



**Increased Waist Circumference and Prevalence of Type 2
Diabetes and Hypertension in Chinese Adults: Two
Population-based Cross-sectional Surveys in Shanghai,
China**

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1 **Increased Waist Circumference and Prevalence of Type 2 Diabetes and Hypertension in**
2 **Chinese Adults: Two Population-based Cross-sectional Surveys in Shanghai, China**

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44 **Abstract:**

45 **Objective:** To evaluate the changes in body mass index (BMI) and waist circumference (WC)
46 and their associations with the prevalence of hypertension and type 2 diabetes (T2DM) in Chinese
47 adults.

48 **Design:** Two consecutive population-based cross-sectional surveys.

49 **Setting:** A total of 12 districts and 7 counties in Shanghai, China.

50 **Participants:** 12,329 randomly selected participants of the survey in 2002-2003, and 7,423
51 randomly selected participants of the survey in 2009. All subjects were residents of Shanghai aged
52 35-74 years old.

53 **Outcome measures:** Measured BMI and WC. Previously-diagnosed and newly-identified
54 hypertension and T2DM by measured blood pressure, fasting and post-load glucose.

55 **Results:** While the participants of the two surveys were comparable in BMI in each age group,
56 the participants of the 2009 survey had significantly larger WC than those of the 2002-03 survey,
57 with an annual percentage change (APC) being higher among subjects aged 45-49 years old in both
58 men and women. The increase in prevalence of T2DM was observed in all age groups and also
59 appeared more evident in subjects aged 45-49 years old. The prevalence of hypertension was
60 observed to increase more rapidly in elderly men and middle-aged women. Obesity, both overt and
61 central, was associated with the risk of the two diseases, but BMI was more strongly linked to
62 hypertension while WC appeared more evidently related with T2DM.

63 **Conclusion:** The prevalence of central obesity and related chronic diseases has been
64 increasing in Shanghai, China. Our findings provide useful information for the projection of a more
65 rapidly growing burden of T2DM than hypertension in Chinese adults.

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67 **Keywords:** type 2 diabetes; hypertension; prevalence; body mass index; waist circumference

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Article summary

Article focus

- The shift in BMI and WC among Chinese adults over past one decade.
- The contribution of changes in overall and central obesity to the increasing burden of chronic disease in China.

Key messages

- The WC increased in Chinese adults over the decade spanning 2002-2009, while BMI did not change over the same period.
- BMI was more strongly linked to hypertension while WC appeared more evidently related with T2DM in Chinese adults.
- Our findings provide useful information for the projection of a more rapidly growing burden of T2DM than hypertension in Chinese adults.

Strengths and limitations of this study

- The strengths of this study include the strict process of multistage sampling in adult population of Shanghai, anthropometric measurement according to a standardized protocol and fasting and postprandial blood glucose tests for the participants.
- The nature of the cross-sectional study design limits our ability to directly evaluate the influence of overall and central obesity as well as the change of their prevalence on the risk of hypertension and T2DM.
- The differences in several demographic characteristics between the participants of the two surveys indicate the possibility of selection bias.

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71 Introduction

72 A rising worldwide prevalence of chronic disease, manifested primarily as hypertension and
73 type 2 diabetes (T2DM), has been well documented [1-4]. In Chinese aged 15-74 years old, the
74 prevalence of hypertension increased from 5.11% in 1959, 7.73% in 1979 [5] and 13.58% in 1991[6]
75 to 17.65% in 2002 [7]. The prevalence of T2DM tripled between 1980 (about 1.0%) and 1996
76 (3.2%) [8 9], and reached 9.7% in 2008 among adults at 20 years old or above [10]. It is estimated
77 that over 92 million people in China have T2DM. This represents approximately half of the world's
78 diabetic population, and places China at the "global epicenter of the diabetes epidemic" [4].

79 Both hypertension and T2DM are associated with obesity [11 12]. Obesity is often measured
80 by body mass index (BMI). Across the entire range of BMI, the risk of hypertension and T2DM
81 increases, making a higher BMI a strong predictor of both hypertension and T2DM [4 12-14].
82 However, a significant proportion of Asian adults diagnosed with T2DM are with the normal BMI,
83 ie.18.5-25.0 kg/m² [15 16]. BMI is a general indicator of overt obesity, but does not give
84 information about the distribution of obesity. Central obesity, often assessed via waist
85 circumference (WC), is also strongly correlated with T2DM in both European and Asian adults [11
86 17]. While changes in BMI have been well documented in China over past several decades [2 18],
87 changes in WC, and thus central obesity, are not well described.

88 In this study, we took advantage of the data from population based cross-sectional surveys
89 conducted in Shanghai in 2002-03 and in 2009. We used the data from the two surveys to evaluate
90 correlations between shifts in BMI and WC with the prevalence of hypertension and T2DM in
91 Chinese adults. Our results may help to better understand the contribution of overall obesity and
92 central obesity in the increasing burden of chronic disease in China.

93 Materials and Methods

94 Study Participants

95 A representative sample of the general population was randomly selected through a multistage
96 sampling process in the 2002-03 survey. Firstly, 4 districts and 2 counties were randomly selected

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2 97 from a total of 12 districts and 7 counties in Shanghai, China. And then, 1-2 sub-districts or towns
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4 98 were randomly selected from each selected district or county. Next, 1-2 communities or villages,
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6 99 usually 1,000-2,000 residents for each, were randomly selected from each selected sub-district or
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8 100 town. Finally, eligible subjects (permanent residents of Shanghai, 15-74 years old and having been
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10 101 in the city for at least 5 years) were randomly selected from the selected communities and villages
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12 102 and were invited for participation. Pregnant women, individuals with type I diabetes, and physically
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14 103 or mentally disabled persons were excluded from the participation. During the period of May
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16 104 2002-October 2003, a total of 17,526 eligible subjects were recruited, and 14,401 (82.17%)
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18 105 participated the survey.

21 106 The 2009 survey used the similar sampling method except that only 7 communities and
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23 107 villages were randomly selected in the third stage of sampling. The inclusion and exclusion criteria
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25 108 of the 2009 survey were also similar to those for the 2002-03 survey, except that only those at the
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27 109 age of 35-74 years old were eligible for the 2009 survey. Among 7,627 eligible adults contacted
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29 110 during the period of May-July 2009, 7,414 (97.21%) were interviewed and donated blood samples.

32 111 To make the two surveys comparable, we excluded 1,071 subjects younger than 35 years from
33
34 112 the 2002-03 survey. After further excluding subjects with missing information, the final analysis
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36 113 included 5,050 men and 7,279 women in the 2002-03 survey and 3,461 men and 3,962 women in
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38 114 the 2009 survey. The Institutional Review Board at Shanghai Municipal Center of Disease Control
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40 115 and Prevention approved the study. Informed consent was obtained from each participant before
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42 116 data collection.

46 117 **Data Collection**

48 118 A similar survey approach was followed by the two investigations. In both surveys,
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50 119 information on demographic and socioeconomic factors, diagnosis of diabetes, tobacco and alcohol
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52 120 use, physical activity and family history of diabetes was collected by trained interviewers with a
53
54 121 structured questionnaire at community clinics located in the residential areas of the participants.

56 122 At the interview, each participant's blood pressure, body weight, standing height, and waist

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2 123 circumference (WC) were measured by trained staff. Blood pressure was measured on the right arm
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4 124 in the sitting position using standard mercury sphygmomanometer after at least 5 minutes of rest.
5
6 125 The first and fifth Korotkoff sounds were recorded. Body weight and height were recorded while
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8 126 the subject was in light clothing and without shoes. Body weight was measured with electronic
9
10 127 scales to the nearest 0.1 kg. Body height was measured to the nearest 0.1 cm by using a stadiometer.
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12 128 WC, recorded to the nearest 0.1 cm, was taken with a cloth tape and was measured on bare skin at
13
14 129 the midline between the lower border of the ribs and the iliac crest in the horizontal plane after a
15
16 130 normal expiration. Two measurements were taken and the mean of the replicates was used in the
17
18 131 following analyses. Body mass index (BMI) was calculated as weight in kilograms divided by
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20 132 height in meters squared (kg/m^2) using the direct measurements.
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24 133 **Laboratory Measurements**

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26 134 After at least 10 hours of overnight fasting, 1-1.5 ml venous blood specimen was collected in a
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28 135 vacuum tube containing sodium fluoride. All participants with no history of diabetes and having a
29
30 136 fasting plasma glucose level of < 7.0 mmol per liter (mmol/l) were then asked to have an oral
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32 137 glucose-tolerance test (OGTT). Blood samples were drawn at 0 and 120 minutes after a standard 75
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34 138 gram glucose load. Plasma glucose was measured with Glucose oxidase-peroxidase (GOD-PAP)
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36 139 method.
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39 140 **Diagnosis of T2DM and Hypertension**

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41 141 Previously diagnosed T2DM and hypertension was identified by a positive response from the
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43 142 participant to the question of “Have you ever diagnosed with T2DM/hypertension by a doctor?” and
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45 143 confirmed by medical records in which prescriptions of anti-hypertensive or hypoglycemic
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47 144 medications were presented. The consistent rate was 100%. For those who had a negative response,
48
49 145 the T2DM was diagnosed with measured glucose level by using the 1999 World Health
50
51 146 Organization diagnostic criteria [Department of Noncommunicable Disease Surveillance. Definition,
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53 147 diagnosis and classification of diabetes mellitus and its complications: report of a WHO
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55 148 consultation. Part 1. Diagnosis and classification of diabetes mellitus. Geneva: World Health
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2 149 Organization, 1999. (Accessed July 5, 2010, at
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4 150 http://www.staff.ncl.ac.uk/philip.home/who_dmg.pdf.)] and hypertension referred to the subjects
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6 151 with measured systolic blood pressure (SBP) \geq 140 mmHg or diastolic blood pressure (DBP) \geq 90
7
8 152 mmHg and confirmed by clinical visits. Total T2DM and hypertension included both previously
9
10 153 diagnosed and newly-diagnosed patients. 42.7% (1,110 of 2,598) diabetic patients and 10.3% (694
11
12 154 of 6,735) hypertensive patients were newly-diagnosed in the two surveys.

