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## Changes in waist circumference relative to body mass index in Chinese adults, 1993–2009

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### Abstract

**Background**—Although BMI and waist circumference (WC) are correlated, the relationship between WC and BMI may have changed over time.

**Objectives**—Describe temporal trends in BMI and WC distributions and quantify the increase in WC at a given BMI over time.

**Subjects/Methods**—Data on adults aged 20–59 years from two waves (1993 and 2009) of the China Health and Nutrition Survey (CHNS) were used in a pooled cross-sectional analysis. Quantile regression examined age-adjusted temporal trends in the distributions of BMI and WC. Linear regression examined changes in mean WC over time, adjusting for BMI, age at survey and survey year. All models were stratified by gender.

**Results**—There was a significant increase in BMI and WC over time, particularly at the 95<sup>th</sup> quantile: on average, men had 2.8 kg/m<sup>2</sup> (95% CI: 2.4, 3.3) and women 1.5 kg/m<sup>2</sup> (95% CI: 1.1, 2.0) higher BMI in 2009 compared to their counterparts in 1993. WC increased by 9.0 cm (95% CI: 7.5, 10.1) and 5.0 cm (95% CI: 3.4, 6.6) for men and women had a 3.2 cm (95% CI: 2.8, 3.7) and 2.1 cm (95% CI: 1.7, 2.5) higher WC in 2009 compared to their counterparts in 1993, holding BMI and age constant. WC adjusted for BMI increased to a larger extent amongst obese versus lean individuals and amongst younger versus older women.

**Conclusions**—For both genders, BMI and WC increased significantly over time, with particularly greatest increase in magnitude in the upper tail of the BMI and WC distributions. Furthermore, WC at equivalent BMI was higher in 2009, compared to their counterparts in 1993.

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#### AUTHORS' CONTRIBUTIONS TO MANUSCRIPT

DS, LPS and BMP were responsible for the study concept and design. DS was responsible for the data analysis, interpretation of results and the draft of the manuscript. LPS, PGL and BMP provided guidance in the interpretation of results and manuscript development. DS, LPS, BZ, PGL and BMP were responsible for the critical revision of the manuscript. None of the authors has conflict of interests of any type with respect to this manuscript.

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Our findings suggest that even if BMI remained constant from 1993 to 2009, adults in 2009 might be at increased cardiometabolic risk as a result of their higher WC.

### Keywords

Waist circumference; body mass index; quantile regression; China; epidemiology

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## INTRODUCTION

China has experienced rapid increases in the prevalence of diabetes, hypertension and other cardiometabolic risk factors<sup>1, 2</sup>. One of the major underlying factors has been the marked increase in the prevalence of overweight and obesity and also abdominal adiposity, as measured by waist circumference (WC)<sup>3</sup>.

A large body of literature has identified the cardiometabolic consequences of increased deposition of fat at the abdominal level, independently of BMI, an indicator of body mass<sup>4-7</sup>. A number of studies conducted in Chinese adults indicate that abdominal adiposity, as measured by WC, is a stronger predictor of coronary heart disease, diabetes and metabolic syndrome than general adiposity<sup>8-11</sup>. Gordon-Larsen et al.<sup>12</sup> found that independent of overweight status, as measured by BMI, abdominal obesity, as measured by WC, conferred increased risk of hypertension, diabetes, dyslipidemia, and inflammation and that overweight individuals with high WC were at highest risk.

In China, research has documented that average body mass index (BMI) and WC have increased over time<sup>3, 13</sup>. However, the nature of the changes across the full distribution of BMI and WC is unknown. Moreover, limited research from U.S. and other countries suggests that WC at selected BMI levels has increased and that the relationship between WC and BMI may have changed over time<sup>14-16</sup>. Yet, it is unclear whether Chinese adults have experienced this same increase in WC at equivalent BMI.

In this study, we take advantage of data on Chinese adults aged 20–59 years (y) in the China Health and Nutrition Survey (CHNS), a prospective, economically and geographically diverse population-based Chinese cohort, to conduct a pooled cross-sectional analysis comparing BMI and WC in 1993 to 2009. Specifically, we examine temporal trends across the BMI and WC distributions and further quantify the increases in WC at equivalent BMIs over the past two decades.

## SUBJECTS AND METHODS

### Study Sample

Details of study design were described previously<sup>17</sup>. Briefly, the CHNS is a prospective household-based study that includes multiple ages and cohorts across nine diverse provinces and eight rounds of surveys between 1989 and 2009. The CHNS was designed to provide representation of rural, urban, and suburban areas varying substantially in geography, economic development, public resources, and health indicators. The focus of the CHNS was on examining household- and individual-level socio-demographic factors, diet, physical activity, health and behavior changes relative to community-level factors related to

urbanization, social and economic change. The original survey in 1989 used a multistage, random cluster design in eight provinces (Liaoning, Jiangsu, Shandong, Henan, Hubei, Hunan, Guangxi, and Guizhou) to select a stratified probability sample. Using this sampling strategy, two cities and four counties were selected. Within cities, two urban and two suburban communities were randomly selected; within counties, one community in the capital city and three rural villages were randomly chosen. Twenty households per community were then randomly selected for participation. Data was collected for every individual in the household.

Since 1993, all new households formed from individuals within the sample households were also added to the sample (e.g., children from the original household who themselves later formed families and new households). In 1997, Heilongjiang province was added because Liaoning was unable to participate in CHNS for that wave of data collection (Liaoning was added back in 2000). The average response rate by province comparing 1993 to 2009 was 70.4%. Additionally, from 1997 onward, new households and communities were added to replace those lost since the previous wave of survey. In 1989, the CHNS cohort initially mirrored national age-gender-education profiles<sup>18</sup>. Given the addition of new provinces and households, attrition in the CHNS is assessed relative to the 1989 primary sample. Response rate for individuals was 80% in 1993 and 66% in 2009, relative to the 1989 primary sample.

Each CHNS participant provided a written informed consent and the study was approved by institutional review boards from the University of North Carolina at Chapel Hill and from the National Institute for Nutrition and Food Safety, Chinese Center for Disease Control and Prevention.

We conducted a pooled cross-sectional analysis using data from two waves: 1993 and 2009. Since WC was initially collected in 1993, the 1989 and 1991 surveys were excluded from this analysis, having 1993 as the referent wave. Eligible individuals were men and non-pregnant women 20-to 59-y old who had a physical exam. For this analysis, we excluded individuals who were not 20-to 59-y old, pregnant women, since they require different BMI and WC cutoff points<sup>19</sup>, and individuals >59-y old to avoid age related decreases in weight due to sarcopenia<sup>20</sup>. From 6 597 and 7 178 eligible individuals in 1993 and 2009, respectively, 6 159 (93.4%) in 1993 and 6 644 (92.6%) in 2009 had complete measures of all covariates and were included in the analysis. Of the 6 159 individuals who participated in the 1993 survey that fit our eligibility criteria, 2 124 (32%) were also eligible for our 2009 analytic sample. There were an additional 4 520 individuals in the 2009 sample who either entered the survey after 1993 or were not eligible at the time of the 1993 survey. The final analytic sample included 6 094 men and 6 709 women, with 2 923 men in 1993 and 3 171 in 2009 and 3 236 women in 1993 and 3 473 in 2009.

## Measurements

Age at survey and gender were self-reported by participants in interviewer-administered household questionnaires. Identical anthropometric measurement techniques were used in all surveys. Weight and height were measured by trained health workers who followed standardized procedures using calibrated equipment (SECA 880 scales and SECA 206 wall-mounted metal tapes). BMI ( $\text{kg}/\text{m}^2$ ) was calculated as weight (kg) divided by height squared

(m<sup>2</sup>). Waist circumference (cm) was measured using a non-elastic tape at a point midway between the lowest rib margin and the iliac crest in a horizontal plane<sup>10</sup>.

### Statistical Analysis

All analyses were conducted in Stata 12 (Stata, College Station, TX, USA). To determine whether differences by age groups exist between 1993 and 2009 in all our analyses, t-tests were used with a  $p < 0.05/5 = 0.01$  considered statistically significant with Bonferroni corrections for multiple (5) comparisons. For each survey, cross sectional univariate descriptive statistics were calculated by age group (20–29y, 30–39y, 40–49y and 50–59y) and reported as mean  $\pm$  SD for continuous variables or percent and 95% confidence intervals (95% CI) for categorical variables. For descriptive purposes, the WHO<sup>19</sup> (<18.5, 18.5–<25.0, 25.0–<30.0, 30.0 kg/m<sup>2</sup>) and the Chinese BMI criteria<sup>21</sup> (<18.5, 18.5–<24.0, 24.0–<28.0, 28.0 kg/m<sup>2</sup>) were used to classify individuals as underweight, normal, overweight, obese, respectively. With respect to abdominal adiposity status, the Chinese criteria were used to classify individuals as pre-obese (WC 85 – <90cm in men and 80 – <85cm in women) and obese (WC 90cm in men and 85cm in women)<sup>21</sup>.

