.5)	61.0 (6.6)	63.6 (6.9)	67.6 (7.5)	72.7 (8.1)	80.3 (10.1)	<.001
Body mass index, mean (SD)	17.2 (1.1)	19.3 (0.4)	20.5 (0.3)	21.5 (0.3)	22.5 (0.3)	23.5 (0.3)	24.5 (0.3)	25.9 (0.6)	28.2 (0.8)	32.3 (2.6)	<.001

\*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.

21.9, 22.0-22.9, 23.0-23.9, 24.0-24.9, 25.0-26.9, 27.0-29.9, and ≥30.0). These categories were created to allow a detailed examination of the association between body weight and mortality across a wide range of BMI values without a priori assumptions about the shape of the dose-response curve. In addition, we used WHO/National Heart, Lung, and Blood Institute criteria for BMI (<18.5, 18.5-24.9, 25.0-29.9, and ≥30.0) in sensitivity analyses.<sup>15</sup> Person-years of follow-up were calculated from the date of the baseline examination until the date of death or the date of the follow-up interview for each study participant and grouped according to sex and to age in 5-year categories. Age-standardized mortality was calculated using the 5-year age-specific mortality and the age distribution of the Chinese population from year 2000 census data.

Cox proportional hazards regression models were used to adjust for baseline 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 were reported because all linear terms were not statistically significant (all P>.05). Subgroup analyses by age (<65 or ≥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 ≥3 drinks per day]) were conducted. Methods to estimate variances that take into account sample clustering were used in Cox proportional hazards regression models.<sup>23</sup> 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.

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<.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), and stratified by sampling clusters. The association between BMI and all-cause mortality was consistent in men and women. For example, the multivariate-adjusted RRs were 1.64 (95% confidence interval [CI], 1.49-1.80) and 1.65 (95% CI, 1.49-1.84) for under-

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

	Body Mass Index									
	<18.5	18.5-19.9	20.0-20.9	21.0-21.9	22.0-22.9	23.0-23.9	24.0-24.9	25.0-26.9	27.0-29.9	≥30.0
<b>Total</b>										
No. of deaths	3881	2826	1955	1686	1575	1298	1083	1508	1277	598
Person-years of follow-up	122 262	149 294	124 395	126 797	121 131	107 185	96 489	134 185	95 325	36 099
Age-standardized rate, per 100 000 person-years	1888.0	1499.4	1354.4	1242.8	1209.1	1141.8	1037.3	1037.9	1164.4	1301.3
RR (95% CI)†	1.65 (1.54-1.77)	1.31 (1.22-1.41)	1.20 (1.11-1.29)	1.12 (1.04-1.21)	1.11 (1.03-1.20)	1.09 (1.01-1.19)	1.00	1.00 (0.92-1.08)	1.15 (1.06-1.24)	1.29 (1.16-1.42)
<b>Men</b>										
No. of deaths	2037	1751	1189	999	915	767	614	863	677	235
Person-years of follow-up	54 565	78 213	66 692	66 191	61 138	53 612	46 838	65 080	39 560	10 945
Age-standardized rate, per 100 000 person-years	2168.3	1694.1	1498.4	1345.4	1306.2	1234.7	1116.3	1127.2	1353.8	1422.8
RR (95% CI)†	1.64 (1.49-1.80)	1.32 (1.20-1.45)	1.17 (1.06-1.30)	1.10 (0.99-1.22)	1.10 (0.99-1.22)	1.09 (0.98-1.21)	1.00	1.01 (0.91-1.13)	1.22 (1.10-1.37)	1.34 (1.15-1.55)
<b>Women</b>										
No. of deaths	1844	1075	766	687	660	531	469	645	600	363
Person-years of follow-up	67 697	71 081	57 703	60 606	59 993	53 573	49 651	69 105	55 765	25 154
Age-standardized rate, per 100 000 person-years	1648.3	1233.8	1142.6	1089.3	1073.9	1018.6	958.8	919.2	1016.8	1270.5
RR (95% CI)†	1.65 (1.49-1.84)	1.27 (1.14-1.42)	1.21 (1.08-1.36)	1.14 (1.01-1.28)	1.12 (1.00-1.26)	1.10 (0.97-1.24)	1.00	0.98 (0.87-1.10)	1.07 (0.94-1.20)	1.24 (1.08-1.43)

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.

