

ORIGINAL ARTICLE



# Obesity Prevalence and Risks Among Chinese Adults

## Findings From the China PEACE Million Persons Project, 2014–2018

**BACKGROUND:** China has seen a burgeoning epidemic of obesity in recent decades, but few studies reported nationally on obesity across socio-demographic subgroups. We sought to assess the prevalence and socio-demographic associations of obesity nationwide.

**METHODS:** We assessed the prevalence of overall obesity (body mass index  $\geq 28$  kg/m<sup>2</sup>) and abdominal obesity (waist circumference  $\geq 85/90$  cm for women/men) among 2.7 million community-dwelling adults aged 35 to 75 years in the China PEACE Million Persons Project from 2014 to 2018 and quantified the socio-demographic associations of obesity using multivariable mixed models.

**RESULTS:** Age-standardized rates of overall and abdominal obesity were 14.4% (95% CI, 14.3%–14.4%) and 32.7% (32.6%–32.8%) in women and 16.0% (15.9%–16.1%) and 36.6% (36.5%–36.8%) in men. Obesity varied considerably across socio-demographic subgroups. Older women were at higher risk for obesity (eg, adjusted relative risk [95% CI] of women aged 65–75 versus 35–44 years: 1.29 [1.27–1.31] for overall obesity, 1.76 [1.74–1.77] for abdominal obesity) while older men were not. Higher education was associated with lower risk in women (eg, adjusted relative risk [95% CI] of those with college or university education versus below primary school: 0.47 [0.46–0.48] for overall obesity, 0.61 [0.60–0.62] for abdominal obesity) but higher risk in men (1.07 [1.05–1.10], 1.17 [1.16–1.19]).

**CONCLUSIONS:** In China, over 1 in 7 individuals meet criteria for overall obesity, and 1 in 3 for abdominal obesity. Wide variation exists across socio-demographic subgroups. The associations of age and education with obesity are significant and differ by sex. Understanding obesity in contemporary China has broad domestic policy implications and provides a valuable international reference.

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**Key Words:** body mass index ■ demography ■ obesity ■ prevalence ■ socioeconomic factors ■ waist circumference

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## WHAT IS KNOWN

- Obesity is a global epidemic and has accelerated in China over the past decades, leaving the country with the largest number of obese individuals in the world.
- With rapid socio-demographic transformations, China sees immense heterogeneity within its population of 2.7 billion.

## WHAT THE STUDY ADDS

- This study researched 2.7 billion participants in China and found that more than 1 in 7 individuals meet criteria for overall obesity and 1 in 3 meet criteria for abdominal obesity.
- It also showed that wide variation in obesity prevalence exists across socio-demographic subgroups and that the associations of age and education with obesity are significant and differ by sex.
- These findings provide a sobering update on the current state of obesity in China, fill the knowledge gaps of obesity across socio-demographic subgroups, and provide a valuable international reference on obesity epidemiology.

Obesity is a global epidemic. More than 2 billion people are overweight or obese worldwide, and 62% of the population with obesity live in developing countries.<sup>1</sup> Over the past decades, Asia has seen substantial increases in obesity.<sup>2</sup> In 2014, China became home to the greatest number of obese women and men, totaling 90 million obese individuals and accounting for 14% of the world's obesity based on body mass index (BMI).<sup>3</sup> Furthermore, as central or visceral adiposity becomes increasingly recognized as a key cardiometabolic risk indicator beyond BMI,<sup>4</sup> research suggests that the prevalence of abdominal obesity in China reached 32% in 2013 to 2014.<sup>5</sup>

As China's rising obesity epidemic occurs in the context of its rapid economic and demographic shifts,<sup>6</sup> understanding its current state of obesity helps inform health care policies in China and potentially other countries that undergo similar socioeconomic and epidemiological transitions.<sup>7</sup> In addition, while culprits of obesity at the individual level are known to include unhealthy dietary changes (eg, increased consumption of energy-dense food) and reduced physical activities (eg, associated with occupational shift),<sup>8,9</sup> interventions at the population level require understanding the heterogeneity within 1.4-billion Chinese people and warrant large-scale research to assess obesity across broad socio-demographic subgroups. For example, by 2014, across Chinese provinces, overall obesity rates had differed by about 20% points and abdominal obesity rates by over 30% points.<sup>5</sup> However, current literature has limited reports on obesity

across socio-demographic subgroups at the national level (Supplement I in the [Data Supplement](#)). This knowledge gap may partly result from a limitation of nationally representative studies, whereby potential sampling variability becomes a concern for analyses of subgroups that have very small sample sizes.<sup>10</sup>

In this study, we report obesity prevalence and risks in China from 2014 to 2018, using one of its largest and most recent health surveys—China Patient-centered Evaluative Assessment of Cardiac Events Million Persons Project.<sup>11</sup> By analyzing 2.7 billion participants in Million Persons Project, we aim to describe the prevalence of obesity and associated characteristics in women and men across broad socio-demographic subgroups.

## METHODS

### Data Access Statement

The data are not available to other researchers at this time.

### Project Design

The China Patient-centered Evaluative Assessment of Cardiac Events Million Persons Project protocol has been described previously.<sup>11</sup> From September 2014 to November 2018, we sampled 189 regions (114 rural counties, 75 urban districts) in all 31 provinces of Mainland China to reflect geographic, ethnic, and economic diversity across the country. Within each region, about 5 rural towns or urban sub-districts were sampled based on their size, population stability, and local capacity to execute the study protocol. Participants were recruited by local staff via extensive publicity campaigns on television and in newspapers and enrolled if they were aged 35 to 75 years and currently registered in the selected region's Hukou (an official record identifying residents in the region). Participants were then screened in person for health risks with collection of past medical, medication, family, and social histories and measurement of height, weight, and waist circumference (WC) among other anthropometric and biochemical assessments. Specifically, height and weight were measured to the nearest 0.1 kg or cm, while participants wore light clothes but no shoes or caps. WC was measured midway on skin between the iliac crest and the lower rib margin using a soft tape. Of note, because WC was not collected during the first year of study, we excluded all participants during that period in all WC-related analyses. This project complied with the Declaration of Helsinki and was approved by the central ethics committee at the China National Center for Cardiovascular Disease and the Institutional Review Board at Yale University. All enrolled participants provided informed consent.

### Study Variables

Based on Chinese expert consensus on obesity-related hypertension management,<sup>12</sup> we categorized BMI (calculated as weight in kilograms divided by height in meters squared) into underweight (BMI <18.5 kg/m<sup>2</sup>), normal weight (18.5–23.9 kg/m<sup>2</sup>), overweight (24.0–27.9 kg/m<sup>2</sup>), and obese (≥28.0 kg/m<sup>2</sup>) and defined (1) overall obesity as BMI ≥28.0 kg/m<sup>2</sup> for both women and men and (2) abdominal obesity as WC ≥85 cm for women or WC ≥90 cm for men. We assessed

12 socio-demographic factors that are potentially associated with obesity and available in China Patient-centered Evaluative Assessment of Cardiac Events Million Persons Project, including age group (35–44, 45–54, 55–64, 65–75 in years), sex, ethnicity (Han, non-Han), marital status (married, others), education (below primary school, primary school, middle school, high school, college, or university), occupation (farmer, nonfarmer), annual household income (<10000, 10000–<50000, ≥50000 in RMB; 7 RMB was ≈1 USD during the study period), residence (urban, rural), geographic region (Western, Central, Eastern), health insurance, current smoking, and current drinking, in addition to 5 self-reported comorbidities (hypertension, dyslipidemia, diabetes, myocardial infarction, and stroke).