All analyses were sex-stratified to address previously reported differences in obesity in men and women in China<sup>3</sup>. All analyses were clustered at the household level using robust sandwich variance estimators to account for the fact that the CHNS selection unit was at the household level and to correct for the non-independence of some observations in our sample, since there were individuals who participated in both waves 1993 and 2009.

To answer each of our aims we used two different sets of regression analyses. In our first set of regression analyses, we used quantile regression (QR) to investigate temporal trends in distributions of BMI and WC. Quantile regression is an extension of ordinary least square regression and models the effect of predictors across the distribution of continuous outcome variables. In other words, while ordinary least square regression model specifies the change in the conditional mean of the dependent variable associated with the change in the covariates, the quantile regression model specifies changes in the conditional quantile<sup>22</sup>. For example, if calendar time shifts the entire BMI and WC distribution (i.e., a location shift in the outcome distribution), quantile regression estimates will be constant across the quantiles and also similar to ordinary least squares regression estimates. However, if calendar time is associated with both the location and shape of the BMI and WC distribution, we expect to observe systematic differences in the quantile regression estimates. In the present study the 5<sup>th</sup>, 25<sup>th</sup>, 50<sup>th</sup>, 85<sup>th</sup>, and 95<sup>th</sup> BMI and WC quantiles were specified in the models. BMI and WC were modeled separately as the dependent variables, with survey year (categorical) and age at survey (categorized as 20–29y as the referent, 30–39y, 40–49y and 50–59y) included as independent variables to describe temporal trends in the BMI and WC distributions. We estimated parameter standard errors using 1000 bootstrap replications. Model coefficients were used to predict mean BMI and WC at the 5<sup>th</sup>, 25<sup>th</sup>, 50<sup>th</sup>, 85<sup>th</sup>, and 95<sup>th</sup> BMI and WC quantiles in 1993 and 2009 for individuals aged 40–49y. Predictions for age groups 20–29y, 30–39y and 50–59y old are available in Online Supplement Tables 2 and 3.

In a second set of analyses, we used linear regression to determine if average WC at equivalent BMIs changed over calendar time, adjusting for age at survey (categorized as 20–

29y as the referent, 30–39y, 40–49y and 50–59y) and survey year (categorical) (model 1). Box-Cox transformation was used to assess linearity of the BMI-WC association<sup>23</sup>. We further examined whether changes in WC at equivalent BMIs over time, differed by BMI level and age by testing interactions between survey year and BMI (model 2) and between survey year and age (model 3). The Wald test for significance of the survey year-BMI interaction term was conducted with  $p < 0.10$  considered significant. Chunk test for the joint significance of the survey year-age interaction term was conducted with  $p < 0.10$  considered significant<sup>24–26</sup>. For these regression analyses BMI was centered at 22 kg/m<sup>2</sup>. Using the model coefficients, Stata's margins command was used to predict WC average marginal effects at representative values of each covariate. We present the predicted average WC values for 1993 and 2009 at BMIs of 25 and 28 kg/m<sup>2</sup> for all age groups. WC predictions at BMIs of 18.5, 22, 24, 25 and 28 kg/m<sup>2</sup> for all age groups are available in Online Supplement Table 4. The BMI levels were chosen based on the BMI cutoff points for normal weight, overweight and obesity for the Chinese population (18.5, 24 and 28 kg/m<sup>2</sup>, respectively), the WHO cutoff point for overweight (25 kg/m<sup>2</sup>) and at the mean BMI of our sample (22 kg/m<sup>2</sup>). We do not present predictions for BMI for portions of the distribution comprised of <2% of the sample.

Sensitivity analyses included analyzing (1) the two independent cross-sectional samples in 1993 and 2009, excluding individuals who participated in both surveys and (2) a sample comprised of individuals who only participated in both waves 1993 and 2009.

## RESULTS

Cross-sectional analysis across survey years by age group indicate that while mean BMI changes were small across age groups, mean WC increased substantially over time for both genders regardless of age (Table 1). Additionally, the unadjusted prevalence of overweight and obesity in Chinese men and women increased in all age groups, regardless of whether the WHO or Chinese cut points were used. Overall, overweight and obesity prevalence were higher in men than in women in both surveys, regardless of age. Abdominal obesity prevalence, defined as 90cm in men and 85cm in women for Chinese adults, dramatically increased in all age groups. Abdominal obesity prevalence was higher in women than men in 1993 in all age groups, but in 2009, abdominal obesity prevalence was higher for 20–29y, 30–39y and 40–49y old men than women. Women aged 50–59y had higher abdominal obesity prevalence in 2009 than men.

Table 2 shows the quantile regression estimates for the temporal trends in the distribution of BMI and the WC in Chinese adults. For both men and women, the quantile regression coefficients for survey year across the 25<sup>th</sup>, 50<sup>th</sup>, 85<sup>th</sup> and 95<sup>th</sup> BMI quantiles were statistically significant ( $p < 0.01$ ). At the 95<sup>th</sup> BMI quantile, men had 2.8 kg/m<sup>2</sup> (95% CI: 2.4, 3.3) and women had 1.5 kg/m<sup>2</sup> (95% CI: 1.1, 2.0) higher BMI in 2009 compared to their counterparts in 1993. No statically significant differences were observed at the 5<sup>th</sup> quantile.

Figure 1 illustrates changes across the BMI distribution in 1993 and 2009 for men and women aged 40–49y. With a few exceptions, BMI across the sample distribution was higher in 2009 compared to 1993 for Chinese men and women aged 40–49y. Increases were

comparatively higher at the upper versus the lower end of the BMI distribution, indicating that heavier individuals experienced larger increases in BMI over time, compared to individuals of lower body mass. Additionally, temporal increases across the BMI distribution were greater for men compared to women; however, in 1993 women had higher BMIs across the entire distribution compared to men. Predictions for the 20–29y, 30–39y and 50–59y age groups are available in Online Supplement Table 2.

For both men and women, the quantile regression coefficients for survey year across the 5<sup>th</sup>, 25<sup>th</sup>, 50<sup>th</sup>, 85<sup>th</sup> and 95<sup>th</sup> WC quantiles were statistically significant ( $p < 0.01$ ). Increases in WC from 1993 to 2009 for the 5<sup>th</sup> and the 95<sup>th</sup> quantiles were 3.0 cm (95% CI: 1.9, 4.9) and 9.0 cm (95% CI: 7.1, 10.1) in men, and 2.0 cm (95% CI: 1.1, 2.9) and 5.0 cm (95% CI: 3.4, 6.6) in women. In men, the 16-year increases in the quantiles of WC showed a steep positive gradient from the 5<sup>th</sup> to the 85<sup>th</sup> quantile. The trend to greater increases at the higher quantiles was larger in magnitude in men compared to women.

Figure 2 illustrates changes across the WC distribution in 1993 and 2009 for men and women aged 40–49y. Across the WC distribution, we observed that WC increased over time in men and women aged 40–49y, particularly at the upper end of the WC distribution. Additionally, temporal trends across the WC distribution seem to be greater for men compared to women. Predictions for the 20–29y, 30–39y and 50–59y age groups are available in Online Supplement Table 3.

Table 3 shows the coefficients from the multivariate linear regression models of the differences in WC at equivalent BMIs between 1993 and 2009 in Chinese adults aged 20–59y, stratified by gender. The intercept of the models represents the predicted WC for individuals aged 20–29y old with a BMI of 22 kg/m<sup>2</sup> in 1993. The survey year coefficients in model 1 indicate that on average, for the same BMI and age group, men and women had a 3.2 cm (95% CI: 2.8, 3.7) and 2.1 cm (95% CI: 1.7, 2.5) higher WC in 2009 compared to their counterparts in 1993. There was a statistically significant interaction between survey year and BMI ( $p < 0.10$ ) in men and women (model 2), and a statistically significant interaction between survey year and age groups in women (model 3).

