

# Forecasting the Populations of Overweight and Obese Chinese Adults

This article was published in the following Dove Press journal:  
*Diabetes, Metabolic Syndrome and Obesity: Targets and Therapy*

Ruhai Bai<sup>1,2</sup>  
Wentao Wu<sup>3</sup>  
Wanyue Dong<sup>3,4</sup>  
Jinli Liu<sup>3</sup>  
Lili Yang<sup>5</sup>  
Jun Lyu<sup>1</sup>

<sup>1</sup>Department of Clinical Research, The First Affiliated Hospital of Jinan University, Guangzhou, Guangdong, People's Republic of China; <sup>2</sup>Evidence-Based Research Center of Social Science & Health, Public Affair School of Nanjing University of Science & Technology, Nanjing, People's Republic of China; <sup>3</sup>School of Public Health, Xi'an Jiaotong University, Xi'an, Shaanxi, People's Republic of China; <sup>4</sup>School of Health Economics and Management, Nanjing Chinese Medicine University, Nanjing, People's Republic of China; <sup>5</sup>Department of General Medicine, Lanzhou University Second Hospital, Lanzhou, Gansu, People's Republic of China

**Purpose:** The objective of this study was to forecast the prevalence rates and the populations of overweight and obese in Chinese adults for 2030.

**Materials and Methods:** Nine waves of China Health and Nutrition Survey (CHNS) data from 1991 to 2015 were used. A polynomial regression model was fitted to obtain the average BMI change trajectory of the population born in different years according to different sexes and residence areas (urban and rural). The model fitted to CHNS 2015 survey data was used to forecast the distribution of BMI and the prevalence rates of overweight and obesity in 15 years. The United Nations population forecast was then used to predict the proportions of overweight obese adults in all age groups in China in 2030.

**Results:** The prevalence rates of overweight and obesity were projected to increase in both sexes and all geographic areas in future. By 2030, urban males will have the highest prevalence of overweight, 50.7% (95% CI: 47.5%, 53.9%). Except urban males, the prevalence of overweight and obesity in rural areas will exceed that in urban for both sexes. In 2030, the numbers of overweight and obese people in China aged 20–89 years will reach 540 million and 150 million, respectively, which are 2.8 and 7.5 times higher compared to prevalences in 2000. In 2030, the number of overweight and obese people in China aged 60–89 years will reach 200 million and 40 million, respectively, 6.3 and 8.5 times increments from the year 2000.

**Conclusion:** The prevalence rates of overweight and obese in Chinese adults are projected to increase further, by 2030 more than half of adult males living in urban areas will be overweight. Combined with changes in the population age structure, overweight and obesity will have a huge impact on the health of the Chinese population over the next 15 years.

**Keywords:** aging, BMI, prediction, population; overweight; obesity

## Introduction

Overweight and obesity have become an important public health problem in China.<sup>1</sup> Nationally representative survey data show that their prevalence rates have steadily increased in recent decades, although with large disparities between population groups.<sup>1,2</sup> It is estimated that overweight and obesity caused 34 million deaths worldwide in 2010, which constitutes 3.9% of all deaths.<sup>3</sup> As the most populous country in the world, China's obese population in 2014 surpassed that of the United States, making it the world's most obese country.<sup>3</sup>

With the increase of the prevalence of overweight and obesity, obesity-related chronic disease (such as hypertension, cardiovascular disease (CVD), type 2 diabetes, cancer, etc.)<sup>3,4</sup> have also increased in the past decade. The incidence of hypertension in adults increased from 13.6% in 1991 to 23.2% in 2012 to 2015.<sup>5,6</sup>

Correspondence: Jun Lyu  
Jinan University, No. 601, West Huangpu Avenue, Guangzhou, Guangdong, People's Republic of China  
Email lyujun2020@jnu.edu.cn

And from 1990 to 2017, the prevalence of CVD in China rose from 5265.6/100,000 to 6037.0/100,000,<sup>7</sup> Diabetes rose from 3.7% to 6.6%,<sup>8</sup> cancer increased from 494.74/100,000 to 1587.37/100,000.<sup>9</sup> The rapid increases in the prevalence rates of overweight and obesity and the related chronic diseases are likely to have a tremendous impact on the health of the Chinese population in the future.

Raised prevalence of overweight and obesity will imply increase economic burden for individuals, health-care systems, and overall Chinese society.<sup>10</sup> Between 2000 and 2009, the per capita medical expenses caused by overweight and obesity required an extra 6.18 yuan for a single medical event, accounting for 2.46% of personal medical expenses in China.<sup>11</sup> According to a previous study, the total medical expenses caused by overweight and obesity were 21.11 billion yuan (approximately US\$2.74 billion), accounting for 3.7% of the total national medical expenses in 2003.<sup>12</sup> Overweight and obesity can also reduce labor productivity, resulting in many indirect economic losses.<sup>13</sup>

Forecasting the expansion of the health and economic burdens resulting from the increasing prevalence of obesity is crucial to effective public health planning. This study aimed to predict the future prevalence rates and the populations of overweight and obese among Chinese adults. These changes are described according to different sexes and residence areas (urban and rural), and the age structures of overweight and obesity are compared between 2000 and 2030.