## Statistical Analyses

We calculated the prevalence of overall and abdominal obesity by sex and as a sensitivity analysis determined the age-standardized prevalence at the national level by adjusting observation weights to match the age distributions in the 2010 Chinese Census.<sup>13</sup> In addition, we reported descriptive statistics of obesity by socio-demographic factors and comorbidities and developed multivariable mixed models (with random effects to account for geographic autocorrelation) to quantify the association of socio-demographic factors with obesity. Lastly, we examined the prevalence of obesity in population subgroups that were defined by combinations of the 12 studied socio-demographic factors (details in Methods in the [Data Supplement](#)) and illustrated the probability densities of obesity prevalence in the subgroups with ≥500 people. Analyses were conducted with SAS 9.3 (SAS Institute Inc, Cary, NC) and R 3.02 (The R Foundation for Statistical Computing, Vienna, Austria).

## RESULTS

Of 2 660 666 enrolled participants September 2014 to November 2018, 43 654 (1.6%) were excluded from BMI analysis because of missing data; of 2 270 593 enrolled participants from 2015 to 2018, 18 016 (0.8%) were excluded from WC analysis because of missing data (Figure I in the [Data Supplement](#)). Among women, 15.8% met criteria for overall obesity and 37.6% for abdominal obesity. Among men, 15.0% met criteria for overall obesity and 36.3% for abdominal obesity. About 39% of women and men with abdominal obesity also met criteria for overall obesity (Figure II in the [Data Supplement](#)). Figure 1 shows distributions of BMI and WC in women and men. Using the 2010 Chinese Census data, we report age-standardized rates of overall and abdominal obesity to be 14.4% (95% CI, 14.3%–14.4%) and 32.7% (32.6%–32.8%) in women and 16.0% (15.9%–16.1%) and 36.6% (36.5%–36.8%) in men.

Compared with individuals with normal weight, women with overall obesity had higher prevalence of hypertension, dyslipidemia, diabetes, stroke, and myocardial infarction with percent differences in prevalence

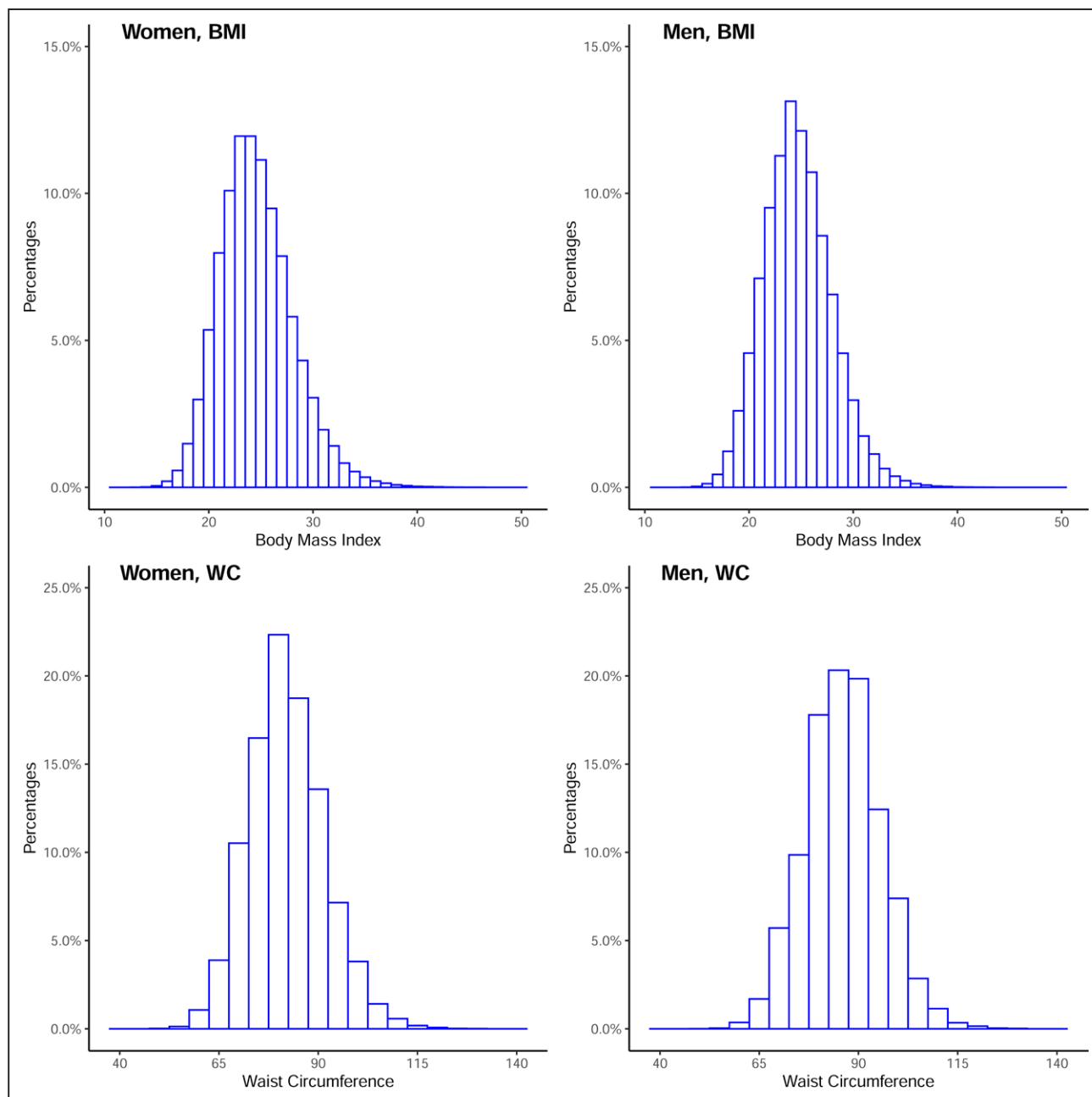
of 30.4, 16.1, 6.0, 1.4, and 0.4, respectively; men with overall obesity had higher prevalence by 29.9, 31.2, 5.8, 1.4, and 0.7 (Table 1 and Table 2). Higher prevalence of these comorbidities was also observed in women and men with abdominal obesity compared with those without (Table 3 and Table 4).