To aid interpretation, we present predicted average WC values using linear regression for 1993 and 2009 at BMIs of 25 and 28 kg/m<sup>2</sup> in all age groups for Chinese men (model 2) and women (model 3). WC predictions at BMIs of 18.5, 22, 24, 25 and 28 kg/m<sup>2</sup> for all age groups are available in Online Supplement Table 4. For both genders, WC was higher at equivalent BMIs in 2009 compared to their counterparts in 1993. Increases in WC at equivalent BMIs were greater amongst obese than amongst normal weight individuals. For example, at 50–59y old and a BMI of 18.5 kg/m<sup>2</sup> in 1993 and 2009, men had a 2.8 cm higher WC in 2009 (predicted WC=73.4 cm) and women a 1.6 cm higher WC in 2009 (predicted WC=71.6 cm), compared to their counterparts in 1993. However, at 50–59y old and a BMI of 28 kg/m<sup>2</sup> in 1993 and 2009, men had a 3.9 cm higher WC in 2009 (predicted WC=95.9 cm) and women a 3.2 cm higher WC in 2009 (predicted WC=92.2 cm), compared to their counterparts in 1993 (Figure 3).



Although differences were small, increases in WC at equivalent BMIs over time were significantly greater in younger versus older women. For example, at 20–29y old and a BMI of 28 kg/m<sup>2</sup>, WC was 3.7 higher in women (predicted WC=88.7 cm) compared to their counterparts in 1993, whereas among 50–59y old women, the corresponding increase was 3.2 cm (Figure 3).

We conducted sensitivity analyses looking at (1) the independent cross-sectional samples in 1993 and 2009, excluding individuals who participated in both surveys and (2) a sample comprised of individuals who only participated in both waves 1993 and 2009. These analyses consistently suggest that there are currently more adults in China with higher BMI and higher WC and adults with higher WC at equivalent BMIs than in the past (Online Supplement Tables 5–9).

## DISCUSSION

Using data from the CHNS, our results indicate that Chinese adults, and men in particular, have higher BMI and WC levels in 2009 than their counterparts in 1993 across the entire BMI and WC distributions. Our results concur with a previous study showing that the distribution of BMI and WC has shifted rightwards over time in Chinese adults<sup>3</sup>. Using quantile regressions, we provide a robust analysis of the temporal changes in WC and BMI by age and across their full distribution. One of our key findings is that the biggest increases in WC and BMI occurred amongst those who had the highest WC and BMI to begin with, compared to normal weight individuals.

A major finding was that the average WC at the same BMI and age category in 1993 and 2009 was higher in 2009 than 1993. Our results concur with studies from the U.S. and other countries that have reported an increase in WC over time at equivalent BMI levels<sup>14, 15, 27, 28</sup>. Increases in WC at equivalent BMIs suggest the body shape of Chinese adults is changing over time. There is no universally accepted cutoff for high WC in China; however 85 cm for women and 90 cm for men is recommended<sup>21</sup>. If these cutoffs are metabolically or clinically meaningful, our results indicate that, for both genders, important segments of the population are above this threshold. A previous study actually showed that two thirds of adults who are classified as obese by WC would have been misclassified as normal weight if they were screened by BMI alone<sup>29</sup>. Clearly this poses an important issue for Chinese clinicians who will need to understand that even BMI levels considered within the “normal” range may represent a major cardiometabolic risk.

Our findings further indicate that the difference for the average WC at equivalent BMIs when comparing 2009 to 1993 was even greater amongst obese individuals than in normal weight individuals. Recent studies in Chinese adults found that the joint effect of BMI and WC significantly increased the power to identify individuals at cardiometabolic risk compared to the WC or BMI effects alone<sup>10, 30</sup>. Therefore, it is important to measure both, BMI and WC, even if overweight or obesity is identified by measuring BMI alone.

Additionally, the increase in WC at equivalent BMI increased to a larger extent among younger versus older Chinese women. A previous study examining age-period-cohort effects

using the CHNS found evidence for a strong cohort effect, where at a given age, later birth cohorts have higher BMIs than earlier birth cohorts<sup>31</sup>. These findings together indicate that not only are BMIs higher for younger versus older Chinese women, but the WC at an equivalent BMI is increased to a larger extent in younger women compared to older women. This translates to higher levels of abdominal adiposity, putting these women at a potentially higher risk of obesity related diseases. However, it is unclear why we observed this shift in women but not in men.

Overall, our findings indicate that a growing segment of the Chinese population may be at risk for chronic disease, owing to comparatively higher WC for equivalent BMI and age categories in the current versus earlier generations. To put our findings into context, in a meta-analysis, De Koning et al. found that a 1 cm increase in WC was associated with a 2% increase in risk of future CVD in adults<sup>32</sup>. Of further concern, Asians have higher body fat at lower BMIs and WCs compared to Western populations, which could mean that the effect of increasing WC on health may be even stronger in Asian versus Western populations<sup>33</sup>.

The present descriptive analysis was not designed to examine the etiology underlying the increase in WC relative to BMI. It is unclear why WC has increased above and beyond the increase in BMI. It may be that reduction in physical activity is linked with increased WC, as a recent systematic review and meta-analysis suggests that increased physical activity may reduce visceral fat and WC<sup>34</sup>. Physical activity in Chinese adults has decreased significantly over the past two decades, which might underlie the proportional increase in WC in our sample<sup>35, 36</sup>. Changes in body composition may also be attributable to shifts in diet. For example, fructose<sup>7, 37, 38</sup> and alcohol<sup>39, 40</sup> have both been associated with increases in abdominal adiposity independent of overall adipose tissue, while dietary fiber and diets with a low glycemic index may be associated with lower WC<sup>41, 42</sup>. More research needs to be done to understand if these elements have changed in China and if they contribute to the increases in WC.

Our study had several strengths. First, the CHNS covers a large time span, allowing us to describe temporal trends in the BMI and WC distributions as well as temporal trends in average WC at equivalent BMIs in 1993 versus 2009. Second, we used identical measured anthropometric indicators in both surveys, reducing problems with validity inherent in self-reported measures. Finally, we had WC measurements on a large sample, which is an advantage since WC is not collected often in many country-level health surveys.

There were also limitations. It is unclear from these increases in WC, which type of abdominal adiposity is increasing. Studies have shown that while both visceral and subcutaneous fat are associated with adverse metabolic risk<sup>43</sup>, visceral fat is the more cardiometabolic active type of fat, contributing to the metabolic consequences of obesity<sup>44</sup>. More research is needed to understand whether it is visceral or subcutaneous fat that is contributing most to these observed increases in WC. The CHNS is not nationally representative, therefore our results are not generalizable to the Chinese population. However, the sample does include 9 provinces encompassing a wide demographic distribution<sup>17</sup>. Due to attrition, migration and various other factors, CHNS cohort membership varies over time, which may introduce sample selection bias. Jaacks et al.



addressed the sample selectivity issue in the CHNS using Heckman corrections, an approach used in econometrics, finding no evidence of bias<sup>31</sup>. Because China is a rapidly developing country, we would expect that key socio-demographic factors, including socioeconomic status and urbanicity<sup>45</sup>, would indeed change across survey years. It is possible that these changes could explain some or all of the observed results. However, this study was not designed to investigate the etiology underlying the increases in BMI, WC and WC at equivalent BMIs. Finally, the Chinese population has aged significantly because of an enormous drop in birth rates across China and our sample reflects this. While we can examine repeated cross-sections using age categorically, it is hard to fully duplicate the baseline age structure with the follow-up age structure.

In summary, our study highlights significant increases in WC and BMI in Chinese adults. Furthermore, we found that WC per BMI unit has increased over time across the full BMI distribution, indicating the potential for adverse cardiometabolic risk in China. Further research is required to understand how these changes in WC at equivalent BMIs relate to the major increases in hypertension, diabetes and overall burden of non-communicable diseases in China.

## Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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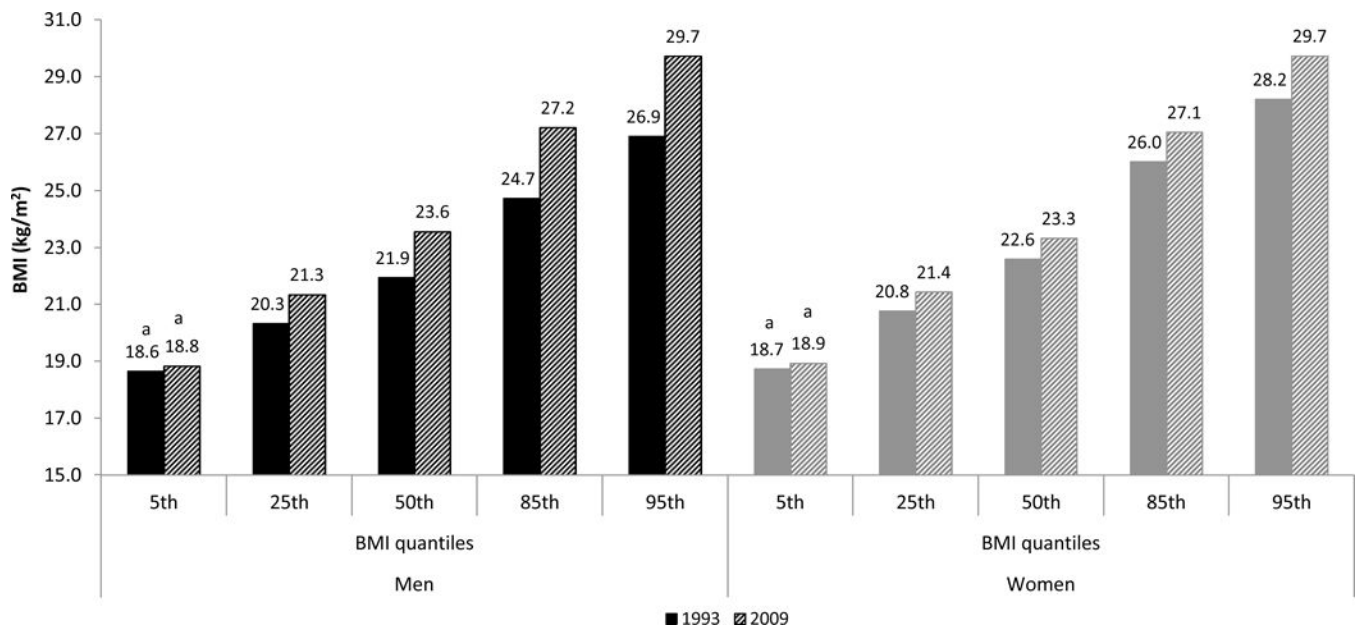
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## References

1. Yang W, Lu J, Weng J, Jia W, Ji L, Xiao J, et al. Prevalence of diabetes among men and women in China. *N Engl J Med*. 2010; 362(12):1090–1101. [PubMed: 20335585]
2. Yan S, Li J, Li S, Zhang B, Du S, Gordon-Larsen P, et al. The expanding burden of cardiometabolic risk in China: the China Health and Nutrition Survey. *Obes Rev*. 2012; 13(9):810–821. [PubMed: 22738663]
3. Xi B, Liang Y, He T, Reilly KH, Hu Y, Wang Q, et al. Secular trends in the prevalence of general and abdominal obesity among Chinese adults, 1993–2009. *Obes Rev*. 2012; 13(3):287–296. [PubMed: 22034908]
4. Snijder MB, van Dam RM, Visser M, Seidell JC. What aspects of body fat are particularly hazardous and how do we measure them? *Int J Epidemiol*. 2006; 35(1):83–92. [PubMed: 16339600]
5. Després J-P. Targeting abdominal obesity and the metabolic syndrome to manage cardiovascular disease risk. *Heart*. 2009; 95(13):1118–1124. [PubMed: 19525261]

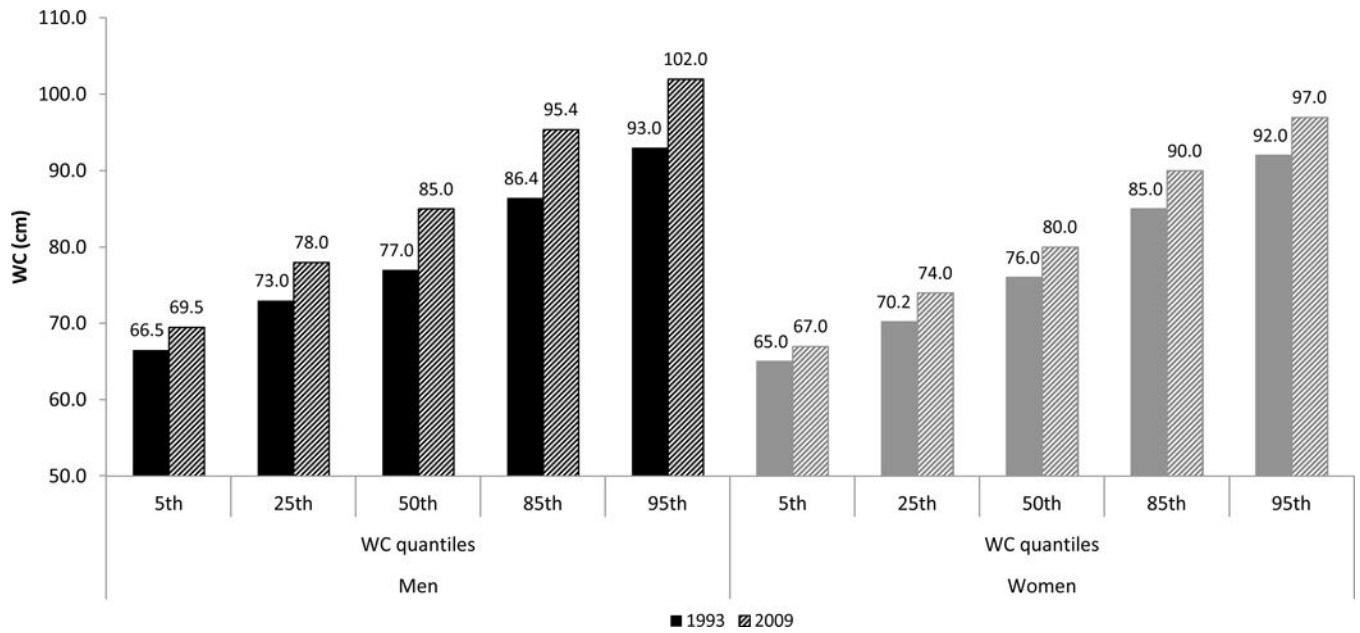
6. Després J-P. Abdominal obesity and cardiovascular disease: is inflammation the missing link? *Can J Cardiol.* 2012; 28(6):642–652. [PubMed: 22889821]
7. Tchernof A, Després J-P. Pathophysiology of human visceral obesity: an update. *Physiol Rev.* 2013; 93(1):359–404. [PubMed: 23303913]
8. Li G, Chen X, Jang Y, Wang J, Xing X, Yang W, et al. Obesity, coronary heart disease risk factors and diabetes in Chinese: an approach to the criteria of obesity in the Chinese population. *Obes Rev.* 2002; 3(3):167–172. [PubMed: 12164468]
9. Zhang X, Shu X-O, Gao Y-T, Yang G, Li H, Zheng W. General and abdominal adiposity and risk of stroke in Chinese women. *Stroke.* 2009; 40(4):1098–1104. [PubMed: 19211490]
10. Tuan NT, Adair LS, Stevens J, Popkin BM. Prediction of hypertension by different anthropometric indices in adults: the change in estimate approach. *Public Health Nutr.* 2010; 13(5):639–646. [PubMed: 19758482]
11. Jia Z, Zhou Y, Liu X, Wang Y, Zhao X, Wang Y, et al. Comparison of different anthropometric measures as predictors of diabetes incidence in a Chinese population. *Diabetes Res Clin Pract.* 2011; 92(2):265–271. [PubMed: 21334088]
12. Gordon-Larsen P, Adair LS, Meigs JB, Mayer-Davis E, Herring A, Yan S-k, et al. Discordant risk: overweight and cardiometabolic risk in Chinese adults. *Obesity (Silver Spring).* 2013; 21(1):E166–174. [PubMed: 23505200]
13. Popkin BM. Recent dynamics suggest selected countries catching up to US obesity. *Am J Clin Nutr.* 2010; 91(1):284S–288S. [PubMed: 19906804]
14. Elobeid MA, Desmond RA, Thomas O, Keith SW, Allison DB. Waist circumference values are increasing beyond those expected from BMI increases. *Obesity (Silver Spring).* 2007; 15(10):2380–2383. [PubMed: 17925462]
15. Janssen I, Shields M, Craig CL, Tremblay MS. Changes in the obesity phenotype within Canadian children and adults, 1981 to 2007–2009. *Obesity (Silver Spring).* 2012; 20(4):916–919. [PubMed: 21566567]
16. McCarthy HD, Ellis SM, Cole TJ. Central overweight and obesity in British youth aged 11–16 years: cross sectional surveys of waist circumference. *BMJ.* 2003; 326(7390)
17. 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. [PubMed: 19887509]
18. Chen CM. Nutrition status of the Chinese people. *Biomed Environ Sci.* 1996; 9(2–3):81–92. [PubMed: 8886318]
19. World Health O. Physical status: the use and interpretation of anthropometry. Report of a WHO Expert Committee. *World Health Organ Tech Rep Ser.* 1995; 854:1–452. [PubMed: 8594834]
20. Stookey JD, Adair L, Stevens J, Popkin BM. Patterns of long-term change in body composition are associated with diet, activity, income and urban residence among older adults in China. *J Nutr.* 2001; 131(9):2433S–40S. [PubMed: 11533290]
21. National, H.; Family Planning Commission of the People’s Republic of C. Health Standard of the People’s Republic of China, No. WS/T 428–2013: Criteria of Weight for Adults. National Health and Family Planning Commission of the People’s Republic of China; Beijing: 2013.
22. Hao, LND. Quantile Regression. Thousand Oaks: Sage Publications; 2007.
23. Box GEP, Cox DR. An analysis of transformations. *Journal of the Royal Statistical Society, Series B.* 1964; 26:211–252.
24. Greenland S. Basic problems in interaction assessment. *Environmental health perspectives.* 1993; 101(Suppl 4):59–66. [PubMed: 8206043]
25. Greenland, SRK. Introduction to stratified analysis. In: Rothman, KJGS.; Lash, TL., editors. *Modern Epidemiology.* Third. Lippincott, Williams and Wilkins; New York: 2008. p. 258-82.
26. Selvin, S. The analysis of contingency table data: logistic model I. In: Selvin, S., editor. *Statistical Analysis of Epidemiologic Data.* Third. Oxford University Press; New York: 2004. p. 191-235.
27. Walls HL, Stevenson CE, Mannan HR, Abdullah A, Reid CM, McNeil JJ, et al. Comparing trends in BMI and waist circumference. *Obesity (Silver Spring).* 2011; 19(1):216–219. [PubMed: 20559295]