## Materials and Methods

### Data Source

Our projection analysis was based on prevalence data from the China Health and Nutrition Survey (CHNS). The CHNS is a large-scale, longitudinal, household-based survey conducted by the Center for Disease Prevention and Control in China and the Population Center of the University of North Carolina in the United States.<sup>14</sup> The CHNS was first performed in 1989 and then subsequently in 1991, 1993, 1997, 2000, 2004, 2006, 2009, 2011, and 2015. The CHNS initially included eight provinces, and then seven more provinces were added over the following two decades.<sup>14,15</sup> A multistage, random-cluster process was used to select the sample in each of the surveyed provinces.<sup>7</sup> Detailed descriptions of the survey design and procedures are available elsewhere.<sup>14,16</sup> Survey protocols and instruments and the process followed for obtaining informed consent for the CHNS were approved by the

institutional review committees of the National Institute of Nutrition and Food Safety at the Chinese Centre for Disease Control and Prevention and the University of North Carolina at Chapel Hill. All participants gave written informed consent.<sup>17</sup> The data accessed from the CHNS are freely available (<http://www.cpc.unc.edu/projects/china/data/data.html>).<sup>14</sup>

The present study used nine waves of survey data from 1991 to 2015. We did not include the first wave in 1989 because this did not collect the data for all age groups. Our study focused on adults aged 20–89 years in each survey year, and the obtained data provided information on age, sex, living area (urban or rural), and detailed physical examinations including weight and height. In the CHNS survey, weight and height were measured by trained health workers in accordance with procedures and standards recommended by the World Health Organization (WHO). Height was measured to the nearest 0.1 cm without shoes using a portable stadiometer and weight was measured to the nearest 0.1 kg while wearing lightweight clothing using a calibrated beam scale.<sup>18</sup> Overweight and obesity were defined using WHO recommended body mass index (BMI) classifications (overweight defined as  $BMI \geq 25$ , and obesity as  $BMI \geq 30 \text{ kg/m}^2$ ) so that our results would be comparable with those from other countries. Pregnant or lactating females were excluded since their raised BMI may exaggerate the forecasts for general population. Population size estimates for China in 2000 and 2030 were derived from the United Nations' World Population Prospects: 2017 revision (WPP 2017).

### Statistical Analysis

We used parametric polynomial regression model to fit BMI curve, this model has been used to forecast the obesity epidemic in the Aging US Population.<sup>19</sup> Continuous age and calendar year as explanatory variables to predict the mean population BMI according to age and year. To explicitly acknowledge the differences in BMI trends by sex and urban/rural residence area, we fit separate models for the following four demographic subgroups: urban males, urban females, rural males, and rural females.

In the process of fitting the polynomial regression model, we only added higher-order items when their inclusion greatly improved the model determinant coefficient ( $R^2 \geq 5\%$ ).<sup>19</sup> The final polynomial model used in our study was as follows:

$$BMI = year + age + age^2 + age \times year$$

We used the above model to predict mean BMI values for ages from 20 to 89 years in calendar years from 2015 to 2030. We then simultaneously increased the age and year in sequence to track the expected trajectory of BMI means for each birth cohort as they age. For example, for a cohort born in 1960, we obtained their mean BMI values at an age of 30 years in 1990, 31 years in 1991, and so forth. These trajectories represent our predictions of age-related BMI changes, and each trajectory was used to calculate the annual variation of the average BMI.

In order to predict the BMI distribution among Chinese adults aged 20–89 years in 2030, we projected 15-year changes in the BMI for the CHNS 2015 data. We matched the derived annual variation change of the average BMI to each individual in 2015 by sex, age, urban/rural residence area, and birth year, and projected their BMI 15 years forward. Since there may be bias in predicting the trajectory of BMI changes in adolescents, this study assumed that the BMI distribution among those aged 20–35 years in 2030 will be consistent with that in 2015.

Based on the past BMI distributions and the predicted BMI distribution in 2030, this study described the trend of the BMI distribution in China from 1991 to 2030, and the prevalence rates of overweight and obesity for adults aged 20–89 years in China. The age-specific prevalence rates of overweight and obesity in 2000 and 2030 were extracted and applied to the Chinese population of different ages in 2000 and 2030. We chose 2000 for comparison because both CHNS data and WPP 2017 data include the year 2000, and it also provides a long enough time for comparison. Bootstrap method was used to obtain 95% Confidence Interval (95% CI). The population pyramid

was used to visually display the numbers of overweight and obese people in 2000 and 2030. In this study, the prevalence rates of overweight and obesity were weighted according to the national census in 2010.

All analyses were performed using R software (version 3.6.0).

## Results

### Prevalence Rates of Overweight and Obesity Among Chinese Adults from 2000 to 2015

Between 1991 and 2015, the prevalence rates of overweight and obesity increased in both sexes and all geographic areas. In 1991, the prevalence rates of overweight and obesity in China were 13.9% (95% CI: 13.2%, 14.6%) and 1.4% (95% CI: 1.1%, 1.6%), respectively; the corresponding values in 2015 were 34.9% (95% CI: 34.1%, 35.8%) and 7.1% (95% CI: 6.6%, 7.6%). Males living in urban areas had the highest prevalence of overweight, at 42.5% (95% CI: 39.9%, 45.4%), while males living in rural areas saw the largest relative increase in the prevalence of overweight. The increase among female subjects was greater among those living in rural areas (Table 1).