Distributions of BMI in socio-demographic subgroups of women and men were shown in Table 1 and Table 2; distributions of WC were shown in Table 3 and Table 4. In multivariable-adjusted models, older women were at substantially higher risks for overall and abdominal obesity while older men were not (Figure 2). For example, compared with women aged 35 to 44 years, those aged 65 to 75 years were 29% and 76% more likely to meet criteria for overall and abdominal obesity, whereas men aged 65 to 75 years were 26% less likely to meet criteria for overall obesity compared with those aged 35 to 44 years. Interestingly, the abdominal obesity rates in subpopulations of women aged 65 to 75 years were evidently higher than those in subpopulations of women aged 35 to 45 years, while the overall and abdominal obesity rates in subpopulations of men aged 35 to 44 and 65 to 75 years overlapped considerably (Figure 3).

Other factors associated with obesity were notable for ethnicity, education, annual household income, and current smoking and drinking status. Overall, non-Han people were at higher adjusted risks for obesity (Figure 2). For both overall and abdominal obesity, higher education was associated with lower adjusted risks in women but higher risks in men (Figure 2). For example, women with college or university education were associated with 3.46 (3.37–3.54) cm smaller WC than those with below primary school education, while men with college or university education were associated with 1.36 (1.26–1.46) cm larger WC than those with below primary school education (Table in the [Data Supplement](#)). For both overall and abdominal obesity, among all annual household income categories, women with annual household income of 10 000 to <50 000 RMB were at the highest adjusted risk, while men with annual household income ≥50 000 RMB were at the highest adjusted risk (Figure 2). Lastly, for both women and men, current smoking was associated with lower adjusted risks for obesity, while current drinking was associated with higher adjusted risks for obesity (Figure 2), although the associations were smaller in magnitude among women than men (Table in the [Data Supplement](#)).

## DISCUSSION

In this study of 2.7 million Chinese adults from 2014 to 2018, we report >15% women and men with overall obesity and over 35% with abdominal obesity. We further show that the significant associations of age and



**Figure 1. Distribution of body mass index (BMI) and waist circumference (WC) in women and men.** Less than 0.1% of data (N=1816) represented BMI >50 kg/m<sup>2</sup>, BMI <10 kg/m<sup>2</sup>, WC >140 cm, or WC <40 cm and were not shown on the histograms above.

education with obesity differ by sex and that considerable heterogeneity in obesity prevalence exists across socio-demographic subgroups. Our results unequivocally document abdominal obesity as a highly prevalent phenotype in China and demonstrate sex differences in age and education as potential risk factors for obesity.

Studying obesity epidemiology is crucial to population health. BMI is strongly associated with higher incidence of ischemic stroke and diabetes in China,<sup>14,15</sup> and for a given BMI, mainland Chinese have higher odds of comorbidities than White people in the US.<sup>16</sup> In our study, the prevalence of hypertension, dyslipidemia, diabetes,

stroke, and myocardial infarction in the overall obese population is about twice that in the normal weight population. In addition, WC is important for obesity research in China, because many high-WC Asians at what is considered a normal BMI (<25 kg/m<sup>2</sup>) in Western studies are at higher risks for cardiometabolic diseases.<sup>4,17</sup> Our study finds an alarmingly high prevalence of abdominal obesity at over 35%, more than twice the prevalence of overall obesity based on BMI alone.

For domestic comparison, our results among adults aged 35 to 75 years are similar to estimates based on the most recently published, nationally

**Table 1. Distributions of Body Mass Index by Socio-Demographic Factors and Comorbidities in Women**

	Overall	BMI <18.5	BMI 18.5–23.9	BMI 24.0–27.9	BMI ≥28.0
N	1574421	36870	678110	586391	248466
Age, y					
35–44	242998	6154 (2.6%)	127149 (53.1%)	78050 (32.6%)	28160 (11.8%)
45–54	519100	9188 (1.8%)	222184 (43.5%)	197871 (38.7%)	81625 (16.0%)
55–64	492818	10815 (2.2%)	198785 (41.0%)	191582 (39.5%)	83723 (17.3%)
65–75	309004	10217 (3.4%)	125308 (41.2%)	115254 (37.9%)	53429 (17.6%)
Ethnicity					
Han	1418244	30850 (2.2%)	606052 (43.4%)	534790 (38.3%)	224232 (16.1%)
Non-Han	155120	6007 (3.9%)	71663 (46.9%)	51170 (33.5%)	24033 (15.7%)
Marital status					
Married	1442445	32925 (2.3%)	622789 (43.9%)	537640 (37.9%)	226502 (16.0%)
Others	131976	3945 (3.0%)	55321 (42.6%)	48751 (37.5%)	21964 (16.9%)
Education					
<Primary school	356717	11049 (3.1%)	145255 (41.4%)	130620 (37.2%)	64060 (18.3%)
Primary school	402110	9729 (2.5%)	161242 (40.7%)	153604 (38.8%)	71313 (18.0%)
Middle school	471487	8971 (1.9%)	200009 (43.1%)	180976 (39.0%)	74021 (16.0%)
High school	223191	4346 (2.0%)	106229 (48.3%)	81427 (37.0%)	27791 (12.6%)
College or university	99393	2331 (2.4%)	55519 (56.7%)	31971 (32.6%)	8148 (8.3%)
Unknown/refused to answer	21500	444 (2.1%)	9845 (46.4%)	7785 (36.7%)	3129 (14.8%)
Occupation					
Farmer	755299	21206 (2.9%)	316501 (42.6%)	277391 (37.3%)	128358 (17.3%)
Nonfarmer	792487	15161 (1.9%)	349560 (44.8%)	299227 (38.4%)	116156 (14.9%)
Unknown/refused to answer	26635	503 (1.9%)	12049 (45.9%)	9773 (37.2%)	3952 (15.0%)
Annual household income, RMB					
<10000	327099	9749 (3.0%)	137594 (42.7%)	118164 (36.7%)	56597 (17.6%)
10000–<50000	844898	17976 (2.2%)	355093 (42.7%)	321994 (38.7%)	136405 (16.4%)
≥50000	238989	5336 (2.3%)	113591 (48.3%)	85663 (36.4%)	30736 (13.1%)
Unknown/refused to answer	148638	3486 (2.4%)	64623 (44.2%)	55149 (37.7%)	23087 (15.8%)
Residence urbanity					
Urban	630974	12545 (2.0%)	278455 (44.8%)	236588 (38.1%)	93609 (15.1%)
Rural	943447	24325 (2.6%)	399655 (43.0%)	349803 (37.7%)	154857 (16.7%)
Geographic region					
Western	549191	16174 (3.0%)	248562 (46.0%)	194974 (36.1%)	81059 (15.0%)
Central	442990	9682 (2.2%)	192424 (44.2%)	167869 (38.5%)	65853 (15.1%)
Eastern	582240	11014 (1.9%)	237124 (41.4%)	223548 (39.0%)	101554 (17.7%)
Health insurance status					
Insured	1539334	36082 (2.4%)	662906 (43.7%)	573336 (37.8%)	242931 (16.0%)
Uninsured	10454	238 (2.3%)	4360 (42.4%)	3998 (38.9%)	1687 (16.4%)
Unknown/refused to answer	24633	550 (2.3%)	10844 (44.6%)	9057 (37.3%)	3848 (15.8%)
Current smoker	29758	1265 (4.3%)	11926 (40.6%)	10785 (36.7%)	5374 (18.3%)
Current drinker	135441	2617 (2.0%)	59660 (44.8%)	51361 (38.5%)	19619 (14.7%)
Comorbidities					
Hypertension	680731	9731 (1.5%)	221513 (33.1%)	281366 (42.0%)	156693 (23.4%)
Dyslipidemia	502364	6414 (1.3%)	174284 (35.3%)	209363 (42.4%)	103827 (21.0%)
Diabetes	101362	1044 (1.0%)	30016 (30.1%)	42792 (42.9%)	25797 (25.9%)
Stroke	32893	525 (1.6%)	10792 (34.4%)	13653 (42.3%)	7333 (22.7%)
Myocardial infarction	9875	203 (2.1%)	3387 (34.8%)	3950 (40.6%)	2181 (22.4%)

Data are N (%). BMI indicates body mass index in kg/m<sup>2</sup>. Because BMI >1000 was treated as a recording error and excluded, 1.0%–2.0% participants were excluded in each subgroup/row. 7 RMB was ≈1 USD during the study period.