28. Liese AD, Döring A, Hense HW, Keil U. Five year changes in waist circumference, body mass index and obesity in Augsburg, Germany. *Eur J Nutr.* 2001; 40(6):282–288. [PubMed: 11876492]
29. Du T, Sun X, Yin P, Huo R, Ni C, Yu X. Increasing trends in central obesity among Chinese adults with normal body mass index, 1993–2009. *BMC Public Health.* 2013; 13
30. Hou X, Lu J, Weng J, Ji L, Shan Z, Liu J, et al. Impact of waist circumference and body mass index on risk of cardiometabolic disorder and cardiovascular disease in Chinese adults: a national diabetes and metabolic disorders survey. *PLoS ONE.* 2013; 8(3)
31. Jaacks, LM.; Gordon-Larsen, P.; Mayer-Davis, EJ.; Adair, LS.; Popkin, BM. Age and period effects on adult body mass index and overweight from 1991 to 2009 in China: The China Health and Nutrition Survey.
32. de Koning L, Merchant AT, Pogue J, Anand SS. Waist circumference and waist-to-hip ratio as predictors of cardiovascular events: meta-regression analysis of prospective studies. *Eur Heart J.* 2007; 28(7):850–856. [PubMed: 17403720]
33. Deurenberg P, Deurenberg-Yap M, Guricci S. Asians are different from Caucasians and from each other in their body mass index/body fat per cent relationship. *Obes Rev.* 2002; 3(3):141–146. [PubMed: 12164465]
34. Ismail I, Keating SE, Baker MK, Johnson NA. A systematic review and meta-analysis of the effect of aerobic vs. resistance exercise training on visceral fat. *Obes Rev.* 2012; 13(1):68–91. [PubMed: 21951360]
35. Ng SW, Norton EC, Popkin BM. Why have physical activity levels declined among Chinese adults? Findings from the 1991–2006 China Health and Nutrition Surveys. *Soc Sci Med.* 2009; 68(7):1305–1314. [PubMed: 19232811]
36. Ng SW, Popkin BM. Time use and physical activity: a shift away from movement across the globe. *Obes Rev.* 2012; 13(8):659–680. [PubMed: 22694051]
37. Stanhope KL, Schwarz JM, Keim NL, Griffen SC, Bremer AA, Graham JL, et al. Consuming fructose-sweetened, not glucose-sweetened, beverages increases visceral adiposity and lipids and decreases insulin sensitivity in overweight/obese humans. *J Clin Invest.* 2009; 119(5):1322–1334. [PubMed: 19381015]
38. Stanhope KL, Havel PJ. Fructose consumption: considerations for future research on its effects on adipose distribution, lipid metabolism, and insulin sensitivity in humans. *J Nutr.* 2009; 139(6):1236S–1241S. [PubMed: 19403712]
39. Halkjaer J, Sørensen TIA, Tjønneland A, Togo P, Holst C, Heitmann BL. Food and drinking patterns as predictors of 6-year BMI-adjusted changes in waist circumference. *Br J Nutr.* 2004; 92(4):735–748. [PubMed: 15522143]
40. Bergmann MM, Schütze M, Steffen A, Boeing H, Halkjaer J, Tjønneland A, et al. The association of lifetime alcohol use with measures of abdominal and general adiposity in a large-scale European cohort. *Eur J Clin Nutr.* 2011; 65(10):1079–1087. [PubMed: 21559044]
41. Du H, van der ADL, van Bakel MME, Slimani N, Forouhi NG, Wareham NJ, et al. Dietary glycaemic index, glycaemic load and subsequent changes of weight and waist circumference in European men and women. *Int J Obes (Lond).* 2009; 33(11):1280–1288. [PubMed: 19704411]
42. Du H, van der ADL, Boshuizen HC, Forouhi NG, Wareham NJ, Halkjaer J, et al. Dietary fiber and subsequent changes in body weight and waist circumference in European men and women. *Am J Clin Nutr.* 2010; 91(2):329–336. [PubMed: 20016015]
43. Fox CS, Massaro JM, Hoffmann U, Pou KM, Maurovich-Horvat P, Liu C-Y, et al. Abdominal visceral and subcutaneous adipose tissue compartments: association with metabolic risk factors in the Framingham Heart Study. *Circulation.* 2007; 116(1):39–48. [PubMed: 17576866]
44. Liu J, Fox CS, Hickson DA, May WD, Hairston KG, Carr JJ, et al. Impact of abdominal visceral and subcutaneous adipose tissue on cardiometabolic risk factors: the Jackson Heart Study. *J Clin Endocrinol Metab.* 2010; 95(12):5419–5426. [PubMed: 20843952]
45. Jones-Smith JC, Popkin BM. Understanding community context and adult health changes in China: development of an urbanicity scale. *Soc Sci Med.* 2010; 71(8):1436–1446. [PubMed: 20810197]



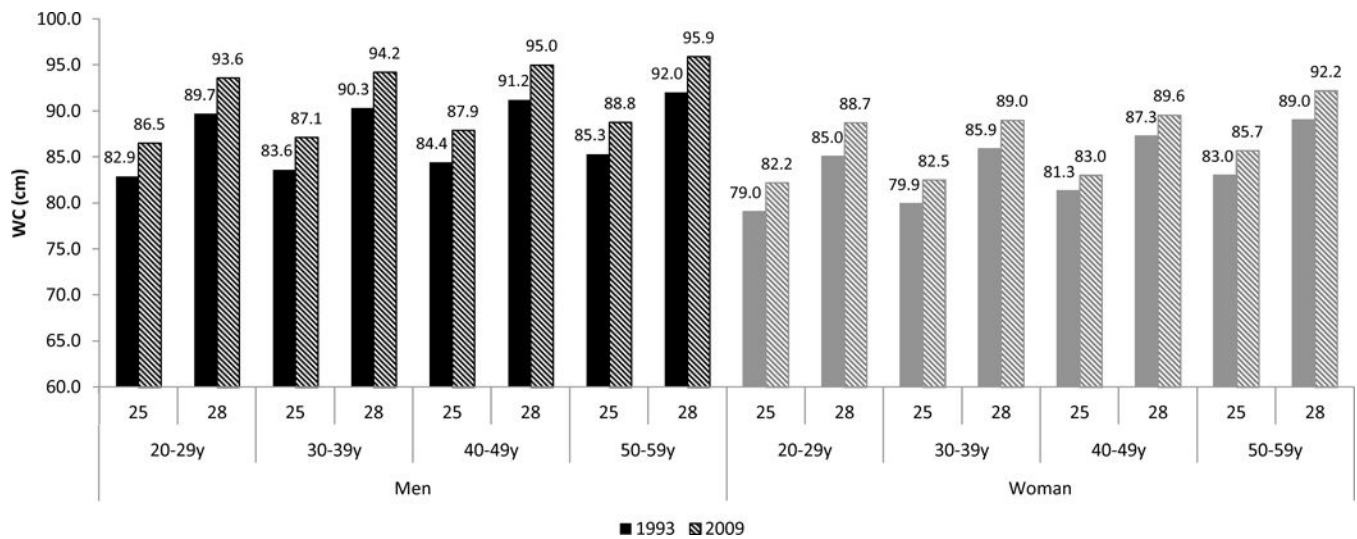
**Figure 1. BMI (kg/m<sup>2</sup>) predictions from the quantile regression model for 40–49y old men and women in 1993 compared with 40–49y old men and women in 2009, CHNS**

<sup>a</sup>Within each age category, comparisons were made between years at each BMI quantile. Estimates with a common letter do not differ at a  $p < 0.05/5 = 0.01$  (Bonferroni-adjusted Student's *t* test).