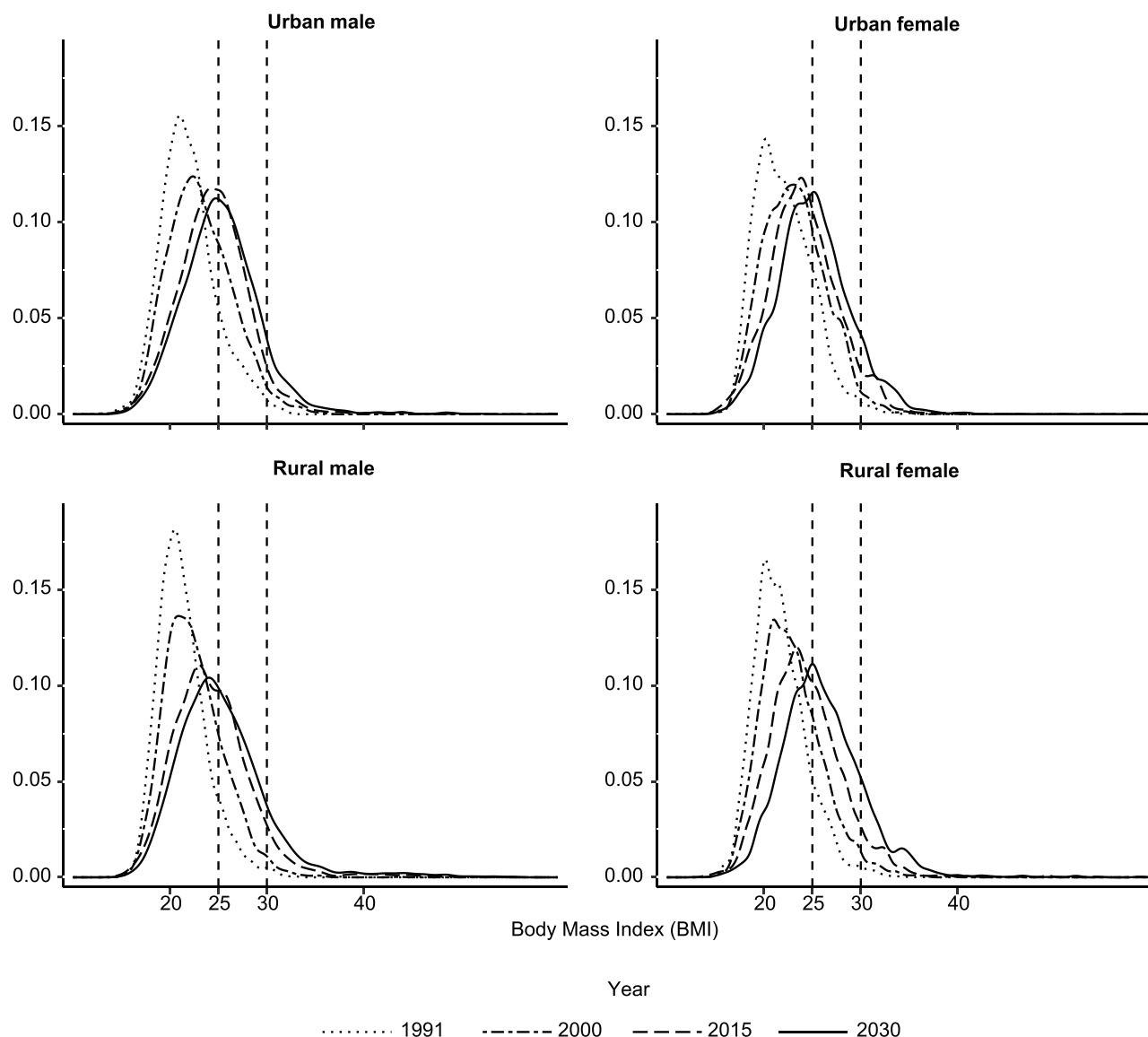
### Forecasting Prevalence Rates of Overweight and Obesity in Chinese Adults

Figure 1 shows the distribution of BMI of Chinese adults in the past and the predicted distribution of BMI in 2030. Regardless of males and females, urban and rural areas, the overall distribution of Chinese adult BMI shifts to the

**Table 1** Prevalence of Overweight and Obesity in Chinese Adults from 1991 to 2015

		Men		Women (%)		Total (%)	
		1991 Rate (95% CI)	2015 Rate (95% CI)	1991 Rate (95% CI)	2015 Rate (95% CI)	1991 Rate (95% CI)	2015 Rate (95% CI)
Urban	Overweight	14.1(12.1,16)	42.5(39.9,45.4)	19.5(17.8,21.2)	29.3(27.9,30.8)	17.8(16.4,19.2)	33.5(32,34.9)
	Obesity	0.7(0.3,1.3)	6.1(4.7,7.7)	2.0(1.4,2.9)	4.9(4.1,5.7)	1.5(1.1,2)	5.4(4.7,6.1)
Rural	Overweight	9.0(7.8,10.2)	39.1(37.3,41)	13.6(12.6,14.6)	33.8(32.5,35)	12.0(11.3,12.7)	35.5(34.4,36.6)
	Obesity	0.8(0.5,1.2)	8.5(7.3,9.6)	1.6(1.2,2.1)	7.3(6.5,8.1)	1.3(1,1.6)	7.9(7.3,8.7)
Total	Overweight	10.6(9.7,11.6)	40.5(38.8,41.9)	15.5(14.6,16.3)	32.3(31.4,33.3)	13.9(13.2,14.6)	34.9(34.1,35.8)
	Obesity	0.8(0.5,1.1)	7.8(6.9,8.9)	1.7(1.4,2.1)	6.5(5.9,7.1)	1.4(1.1,1.6)	7.1(6.6,7.6)