**Table 2. Distributions of Body Mass Index by Socio-Demographic Factors and Comorbidities in Men**

	Overall	BMI <18.5	BMI 18.5–23.9	BMI 24.0–27.9	BMI ≥28.0
N	1 070 300	19 665	432 751	439 287	160 429
Age, y					
35–44	160 190	2 159 (1.4%)	61 236 (38.9%)	65 955 (41.9%)	28 085 (17.8%)
45–54	318 621	3 741 (1.2%)	118 307 (37.8%)	136 696 (43.7%)	54 224 (17.3%)
55–64	334 504	5 911 (1.8%)	137 805 (41.9%)	138 284 (42.1%)	46 810 (14.2%)
65–75	247 014	7 418 (3.1%)	110 592 (45.5%)	94 841 (39.0%)	30 257 (12.4%)
Ethnicity					
Han	961 221	17 000 (1.8%)	382 938 (40.5%)	399 838 (42.3%)	144 941 (15.3%)
Non-Han	108 228	2 655 (2.5%)	49 528 (46.5%)	39 078 (36.7%)	15 319 (14.4%)
Marital status					
Married	1 016 412	18 061 (1.8%)	408 715 (40.9%)	419 281 (42.0%)	153 016 (15.3%)
Others	53 888	1 604 (3.0%)	24 036 (45.3%)	20 006 (37.7%)	7 413 (14.0%)
Education					
<Primary school	133 539	4 452 (3.4%)	66 848 (50.8%)	45 136 (34.3%)	15 075 (11.5%)
Primary school	254 859	5 965 (2.4%)	114 210 (45.5%)	96 338 (38.4%)	34 403 (13.7%)
Middle school	376 741	5 710 (1.5%)	144 365 (39.0%)	158 862 (42.9%)	61 195 (16.5%)
High school	187 486	2 354 (1.3%)	67 761 (36.8%)	83 915 (45.6%)	30 092 (16.3%)
College or university	103 926	962 (0.9%)	34 076 (33.4%)	49 241 (48.3%)	17 661 (17.3%)
Unknown/refused to answer	13 737	221 (1.6%)	5 487 (40.6%)	5 792 (42.9%)	1 999 (14.8%)
Occupation					
Farmer	514 707	12 457 (2.5%)	234 574 (46.3%)	190 408 (37.6%)	69 070 (13.6%)
Nonfarmer	537 269	6 953 (1.3%)	191 146 (36.2%)	241 070 (45.7%)	88 435 (16.8%)
Unknown/refused to answer	18 324	255 (1.4%)	7 031 (39.0%)	7 809 (43.3%)	2 924 (16.2%)
Annual household income, RMB					
<10 000	199 069	5 494 (2.8%)	92 214 (47.1%)	71 983 (36.7%)	26 190 (13.4%)
10 000–<50 000	581 186	9 792 (1.7%)	229 969 (40.3%)	242 473 (42.4%)	89 071 (15.6%)
≥50 000	189 527	2 461 (1.3%)	67 964 (36.5%)	84 425 (45.4%)	31 225 (16.8%)
Unknown/refused to answer	89 592	1 772 (2.0%)	37 327 (42.3%)	36 165 (41.0%)	12 876 (14.6%)
Residence urbanity					
Urban	424 126	6 185 (1.5%)	158 658 (38.1%)	185 592 (44.6%)	66 118 (15.9%)
Rural	646 174	13 480 (2.1%)	274 093 (43.1%)	253 695 (39.9%)	94 311 (14.8%)
Geographic region					
Western	375 139	8 679 (2.4%)	162 715 (44.1%)	144 470 (39.2%)	53 100 (14.4%)
Central	296 441	5 312 (1.8%)	121 314 (41.6%)	122 180 (41.9%)	42 517 (14.6%)
Eastern	398 720	5 674 (1.4%)	148 722 (38.0%)	172 637 (44.1%)	64 812 (16.5%)
Health insurance status					
Insured	1 048 462	19 324 (1.9%)	424 279 (41.2%)	430 314 (41.8%)	156 744 (15.2%)
Uninsured	6 249	90 (1.5%)	2 349 (38.2%)	2 617 (42.6%)	1 087 (17.7%)
Unknown/refused to answer	15 589	251 (1.6%)	6 123 (39.9%)	6 356 (41.5%)	2 598 (16.9%)
Current smoker	484 713	10 728 (2.3%)	210 325 (44.1%)	187 715 (39.4%)	67 955 (14.3%)
Current drinker	497 974	7 470 (1.5%)	190 025 (38.8%)	209 797 (42.9%)	81 888 (16.7%)
Comorbidities					
Hypertension	498 622	5 942 (1.2%)	156 696 (32.0%)	221 068 (45.1%)	106 031 (21.7%)
Dyslipidemia	415 924	3 289 (0.8%)	116 636 (28.6%)	194 952 (47.7%)	93 442 (22.9%)
Diabetes	69 956	550 (0.8%)	18 837 (27.5%)	32 887 (47.9%)	16 348 (23.8%)
Stroke	30 575	404 (1.3%)	10 078 (33.6%)	13 602 (45.3%)	5 930 (19.8%)
Myocardial infarction	9 751	155 (1.6%)	2 903 (30.3%)	4 326 (45.2%)	2 192 (22.9%)

Data are N (%). BMI indicates body mass index in kg/m<sup>2</sup>. Because BMI >1000 was treated as a recording error and excluded, 1.0%–2.0% participants were excluded in each subgroup/row. 7 RMB was ≈1 USD during the study period.