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, 25.0 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 (<18.5, 18.5-19.9, 20.0-20.9, 21.0-21.9, 22.0-22.9, 23.0-23.9, 24.0-24.9, 25.0-26.9, 27.0-29.9, and ≥30.0) was 1518.1, 991.2, 839.5, 735.1, 683.2, 687.4, 612.2, 656.2, 812.6, and 947.0 per 100 000 person-years, respectively, for participants aged 40 to 64

years; and 6948.9, 5516.5, 5078.6, 4476.4, 4685.4, 4138.9, 4011.3, 3741.6, 4088.9, and 4520.7 per 100 000 person-years, respectively, for participants aged 65 years or older. The corresponding 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 healthy participants; and 2262.2, 1806.2, 1780.8, 1563.0, 1640.2, 1463.4, 1419.5, 1401.8, 1578.4, and 1671.5 per 100 000 person-years, respectively, for high-risk participants who had prevalent cardiovascular disease, stroke, cancer, end-stage renal disease, or chronic obstructive pulmonary disease, or who were heavy alcohol drinkers or cigarette smokers at the baseline examination. After adjustment for important risk factors, a statistically significant (all P<.001) U-shaped association between BMI and all-cause mortality was observed among all subgroups by age

and health status (FIGURE). In addition, the U-shaped association was consistently present among the age groups of 40 to 49, 50 to 59, 60 to 69, and 70 or more years (data not shown). The U-shaped association was also present for urban and rural residents.

After excluding study participants who died during the first 3 years of follow-up, the multivariate-adjusted RRs for all-cause mortality across BMI categories were 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 25.0 to 26.9, 1.18 (95% CI, 1.08-1.30) for BMI 27.0 to 29.9, and 1.29 (95% CI, 1.14-1.45) for BMI 30.0 or more compared with those participants with a BMI of 24.0 to 24.9.

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, 496.8, 526.5, 617.9, 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

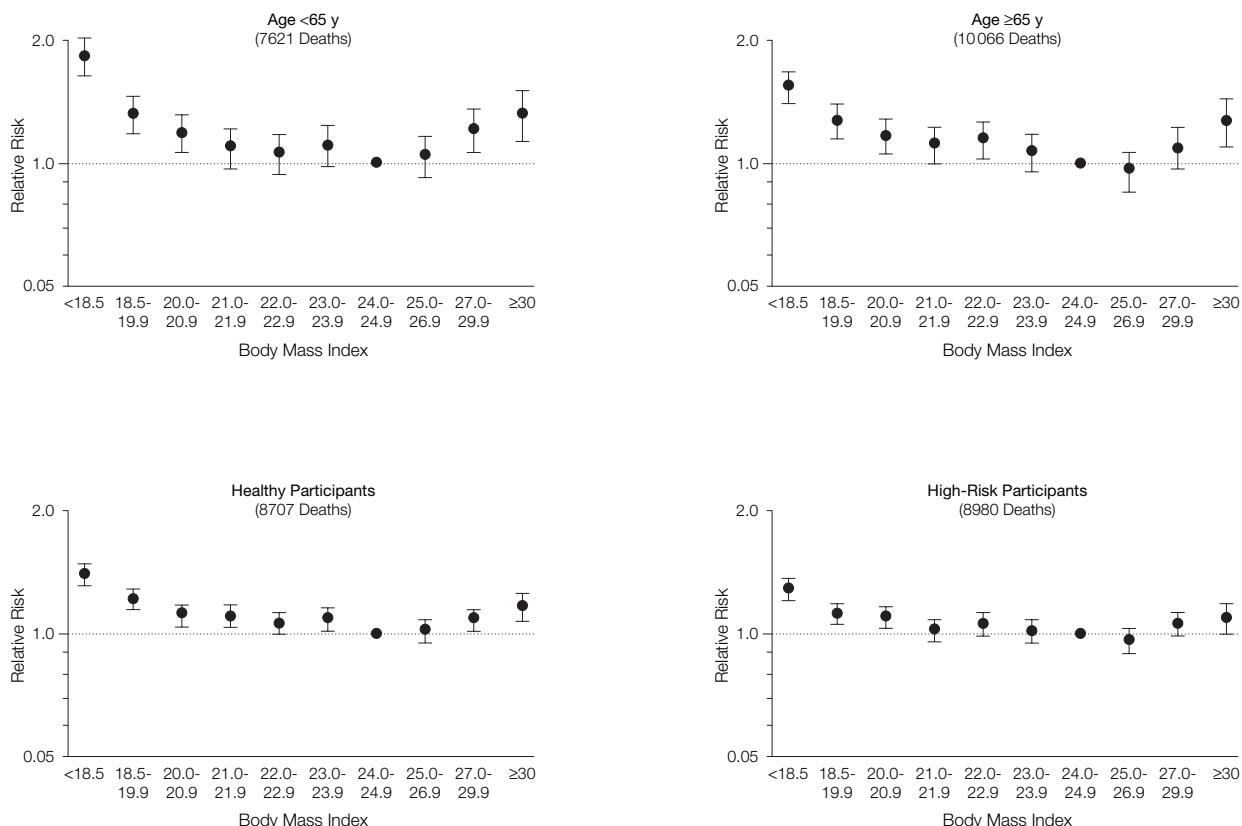
and mortality from cardiovascular disease, cancer, and other causes after adjustment for important risk factors (TABLE 3). The relationship between BMI and cause-specific mortality was consistent among men and women.