**Note:** Prevalence was weighted according to the national census in 2010.



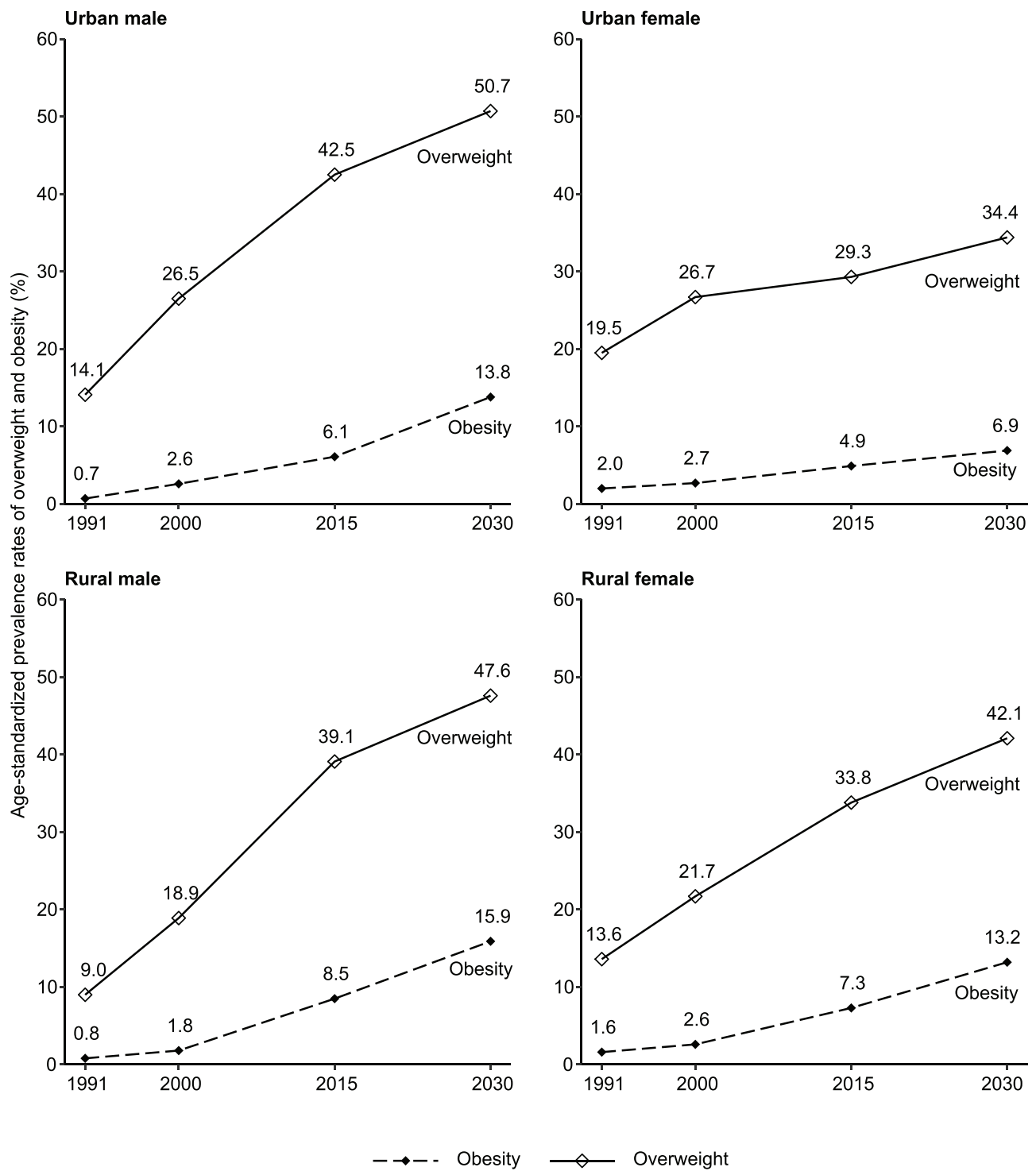
**Figure 1** Shifts in BMI distribution among Chinese adults between 1991 and 2030.

right, that is, the median BMI increases as time goes on. While the lower part of BMI distribution among Chinese adults is predicted to show a decrease, the upper part of BMI distribution is predicted to show a large increase from 1991 to 2030 in both the urban/rural and sex subgroups.

As showed in Figure 2, in 2000, female living in urban have the highest prevalence of overweight and obesity in 26.7% (95% CI: 25.2%, 27.9%) and 2.7% (95% CI: 2.2%, 3.3%), respectively. The lowest prevalence of overweight and obesity was found in males living in rural in 18.9% (95% CI: 17.5%, 20.4%) and 1.8% (95% CI: 1.3%, 2.3%), respectively. It is estimated that by 2030, the prevalence of overweight and obesity will increase for both men and women, urban and rural areas. The highest projected

prevalence of overweight was found in males living in urban areas at 50.7% (95% CI: 47.5%, 53.9%) in 2030. And the highest projected prevalence of obesity was found in males living in rural areas at 15.9% (95% CI: 14.3%, 17.6%) in 2030. Females living in urban area have the lowest projected prevalence of overweight and obesity in 34.4% (95% CI: 32.2%, 36.8%) and 6.9% (95% CI: 5.7%, 8.3%), respectively.