155 **Statistical Analysis**

156 SAS software 9.2 was used for all the statistical analyses. Characteristics of the subgroups
157 were described using summary statistics (median, 25th and 75th percentile, frequencies, and
158 percentages) separately for men and women. The differences between two surveys were compared
159 using χ^2 test (category variables) and Wilcoxon tests (continuous variables). The annual percentage
160 changes (APC) in prevalence between two surveys were calculated as (prevalence in 2009 –
161 prevalence in 2002-03) / number of years using logarithms for each age group. Percentile curves
162 were constructed for BMI and WC values in the two surveys by gender using the LMS (lambda, mu,
163 sigma) method. Restricted cubic splines (RCS) were used to model a potential curvilinear
164 relationship of BMI and WC with hypertension and diabetes using the 5th, 25th, 75th and 95th
165 percentiles as fixed knots and the 50th percentile as the reference. Polynomial logistic regression
166 were used to estimate the odds ratios (OR) and 95% confidence intervals (95% CI) of BMI and WC
167 with T2DM and hypertension. Meta-analysis was applied to obtain the combined ORs and 95% CI
168 considering the potential heterogeneity of the populations in the two surveys. The residual method
169 was used to derive the independent effect of BMI and WC with each other in the models. *P* value
170 less than 0.05 was considered as a test of significance based on two sides.

171 **Results**

172 The male participants in two surveys were similar in age, resident site and cigarette smoking
173 while the females were comparable in cigarette smoking ($P > 0.05$) (Table 1). Compared to the
174 subjects in 2002-03 survey, the participants of 2009 survey, both men and women, had lower level

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2 175 of education, higher level of income per capita, more prior history of T2DM, higher frequency of
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4 176 alcohol drinking and lower frequency of leisure time activity, and were more likely to have a family
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6 177 history of diabetes.
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8
9 178 Figure 1 shows the shapes of the BMI and WC distribution curves among men and women
10
11 179 changed over the period of the two surveys. After adjusting for age, education, per capita income,
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13 180 resident site, smoking, drinking, regular exercise, and family history of T2DM, the curves of BMI
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15 181 were almost overlapped in both men and women. However, the WC curves for men and women
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17 182 were shifted to the right between 2002-03 and 2009, with the mean WC increasing from 83.6 to
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19 183 85.3 cm for men and from 78.4 to 80.6 cm for women.
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22 184 As presented in table 2, the prevalence of obesity, both overall and central, increased with
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24 185 increasing age groups. While the prevalence of overall obesity ($BMI \geq 28 \text{ kg/m}^2$) did not changed
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26 186 between two surveys (all P values > 0.05), the prevalence of central obesity were significantly
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28 187 higher in 2009 survey in each age group (all P values < 0.001). A more pronounced increase in
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30 188 prevalence of central obesity and T2DM was observed among subjects aged 45-49 years old in both
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32 189 men and women; whereas the change in prevalence of hypertension between two surveys appeared
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34 190 more evident in older men and younger women over the period. Using the World Health
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36 191 Organization (WHO) criteria for obesity did not change the results substantially (data not shown in
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38 192 the tables).
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41 193 BMI and WC were highly correlated with each other, with a correlation coefficient of 0.77 ($P <$
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43 194 0.0001) among men and 0.78 ($P < 0.0001$) among women after adjusting for age. Therefore, the
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45 195 residual method was used to test the potential respective non-linear relationships of BMI and WC
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47 196 with the risk of T2DM and hypertension (Figure 2). The dose-response analysis likewise showed a
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49 197 statistically significant increased risk of T2DM at high level of WC and a significant elevated risk
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51 198 of hypertension at high level of BMI in both men and women after adjusting for age, education, per
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53 199 capita income, resident site, smoking, drinking, regular exercise, family history of T2DM and phase
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55 200 of surveys, with P values for non-linear relationship tests < 0.05 . No significant relationship was
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2 201 observed between BMI and T2DM in men and between WC and hypertension in women.

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4 202 As shown in table 3, in both sexes, BMI adjusted for WC (residuals) appeared more strongly
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6 203 associated with hypertension while WC adjusted for BMI (residuals) was more evidently related
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8 204 with T2DM. Comparing with the lowest quartile of BMI residuals, the risk of hypertension
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10 205 increased 85% (95%CI: 1.59-2.15) in men and 1.23-fold (95%CI: 1.94-2.57) in women, whereas
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12 206 the risk of T2DM did not increase significantly in both sexes. On the other hand, the ORs of the
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14 207 highest versus the lowest quartile WC residuals for T2DM were 1.75 (95%CI: 1.33-2.30) in men
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17 208 and 2.37 (95%CI: 1.78-3.15) in women, higher than the OR of 1.57 (95%CI: 1.35-1.82) in men and
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19 209 1.13 (95%CI: 0.98-1.30) in women for hypertension.

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21 210 We further evaluated the potential joint effect of BMI and WC on T2DM and hypertension
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23 211 (table 4). The participants were classified into normal weight (BMI 18.5-23.9 kg/m²), overweight
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25 212 (24.0-27.9 kg/m²), or obese (≥ 28 kg/m²) based on data from Chinese adults, and were defined as
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27 213 with normal or increased WC using sex-specific cut-offs (85 cm in men and 80 cm in women) [19].
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29 214 The risk of T2DM and hypertension increased across groups defined by BMI and WC, with the
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31 215 highest risk observed among men with the lowest BMI but a higher WC, and among those with the
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33 216 highest BMI and a higher WC for hypertension. However, no significant interaction was observed
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35 217 between BMI and WC (all *P* values for interaction tests > 0.05).

36 37 38 39 40 218 **Discussion**

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42 219 In this representative sample of the adult population in Shanghai, the largest city in China, we
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44 220 observed an increased prevalence of central obesity, hypertension and T2DM over the decade
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46 221 spanning 2002-2009. In contrast, BMI did not change over the same period. Our results present a
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48 222 snapshot of overt versus central obesity in the Chinese population and suggest that the epidemic of
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50 223 central obesity in this population, which has been more closely associated with the prevalence of
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52 224 T2DM, may lead to a more rapidly growing burden of T2DM in China.

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55 225 Chinese adults have lower rates of overweight and obesity than their Western counterparts
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57 226 using the WHO criteria (BMI ≥ 25 kg/m² for overweight and BMI ≥ 30 kg/m² for obesity) [15 16].
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2 227 Nevertheless, increasing trends of BMI in Chinese adults have been well documented [18 20]. In
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4 228 two national nutritional surveys undertaken in 1982 and 1992 in China, the prevalence of
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6 229 overweight/obesity ($\text{BMI} \geq 25 \text{ kg/m}^2$) in subjects 20-70 years of age was 10% and 15%,
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8 230 respectively. Between 1992 and 2002, the combined prevalence of overweight and obesity increased
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10 231 from 14.6 to 21.8% [21]. Interestingly, the increase in BMI among Chinese adults has slowed down
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12 232 during past decades [2]. In this study, we did not observe an increase in BMI and prevalence of
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14 233 obesity defined by the Chinese obesity standards or by WHO criteria (data not shown). Instead, we
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16 234 observed a significant increase in WC, a measure of central obesity between surveys. Our
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18 235 observation of increased WC in Chinese adults, without a concomitant increase in BMI, represents
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20 236 an increasing burden of central obesity in this population. The increase in central obesity indicates
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22 237 an upward trend in body fat percentages in the population who have been previously observed with
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24 238 higher body fat percentages compared to other ethnic people with the same BMI [22 23].

239 Both epidemic of overall and central obesity parallel a continuously increasing prevalence of
240 hypertension and T2DM in China [21]. Several studies indicate that overall obesity (BMI) is more
241 strongly associated with hypertension, while central obesity (WC) is more strongly associated with
242 T2DM [17 24-26]. The rationale for these associations is based on the notion that central obesity
243 reflects specific accumulation of visceral adipose tissue. Excess visceral adipose tissue is
244 metabolically unfavorable due to productions of free fatty acids and inflammatory mediators.
245 Overall obesity, on the other hand, represents a greater overall physiologic strain and effects
246 vascular and cardiac parameters more significantly. In this study, we observed a significant increase
247 in prevalence of T2DM regardless of gender or age groups, which was more pronounced than the
248 change in the prevalence of hypertension during the period of 2002-03 and 2009. We also observed
249 a closer association of central obesity with the prevalence of T2DM than with the prevalence of
250 hypertension. These results support the notion that central obesity in particular is a stronger risk
251 factor for T2DM than for hypertension in Chinese adults. Due to the cross-sectional design,
252 however, our study was unable to make a causal inference.