**Figure 2. WC (cm) predictions from the quantile regression model for 40–49y old men and women in 1993 compared with 40–49y old men and women in 2009, CHNS**

<sup>a</sup>Within each age category, comparisons were made between years at each WC quantile. All comparisons were statistically significant at a  $p = 0.05/5 = 0.01$  (Bonferroni-adjusted Student's *t* test).



**Figure 3. Predicted mean WC (cm) at equivalent BMIs (kg/m<sup>2</sup>) using linear regression in Chinese men and women in 1993 compared to their counterparts in 2009, CHNS**  
 Predictions are shown for a BMI of 25 and 28 kg/m<sup>2</sup> across all age groups. <sup>a</sup>Within each age category, comparisons were made between years at each WC quantile. All comparisons were statistically significant at a  $p < 0.05/5 = 0.01$  (Bonferroni-adjusted Student's t test).



**Table 1**  
Cross-sectional univariate descriptive statistics by age group and year in Chinese adults aged 20–59y old, CHNS<sup>1</sup>

|   | 20–29 y |            | 30–39 y |            | 40–49 y |            | 50–59 y |            |      |            |      |            |      |            |      |            |
|---|---------|------------|---------|------------|---------|------------|---------|------------|------|------------|------|------------|------|------------|------|------------|
|   | 1993    | 2009       | 1993    | 2009       | 1993    | 2009       | 1993    | 2009       |      |            |      |            |      |            |      |            |
| <b>Men</b>                                    |         |            |         |            |         |            |         |            |      |            |      |            |      |            |      |            |
| n   | 836     | 408        | 819     | 715        | 772     | 982        | 496     | 1 066      |      |            |      |            |      |            |      |            |
| WC (cm)                                       | 74.0    | 79.8       | 9.9     | 76.6       | 7.9     | 83.7       | 10.2    | 77.6       | 8.3  | 85.5       | 9.8  | 78.6       | 8.9  | 85.2       | 9.6  |            |
| BMI (kg/m <sup>2</sup> )                      | 21.1    | 22.1       | 2.4     | 21.9       | 2.4     | 23.6       | 3.4     | 22.0       | 2.5  | 24.0       | 3.2  | 22.0       | 2.9  | 23.5       | 3.2  |            |
| <b>Abdominal adiposity status<sup>2</sup></b> |         |            |         |            |         |            |         |            |      |            |      |            |      |            |      |            |
| Normal  | 90.0    | 87.7, 91.8 | 69.1    | 64.4, 73.4 | 83.0    | 80.1, 85.5 | 54.6    | 50.9, 58.2 | 80.6 | 77.6, 83.2 | 48.0 | 44.8, 51.1 | 77.2 | 73.3, 80.7 | 48.6 | 45.6, 51.2 |
| Pre-obese                                     | 6.3     | 4.9, 8.2   | 14.7    | 11.6, 18.5 | 10.1    | 8.2, 12.4  | 16.8    | 14.2, 19.7 | 10.1 | 8.2, 12.4  | 18.8 | 16.5, 21.4 | 8.9  | 6.7, 11.7  | 18.8 | 16.5, 21.2 |
| Obese   | 3.7     | 2.6, 5.2   | 16.2    | 12.9, 20.1 | 6.8     | 5.3, 8.8   | 28.7    | 25.5, 32.1 | 9.3  | 7.5, 11.6  | 35.2 | 30.3, 36.2 | 13.9 | 11.1, 17.3 | 32.7 | 29.9, 35.5 |
| <b>Obesity status</b>                         |         |            |         |            |         |            |         |            |      |            |      |            |      |            |      |            |
| <b>WHO BMI cut-points<sup>3</sup></b>         |         |            |         |            |         |            |         |            |      |            |      |            |      |            |      |            |
| Underweight <sup>4</sup>                      | 8.9     | 7.1, 11.0  | 12.0    | 9.2, 15.6  | 4.6     | 3.4, 6.3   | 5.3     | 3.9, 7.2   | 5.8  | 4.4, 7.7   | 2.8  | 1.9, 4.0   | 9.5  | 7.2, 12.4  | 4.2  | 3.2, 5.6   |
| Normal  | 86.0    | 83.5, 88.2 | 68.9    | 64.2, 73.2 | 84.6    | 82.0, 86.9 | 63.1    | 59.5, 66.5 | 81.5 | 78.6, 84.1 | 62.1 | 59.0, 65.1 | 75.0 | 71.0, 78.6 | 65.8 | 62.9, 68.6 |
| Overweight                                    | 4.7     | 3.4, 6.3   | 17.2    | 13.8, 21.1 | 10.4    | 8.5, 12.7  | 27.1    | 23.4, 30.5 | 12.6 | 10.4, 15.1 | 30.6 | 27.7, 33.5 | 14.5 | 11.7, 18.0 | 26.6 | 24.0, 29.3 |
| Obese   | 0.5     | 0.2, 1.3   | 2.0     | 1.0, 3.9   | 0.4     | 0.1, 1.1   | 4.5     | 3.2, 6.3   | 0.1  | 0.0, 0.1   | 4.6  | 3.2, 6.3   | 1.0  | 0.4, 2.4   | 3.5  | 2.5, 4.8   |
| <b>Chinese BMI cut-points<sup>5</sup></b>     |         |            |         |            |         |            |         |            |      |            |      |            |      |            |      |            |
| Normal  | 83.4    | 80.7, 85.8 | 61.5    | 56.7, 66.1 | 77.3    | 74.3, 80.0 | 52.0    | 48.4, 55.7 | 73.2 | 70.0, 76.2 | 48.4 | 45.3, 51.5 | 68.6 | 64, 7.2    | 54.3 | 51.3, 57.3 |
| Overweight                                    | 6.8     | 5.3, 8.7   | 19.1    | 15.6, 23.2 | 17.0    | 14.5, 19.7 | 32.3    | 29.0, 35.8 | 18.9 | 16.3, 21.8 | 37.6 | 34.6, 40.7 | 18.2 | 15.0, 21.8 | 33.3 | 30.5, 36.2 |
| Obese   | 1.0     | 0.4, 1.9   | 7.4     | 5.2, 10.3  | 1.1     | 0.6, 2.1   | 10.4    | 8.3, 12.8  | 2.1  | 1.3, 3.4   | 11.3 | 9.5, 13.4  | 3.8  | 2.5, 5.9   | 8.2  | 6.7, 10.0  |
| <b>Women</b>                                  |         |            |         |            |         |            |         |            |      |            |      |            |      |            |      |            |
| n   | 859     | 415        | 990     | 754        | 820     | 754        | 820     | 820        | 820  | 1 127      | 567  | 1 177      | 567  | 1 177      | 567  | 1 177      |
| WC (cm)                                       | 71.0    | 71.0       | 73.6    | 8.7        | 73.9    | 7.8        | 77.5    | 9.4        | 76.8 | 8.6        | 80.5 | 9.0        | 78.0 | 9.8        | 83.5 | 9.7        |
| BMI (kg/m <sup>2</sup> )                      | 21.0    | 2.3        | 21.1    | 2.9        | 22.0    | 2.7        | 22.7    | 3.3        | 22.8 | 3.1        | 23.8 | 3.3        | 22.5 | 3.5        | 23.9 | 3.3        |
| <b>Abdominal adiposity status</b>             |         |            |         |            |         |            |         |            |      |            |      |            |      |            |      |            |
| Normal  | 88.5    | 86.2, 90.4 | 76.9    | 72.5, 80.1 | 78.7    | 76.0, 81.1 | 62.2    | 58.7, 65.6 | 63.7 | 60.3, 66.9 | 47.8 | 44.9, 50.8 | 58.0 | 53.9, 62.0 | 35.1 | 32.4, 37.9 |
| Pre-obese                                     | 6.2     | 4.7, 8.0   | 11.3    | 8.6, 14.8  | 11.4    | 9.6, 13.6  | 16.8    | 14.3, 19.7 | 18.1 | 15.6, 20.8 | 21.7 | 19.3, 24.2 | 16.8 | 13.9, 20.1 | 20.1 | 17.9, 22.5 |
| Obese   | 5.4     | 4.0, 7.1   | 11.8    | 9.0, 15.3  | 9.9     | 8.2, 11.9  | 21.0    | 18.2, 24.0 | 18.3 | 15.8, 21.1 | 30.5 | 27.9, 33.9 | 25.2 | 21.8, 29.0 | 44.8 | 41.9, 47.6 |