From 2000 to 2015, the highest increase of overweight and obesity was found in males living in rural, which increased from 18.9% (95% CI: 17.3%, 20.5%) to 39.1% (95% CI: 37.4%, 40.9%) and 1.8% (95% CI: 1.3%, 2.3%) to 8.5% (95% CI: 7.3%, 9.8%), respectively. The lowest increase of overweight and obesity was found in females living in urban, which



**Figure 2** Current and projected prevalence of overweight and obesity for the years of 1991, 2000, 2015 and 2030.

increased from 26.7% (95% CI: 25.5%, 28.0%) to 29.3% (95% CI: 27.8%, 31.1%) and 2.7% (95% CI: 2.1%, 3.3%) to 4.9% (95% CI: 4.1%, 5.7%), respectively.

From 2015 to 2030, males living in rural were projected to have the highest increase of overweight, which

increased from 39.1% (95% CI: 37.4%, 40.9%) to 47.6% (95% CI: 45.6%, 49.8%). Males living in urban were projected to have the highest increase of obesity, which increased from 6.1% (95% CI: 4.9%, 7.8%) to 13.8% (95% CI: 11.5%, 16.3%). Females living in urban still

have lowest increase of the prevalence of overweight and obesity, which increased from 29.3% (95% CI: 27.8%, 31.1%) to 34.4% (95% CI: 32.3%, 36.6%) and 4.9% (95% CI: 4.1%, 5.7%) to 6.9% (95% CI: 5.7%, 8.3%), respectively.

It is worth noting that in 1991 and 2000, the prevalence of overweight and obesity in urban China was higher than that in rural areas for both men and women, but after 2015, except males living in urban area, the prevalence of overweight and obesity in rural areas exceeded that in urban areas for both sexes.

## Forecasting the Populations of Overweight and Obese Chinese Adults

In 2000, the overweight and obese populations in China aged from 20 to 89 years were 190 million and 20 million, respectively, and it is estimated that by 2030 they will reach 540 million and 150 million. By 2030, the overweight population aged 20–89 years in China will be 2.8 times larger than that in 2000, while the obese population will be 7.5 times larger.

Compared with 2010, the populations of overweight and obesity adults will increase in all groups in 2030 with the exception of females aged 20–29 years. In 2000, the overweight and obese populations were largest among those aged 30–49 years, while in 2030 they will be largest among those aged 40–69 years. The populations of overweight and obesity adults older than 60 years have increased significantly. It is estimated that by 2030, the numbers of elderly overweight and obesity patients will reach 200 million and 40 million, respectively, representing increases of 6.3 and 8.5 times compared with 2000. These increases are substantially larger than the average population increase across all adults (Figure 3).

## Discussion

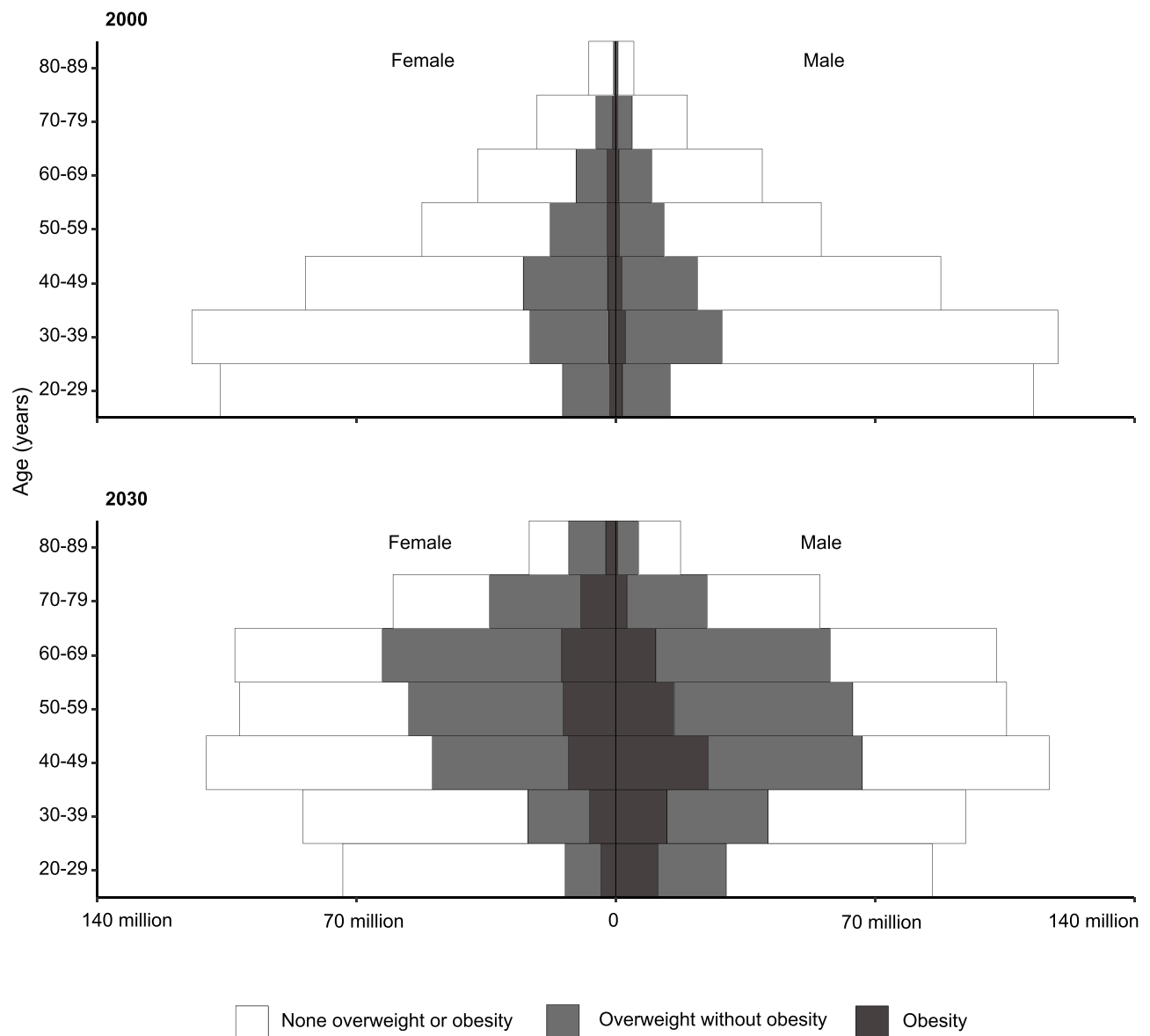
This study reveals that the prevalence rates of overweight and obesity among Chinese adults have increased over the past 20 years. If the past trends continue, more than half of urban males will be overweight by 2030. The increasing overweight and obese populations and especially their rapid growth among the elderly will greatly increase the burden on health-care services related to overweight- and obesity-related diseases.