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2 253 The nature of the cross-sectional study design limits our ability to directly evaluate the
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4 254 influence of overall and central obesity as well as the change of their prevalence on the risk of
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6 255 hypertension and T2DM. The differences in several demographic characteristics between the
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8 256 participants of the two surveys indicate the possibility of selection bias. However, there are several
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10 257 strengths, including the strict process of multistage sampling in adult population in Shanghai,
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12 258 anthropometric measurement according to a standardized protocol and fasting and postprandial
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14 259 blood glucose tests for the participants.

18 260 **Conclusions**

20 261 In summary, this study describes the potential association of central obesity with an upward
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22 262 trend of T2DM, implicating a more rapidly growing burden of T2DM than hypertension in Chinese
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24 263 adults. The findings in Shanghai, the largest city and one of the most economically developed areas
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26 264 in China, provide useful information for the projection of future trends in the whole country.

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39 269 **Footnotes**

42 270 **Contributors** YR and MM contributed to data collection, data analysis and draft of the paper.
43
44 271 YR, YYL, QDY, and LS contributed to data collection and quality control. LJM contributed to
45
46 272 revision of the paper. HZ contributed to data clean and analysis. RL and WHX contributed to study
47
48 273 design, statistical analysis and revision of the paper. All authors contributed to the interpretation of
49
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281 **Conflict of Interest:** None declared.

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2 358 Figure 1. Shift in BMI and WC over the period of the two population-based surveys

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4 359 Figure 2. Non-linear dose-response relationship of BMI and WC with hypertension and T2DM

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6 360 among participants of the two population-based surveys

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362 Table 1. Characteristics of participants in two population-based surveys in Shanghai, China

Characteristics	1 st survey		2 nd survey		<i>P</i> -value between surveys ^a	
	Men (N=5,050)	Women (N=7,279)	Men (N=3,461)	Women (N=3,962)	<i>In men</i>	<i>In women</i>
Age (yrs., mean ± SD)	54.8 ± 10.8	53.1 ± 10.3	54.7 ± 9.5	54.7 ± 9.1	0.55	<0.0001
Resident site (%)						
Urban	71.1	63.0	72.4	72.0		
Rural	29.0	37.0	27.7	28.0	0.19	<0.0001
Education (%)						
No formal education	4.1	18.4	3.2	9.5		
Primary school	18.2	23.0	14.7	17.7		
Middle school	35.3	31.1	45.7	45.2		
High school	27.6	22.6	27.6	23.8		
College or above	14.8	4.9	8.8	3.9	0.0025	<0.0001
Per capita income (yuan/mo.) (%)						
<1000	37.0	45.5	4.9	4.0		
1000-2999	38.3	38.4	41.8	46.7		
3000-5000	22.5	17.9	33.2	33.3		
>5000	2.2	1.3	20.0	16.0	<0.0001	<0.0001
Family history of type 2diabetes	12.3	13.1	16.4	19.0	<0.0001	<0.0001
Prevalence of type 2diabetes (%)	13.6	10.3	17.4	14.1	<0.0001	<0.0001
Prevalence of hypertension (%)	34.8	28.3	41.8	37.1	<0.0001	<0.0001
Cigarette smoking (%)	61.4	1.7	62.6	1.8	0.22	0.93
Alcohol drinking (%)	40.4	2.4	54.0	5.0	<0.0001	<0.0001
Leisure-time activity (%)	13.3	13.1	10.8	9.0	0.0009	<0.0001

363 ^a *P* for Wilcoxon tests or chi-square tests

Table 2. Prevalence of obesity, hypertension and type 2 diabetes in participants of the two population-based surveys by age groups in Shanghai, China

	No. of subjects		Overall Obesity		APC	Central obesity		APC	Hypertension		APC	Type 2 diabetes		APC	
	1 st survey	2 nd survey	1 st survey	2 nd survey	(%)	1 st survey	2 nd survey	(%)	1 st survey	2 nd survey	(%)	1 st survey	2 nd survey	(%)	
Men															
Overall	5050	3461	11.7	11.9	0.21	46.3	53.8	2.35	34.8	41.8	2.87	13.6	17.4	3.78	
Age-groups															
35-	414	230	10.5	9.1	-2.11	41.8	45.2	1.22	15.2	11.7	-3.92	4.6	5.7	3.25	
40-	574	302	10.0	8.3	-2.83	41.8	47.00	1.85	22.5	21.9	-0.43	7.8	7.6	-0.44	
45-	837	445	12.6	12.6	-0.04	44.0	53.7	3.12	25.3	31.0	3.16	7.8	13.7	9.13	
50-	833	739	12.2	10.8	-1.76	44.1	53.8	3.12	33.1	40.3	3.07	12.7	18.3	5.72	
55-	628	669	10.4	13.2	3.78	47.3	54.6	2.25	35.4	45.6	3.99	15.0	17.9	2.82	
60-	507	513	10.5	15.4	6.18	48.7	56.1	2.19	44.6	51.7	2.29	15.6	20.1	3.98	
65-	674	313	12.6	11.8	-0.99	51.4	61.0	2.67	49.4	59.4	2.88	20.8	26.2	3.64	
70-	583	250	13.8	9.6	-5.40	51.1	54.0	0.85	50.9	65.2	3.87	24.2	25.6	0.88	
Women															
Overall	7279	3962	13.8	13.8	0.02	41.7	54.2	4.10	28.3	37.1	4.28	10.3	14.1	4.84	
Age-groups															
35-	615	251	7.5	7.2	-0.65	22.6	26.3	2.35	6.8	10.8	7.24	3.3	4.0	3.17	
40-	1000	287	9.4	11.2	2.66	27.6	38.0	5.05	11.7	15.7	4.61	4.1	5.9	5.81	
45-	1491	563	11.0	9.8	-1.82	32.3	42.6	4.38	19.3	23.5	3.03	5.8	8.7	6.32	
50-	1309	866	15.1	14.1	-1.00	43.9	54.0	3.24	28.7	31.0	1.16	8.3	9.4	1.94	
55-	838	818	15.7	13.6	-2.17	47.5	60.6	3.83	33.9	39.7	2.48	8.8	15.3	8.80	
60-	610	585	19.2	18.1	-0.87	53.5	63.1	2.58	40.5	52.8	4.17	16.7	19.2	2.11	
65-	799	327	18.0	18.4	0.28	59.0	66.1	1.76	48.4	59.3	3.17	23.7	27.8	2.54	
70-	617	265	18.2	16.6	-1.36	60.2	68.7	2.05	51.4	64.5	3.57	21.4	27.2	3.75	
All subjects															
Overall	12329	7423	13.0	12.9	-0.05	43.6	54.0	3.35	31.0	39.3	3.75	11.7	15.6	4.53	
Age-groups ^a															
35-	1029	481	8.7	8.0	-1.04	30.3	33.9	2.39	10.2	11.2	1.49	3.8	4.7	3.63	
40-	1574	589	9.6	10.1	0.11	32.7	41.3	4.14	15.6	17.9	2.92	5.5	6.5	3.41	
45-	2328	1008	11.6	10.8	-0.77	36.5	46.6	4.16	21.5	26.2	3.46	6.5	10.5	8.22	
50-	2142	1605	13.9	12.8	-1.53	44.0	53.9	3.19	30.4	34.6	0.90	10.0	12.8	4.69	
55-	1466	1487	13.4	13.4	0.01	47.4	58.1	3.13	34.5	42.2	3.20	11.5	16.4	5.75	
60-	1117	1098	15.2	16.9	1.59	51.3	59.9	2.39	42.4	52.3	3.29	16.2	19.6	2.96	
65-	1473	640	15.6	15.4	-0.39	55.5	63.8	2.11	48.9	59.4	3.04	22.3	27.1	2.98	
70-	1200	515	16.0	13.2	-2.94	55.8	61.5	1.52	51.2	64.9	3.71	22.8	26.4	2.32	

^a adjusted for sex according to the distribution in the first survey.