**Table 3. Distributions of Waist Circumference by Socio-Demographic Factors and Comorbidities in Women**

	Overall	WC <85	WC ≥85
N	1 354 358	845 338	509 020
Age, y			
35–44	215 854	164 963 (76.4%)	50 891 (23.6%)
45–54	444 535	291 707 (65.6%)	152 828 (34.4%)
55–64	418 839	240 776 (57.5%)	178 063 (42.5%)
65–75	266 451	143 133 (53.7%)	123 318 (46.3%)
Ethnicity			
Han	1 235 413	774 863 (62.7%)	460 550 (37.3%)
Non-Han	117 888	69 848 (59.2%)	48 040 (40.8%)
Marital status			
Married	1 240 004	778 653 (62.8%)	461 351 (37.2%)
Others	114 354	66 685 (58.3%)	47 669 (41.7%)
Education			
<Primary school	325 667	186 821 (57.4%)	138 846 (42.6%)
Primary school	338 845	198 368 (58.5%)	140 477 (41.5%)
Middle school	398 269	254 627 (63.9%)	143 642 (36.1%)
High school	185 448	125 925 (67.9%)	59 523 (32.1%)
College or university	85 949	66 892 (77.8%)	19 057 (22.2%)
Unknown/refused to answer	20 157	12 692 (63.0%)	7 465 (37.0%)
Occupation			
Farmer	661 857	398 915 (60.3%)	26 294 (39.7%)
Nonfarmer	668 093	430 959 (64.5%)	237 134 (35.5%)
Unknown/refused to answer	24 408	15 464 (63.4%)	8 944 (36.6%)
Annual household income, RMB			
<10 000	285 646	166 594 (58.3%)	119 052 (41.7%)
10 000–<50 000	722 265	450 089 (62.3%)	272 176 (37.7%)
≥50 000	210 895	142 634 (67.6%)	68 261 (32.4%)
Unknown/refused to answer	135 522	86 008 (63.5%)	49 514 (36.5%)
Residence urbanity			
Urban	533 703	338 200 (63.4%)	195 503 (36.6%)
Rural	820 655	507 138 (61.8%)	313 517 (38.2%)
Geographic region			
Western	493 938	314 962 (63.8%)	178 976 (36.2%)
Central	387 625	249 694 (64.4%)	137 931 (35.6%)
Eastern	472 795	280 682 (59.4%)	192 113 (40.6%)
Health insurance status			
Insure	1 321 652	824 788 (62.4%)	496 864 (37.6%)
Uninsured	8836	5579 (63.1%)	3257 (36.9%)
Unknown/refused to answer	23 870	14 971 (62.7%)	8 899 (37.3%)
Current smoker	26 316	15 103 (57.4%)	11 213 (42.6%)
Current drinker	117 502	75 667 (64.4%)	41 835 (35.6%)
Comorbidities			
Hypertension	589 528	299 867 (50.9%)	289 661 (49.1%)
Dyslipidemia	411 398	217 937 (53.0%)	193 461 (47.0%)
Diabetes	91 183	39 376 (43.2%)	51 807 (56.8%)
Stroke	27 005	13 251 (49.1%)	13 754 (50.9%)
Myocardial infarction	8 531	4 259 (49.9%)	4 272 (50.1%)

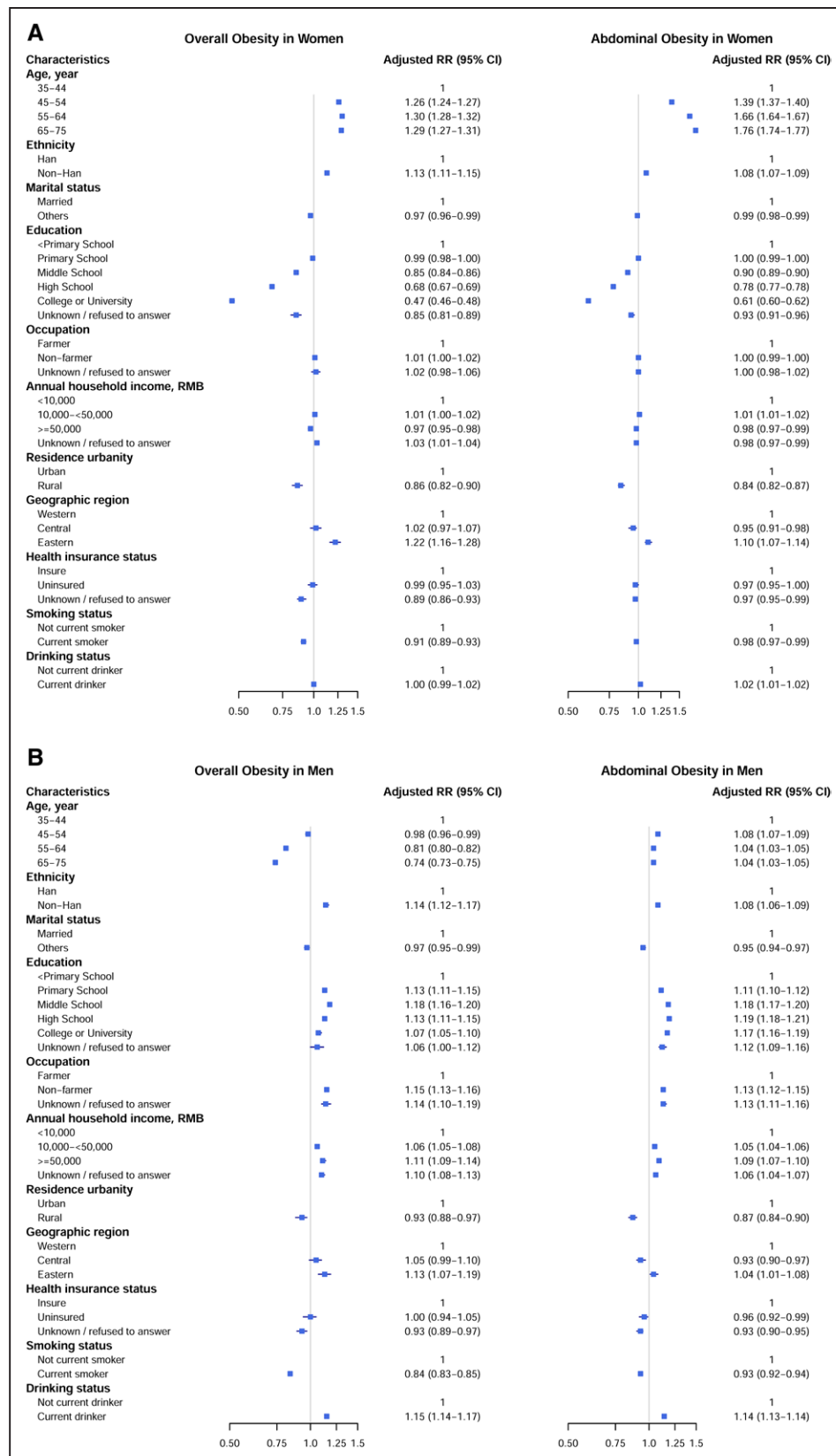
Data are N (%). WC indicates waist circumference in cm. 7 RMB was ≈1 USD during the study period.