Obesity is an abnormal or excessive accumulation of fat that may damage health.<sup>20</sup> The rapid developments of China's economy and society over the past 2 decades have

significantly increased household incomes, resulting in larger amounts of high-fat and high-energy food being consumed.<sup>2,21–23</sup> At the same time, technological advances have reduced physical activity, and so the increased intake and decreased energy expenditure in both working and private lives have together contributed to the increases of the prevalence rates of overweight and obesity in China.<sup>2,22,24</sup>

The prevalence of overweight and obesity in China has exceeded that of many Asian countries.<sup>25</sup> Although in terms of prevalence, the prevalence of overweight and obesity in China is lower than that of countries with high prevalence of overweight and obesity such as the United States,<sup>26</sup> considering the huge population base, the number of overweight and obese population in China is huge. Since 2014, China has surpassed the United States to become the country with the largest number of obese people around the world.<sup>3</sup> What is particularly worrying is that by 2030, the prevalence of overweight and obesity in China, whether in urban or rural areas, both men and women, will further increase, and more than half of urban males will be overweight. Previous study has shown that in 2030 the global prevalence of overweight adults is 38%, and obesity is 20%.<sup>27</sup> Based on this results, except for urban women, the prevalence of overweight in urban and rural men and rural women in China will exceed the world average level in 2030. As the prevalence of overweight and obesity increases, overweight and obesity-related chronic diseases will also increase.<sup>20</sup> In the past few decades, China's mortality and morbidity have undergone tremendous changes, especially the reduction of infectious diseases and the increase of obesity-related chronic diseases (such as hypertension, CVD and type 2 diabetes).<sup>2,28</sup> National programs and strategies are urgently needed in China to face the challenges of the growing obesity and chronic disease epidemic.

The prevalence rates of overweight and obesity have increased more among rural than urban residents, with the exception of overweight among urban males. The lower prevalence rates of overweight and obesity in rural areas in the past may be attributed to the higher energy consumption of rural residents in their daily lives, especially in relation to agricultural activities.<sup>2,21</sup> The lower prevalence rates may also be due to their lower household incomes restricting their expenditure on food.<sup>23,29</sup> The advancements of the rural infrastructure, improved water conservancy, improved traffic mobility, and electrification in recent years have all contributed to reducing the energy consumption of laborers, and meanwhile the increased incomes of rural residents have increased their food consumption, which all contribute to weight gain.<sup>29,30</sup> In the



**Figure 3** Population pyramid and BMI distribution for people age 20–89 by gender for 2000 and 2030.

United States, due to less leisure-time physical activity, lower intake of fiber and fruits and higher intake of sweetened beverages, the odds of being obese among rural adults were 1.19 times higher than that among urban adults.<sup>31</sup> In recent years, the rural population in China has found the same phenomenon. In 2015, the prevalence of obesity in rural men and women exceeded that in urban areas, and this phenomenon is not expected to change in 2030. Although China has made great achievements in poverty eradication, we must not ignore the problem of overweight and obesity in rural areas. Otherwise, the growth of overweight and obesity and the resulting loss of productivity may damage the prosperity enjoyed by the rural population. Effective

and practical policies are needed for preventing obesity and overweight in rural China. The present study found that the increases in the rates of overweight and obesity were smallest among urban females. This may be because urban females usually have more family responsibilities, which consume more energy, and also pay more attention to their own physical health.<sup>2</sup>

The results of this study show that by 2030, while the prevalence rates of overweight and obesity in China are increasing, this will be even more significant among the elderly. It can be predicted that overweight and obesity will have a huge impact on the health of the Chinese population in the future. The increasing age of the elderly is associated with

the function of various organs gradually declining, and their risk of disease is significantly higher than in other age groups.<sup>32–34</sup> Accompanied by diseases related to being overweight and obese, such as cardiovascular diseases, diabetes, cancer, musculoskeletal diseases, and chronic kidney disease, the elderly will face greater risks of chronic diseases that increase their risk of death.<sup>22</sup> In addition, the relatively low income of the elderly will mean that the economic burden on society will increase, and their quality of life will be affected.<sup>32</sup> The huge numbers of overweight and obese adults and the aging of the China society together mean that overweight and obesity will pose a huge potential challenge to China's health-care system. Advance preparations are needed to confront this challenge and attempt to halt the growing problem of overweight and obesity.