Table 3. Association of body size with hypertension and type 2 diabetes in two population-based surveys in Shanghai, China

	No. of subjects with neither diseases	Type 2 diabetes only		Hypertension only		Both	
		N	OR (95%CI)	N	OR (95%CI)	N	OR (95%CI)
BMI residuals							
Men							
Q1	1260	156	1.00	529	1.00	175	1.00
Q2	1224	142	0.99 (0.77, 1.27)	583	1.16 (1.00, 1.34)	172	1.11(0.87, 1.41)
Q3	1164	132	1.09 (0.84, 1.41)	651	1.50 (1.29, 1.74)	171	1.36(1.07, 1.73)
Q4	1079	123	1.16 (0.88, 1.51)	709	1.85 (1.59, 2.15)	207	1.95(1.54, 2.47)
			<i>P for trend</i>				
			0.2472		<0.0001		<0.0001
Women							
Q1	1816	166	1.00	600	1.00	223	1.00
Q2	1866	148	1.02 (0.80, 1.29)	629	1.29 (1.12, 1.48)	162	0.96(0.77, 1.21)
Q3	1835	125	0.89 (0.69, 1.15)	687	1.51 (1.31, 1.73)	158	1.03(0.82, 1.31)
Q4	1634	109	0.94 (0.73, 1.23)	847	2.23 (1.94, 2.57)	215	1.85(1.15, 2.98)
			<i>P for trend</i>				
			0.4864		<0.0001		0.0067
All subjects							
Q1	3048	330	1.00	1162	1.00	385	1.00
Q2	3079	282	1.00 (0.84, 1.19)	1200	1.22 (1.11, 1.35)	363	1.03(0.87, 1.22)
Q3	2998	278	0.98 (0.82, 1.18)	1346	1.50 (1.36, 1.67)	302	1.18(1.00, 1.40)
Q4	2753	211	1.04 (0.86, 1.26)	1527	2.05 (1.85, 2.27)	433	1.88(1.60, 2.21)
			<i>P for trend</i>				
			0.2280		<0.0001		<0.0001
WC residuals							
Men							
Q1	1376	102	1.00	531	1.00	111	1.00
Q2	1232	131	1.34 (1.02, 1.78)	601	1.23 (1.06, 1.42)	155	1.41(1.07, 1.84)
Q3	1130	148	1.39 (0.70, 2.77)	644	1.39 (1.20, 1.62)	197	1.73(1.33, 2.25)
Q4	989	172	1.75 (1.33, 2.30)	696	1.57 (1.35, 1.82)	262	2.25(1.74, 2.90)
			<i>P for trend</i>				
			<0.0001		<0.0001		<0.0001
Women							
Q1	2019	80	1.00	598	1.00	108	1.00
Q2	1935	102	1.17 (0.86, 1.59)	651	1.04 (0.91, 1.18)	117	0.94(0.71, 1.25)
Q3	1708	172	2.04 (1.54, 2.70)	732	1.14 (0.99, 1.30)	194	1.40(1.08, 1.82)
Q4	1489	194	2.37 (1.78, 3.15)	782	1.13 (0.98, 1.30)	339	2.06(1.26, 3.38)
			<i>P for trend</i>				
			<0.0001		0.0216		<0.0001
All subjects							
Q1	3453	161	1.00	1109	1.00	203	1.00
Q2	3192	260	1.26 (0.99, 1.60)	1211	1.12 (1.01, 1.23)	260	1.16(0.82, 1.62)
Q3	2838	301	1.66 (1.16, 2.36)	1373	1.25 (1.13, 1.38)	412	1.55(1.29, 1.87)
Q4	2395	379	2.03 (1.66, 2.47)	1542	1.34 (1.09, 1.64)	608	2.18(1.83, 2.61)
			<i>P for trend</i>				
			0.0001		0.0021		<0.0001

Missing value excluded from the analysis.

OR: Adjusted for age (continuous variable), education (no formal education, primary school, middle school, high school, colleague or above, dummy variables), per capita income (<1000, 1000-2999, 3000-5000 and >5000 RMB Yuan / month, dummy variables), resident site (urban/rural area), family history of type 2 diabetes (yes/no), smoking (ever/never), alcohol drinking (ever/never), regular exercise (never/ever), phase of study (first /second survey); Additionally adjusted for sex (male/female) for all subjects.

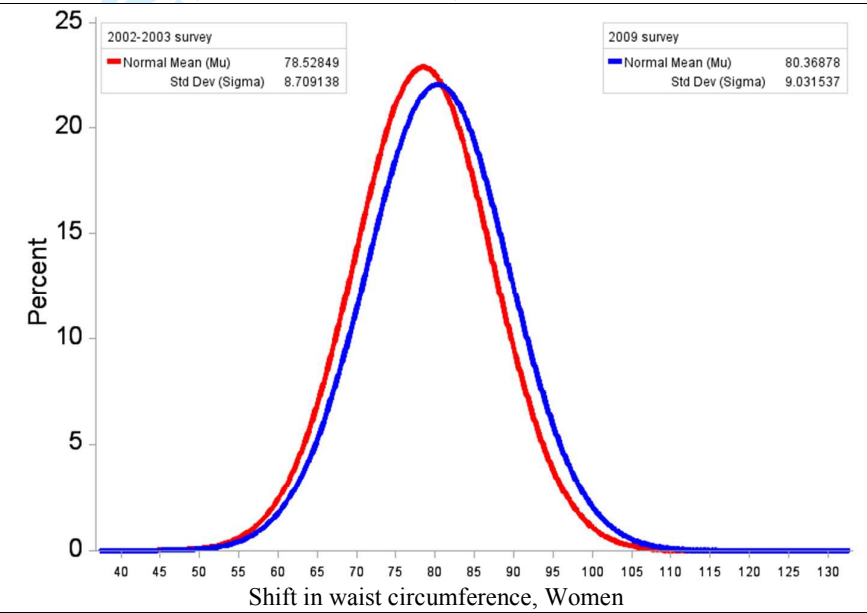
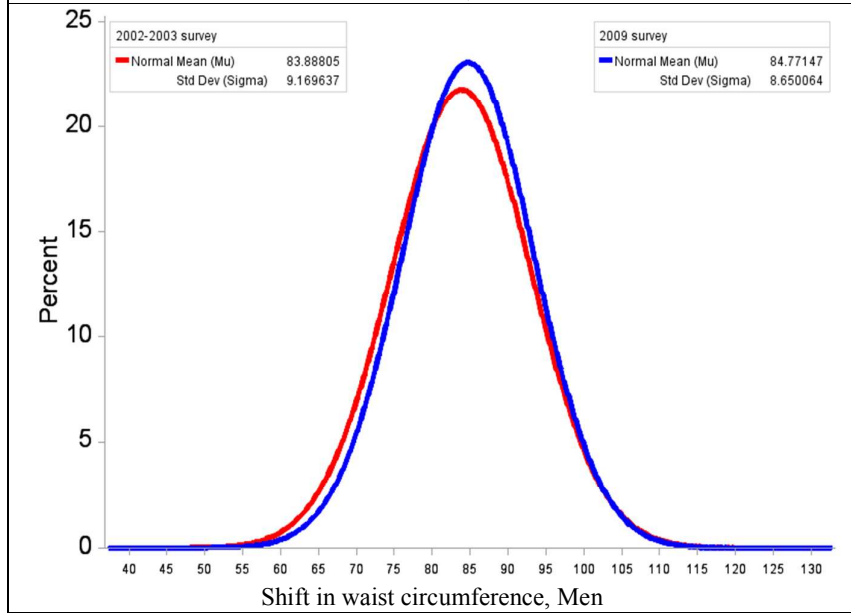
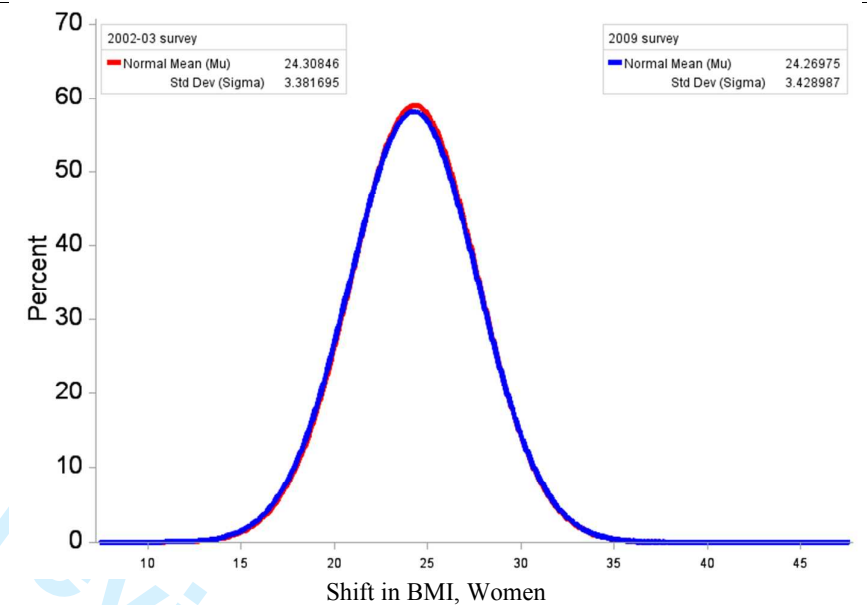
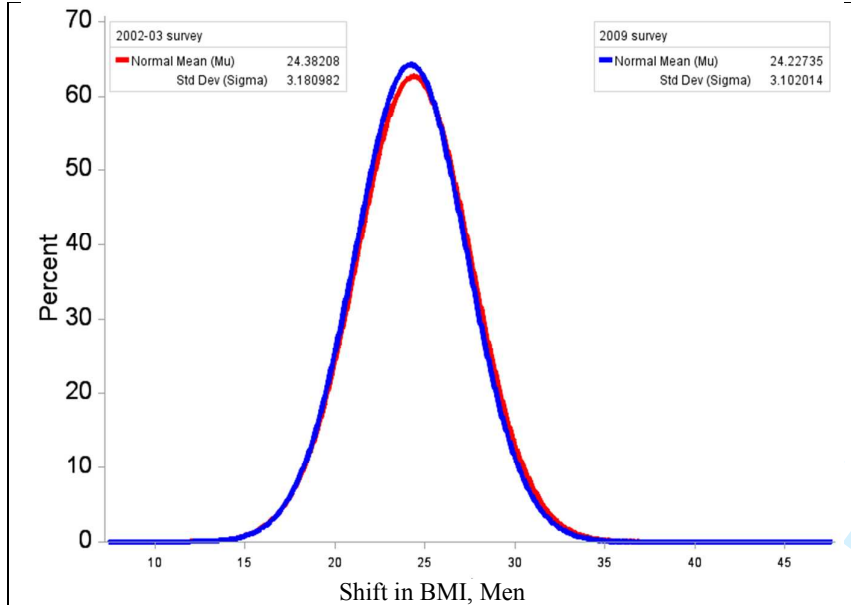
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4 Table 4. Joint effect of general obesity and central obesity on type 2 diabetes among Chinese adults