|                        | 20–29 y |            | 30–39 y |            | 40–49 y |            | 50–59 y |            |      |            |      |            |      |            |      |            |
|------------------------|---------|------------|---------|------------|---------|------------|---------|------------|------|------------|------|------------|------|------------|------|------------|
|                        | 1993    | 2009       | 1993    | 2009       | 1993    | 2009       | 1993    | 2009       |      |            |      |            |      |            |      |            |
| Obesity status         |         |            |         |            |         |            |         |            |      |            |      |            |      |            |      |            |
| WHO BMI cut-points     |         |            |         |            |         |            |         |            |      |            |      |            |      |            |      |            |
| Underweight            | 11.8    | 9.8, 14.1  | 18.8    | 15.3, 22.8 | 8.5     | 6.9, 10.4  | 7.2     | 5.5, 9.2   | 4.5  | 3.3, 6.2   | 3.0  | 2.2, 4.2   | 10.6 | 8.3, 13.4  | 3.8  | 2.9, 5.1   |
| Normal                 | 83.2    | 80.6, 85.6 | 71.6    | 67.0, 75.7 | 77.3    | 74.6, 79.8 | 71.8    | 68.4, 74.9 | 73.7 | 70.5, 76.6 | 64.7 | 61.8, 67.4 | 66.8 | 62.8, 70.6 | 60.5 | 57.7, 63.3 |
| Overweight             | 4.8     | 3.5, 6.4   | 8.9     | 6.5, 12.1  | 13.9    | 11.9, 16.2 | 17.2    | 14.7, 20.1 | 20.0 | 17.4, 22.9 | 27.8 | 25.3, 30.5 | 19.8 | 16.7, 23.2 | 31.4 | 28.8, 34.1 |
| Obese                  | 0.2     | 0.0, 0.9   | 0.7     | 0.2, 2.2   | 0.3     | 0.0, 0.9   | 3.9     | 2.7, 5.5   | 1.8  | 1.1, 3.0   | 4.5  | 3.4, 5.9   | 2.8  | 1.7, 4.6   | 4.3  | 3.3, 5.7   |
| Chinese BMI cut-points |         |            |         |            |         |            |         |            |      |            |      |            |      |            |      |            |
| Normal                 | 77.2    | 74.2, 79.9 | 65.3    | 60.6, 69.7 | 69.2    | 66.2, 72.0 | 62.2    | 58.7, 65.6 | 63.4 | 60.0, 66.7 | 55.6 | 52.6, 58.4 | 59.1 | 55.0, 63.1 | 48.3 | 45.5, 51.2 |
| Overweight             | 10.5    | 8.6, 12.7  | 12.8    | 9.9, 16.4  | 20.3    | 17.9, 22.9 | 23.2    | 20.3, 26.4 | 27.1 | 24.1, 30.2 | 30.2 | 27.6, 32.9 | 22.1 | 18.8, 25.7 | 35.4 | 32.7, 38.2 |
| Obese                  | 0.6     | 0.2, 1.4   | 3.1     | 1.8, 5.3   | 2.0     | 1.3, 3.1   | 7.4     | 5.8, 9.5   | 5.0  | 3.7, 6.7   | 11.3 | 9.5, 13.3  | 8.3  | 6.3, 10.9  | 12.4 | 10.6, 14.4 |

<sup>1</sup> Values are presented as mean ± SD for continuous variables or column proportions and 95% confidence intervals for categorical variables. All data were derived from the 1993 and 2009 waves of the China Health and Nutrition Survey (CHNS). Eligible individuals were those aged 20-to 59-y men and non-pregnant women who had a physical exam and complete measures of all covariates.

<sup>2</sup> Chinese WC cut-points: obese (men 90cm, women 85cm), pre-obese (men 85 – <90cm, women 80 – <85cm), normal risk (men <85cm, women <80cm).

<sup>3</sup> WHO BMI cut-points: underweight (<18.5 kg/m<sup>2</sup>), normal ( 18.5 – <25 kg/m<sup>2</sup>), overweight ( 25 – <30 kg/m<sup>2</sup>), and obese ( 30 kg/m<sup>2</sup>).

<sup>4</sup> The WHO BMI cut-point for underweight is the same as the Chinese BMI cut-points, therefore, prevalence for underweight are shown once.

<sup>5</sup> Chinese BMI cut-points: underweight (<18.5 kg/m<sup>2</sup>), normal ( 18.5 – <24 kg/m<sup>2</sup>), overweight ( 24 – <28 kg/m<sup>2</sup>) and obese ( 28 kg/m<sup>2</sup>).

**Table 2**  
Quantile regression estimates (95% confidence intervals) for the secular trends in the BMI and WC distributions in Chinese adults aged 20–59y old in the CHNS, 1993 and 2009/

|                                    | 5 <sup>th</sup> quantile | 25 <sup>th</sup> quantile | 50 <sup>th</sup> quantile | 85 <sup>th</sup> quantile | 95 <sup>th</sup> quantile |
|------------------------------------|--------------------------|---------------------------|---------------------------|---------------------------|---------------------------|
| <b>BMI (kg/m<sup>2</sup>)</b>      |                          |                           |                           |                           |                           |
| <b>Men</b>                         |                          |                           |                           |                           |                           |
| Intercept <sup>2</sup>             | 17.7 (17.5, 17.9)        | 19.4 (19.3, 19.5)         | 20.6 (20.4, 20.8)         | 23.1 (22.9, 23.4)         | 25.4 (24.8, 25.9)         |
| Survey year <sup>3</sup>           | 0.2 (0.1, 0.5)           | 1.0 (0.9, 1.2)            | 1.6 (1.4, 1.8)            | 2.5 (2.2, 2.8)            | 2.8 (2.4, 3.3)            |
| Age 20–29y (referent) <sup>4</sup> | 0.0                      | 0.0                       | 0.0                       | 0.0                       | 0.0                       |
| Age 30–39y                         | 0.8 (0.5, 1.1)           | 0.7 (0.5, 0.9)            | 1.0 (0.7, 1.3)            | 1.4 (1.0, 1.7)            | 1.2 (0.5, 1.9)            |
| Age 40–49y                         | 0.9 (0.6, 1.3)           | 0.9 (0.7, 1.1)            | 1.3 (1.0, 1.6)            | 1.6 (1.2, 1.9)            | 1.5 (1.0, 2.1)            |
| Age 50–59y                         | 0.6 (0.3, 0.9)           | 0.8 (0.6, 1.0)            | 1.0 (0.7, 1.3)            | 1.4 (1.0, 1.8)            | 1.3 (0.6, 2.0)            |
| <b>Women</b>                       |                          |                           |                           |                           |                           |
| Intercept                          | 17.4 (17.2, 17.6)        | 19.0 (18.9, 19.2)         | 20.5 (20.3, 20.7)         | 23.3 (23.1, 23.6)         | 25.0 (24.5, 25.5)         |
| Survey year                        | 0.2 (-0.0, 0.4)          | 0.7 (0.5, 0.8)            | 0.7 (0.5, 0.9)            | 1.1 (0.7, 1.4)            | 1.5 (1.1, 2.0)            |
| Age 20–29y (referent)              | 0.0                      | 0.0                       | 0.0                       | 0.0                       | 0.0                       |
| Age 30–39y                         | 0.5 (0.2, 0.8)           | 0.8 (0.6, 1.0)            | 1.1 (0.9, 1.4)            | 1.5 (1.2, 1.9)            | 2.4 (1.8, 3.0)            |
| Age 40–49y                         | 1.3 (1.1, 1.6)           | 1.7 (1.5, 1.9)            | 2.1 (1.8, 2.3)            | 2.7 (2.3, 3.0)            | 3.2 (2.6, 3.8)            |
| Age 50–59y                         | 0.8 (0.5, 1.0)           | 1.6 (1.4, 1.8)            | 2.2 (2.0, 2.5)            | 2.9 (2.5, 3.4)            | 3.5 (2.9, 4.1)            |
| <b>WC (cm)</b>                     |                          |                           |                           |                           |                           |
| <b>Men</b>                         |                          |                           |                           |                           |                           |
| Intercept                          | 63.5 (62.3, 64.7)        | 69.0 (67.8, 70.2)         | 72.0 (70.9, 73.1)         | 81.0 (79.5, 82.5)         | 88.0 (86.2, 90.0)         |
| Survey year                        | 3.0 (1.9, 4.9)           | 5.0 (3.8, 6.2)            | 8.0 (6.9, 9.2)            | 9.0 (7.6, 10.4)           | 9.0 (7.1, 10.1)           |
| Age 20–29y (referent)              | 0.0                      | 0.0                       | 0.0                       | 0.0                       | 0.0                       |
| Age 30–39y                         | 1.5 (0.0, 3.0)           | 2.0 (0.5, 3.5)            | 3.0 (1.5, 4.5)            | 4.0 (2.1, 5.9)            | 4.0 (1.4, 6.6)            |
| Age 40–49y                         | 3.0 (1.5, 4.5)           | 4.0 (2.6, 5.4)            | 5.0 (3.6, 6.4)            | 5.4 (3.5, 7.3)            | 5.0 (2.5, 7.5)            |
| Age 50–59y                         | 3.5 (1.9, 4.1)           | 4.0 (3.8, 6.2)            | 5.0 (3.7, 6.3)            | 6.0 (4.1, 7.9)            | 5.5 (2.8, 8.2)            |
| <b>Women</b>                       |                          |                           |                           |                           |                           |
| Intercept                          | 60.0 (59.0, 61.0)        | 65.0 (63.8, 66.2)         | 70.0 (69.6, 74.4)         | 78.0 (76.7, 79.3)         | 85.0 (83.2, 86.8)         |
| Survey year                        | 2.0 (1.1, 2.9)           | 3.8 (2.7, 4.9)            | 4.0 (3.4, 4.6)            | 5.0 (3.9, 6.1)            | 5.0 (3.4, 6.6)            |