Considering the special economic, cultural, social and contextual factors in China, the following strategies and programs were recommended. First, inter-departmental cooperation in obesity prevention should be strengthened with the support by the central and local governments. Integrate obesity prevention into multi-sectoral policies and daily work. Secondly, professional institutions should play an important role in obesity prevention. Obesity prevention agencies need to carry out obesity-related health education and promote healthy lifestyle at the whole population level. Thirdly, promote families and individuals to participate in obesity prevention. In addition, it is vital to develop and strengthen national plans for screening for hypertension, type 2 diabetes and dyslipidemia, and provide patients with timely and affordable treatment.<sup>35,36</sup>

This study was subject to some limitations. First, it was assumed that the BMI distribution among those aged 20–35 years in 2030 will be consistent with that in 2015 in order to avoid bias in predicting the trajectory of BMI changes in adolescents. Considering the increasing trends of the prevalence rates of overweight and obesity in Chinese children,<sup>37,38</sup> we might have underestimated the prevalence. Second, we did not predict the overweight and obese populations in China's urban and rural areas since the United Nations does not distinguish between urban and rural populations in their population forecasts for China. Third, beside the WHO standard of overweight and obesity, there is another standard recommend used in China (BMI of 24.0 to 27.9 as overweight, and 28.0 and above as obese). If using this standard, the prevalence and population of obesity would be underestimated in our study. Finally, although BMI provides the most useful population-level measure of overweight and obesity and was widely used, BMI is less

accurate for assessing healthy weight in some groups of people because it does not distinguish between the proportion of weight due to fat or muscle.<sup>40</sup>

## Conclusion

In summary, the prevalence of overweight and obesity has increased steadily among all Chinese population groups over the past nearly two decades. If the current trend continues, more than half of Chinese males living in urban areas are expected to be overweight by 2030. With the exception of overweight among urban males, the prevalence of overweight and obesity in rural China has surpassed that in urban areas. Therefore, more attention should be taken to control the rapid rise of obesity among rural residents. The huge numbers of overweight and obese adults combine with the aging of the China society will pose a huge potential challenge to China's health-care system. These results may provide theoretical support for the rational allocation of health resources and for controlling the prevalence rates of overweight and obesity in the future.

## Acknowledgments

We are grateful to individuals who participated in the study.

## Disclosure

The authors report no conflicts of interest in this work.

## References

1. Wu Y. Overweight and obesity in China. *BMJ*. 2006;333(7564):362–363. doi:10.1136/bmj.333.7564.362
2. Wang Y, Mi J, Shan XY, Wang QJ, Ge KY. Is China facing an obesity epidemic and the consequences? The trends in obesity and chronic disease in China. *Int J Obesity*. 2007;31(1):177–188. doi:10.1038/sj.ijo.0803354
3. Ng M, Fleming T, Robinson M, 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(9945):766–781. doi:10.1016/S0140-6736(14)60460-8
4. Stevens GA, Singh GM, Lu Y, et al. National, regional, and global trends in adult overweight and obesity prevalences. *Popul Health Metr*. 2012;10(1):22. doi:10.1186/1478-7954-10-22
5. Wang Z, Chen Z, Zhang L, et al. Status of hypertension in China: results from the China hypertension survey, 2012–2015. *Circulation*. 2018;137(22):2344–2356. doi:10.1161/CIRCULATIONAHA.117.032380
6. Tao S, Zhou B. Epidemiology of hypertension in China. *Chin Med J*. 1999;112(10):878–882.
7. Liu S, Li Y, Zeng X, et al. Burden of cardiovascular diseases in China, 1990–2016: findings from the 2016 global burden of disease study. *JAMA Cardiol*. 2019;4(4):342–352. doi:10.1001/jamcardio.2019.0295
8. Liu M, Liu SW, Wang LJ, et al. Burden of diabetes, hyperglycaemia in China from 1990 to 2016: findings from the 1990 to 2016, global burden of disease study. *Diabetes Metab*. 2019;45(3):286–293. doi:10.1016/j.diabet.2018.08.008