BMI	WC: Lower			WC: Higher			OR (95%CI) for hypertension		OR (95%CI) for type 2 diabetes	
	No. of subjects	Hypertension N (%)	Diabetes N (%)	No. of subjects	Hypertension N (%)	Diabetes N (%)	WC: Lower	WC: Higher	WC: Lower	WC: Higher
Men										
<18.5	212	36	20	16	10	6	0.61(0.42, 0.89)	3.68(1.28, 10.59)	1.02(0.62, 1.67)	3.77(1.13, 12.56)
18.5-23.9	3034	767	296	679	249	111	1.00	1.56(0.94, 2.57)	1.00	1.48(1.15, 1.90)
24.0-27.9	1010	356	134	2530	1179	483	1.61(1.13, 2.32)	2.38(1.78, 3.17)	1.46(1.16, 1.83)	1.85(1.16, 2.96)
≥28.0	36	20	4	960	580	224	3.91(1.95, 7.82)	4.67(3.97, 5.49)	1.71(0.55, 5.37)	2.60(2.12, 3.18)
<i>P for interaction</i>							<i>0.0711</i>		<i>0.0933</i>	
Women										
<18.5	313	51	19	8	2	1	0.68(0.49, 0.94)	0.85(0.16, 4.51)	0.93(0.56, 1.54)	2.45(0.22, 26.72)
18.5-23.9	4323	821	265	974	314	165	1.00	1.48(1.26, 1.75)	1.00	2.36(1.89, 2.94)
24.0-27.9	1330	384	93	2724	1102	437	1.84(1.59, 2.14)	2.21(1.97, 2.49)	1.19(0.92, 1.53)	2.14(1.81, 2.54)
≥28.0	81	32	9	1467	815	317	3.10(1.93, 5.00)	4.33(3.77, 4.96)	2.14(1.01, 4.52)	3.08(2.56, 3.71)
<i>P for interaction</i>							<i>0.3524</i>		<i>0.4011</i>	
Total										
<18.5	525	87	39	24	12	7	0.65(0.51, 0.83)	2.25(0.85, 5.93)	0.97(0.68, 1.39)	3.45(1.18, 10.12)
18.5-23.9	7357	1588	561	1653	563	276	1.00	1.52(1.25, 1.85)	1.00	1.88(1.42, 2.49)
24.0-27.9	2340	740	227	5254	2281	920	1.74(1.50, 2.03)	2.31(2.03, 2.62)	1.33(1.12, 1.58)	1.99(1.62, 2.45)
≥28.0	117	5	13	2427	1395	541	3.34(2.26, 4.94)	4.46(4.02, 4.96)	2.00(1.07, 3.74)	2.85(2.49, 3.27)
<i>P for interaction</i>							<i>0.0562</i>		<i>0.0798</i>	

2 Higher WC defined as ≥ 85 cm for men and ≥ 80 cm for women

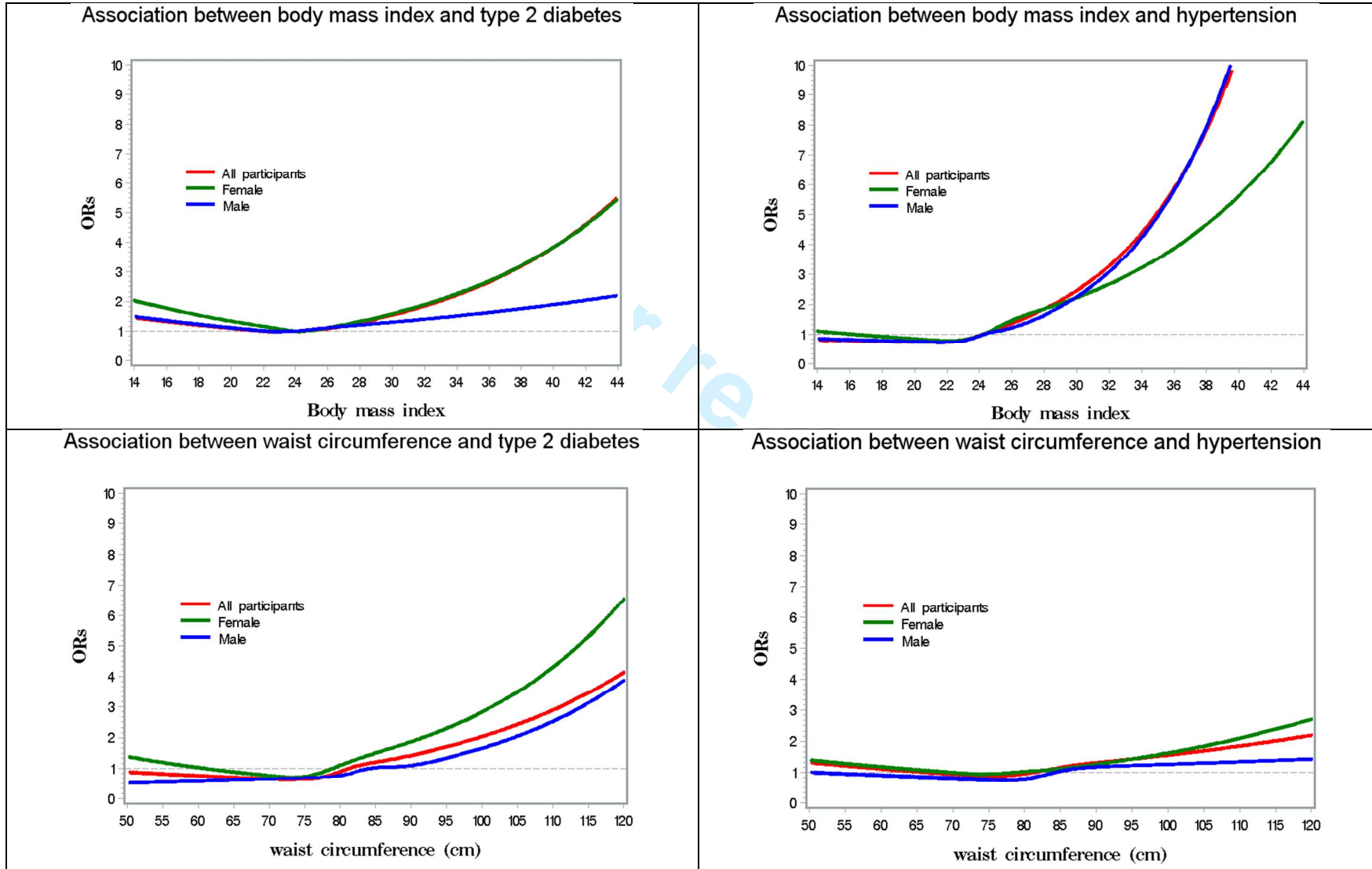
3 OR: Adjusted for age (continuous variable), education (no formal education, primary school, middle school, high school, colleague or above, dummy variables), per capita
4 income (<1000, 1000-2999, 3000-5000 and >5000 RMB Yuan / month, dummy variables), resident site (urban/rural area), family history of type 2 diabetes (yes/no),
5 smoking (ever/never), alcohol drinking (ever/never), regular exercise (never/ever), and phase of study (first /second survey).

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STROBE Statement—Checklist of items that should be included in reports of *cross-sectional studies*

	Item No	Recommendation	Results of check
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	We have indicated that the study was based on two population-based cross-sectional surveys in the title and the abstract
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	Line 53-62
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	Line 72-87
Objectives	3	State specific objectives, including any prespecified hypotheses	Line 89-92
Methods			
Study design	4	Present key elements of study design early in the paper	Line 95-104
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	Line 95-104
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants	Line 95-104
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	Line 117-153
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	Line 117-153
Bias	9	Describe any efforts to address potential sources of bias	Line 117-153
Study size	10	Explain how the study size was arrived at	NA
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	Line 155-169
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	Line 155-169
		(b) Describe any methods used to	Line 166-167

		examine subgroups and interactions	
		(c) Explain how missing data were addressed	There were very few missing data in this study. Please see footnote of the Table 3
		(d) If applicable, describe analytical methods taking account of sampling strategy	
		(e) Describe any sensitivity analyses	No
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Line 95-105
		(b) Give reasons for non-participation at each stage	No information
		(c) Consider use of a flow diagram	No
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Line 172-177, and Table 1
		(b) Indicate number of participants with missing data for each variable of interest	Yes, we provide number of subjects for each variable of interest (Please see tables)
Outcome data	15*	Report numbers of outcome events or summary measures	Yes (Please see tables)
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	No. Due to the large table, we present only adjusted ORs
		(b) Report category boundaries when continuous variables were categorized	Yes (Please see table 4)
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Line 210-217
Discussion			
Key results	18	Summarise key results with reference to study objectives	Line 219-224
Limitations	19	Discuss limitations of the study, taking into account sources of	Line 253-259

		potential bias or imprecision. Discuss both direction and magnitude of any potential bias	
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	Line 251-252
Generalisability	21	Discuss the generalisability (external validity) of the study results	Line 263-264
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	Line 275-280

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at www.strobe-statement.org.