**Table 4. Distributions of Waist Circumference by Socio-Demographic Factors and Comorbidities in Men**

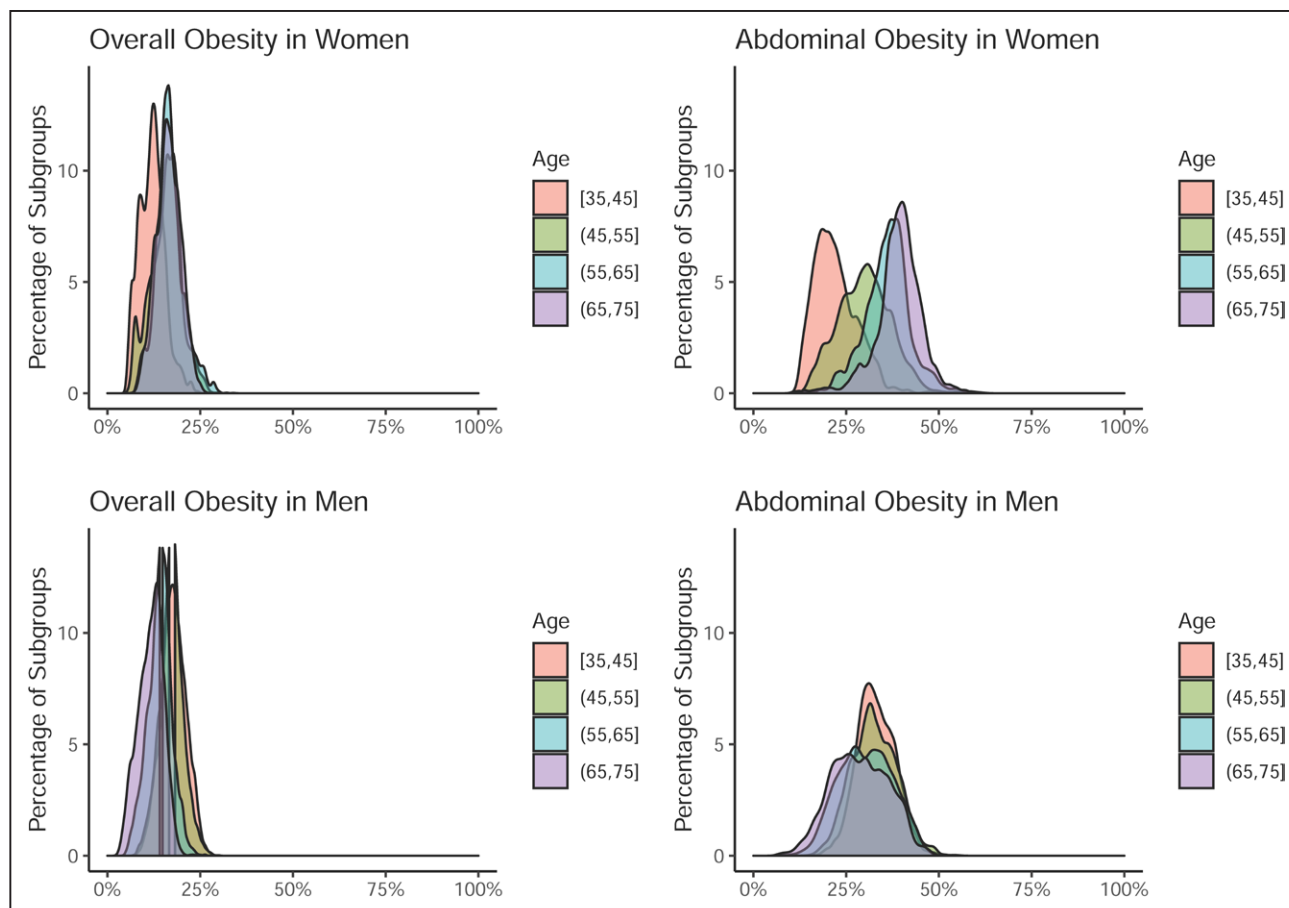
	Overall	WC <90	WC ≥90
N	900 260	573 239	327 021
Age, y			
35–44	138 896	87 969 (63.3%)	50 927 (36.7%)
45–54	263 678	161 652 (61.3%)	102 026 (38.7%)
55–64	278 320	178 432 (64.1%)	99 888 (35.9%)
65–75	211 126	139 570 (66.1%)	71 556 (33.9%)
Ethnicity			
Han	819 187	521 639 (63.7%)	297 548 (36.3%)
Non-Han	80 222	51 099 (63.7%)	29 123 (36.3%)
Marital status			
Married	854 146	542 231 (63.5%)	311 915 (36.5%)
Others	46 114	31 008 (67.2%)	15 106 (32.8%)
Education			
<Primary school	119 213	86 867 (72.9%)	32 346 (27.1%)
Primary school	209 931	142 741 (68.0%)	67 190 (32.0%)
Middle school	316 891	195 247 (61.6%)	121 644 (38.4%)
High school	153 272	89 664 (58.5%)	63 608 (41.5%)
College or university	88 129	50 567 (57.4%)	37 562 (42.6%)
Unknown/refused to answer	12 812	8 148 (63.6%)	4 664 (36.4%)
Occupation			
Farmer	439 287	301 367 (68.6%)	137 920 (31.4%)
Nonfarmer	444 360	261 740 (58.9%)	182 620 (41.1%)
Unknown/refused to answer	16 613	10 132 (61.0%)	6 481 (39.0%)
Annual household income, RMB			
<10 000	169 880	114 856 (67.6%)	55 024 (32.4%)
10 000–<50 000	486 432	307 588 (63.2%)	178 844 (36.8%)
≥50 000	162 895	97 322 (59.7%)	65 573 (40.3%)
Unknown/refused to answer	81 029	53 460 (66.0%)	27 569 (34.0%)
Residence urbanity			
Urban	346 803	207 879 (59.9%)	138 924 (40.1%)
Rural	553 457	365 360 (66.0%)	188 097 (34.0%)
Geographic region			
Western	331 777	217 344 (65.5%)	114 433 (34.5%)
Central	255 486	168 909 (66.1%)	86 577 (33.9%)
Eastern	312 997	186 986 (59.7%)	126 011 (40.3%)
Health insurance status			
Insured	879 998	560 694 (63.7%)	319 304 (36.3%)
Uninsured	5133	3110 (60.6%)	2023 (39.4%)
Unknown/refused to answer	15 129	9435 (62.4%)	5694 (37.6%)
Current smoker	420 942	274 852 (65.3%)	146 090 (34.7%)
Current drinker	422 274	257 742 (61.0%)	164 532 (39.0%)
Comorbidities			
Hypertension	422 668	229 864 (54.4%)	192 804 (45.6%)
Dyslipidemia	344 711	176 129 (51.1%)	168 582 (48.9%)
Diabetes	62 878	29 423 (46.8%)	33 455 (53.2%)
Stroke	25 446	13 995 (55.0%)	11 451 (45.0%)
Myocardial infarction	8422	4200 (49.9%)	4222 (50.1%)

Data are N (%). WC indicates waist circumference in cm. 7 RMB was ≈1 USD during the study period.





**Figure 2.** Multivariable-adjusted relative risks (RR) for overall and abdominal obesity in (A) women and (B) men. All variables are mutually adjusted in log-binomial models with community/village-specific random effects. For analysis of abdominal obesity in men, Poisson-binomial models were used to achieve convergence. 7 RMB was ≈1 USD during the study period.