**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.<sup>13,14,24</sup> The study by Allison et al<sup>24</sup> 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,<sup>13</sup> a prospective study of mortality among 1 184 657 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

**Figure.** Multivariate-Adjusted Relative Risks of All-Cause Mortality According to Categories of Body Mass Index by Age and Health Status



Error bars indicate 95% confidence intervals. The high-risk participants included those who had prevalent cardiovascular disease, stroke, cancer, end-stage renal disease, or chronic obstructive pulmonary disease at the baseline examination, or who were heavy alcohol drinkers (consumed ≥3 drinks per day), or who were cigarette smokers. Multivariate-adjusted relative risk was calculated using study participants with a body mass index (calculated as weight in kilograms divided by square of height in meters) 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. All P values for the quadratic term were significant (P<.001).

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,<sup>9,13</sup> 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\*

		Body Mass Index									
		<18.5	18.5-19.9	20.0-20.9	21.0-21.9	22.0-22.9	23.0-23.9	24.0-24.9	25.0-26.9	27.0-29.9	≥30.0
<b>Cardiovascular Disease†</b>											
Men	Age-standardized rate, per 100 000 person-years	875.9	698.8	596.1	561.7	594.6	571.1	534.3	589.9	717.5	809.1
	RR (95% CI)‡	1.45 (1.26-1.66)	1.18 (1.03-1.35)	0.99 (0.85-1.14)	0.95 (0.82-1.11)	1.03 (0.88-1.19)	1.03 (0.89-1.21)	1.00	1.08 (0.93-1.25)	1.33 (1.14-1.55)	1.44 (1.17-1.77)
Women	Age-standardized rate, per 100 000 person-years	671.6	508.0	541.7	503.9	475.7	484.6	456.1	448.7	538.1	605.2
	RR (95% CI)‡	1.48 (1.27-1.72)	1.14 (0.97-1.34)	1.23 (1.04-1.46)	1.12 (0.94-1.32)	1.04 (0.88-1.24)	1.09 (0.91-1.30)	1.00	0.96 (0.81-1.14)	1.16 (0.97-1.37)	1.31 (1.08-1.59)
<b>Cancer‡</b>											
Men	Age-standardized rate, per 100 000 person-years	478.0	445.7	421.7	335.5	338.2	319.0	299.7	261.5	343.0	318.6
	RR (95% CI)‡	1.49 (1.23-1.81)	1.40 (1.16-1.68)	1.28 (1.06-1.56)	1.11 (0.91-1.35)	1.10 (0.90-1.34)	1.11 (0.91-1.37)	1.00	0.90 (0.73-1.10)	1.21 (0.97-1.50)	1.28 (0.95-1.74)
Women	Age-standardized rate, per 100 000 person-years	305.3	233.8	165.9	191.1	213.9	191.9	191.9	194.3	210.9	218.8
	RR (95% CI)‡	1.56 (1.24-1.97)	1.27 (1.00-1.62)	0.91 (0.70-1.19)	1.02 (0.78-1.32)	1.08 (0.83-1.39)	1.03 (0.79-1.34)	1.00	1.08 (0.84-1.38)	1.06 (0.82-1.37)	1.21 (0.90-1.63)
<b>Other Causes</b>											
Men	Age-standardized rate, per 100 000 person-years	814.3	549.7	480.5	448.3	373.4	344.6	282.3	275.7	293.3	295.1
	RR (95% CI)‡	2.12 (1.77-2.55)	1.55 (1.28-1.87)	1.43 (1.18-1.73)	1.39 (1.14-1.70)	1.25 (1.02-1.54)	1.18 (0.95-1.46)	1.00	1.01 (0.81-1.24)	1.02 (0.81-1.29)	1.19 (0.86-1.64)
Women	Age-standardized rate, per 100 000 person-years	671.4	492.0	436.4	394.4	384.2	342.1	310.8	276.2	267.8	446.4
	RR (95% CI)‡	2.00 (1.66-2.42)	1.50 (1.23-1.83)	1.40 (1.14-1.73)	1.27 (1.03-1.57)	1.28 (1.03-1.59)	1.17 (0.93-1.48)	1.00	0.92 (0.73-1.15)	0.92 (0.73-1.17)	1.17 (0.90-1.53)