**Increased Waist Circumference and Prevalence of Type 2
Diabetes and Hypertension in Chinese Adults: Two
Population-based Cross-sectional Surveys in Shanghai,
China**

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1 **Increased Waist Circumference and Prevalence of Type 2 Diabetes and Hypertension in**
2 **Chinese Adults: Two Population-based Cross-sectional Surveys in Shanghai, China**

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26 38 **RUNNING HEADER:** Obesity and prevalence of hypertension and T2DM in Chinese adults

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44 **Abstract:**

45 **Objective:** To evaluate the changes in body mass index (BMI) and waist circumference (WC)
46 and their associations with the prevalence of hypertension and type 2 diabetes (T2DM) in Chinese
47 adults.

48 **Design:** Two consecutive population-based cross-sectional surveys.

49 **Setting:** A total of 12 districts and 7 counties in Shanghai, China.

50 **Participants:** 12,329 randomly selected participants of the survey in 2002-2003, and 7,423
51 randomly selected participants of the survey in 2009. All subjects were residents of Shanghai aged
52 35-74 years old.

53 **Outcome measures:** Measured BMI and WC. Previously-diagnosed and newly-identified
54 hypertension and T2DM by measured blood pressure, fasting and post-load glucose.

55 **Results:** While the participants of the two surveys were comparable in BMI in each age group,
56 the participants of the 2009 survey had significantly larger WC than those of the 2002-03 survey,
57 with an annual percentage change (APC) being higher among subjects aged 45-49 years old in both
58 men and women. The increase in prevalence of T2DM was observed in all age groups and also
59 appeared more evident in subjects aged 45-49 years old. The prevalence of hypertension was
60 observed to increase more rapidly in elderly men and middle-aged women. Obesity, both overt and
61 central, was associated with the risk of the two diseases, but BMI was more strongly linked to
62 hypertension while WC appeared more evidently related with T2DM.

63 **Conclusion:** The prevalence of central obesity and related chronic diseases has been
64 increasing in Shanghai, China. Our findings provide useful information for the projection of
65 growing burden of T2DM and hypertension in Chinese adults.

66

67 **Keywords:** type 2 diabetes; hypertension; prevalence; body mass index; waist circumference

68

Article summary

Article focus

- The shift in BMI and WC among Chinese adults over past one decade.
- The contribution of changes in overall and central obesity to the increasing burden of chronic disease in China.

Key messages

- The WC increased in Chinese adults over the decade spanning 2002-2009, while BMI did not change over the same period.
- BMI was more strongly linked to hypertension while WC appeared more evidently related with T2DM in Chinese adults.
- Our findings provide useful information for the projection of a more rapidly growing burden of T2DM than hypertension in Chinese adults.

Strengths and limitations of this study

- The strengths of this study include the strict process of multistage sampling in adult population of Shanghai, anthropometric measurement according to a standardized protocol and fasting and postprandial blood glucose tests for the participants.
- The nature of the cross-sectional study design limits our ability to directly evaluate the influence of overall and central obesity as well as the change of their prevalence on the risk of hypertension and T2DM.
- The differences in several demographic characteristics between the participants of the two surveys indicate the possibility of selection bias.

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71 Introduction

72 A rising worldwide prevalence of chronic disease, manifested primarily as hypertension and
73 type 2 diabetes (T2DM), has been well documented [1-4]. In Chinese aged 15-74 years old, the
74 prevalence of hypertension increased from 5.11% in 1959, 7.73% in 1979 [5] and 13.58% in 1991[6]
75 to 17.65% in 2002 [7]. The prevalence of T2DM tripled between 1980 (about 1.0%) and 1996
76 (3.2%) [8 9], and reached 9.7% in 2008 among adults at 20 years old or above [10]. It is estimated
77 that over 92 million people in China have T2DM. This represents approximately half of the world's
78 diabetic population, and places China at the "global epicenter of the diabetes epidemic" [4].

79 Both hypertension and T2DM are associated with obesity [11 12]. Obesity is often measured
80 by body mass index (BMI). Across the entire range of BMI, the risk of hypertension and T2DM
81 increases, making a higher BMI a strong predictor of both hypertension and T2DM [4 12-14].
82 However, a significant proportion of Asian adults diagnosed with T2DM are with the normal BMI,
83 ie.18.5-25.0 kg/m² [15 16]. BMI is a general indicator of overt obesity, but does not give
84 information about the distribution of obesity. Central obesity, often assessed via waist
85 circumference (WC), is also strongly correlated with T2DM in both European and Asian adults [11,
86 17]. While changes in BMI have been well documented in China over past several decades [2 18],
87 changes in WC, and thus central obesity, are not well described.

88 In this study, we took advantage of the data from population based cross-sectional surveys
89 conducted in Shanghai in 2002-03 and in 2009. We used the data from the two surveys to evaluate
90 correlations between shifts in BMI and WC with the prevalence of hypertension and T2DM in
91 Chinese adults. Our results may help to better understand the contribution of overall obesity and
92 central obesity in the increasing burden of chronic disease in China.

93 Materials and Methods

94 Study Participants

95 A representative sample of the general population was randomly selected through a multistage
96 sampling process in the 2002-03 survey. Firstly, 4 districts and 2 counties were randomly selected

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97 from a total of 12 districts and 7 counties in Shanghai, China. And then, 1-2 sub-districts or towns
98 were randomly selected from each selected district or county. Next, 1-2 communities or villages,
99 usually 1,000-2,000 residents for each, were randomly selected from each selected sub-district or
100 town. Finally, eligible subjects (permanent residents of Shanghai, 15-74 years old and having been
101 in the city for at least 5 years) were randomly selected from the selected communities and villages
102 and were invited for participation. Pregnant women, individuals with type I diabetes, and physically
103 or mentally disabled persons were excluded from the participation. During the period of May
104 2002-October 2003, a total of 17,526 eligible subjects were recruited, and 14,401 (82.17%)
105 participated the survey.

106 The 2009 survey used the similar sampling method except that only 7 communities and
107 villages were randomly selected in the third stage of sampling. The inclusion and exclusion criteria
108 of the 2009 survey were also similar to those for the 2002-03 survey, except that only those at the
109 age of 35-74 years old were eligible for the 2009 survey. Among 7,627 eligible adults contacted
110 during the period of May-July 2009, 7,414 (97.21%) were interviewed and donated blood samples.

111 To make the two surveys comparable, we excluded 1,071 subjects younger than 35 years from
112 the 2002-03 survey. After further excluding subjects with missing information, the final analysis
113 included 5,050 men and 7,279 women in the 2002-03 survey and 3,461 men and 3,962 women in
114 the 2009 survey. The Institutional Review Board at Shanghai Municipal Center of Disease Control
115 and Prevention approved the study. Informed consent was obtained from each participant before
116 data collection.

117 **Data Collection**

118 A similar survey approach was followed by the two investigations. In both surveys,
119 information on demographic and socioeconomic factors, diagnosis of diabetes, tobacco and alcohol
120 use, physical activity and family history of diabetes was collected by trained interviewers with a
121 structured questionnaire at community clinics located in the residential areas of the participants.