**Figure 3. Prevalence of obesity across population subgroups with ≥500 people each.** This figure illustrates the distribution of obesity prevalence among 337 956 population subgroups that were defined by different combinations of the 12 studied socio-demographic factors and that had a minimal size of 500 people (details in Methods in the [Data Supplement](#)). For example, the top right panel shows that among women aged 65–75 y, about half (the right half of the purple curve) of population subgroups had a prevalence of abdominal obesity above 40% (x axis).

representative data. For example, the China Chronic Disease and Risk Factor Surveillance data suggest that among adults aged 18 years or older in 2013 to 2014, prevalence of overall and abdominal obesity were 14% and 31% in men and 14% and 32% in women,<sup>5</sup> and the China Physical Fitness Surveillance Center data suggest that among Chinese adults aged 35 to 59 years in 2014, prevalence of overall and abdominal obesity were 14% to 15% and 25% to 37%, respectively.<sup>18</sup> For international comparison, take the United States as an example: in 2015 to 2016, rates of overall and abdominal obesity were 41% and 69% among females and 38% and 48% among males<sup>19</sup>; before that, overall obesity had appeared stabilized from 2003 to 2012,<sup>20</sup> while abdominal obesity had continued climbing.<sup>21</sup> Given the prevalent burden of abdominal obesity in China and perhaps globally, WC should be considered as a routine measure in clinical services, a meaningful target in preventive health care, and an important metric in public health policy.

One other important finding of this study is the strong, positive association of age groups with BMI

and WC in women but the strong, negative association of age groups with BMI in men. This pattern is not widely reported or characterized in the literature. One possible biological explanation is that postmenopausal women tend to accumulate more abdominal fat due to the deficiency of estrogen, which normally reduces visceral fat by modulating adipose tissue metabolism and leptin responsiveness.<sup>22</sup> Our study also finds that the association of education with obesity differs by sex. This interesting pattern has been noted in the literature, and a recent study of Chinese monozygotic twins suggests that genetic and shared environmental factors confound the (negative) association between education and BMI in females and that unique environmental correlations between education and BMI were only significant in males.<sup>23</sup> While future research should examine how education may affect obesity differently in different demographics, increasing educational attainment and reducing inequality remains a top public health priority as lower educational level has been shown to be the leading modifiable risk factor for death worldwide and the second for cardiovascular disease in middle-income countries.<sup>24</sup>

One notable complex finding of our study is on the relationship between household income and obesity for several reasons. First, data from 1991 to 2011 in China suggest that socioeconomic status positively affected BMI trajectories in males but not females, a reflection of social disparity.<sup>25</sup> Our study similarly found positive associations between household income and obesity in men but not women and may add to this literature. Second, increasing household income could exhibit both deleterious effects of nutritional excess and protective effects of improved dietary quality. For example, the negative income elasticity of demand for inferior goods supports that increasing household income may reduce demand for staple food like rice and potato in favor of substitutes with higher dietary quality and diversity. Third, annual household income may misrepresent long-term household resource, which more reliably determines nutritional status. For example, when Russia experienced rapid economic decline followed by a drastic rebound in 1996 to 2000, population nutritional status was affected by long-term household resource but resilient to short-term fluctuation.<sup>26</sup> Therefore, favorable dietary changes and an imperfect household resource measure may obscure the link between income and obesity in our study.

Understanding the state of obesity in China has implications for the world. Current global trends predict obesity prevalence of 18% in men and 21% in women by 2025.<sup>3</sup> In health trajectory forecasts of 195 countries and territories for 2016 to 2040, rising BMI will slow down the global progress in extending life expectancy and by 2040 become the leading risk factor for years of life lost in 76 countries, followed by tobacco in 48 and high blood pressure in 25; because rising BMI is amenable to population-level interventions, ample room exists for both improvement and deterioration of future health trajectories.<sup>27</sup> In high-income countries, abdominal obesity is the third leading modifiable risk factor for death with a population attributable fraction of 11%.<sup>24</sup> In low-income and middle-income countries, nutritional transition has followed similar patterns that high-income countries experienced in the past, but it has occurred faster and earlier relative to their levels of socioeconomic development.<sup>28</sup> In addition, socioeconomic advancement in low-income populations may increase cardiometabolic disease risk even at levels that do not substantially affect high-income populations.<sup>29</sup> In fact, over the past 3 decades, over half of the global rise in BMI was due to increases in BMI in rural areas in low- and middle-income countries.<sup>30</sup> Interpreting our results in this context highlights the urgency to address the rising obesity epidemic globally and particularly in emerging economies via early, proactive, multi-level interventions.

Several limitations apply to our study. First, timely recruitment of 2.7 million participants across China came with the trade-off of fully representative sampling. For example, compared with the underlying population, rural participants could be healthier (eg, healthy worker effect) or less healthy (eg, participation in research to fulfill unmet healthcare needs). However, our main results closely resemble age-standardized prevalence estimates using the 2010 Chinese Census data and 2 most recently published, independent reports based on nationally representative data from 2014.<sup>5,18</sup> Second, we do not currently have diet and physical activity data on all participants to interrogate their associations with obesity at the individual level; instead, we focus on understanding socio-demographic factors in China to address obesity at the population level. Third, given its cross-sectional design, this study lacks data to assess BMI and WC patterns over time or establish causal determinants of obesity, although a longitudinal study on a similar scale is unprecedented.

In summary, we estimated the prevalence of obesity and its socio-demographic associations in China and report more than one in 7 individuals with overall obesity and one in 3 with abdominal obesity. We show that wide variation in obesity prevalence exists across socio-demographic subgroups and that the associations of age and education with obesity are significant and differ by sex. Understanding the current state of obesity in China has broad implications on public health policy in China and in other emerging economies.