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 420-429), 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.

ate the association between weight change and mortality.

Age has been proposed as an effect modifier for the relationship between body weight and all-cause mortality in several epidemiological studies.<sup>10,11,13</sup> 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.<sup>9,12,13,25,26</sup> 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.<sup>21</sup> Few prospective cohort studies have examined the association between body weight and mortality from all causes in Asian populations.<sup>27-31</sup> Yuan et al<sup>30</sup> 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 all-cause mortality was 1.73 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<sup>31</sup> reported a meta-analysis of 4 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.<sup>31</sup> 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.<sup>13,14,24</sup> 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.

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**Drafting of the manuscript:** He.

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## REFERENCES

1. Abelson P, Kennedy D. The obesity epidemic. *Science*. 2004;304:1413.
2. James PT, Leach R, Kalamara E, Shayeghi M. The

- worldwide obesity epidemic. *Obes Res.* 2001;9(suppl 4):228S-233S.
3. Hedley AA, Ogden CL, Johnson CL, Carroll MD, Curtin LR, Flegal KM. Prevalence of overweight and obesity among US children, adolescents, and adults, 1999-2002. *JAMA.* 2004;291:2847-2850.
  4. Gu D, Reynolds K, Wu X, et al. Prevalence of the metabolic syndrome and overweight among adults in China. *Lancet.* 2005;365:1398-1405.
  5. Misra A, Vikram NK. Insulin resistance syndrome (metabolic syndrome) and obesity in Asian Indians: evidence and implications. *Nutrition.* 2004;20:482-491.
  6. Aekplakorn W, Chaiyapong Y, Neal B, et al. Prevalence and determinants of overweight and obesity in Thai adults: results of the Second National Health Examination Survey. *J Med Assoc Thai.* 2004;87:685-693.
  7. Must A, Spadano J, Coakley EH, Field AE, Colditz G, Dietz WH. The disease burden associated with overweight and obesity. *JAMA.* 1999;282:1523-1529.
  8. Krauss RM, Winston M, Fletcher RN, Grundy SM. Obesity: impact of cardiovascular disease. *Circulation.* 1998;98:1472-1476.
  9. Manson JE, Willett WC, Stampfer MJ, et al. Body weight and mortality among women. *N Engl J Med.* 1995;333:677-685.
  10. Stevens J, Cai J, Pamuk ER, Williamson DF, Thun MJ, Wood JL. The effect of age on the association between body-mass index and mortality. *N Engl J Med.* 1998;338:1-7.
  11. Bender R, Jockel KH, Trautner C, Spraul M, Berger M. Effect of age on excess mortality in obesity. *JAMA.* 1999;281:1498-1504.
  12. Hu FB, Willett WC, Li T, Stampfer MJ, Colditz GA, Manson JE. Adiposity as compared with physical activity in predicting mortality among women. *N Engl J Med.* 2004;351:2694-2703.
  13. Calle EE, Thun MJ, Petrelli JM, Rodriguez C, Heath CW Jr. Body-mass index and mortality in a prospective cohort of U.S. adults. *N Engl J Med.* 1999;341:1097-1105.
  14. Flegal KM, Graubard BI, Williamson DF, Gail MH. Excess deaths associated with underweight, overweight, and obesity. *JAMA.* 2005;293:1861-1867.