122 At the interview, each participant's blood pressure, body weight, standing height, and waist

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2 123 circumference (WC) were measured by trained staff. Blood pressure was measured on the right arm
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4 124 in the sitting position using standard mercury sphygmomanometer after at least 5 minutes of rest.
5
6 125 The first and fifth Korotkoff sounds were recorded. Body weight and height were recorded while
7
8 126 the subject was in light clothing and without shoes. Body weight was measured with electronic
9
10 127 scales to the nearest 0.1 kg. Body height was measured to the nearest 0.1 cm by using a stadiometer.
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12 128 WC, recorded to the nearest 0.1 cm, was taken with a cloth tape and was measured on bare skin at
13
14 129 the midline between the lower border of the ribs and the iliac crest in the horizontal plane after a
15
16 130 normal expiration. Two measurements were taken and the mean of the replicates was used in the
17
18 131 following analyses. Body mass index (BMI) was calculated as weight in kilograms divided by
19
20 132 height in meters squared (kg/m^2) using the direct measurements.
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24 133 **Laboratory Measurements**

25
26 134 After at least 10 hours of overnight fasting, 1-1.5 ml venous blood specimen was collected in a
27
28 135 vacuum tube containing sodium fluoride. All participants with no history of diabetes and having a
29
30 136 fasting plasma glucose level of < 7.0 mmol per liter (mmol/l) were then asked to have an oral
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32 137 glucose-tolerance test (OGTT). Blood samples were drawn at 0 and 120 minutes after a standard 75
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34 138 gram glucose load. Plasma glucose was measured with Glucose oxidase-peroxidase (GOD-PAP)
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36 139 method.
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39 140 **Diagnosis of T2DM and Hypertension**

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41 141 Previously diagnosed T2DM and hypertension was identified by a positive response from the
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43 142 participant to the question of “Have you ever diagnosed with T2DM/hypertension by a doctor?” and
44
45 143 confirmed by medical records in which prescriptions of anti-hypertensive or hypoglycemic
46
47 144 medications were presented. The consistent rate was 100%. For those who had a negative response,
48
49 145 the T2DM was diagnosed with measured glucose level by using the 1999 World Health
50
51 146 Organization diagnostic criteria [Department of Noncommunicable Disease Surveillance. Definition,
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53 147 diagnosis and classification of diabetes mellitus and its complications: report of a WHO
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55 148 consultation. Part 1. Diagnosis and classification of diabetes mellitus. Geneva: World Health
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2 149 Organization, 1999. (Accessed July 5, 2010, at_
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4 150 http://www.staff.ncl.ac.uk/philip.home/who_dmg.pdf.)] and hypertension referred to the subjects
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6 151 with measured systolic blood pressure (SBP) \geq 140 mmHg or diastolic blood pressure (DBP) \geq 90
7
8 152 mmHg and confirmed by clinical visits. Total T2DM and hypertension included both previously
9
10 153 diagnosed and newly-diagnosed patients. 42.7% (1,110 of 2,598) diabetic patients and 10.3% (694
11
12 154 of 6,735) hypertensive patients were newly-diagnosed in the two surveys.

155 **Statistical Analysis**

156 SAS software 9.2 was used for all the statistical analyses. Characteristics of the subgroups
157 were described using summary statistics (median, 25th and 75th percentile, frequencies, and
158 percentages) separately for men and women. The differences between two surveys were compared
159 using χ^2 test (category variables) and Wilcoxon tests (continuous variables). The annual percentage
160 changes (APC) in prevalence between two surveys were calculated as (prevalence in 2009 –
161 prevalence in 2002-03) / number of years using logarithms for each age group. Percentile curves
162 were constructed for BMI and WC values in the two surveys by gender using the LMS (lambda, mu,
163 sigma) method. Restricted cubic splines (RCS) were used to model a potential curvilinear
164 relationship of BMI and WC with hypertension and diabetes using the 5th, 25th, 75th and 95th
165 percentiles as fixed knots and the 50th percentile as the reference. Polynomial logistic regression
166 were used to estimate the odds ratios (OR) and 95% confidence intervals (95% CI) of BMI and WC
167 with T2DM and hypertension. Meta-analysis was applied to obtain the combined ORs and 95% CI
168 considering the potential heterogeneity of the populations in the two surveys. The residual method
169 was used to derive the independent effect of BMI and WC with each other in the models. *P* value
170 less than 0.05 was considered as a test of significance based on two sides.

171 **Results**

172 The male participants in two surveys were similar in age, resident site and cigarette smoking
173 while the females were comparable in cigarette smoking ($P > 0.05$) (Table 1). Compared to the
174 subjects in 2002-03 survey, the participants of 2009 survey, both men and women, had lower level

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2 175 of education, higher level of income per capita, more prior history of T2DM, higher frequency of
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4 176 alcohol drinking and lower frequency of leisure time activity, and were more likely to have a family
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6 177 history of diabetes.
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8
9 178 Figure 1 shows the shapes of the BMI and WC distribution curves among men and women
10
11 179 changed over the period of the two surveys. After adjusting for age, education, per capita income,
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13 180 resident site, smoking, drinking, regular exercise, and family history of T2DM, the curves of BMI
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15 181 were almost overlapped in both men and women. However, the WC curves for men and women
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17 182 were shifted to the right between 2002-03 and 2009, with the mean WC increasing from 83.6 to
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19 183 85.3 cm for men and from 78.4 to 80.6 cm for women.
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21
22 184 As presented in table 2, the prevalence of obesity, both overall and central, increased with
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24 185 increasing age groups. While the prevalence of overall obesity ($\text{BMI} \geq 28 \text{ kg/m}^2$) did not changed
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26 186 between two surveys (all P values > 0.05), the prevalence of central obesity were significantly
27
28 187 higher in 2009 survey in each age group (all P values < 0.001). A more pronounced increase in
29
30 188 prevalence of central obesity and T2DM was observed among subjects aged 45-49 years old in both
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32 189 men and women; whereas the change in prevalence of hypertension between two surveys appeared
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34 190 more evident in older men and younger women over the period. Using the World Health
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36 191 Organization (WHO) criteria for obesity did not change the results substantially (data not shown in
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38 192 the tables).
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42 193 BMI and WC were highly correlated with each other, with a correlation coefficient of 0.77 ($P <$
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44 194 0.0001) among men and 0.78 ($P < 0.0001$) among women after adjusting for age. Therefore, the
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46 195 residual method was used to test the potential respective non-linear relationships of BMI and WC
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48 196 with the risk of T2DM and hypertension (Figure 2). The dose-response analysis likewise showed a
49
50 197 statistically significant increased risk of T2DM at high level of WC and a significant elevated risk
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52 198 of hypertension at high level of BMI in both men and women after adjusting for age, education, per
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54 199 capita income, resident site, smoking, drinking, regular exercise, family history of T2DM and phase
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56 200 of surveys, with P values for non-linear relationship tests < 0.05 . No significant relationship was
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2 201 observed between BMI and T2DM in men and between WC and hypertension in women.

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4 202 As shown in table 3, in both sexes, BMI adjusted for WC (residuals) appeared more strongly
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6 203 associated with hypertension while WC adjusted for BMI (residuals) was more evidently related
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8 204 with T2DM. Comparing with the lowest quartile of BMI residuals, the risk of hypertension
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10 205 increased 85% (95%CI: 1.59-2.15) in men and 1.23-fold (95%CI: 1.94-2.57) in women, whereas
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12 206 the risk of T2DM did not increase significantly in both sexes. On the other hand, the ORs of the
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14 207 highest versus the lowest quartile WC residuals for T2DM were 1.75 (95%CI: 1.33-2.30) in men
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17 208 and 2.37 (95%CI: 1.78-3.15) in women, higher than the OR of 1.57 (95%CI: 1.35-1.82) in men and
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19 209 1.13 (95%CI: 0.98-1.30) in women for hypertension.

20
21 210 We further evaluated the potential joint effect of BMI and WC on T2DM and hypertension
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23 211 (table 4). The participants were classified into normal weight (BMI 18.5-23.9 kg/m²), overweight
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25 212 (24.0-27.9 kg/m²), or obese (≥ 28 kg/m²) based on data from Chinese adults, and were defined as
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27 213 with normal or increased WC using sex-specific cut-offs (85 cm in men and 80 cm in women) [19].
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29 214 The risk of T2DM and hypertension increased across groups defined by BMI and WC, with the
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31 215 highest risk observed among men with the lowest BMI but a higher WC, and among those with the
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33 216 highest BMI and a higher WC for hypertension. However, no significant interaction was observed
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35 217 between BMI and WC (all *P* values for interaction tests > 0.05).

36 37 38 39 40 218 **Discussion**

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42 219 In this representative sample of the adult population in Shanghai, the largest city in China, we
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44 220 observed an increased prevalence of central obesity, hypertension and T2DM over the decade
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46 221 spanning 2002-2009. In contrast, BMI did not change over the same period. Our results present a
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48 222 snapshot of overt versus central obesity in the Chinese population and suggest that the epidemic of
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50 223 central obesity in this population, which has been more closely associated with the prevalence of
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52 224 T2DM, may lead to a more rapidly growing burden of T2DM in China.