## ARTICLE INFORMATION

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### Supplemental Materials

Supplements I and II  
Expanded Methods  
Figures I and II  
Table

### REFERENCES

- Ng M, Fleming T, Robinson M, Thomson B, Graetz N, Margono C, Mullany EC, Biryukov S, Abbafati C, Abera SF, et al. Global, regional, and national prevalence of overweight and obesity in children and adults during 1980-2013: a systematic analysis for the Global Burden of Disease Study 2013. *Lancet*. 2014;384:766-781. doi: 10.1016/S0140-6736(14)60460-8
- Ramachandran A, Snehalatha C. Rising burden of obesity in Asia. *J Obes*. 2010;2010:868573. doi: 10.1155/2010/868573
- NCD Risk Factor Collaboration (NCD-RisC). Trends in adult body-mass index in 200 countries from 1975 to 2014: a pooled analysis of 1698 population-based measurement studies with 19.2 million participants. *Lancet*. 2016;387:1377-1396. doi: 10.1016/S0140-6736(16)30054-X
- Hiuge-Shimizu A, Kishida K, Funahashi T, Ishizaka Y, Oka R, Okada M, Suzuki S, Takaya N, Nakagawa T, Fukui T, et al. Reduction of visceral fat correlates with the decrease in the number of obesity-related cardiovascular risk factors in Japanese with Abdominal Obesity (VACATION-J Study). *J Atheroscler Thromb*. 2012;19:1006-1018. doi: 10.5551/jat.12963
- Zhang X, Zhang M, Zhao Z, Huang Z, Deng Q, Li Y, Pan A, Li C, Chen Z, Zhou M, et al. Geographic variation in prevalence of adult obesity in China: results from the 2013-2014 National Chronic Disease and risk factor surveillance. *Ann Intern Med*. 2020;172:291-293. doi: 10.7326/M19-0477
- Wu Y, Benjamin EJ, MacMahon S. Prevention and control of cardiovascular disease in the rapidly changing economy of China. *Circulation*. 2016;133:2545-2560. doi: 10.1161/CIRCULATIONAHA.115.008728
- Popkin BM. Synthesis and implications: China's nutrition transition in the context of changes across other low- and middle-income countries. *Obes Rev*. 2014;15(suppl 1):60-67. doi: 10.1111/obr.12120
- Batis C, Sotres-Alvarez D, Gordon-Larsen P, Mendez MA, Adair L, Popkin B. Longitudinal analysis of dietary patterns in Chinese adults from 1991 to 2009. *Br J Nutr*. 2014;111:1441-1451. doi: 10.1017/S0007114513003917
- Ng SW, Howard AG, Wang HJ, Su C, Zhang B. The physical activity transition among adults in China: 1991-2011. *Obes Rev*. 2014;15(suppl 1):27-36. doi: 10.1111/obr.12127
- Ford ES, Li C, Zhao G, Tsai J. Trends in obesity and abdominal obesity among adults in the United States from 1999-2008. *Int J Obes (Lond)*. 2011;35:736-743. doi: 10.1038/ijo.2010.186
- Lu J, Xuan S, Downing NS, Wu C, Li L, Krumholz HM, Jiang L. Protocol for the China PEACE (Patient-centered Evaluative Assessment of Cardiac Events) Million Persons Project pilot. *BMJ Open*. 2016;6:e010200. doi: 10.1136/bmjopen-2015-010200
- Hypertension Study Group of Chinese Society of Cardiology of Chinese Medical Association. Chinese expert consensus on obesity-related hypertension management. *Zhonghua Xin Xue Guan Bing Za Zhi*. 2016;44:212-219. doi: 10.3760/cma.j.issn.0253-3758.2016.03.006 (in Chinese)
- National Bureau of Statistics of China. 2010 Population Census of People's Republic of China. Accessed March 5, 2020. <http://www.stats.gov.cn/english/Statisticaldata/CensusData/rkpc2010/indexch.htm>.
- Chen Z, Iona A, Parish S, Chen Y, Guo Y, Bragg F, Yang L, Bian Z, Holmes MV, Lewington S, et al; China Kadoorie Biobank collaborative group. Adiposity and risk of ischaemic and haemorrhagic stroke in 0.5 million Chinese men and women: a prospective cohort study. *Lancet Glob Health*. 2018;6:e630-e640. doi: 10.1016/S2214-109X(18)30216-X
- Bragg F, Tang K, Guo Y, Iona A, Du H, Holmes MV, Bian Z, Kartsonaki C, Chen Y, Yang L, et al; China Kadoorie Biobank (CKB) Collaborative Group. Associations of general and central adiposity with incident diabetes in Chinese men and women. *Diabetes Care*. 2018;41:494-502. doi: 10.2337/dc17-1852
- He W, Li Q, Yang M, Jiao J, Ma X, Zhou Y, Song A, Heymsfield SB, Zhang S, Zhu S. Lower BMI cutoffs to define overweight and obesity in China. *Obesity (Silver Spring)*. 2015;23:684-691. doi: 10.1002/oby.20995
- WHO Expert Consultation. Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. *Lancet*. 2004;363:157-163. doi: 10.1016/S0140-6736(03)15268-3
- Tian Y, Jiang C, Wang M, Cai R, Zhang Y, He Z, Wang H, Wu D, Wang F, Liu X, et al. BMI, leisure-time physical activity, and physical fitness in adults in China: results from a series of national surveys, 2000-14. *Lancet Diabetes Endocrinol*. 2016;4:487-497. doi: 10.1016/S2213-8587(16)00081-4
- Centers for Disease Control and Prevention. Chronic Kidney Disease Surveillance System—United States. Accessed March 5, 2020. <https://nccd.cdc.gov/ckd/TopicHome/BurdenOfRiskFactors.aspx>.
- Ogden CL, Carroll MD, Kit BK, Flegal KM. Prevalence of childhood and adult obesity in the United States, 2011-2012. *JAMA*. 2014;311:806-814. doi: 10.1001/jama.2014.732
- Ford ES, Maynard LM, Li C. Trends in mean waist circumference and abdominal obesity among US adults, 1999-2012. *JAMA*. 2014;312:1151-1153. doi: 10.1001/jama.2014.8362
- Lovejoy JC, Sainsbury A; Stock Conference 2008 Working Group. Sex differences in obesity and the regulation of energy homeostasis. *Obes Rev*. 2009;10:154-167. doi: 10.1111/j.1467-789X.2008.00529.x
- Liao C, Gao W, Cao W, Lv J, Yu C, Wang S, Li C, Pang Z, Cong L, Dong Z, et al. Association of educational level and marital status with obesity: a study of Chinese twins. *Twin Res Hum Genet*. 2018;21:126-135. doi: 10.1017/thg.2018.8
- Yusuf S, Joseph P, Rangarajan S, Islam S, Mente A, Hystad P, Brauer M, Kutty VR, Gupta R, Wielgosz A, et al. Modifiable risk factors, cardiovascular disease, and mortality in 155 722 individuals from 21 high-income, middle-income, and low-income countries (PURE): a prospective cohort study. *Lancet*. 2020;395:795-808. doi: 10.1016/S0140-6736(19)32008-2
- Fang C, Liang Y. Social disparities in body mass index (BMI) trajectories among Chinese adults in 1991-2011. *Int J Equity Health*. 2017;16:146. doi: 10.1186/s12939-017-0636-5
- Stillman S, Thomas D. Nutritional status during an economic crisis: evidence from Russia. *Econ J*. 2008;118:1385-1417.
- Foreman KJ, Marquez N, Dolgert A, Fukutaki K, Fullman N, McGaughey M, Pletcher MA, Smith AE, Tang K, Yuan CW, et al. Forecasting life expectancy, years of life lost, and all-cause and cause-specific mortality for

- 
- 250 causes of death: reference and alternative scenarios for 2016-40 for 195 countries and territories. *Lancet*. 2018;392:2052–2090. doi: 10.1016/S0140-6736(18)31694-5
28. Popkin BM. The shift in stages of the nutrition transition in the developing world differs from past experiences! *Public Health Nutr*. 2002;5(1A):205–214. doi: 10.1079/PHN2001295
29. Godfrey KM, Gluckman PD, Hanson MA. Developmental origins of metabolic disease: life course and intergenerational perspectives. *Trends Endocrinol Metab*. 2010;21:199–205. doi: 10.1016/j.tem.2009.12.008
30. NCD Risk Factor Collaboration (NCD-RisC). Rising rural body-mass index is the main driver of the global obesity epidemic in adults. *Nature*. 2019;569:260–264. doi: 10.1038/s41586-019-1171-x