|                       | 5 <sup>th</sup> quantile | 25 <sup>th</sup> quantile | 50 <sup>th</sup> quantile | 85 <sup>th</sup> quantile | 95 <sup>th</sup> quantile |
|-----------------------|--------------------------|---------------------------|---------------------------|---------------------------|---------------------------|
| Age 20–29y (referent) | 0.0                      | 0.0                       | 0.0                       | 0.0                       | 0.0                       |
| Age 30–39y            | 2.0 (0.7, 3.3)           | 3.0 (1.5, 4.5)            | 3.0 (2.3, 3.7)            | 4.0 (2.5, 5.5)            | 4.0 (1.8, 6.2)            |
| Age 40–49y            | 5.0 (3.8, 6.2)           | 5.2 (3.6, 6.8)            | 6.0 (5.2, 6.8)            | 7.0 (5.4, 8.6)            | 7.0 (4.5, 9.5)            |
| Age 50–59y            | 5.0 (3.4, 6.6)           | 7.2 (5.6, 8.8)            | 8.5 (7.2, 9.8)            | 11.0 (9.1, 12.1)          | 10.0 (3.4, 6.6)           |

<sup>1</sup>Data presented are model coefficients and 95% confidence intervals. All data were derived from the 1993 and 2009 waves of the China Health and Nutrition Survey (CHNS). Eligible individuals were those aged 20-to 59-y men and non-pregnant women who had a physical exam and complete measures of all covariates. The number of observations for men is 6 094 and 6 709 for women.

<sup>2</sup>The intercept of the models represents the BMI or WC in 1993 for individuals aged 20–29y.

<sup>3</sup>Survey year is coded as 0 to represent 1993 and 1 to represent 2009.

<sup>4</sup>Age is categorized as 20–29y (referent), 30–39y, 40–49y and 50–59y.

CHNS-China Health and Nutrition Survey; WC-waist circumference

Adjusted mean differences in WC at equivalent BMIs over time in Chinese adults aged 20–59y old using linear regression, CHNS 1993 and 2009<sup>7</sup>

**Table 3**

|                                    | Model 1           | Model 2           | Model 3           |
|------------------------------------|-------------------|-------------------|-------------------|
| <b>Men</b>                         |                   |                   |                   |
| Intercept <sup>2</sup>             | 76.2 (75.7, 76.7) | 76.2 (75.7, 76.7) |                   |
| Survey year <sup>3</sup>           | 3.2 (2.8, 3.7)    | 3.2 (2.7, 3.6)    |                   |
| BMI <sup>4</sup>                   | 2.3 (2.3, 2.4)    | 2.3 (2.1, 2.4)    |                   |
| Age 20–29y (referent) <sup>5</sup> | 0.0               |                   |                   |
| Age 30–39y                         | 0.6 (0.0, 1.2)    | 0.6 (0.0, 1.2)    |                   |
| Age 40–49y                         | 1.4 (0.9, 2.0)    | 1.5 (0.9, 2.0)    |                   |
| Age 50–59y                         | 2.3 (1.7, 2.9)    | 2.3 (1.7, 2.9)    |                   |
| Survey year*BMI                    |                   | 0.1 (–0.0, 0.3)   |                   |
| Survey year*Age 20–29y (referent)  |                   |                   |                   |
| Survey year*Age 30–39y             |                   |                   |                   |
| Survey year*Age 40–49y             |                   |                   |                   |
| Survey year*Age 50–59y             |                   |                   |                   |
| <b>Women</b>                       |                   |                   |                   |
| Intercept                          | 73.3 (72.8, 73.7) | 73.2 (72.7, 73.7) | 73.0 (72.5, 73.6) |
| Survey year                        | 2.1 (1.7, 2.5)    | 2.0 (1.6, 2.4)    | 2.7 (1.7, 3.6)    |
| BMI                                | 2.1 (2.0, 2.2)    | 2.0 (1.9, 2.1)    | 2.0 (1.9, 2.1)    |
| Age 20–29y (referent)              | 0.0               |                   | 0.0               |
| Age 30–39y                         | 0.7 (0.1, 1.2)    | 0.7 (0.1, 1.3)    | 0.8 (0.1, 1.6)    |
| Age 40–49y                         | 1.6 (1.0, 2.1)    | 1.6 (1.0, 2.2)    | 2.2 (1.5, 3.0)    |
| Age 50–59y                         | 3.9 (3.3, 4.5)    | 3.9 (3.3, 4.5)    | 3.9 (3.1, 4.8)    |
| Survey year*BMI                    |                   | 0.1 (0.0, 0.3)    | 0.2 (0.0, 0.3)    |
| Survey year*Age 20–29y (referent)  |                   |                   | 0.0               |
| Survey year*Age 30–39y             |                   |                   | –0.5 (–1.7, 0.7)  |
| Survey year*Age 40–49y             |                   |                   | –1.4 (–2.6, –0.2) |
| Survey year*Age 50–59y             |                   |                   | –0.5 (–1.7, 0.8)  |

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<sup>1</sup>Data presented are coefficients and 95% confidence intervals. All data were derived from the 1993 and 2009 waves of the China Health and Nutrition Survey (CHNS). Eligible individuals were those aged 20-to 59-y men and non-pregnant women who had a physical exam and complete measures of all covariates. The number of observations for men is 6 094 and 6 709 for women.

<sup>2</sup>The intercept of the different models represents the WC at 1993 for individuals aged 20–29y old with a BMI of 22 kg/m<sup>2</sup>.

<sup>3</sup>Survey year is coded 0 to represent 1993 and 1 to represent 2009.

<sup>4</sup>BMI is a continuous variable, centered at 22 kg/m<sup>2</sup>.

<sup>5</sup>Age is categorized as 20–29 years (referent), 30–39 years, 40–49 years and 50–59y.

Wald test for survey year\*BMI interaction term  $p<0.1$ : WC increased to greater extent in Chinese adults with higher BMI level.

Chunk test for survey year\*age interaction terms  $p<0.1$ : younger aged Chinese adult women had larger increases in WC for a given BMI.

CHNS-China Health and Nutrition Survey; WC-waist circumference