9. Global Burden of Disease Cancer Collaboration. Global, regional, and national cancer incidence, mortality, years of life lost, years lived with disability, and disability-adjusted life-years for 29 cancer groups, 1990 to 2017: a systematic analysis for the global burden of disease study. *JAMA oncol*. 2019;5(12):1749–1768. doi:10.1001/jamaoncol.2019.2996.
10. Tremmel M, Gerdtham UG, Nilsson PM, Saha S. Economic burden of obesity: a systematic literature review. *Int J Environ Res Public Health*. 2017;14(4):Apr. doi:10.3390/ijerph14040435
11. Qin X, Pan J. The medical cost attributable to obesity and overweight in China: estimation based on longitudinal surveys. *Health Econ*. 2016;25(10):1291–1311. doi:10.1002/hec.3217
12. Zhao W, Zhai Y, Hu J, et al. Economic burden of obesity-related chronic diseases in Mainland China. *Obesity Reviews*. 2008;9:62–67. doi:10.1111/j.1467-789X.2007.00440.x
13. Lehnert T, Sonntag D, Konnopka A, Riedel-Heller S, König HH. Economic costs of overweight and obesity. *Best Pract Res Clin Endocrinol Metab*. 2013;27(2):105–115. doi:10.1016/j.beem.2013.01.002
14. Popkin BM, Du S, Zhai F, Zhang B. Cohort profile: the China health and nutrition survey—monitoring and understanding socio-economic and health change in China, 1989–2011. *Int J Epidemiol*. 2010;39(6):1435–1440. doi:10.1093/ije/dyp322
15. Popkin BM, Paeratakul S, Ge K, Zhai F. Body weight patterns among the Chinese: results from the 1989 and 1991 China health and nutrition surveys. *Am J Public Health*. 1995;85(5):690–694. doi:10.2105/ajph.85.5.690
16. Zhang B, Zhai FY, Du SF, Popkin BM. The China health and nutrition survey, 1989–2011. *Obes Rev*. 2014;15 Suppl 1:2–7. doi:10.1111/obr.12119
17. Chen Y, Liang X, Zheng S, Wang Y, Lu W. Association of body fat mass and fat distribution with the incidence of hypertension in a population-based Chinese cohort: a 22-year follow-up. *J Am Heart Assoc*. 2018;7(6). doi:10.1161/JAHA.117.007153
18. Wang YC, Colditz GA, Kuntz KM. Forecasting the obesity epidemic in the aging U.S. population. *Obesity*. 2007;15(11):2855–2865. doi:10.1038/oby.2007.339
19. World Health Organization. Obesity and overweight. Available from: <https://www.who.int/en/news-room/fact-sheets/detail/obesity-and-overweight>. Accessed Oct 14, 2020.
20. Levine JA. Obesity in China: causes and solutions. *Chin Med J*. 2008;121(11):1043–1050. doi:10.1097/00029330-200806010-00015
21. Gu D, Reynolds K, Wu X, et al. Prevalence of the metabolic syndrome and overweight among adults in China. *Lancet*. 2005;365(9468):1398–1405. doi:10.1016/S0140-6736(05)66375-1
22. Reynolds K, Gu D, Whelton PK, et al. Prevalence and risk factors of overweight and obesity in China. *Obesity*. 2007;15(1):10–18. doi:10.1038/oby.2007.527
23. He Y, Pan A, Wang Y, et al. Prevalence of overweight and obesity in 15.8 million men aged 15–49 years in rural China from 2010 to 2014. *Sci Rep*. 2017;7(1):5012. doi:10.1038/s41598-017-04135-4
24. 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(10026):1377–1396. doi:10.1016/S0140-6736(16)30054-X.
25. Flegal KM, Kruszon-Moran D, Carroll MD, Fryar CD, Ogden CL. Trends in obesity among adults in the United States, 2005 to 2014. *JAMA*. 2016;315(21):2284–2291. doi:10.1001/jama.2016.6458
26. Smith KB, Smith MS. Obesity statistics. *Prim Care*. 2016;43(1):121–35, ix. doi:10.1016/j.pop.2015.10.001
27. Cook IG, Dummer TJ. Changing health in China: re-evaluating the epidemiological transition model. *Health Policy*. 2004;67(3):329–343. doi:10.1016/j.healthpol.2003.07.005
28. 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(7755):260–264. doi:10.1038/s41586-019-1171-x.
29. Tian H, Xie H, Song G, Zhang H, Hu G. Prevalence of overweight and obesity among 2.6 million rural Chinese adults. *Prev Med*. 2009;48(1):59–63. doi:10.1016/j.ypmed.2008.10.020
30. Trivedi T, Liu J, Probst J, Merchant A, Jones S, Martin AB. Obesity and obesity-related behaviors among rural and urban adults in the USA. *Rural Remote Health*. 2015;15(4):3267.
31. Houston DK, Nicklas BJ, Zizza CA. Weighty concerns: the growing prevalence of obesity among older adults. *J Am Diet Assoc*. 2009;109(11):1886–1895. doi:10.1016/j.jada.2009.08.014
32. Liu H, Byles JE, Xu X, Zhang M, Wu X, Hall JJ. Evaluation of successful aging among older people in China: results from China health and retirement longitudinal study. *Geriatr Gerontol Int*. 2017;17(8):1183–1190. doi:10.1111/ggi.12848
33. Flaherty JH, Liu ML, Ding L, et al. China: the aging giant. *J Am Geriatr Soc*. 2007;55(8):1295–1300. doi:10.1111/j.1532-5415.2007.01273.x
34. Wang YF, Sun MX, Xue H, et al. Understanding the china blue paper on obesity prevention and control and policy implications and recommendations for obesity prevention and control in China. *Chinese J Prevention Med*. 2019;53(9):875–884. doi:10.3760/cma.j.issn.0253-9624.2019.09.003
35. Wang Y, Xue H, Sun M, Zhu X, Zhao L, Yang Y. Prevention and control of obesity in China. *Lancet Global Health*. 2019;7(9):e1166–e1167. doi:10.1016/s2214-109x(19)30276-1
36. Sun G, Jia G, Peng H, Dickerman B, Compher C, Liu J. Trends of childhood obesity in China and associated factors. *Clin Nurs Res*. 2015;24(2):156–171. doi:10.1177/1054773813493286
37. Zhang J, Wang H, Wang Z, et al. Prevalence and stabilizing trends in overweight and obesity among children and adolescents in China, 2011–2015. *BMC Public Health*. 2018;18(1):571. doi:10.1186/s12889-018-5483-9
38. Buss J. Limitations of body mass index to assess body fat. *Workplace Health Saf*. 2014;62(6):264. doi:10.1177/216507991406200608

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