  15. National Institutes of Health. Clinical guidelines on the identification, evaluation, and treatment of overweight and obesity in adults: the evidence report. *Obes Res.* 1998;6(suppl 2):51S-209S.
  16. Deurenberg P, Yap M, van Staveren WA. Body mass index and percent body fat: a meta analysis among different ethnic groups. *Int J Obes Relat Metab Disord.* 1998;22:1164-1171.
  17. He M, Tan KC, Li ET, Kung AW. Body fat determination by dual energy X-ray absorptiometry and its relation to body mass index and waist circumference in Hong Kong Chinese. *Int J Obes Relat Metab Disord.* 2001;25:748-752.
  18. Deurenberg-Yap M, Chew SK, Deurenberg P. Elevated body fat percentage and cardiovascular risks at low body mass index levels among Singaporean Chinese: Malays and Indians. *Obes Rev.* 2002;3:209-215.
  19. Pan WH, Flegal KM, Chang HY, Yeh WT, Yeh CJ, Lee WC. Body mass index and obesity-related metabolic disorders in Taiwanese and US whites and blacks: implications for definitions of overweight and obesity for Asians. *Am J Clin Nutr.* 2004;79:31-39.
  20. Wildman RP, Gu D, Reynolds K, Duan X, He J. Appropriate body mass index and waist circumference cutoffs for categorization of overweight and central adiposity among Chinese adults. *Am J Clin Nutr.* 2004;80:1129-1136.
  21. The World Health Organization Western Pacific Region; The International Association for the Study of Obesity; The International Obesity Task Force. *The Asia-Pacific Perspective: Redefining Obesity and Its Treatment.* Sydney, Australia: Health Communications Australia Pty Limited; 2000.
  22. Wu X, Duan X, Gu D, Hao J, Tao S, Fan D. Prevalence of hypertension and its trends in Chinese populations. *Int J Cardiol.* 1995;52:39-44.
  23. Ingram DD, Makuc DM. Statistical issues in analyzing the NHANES I Epidemiologic Followup Study, series 2: data evaluation and methods research. *Vital Health Stat 2.* 1994;121:1-30.
  24. Allison DB, Fontaine KR, Manson JE, Stevens J, Vanitallie TB. Annual deaths attributable to obesity in the United States. *JAMA.* 1999;282:1530-1538.
  25. Hart CL, Smith GD, Hole DJ, Hawthorne VM. Alcohol consumption and mortality from all causes, coronary heart disease, and stroke: results from a prospective cohort study of scottish men with 21 years of follow up. *BMJ.* 1999;318:1725-1729.
  26. Laatikainen T, Manninen L, Poikolainen K, Vartiainen E. Increased mortality related to heavy alcohol intake pattern. *J Epidemiol Community Health.* 2003;57:379-384.
  27. Miyazaki M, Babazono A, Ishii T, et al. Effects of low body mass index and smoking on all-cause mortality among middle-aged and elderly Japanese. *J Epidemiol.* 2002;12:40-44.
  28. Tsugane S, Sasaki S, Tsubono Y. Under- and overweight impact on mortality among middle-aged Japanese men and women: a 10-y follow-up of JPHC study cohort I. *Int J Obes Relat Metab Disord.* 2002;26:529-537.
  29. Song YM, Sung J. Body mass index and mortality: a twelve-year prospective study in Korea. *Epidemiology.* 2001;12:173-179.
  30. Yuan JM, Ross RK, Gao YT, Yu MC. Body weight and mortality: a prospective evaluation in a cohort of middle-aged men in Shanghai, China. *Int J Epidemiol.* 1998;27:824-832.
  31. Zhou BF. Effect of body mass index on all-cause mortality and incidence of cardiovascular diseases: report for meta-analysis of prospective studies open optimal cut-off points of body mass index in Chinese adults. *Biomed Environ Sci.* 2002;15:245-252.