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55 225 Chinese adults have lower rates of overweight and obesity than their Western counterparts
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57 226 using the WHO criteria (BMI ≥ 25 kg/m² for overweight and BMI ≥ 30 kg/m² for obesity) [15 16].
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2 227 Nevertheless, increasing trends of BMI in Chinese adults have been well documented [18 20]. In
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4 228 two national nutritional surveys undertaken in 1982 and 1992 in China, the prevalence of
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6 229 overweight/obesity ($\text{BMI} \geq 25 \text{ kg/m}^2$) in subjects 20-70 years of age was 10% and 15%,
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8 230 respectively. Between 1992 and 2002, the combined prevalence of overweight and obesity increased
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10 231 from 14.6 to 21.8% [21]. Interestingly, the increase in BMI among Chinese adults has slowed down
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12 232 during past decades [2]. In this study, we did not observe an increase in BMI and prevalence of
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14 233 obesity defined by the Chinese obesity standards or by WHO criteria (data not shown). Instead, we
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16 234 observed a significant increase in WC, a measure of central obesity between surveys. Our
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18 235 observation of increased WC in Chinese adults, without a concomitant increase in BMI, represents
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20 236 an increasing burden of central obesity in this population. The increase in central obesity indicates
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22 237 an upward trend in body fat percentages in the population who have been previously observed with
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24 238 higher body fat percentages compared to other ethnic people with the same BMI [22 23].
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28 239 Both epidemic of overall and central obesity parallels a continuously increasing prevalence of
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30 240 hypertension and T2DM in China [21]. Several studies indicate that overall obesity (BMI) is more
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32 241 strongly associated with hypertension, while central obesity (WC) is more strongly associated with
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34 242 T2DM [17 24-26]. The rationale for these associations is based on the notion that central obesity
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36 243 reflects specific accumulation of visceral adipose tissue. Excess visceral adipose tissue is
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38 244 metabolically unfavorable due to productions of free fatty acids and inflammatory mediators.
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40 245 Overall obesity, on the other hand, represents a greater overall physiologic strain and effects
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42 246 vascular and cardiac parameters more significantly. In this study, we observed a significant increase
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44 247 in prevalence of T2DM regardless of gender or age groups, which was more pronounced than the
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46 248 change in the prevalence of hypertension during the period of 2002-03 and 2009. We also observed
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48 249 a closer association of central obesity with the prevalence of T2DM than with the prevalence of
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50 250 hypertension. These results support the notion that central obesity in particular is a stronger risk
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52 251 factor for T2DM than for hypertension in Chinese adults. Due to the cross-sectional design,
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54 252 however, our study was unable to make a causal inference.
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2 253 The nature of the cross-sectional study design limits our ability to directly evaluate the
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4 254 influence of overall and central obesity as well as the change of their prevalence on the risk of
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6 255 hypertension and T2DM. The differences in several demographic characteristics between the
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8 256 participants of the two surveys indicate the changes in general population over time. However,
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10 257 selection bias could not be excluded. However, there are several strengths, including the strict
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12 258 process of multistage sampling in adult population in Shanghai, anthropometric measurement
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14 259 according to a standardized protocol and fasting and postprandial blood glucose tests for the
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16 260 participants.

20 261 **Conclusions**

22 262 In summary, this study describes the potential association of central obesity with an upward
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24 263 trend of T2DM, implicating a more rapidly growing burden of T2DM than hypertension in Chinese
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26 264 adults. The findings in Shanghai, the largest city and one of the most economically developed areas
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28 265 in China, provide useful information for the projection of future trends in the whole country.

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2 359 Figure 1. Shift in BMI and WC over the period of the two population-based surveys

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4 360 Figure 2. Non-linear dose-response relationship of BMI and WC with hypertension and T2DM

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6 361 among participants of the two population-based surveys

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363 Table 1. Characteristics of participants in two population-based surveys in Shanghai, China

Characteristics	1 st survey		2 nd survey		<i>P-value between surveys^a</i>	
	Men (N=5,050)	Women (N=7,279)	Men (N=3,461)	Women (N=3,962)	<i>In men</i>	<i>In women</i>
Age (yrs., mean ± SD)	54.8 ± 10.8	53.1 ± 10.3	54.7 ± 9.5	54.7 ± 9.1	0.55	<0.0001
Resident site (%)						
Urban	71.1	63.0	72.4	72.0		
Rural	29.0	37.0	27.7	28.0	0.19	<0.0001
Education (%)						
No formal education	4.1	18.4	3.2	9.5		
Primary school	18.2	23.0	14.7	17.7		
Middle school	35.3	31.1	45.7	45.2		
High school	27.6	22.6	27.6	23.8		
College or above	14.8	4.9	8.8	3.9	0.0025	<0.0001
Per capita income (yuan/mo.) (%)						
<1000	37.0	45.5	4.9	4.0		
1000-2999	38.3	38.4	41.8	46.7		
3000-5000	22.5	17.9	33.2	33.3		
>5000	2.2	1.3	20.0	16.0	<0.0001	<0.0001
Family history of type 2diabetes	12.3	13.1	16.4	19.0	<0.0001	<0.0001
Prevalence of type 2diabetes (%)	13.6	10.3	17.4	14.1	<0.0001	<0.0001
Prevalence of hypertension (%)	34.8	28.3	41.8	37.1	<0.0001	<0.0001
Cigarette smoking (%)	61.4	1.7	62.6	1.8	0.22	0.93
Alcohol drinking (%)	40.4	2.4	54.0	5.0	<0.0001	<0.0001
Leisure-time activity (%)	13.3	13.1	10.8	9.0	0.0009	<0.0001

364 ^a *P* for Wilcoxon tests or chi-square tests

Table 2. Prevalence of obesity, hypertension and type 2 diabetes in participants of the two population-based surveys by age groups in Shanghai, China

	No. of subjects		Overall Obesity			Central obesity			Hypertension			Type 2 diabetes		
	1 st survey	2 nd survey	1 st survey	2 nd survey	APC (%)	1 st survey	2 nd survey	APC (%)	1 st survey	2 nd survey	APC (%)	1 st survey	2 nd survey	APC (%)
Men														
Overall	5050	3461	11.7	11.9	0.21	46.3	53.8	2.35	34.8	41.8	2.87	13.6	17.4	3.78
Age-groups														
35-	414	230	10.5	9.1	-2.11	41.8	45.2	1.22	15.2	11.7	-3.92	4.6	5.7	3.25
40-	574	302	10.0	8.3	-2.83	41.8	47.00	1.85	22.5	21.9	-0.43	7.8	7.6	-0.44
45-	837	445	12.6	12.6	-0.04	44.0	53.7	3.12	25.3	31.0	3.16	7.8	13.7	9.13
50-	833	739	12.2	10.8	-1.76	44.1	53.8	3.12	33.1	40.3	3.07	12.7	18.3	5.72
55-	628	669	10.4	13.2	3.78	47.3	54.6	2.25	35.4	45.6	3.99	15.0	17.9	2.82
60-	507	513	10.5	15.4	6.18	48.7	56.1	2.19	44.6	51.7	2.29	15.6	20.1	3.98
65-	674	313	12.6	11.8	-0.99	51.4	61.0	2.67	49.4	59.4	2.88	20.8	26.2	3.64
70-	583	250	13.8	9.6	-5.40	51.1	54.0	0.85	50.9	65.2	3.87	24.2	25.6	0.88
Women														
Overall	7279	3962	13.8	13.8	0.02	41.7	54.2	4.10	28.3	37.1	4.28	10.3	14.1	4.84
Age-groups														
35-	615	251	7.5	7.2	-0.65	22.6	26.3	2.35	6.8	10.8	7.24	3.3	4.0	3.17
40-	1000	287	9.4	11.2	2.66	27.6	38.0	5.05	11.7	15.7	4.61	4.1	5.9	5.81
45-	1491	563	11.0	9.8	-1.82	32.3	42.6	4.38	19.3	23.5	3.03	5.8	8.7	6.32
50-	1309	866	15.1	14.1	-1.00	43.9	54.0	3.24	28.7	31.0	1.16	8.3	9.4	1.94
55-	838	818	15.7	13.6	-2.17	47.5	60.6	3.83	33.9	39.7	2.48	8.8	15.3	8.80
60-	610	585	19.2	18.1	-0.87	53.5	63.1	2.58	40.5	52.8	4.17	16.7	19.2	2.11
65-	799	327	18.0	18.4	0.28	59.0	66.1	1.76	48.4	59.3	3.17	23.7	27.8	2.54
70-	617	265	18.2	16.6	-1.36	60.2	68.7	2.05	51.4	64.5	3.57	21.4	27.2	3.75
All subjects														
Overall	12329	7423	13.0	12.9	-0.05	43.6	54.0	3.35	31.0	39.3	3.75	11.7	15.6	4.53
Age-groups ^a														
35-	1029	481	8.7	8.0	-1.04	30.3	33.9	2.39	10.2	11.2	1.49	3.8	4.7	3.63
40-	1574	589	9.6	10.1	0.11	32.7	41.3	4.14	15.6	17.9	2.92	5.5	6.5	3.41
45-	2328	1008	11.6	10.8	-0.77	36.5	46.6	4.16	21.5	26.2	3.46	6.5	10.5	8.22
50-	2142	1605	13.9	12.8	-1.53	44.0	53.9	3.19	30.4	34.6	0.90	10.0	12.8	4.69
55-	1466	1487	13.4	13.4	0.01	47.4	58.1	3.13	34.5	42.2	3.20	11.5	16.4	5.75
60-	1117	1098	15.2	16.9	1.59	51.3	59.9	2.39	42.4	52.3	3.29	16.2	19.6	2.96
65-	1473	640	15.6	15.4	-0.39	55.5	63.8	2.11	48.9	59.4	3.04	22.3	27.1	2.98
70-	1200	515	16.0	13.2	-2.94	55.8	61.5	1.52	51.2	64.9	3.71	22.8	26.4	2.32

^a adjusted for sex according to the distribution in the first survey.

Table 3. Association of body size with hypertension and type 2 diabetes in two population-based surveys in Shanghai, China

	No. of subjects with neither diseases	Type 2 diabetes only		Hypertension only		Both	
		N	OR (95%CI)	N	OR (95%CI)	N	OR (95%CI)
BMI residuals							
Men							
Q1	1260	156	1.00	529	1.00	175	1.00
Q2	1224	142	0.99 (0.77, 1.27)	583	1.16 (1.00, 1.34)	172	1.11(0.87, 1.41)
Q3	1164	132	1.09 (0.84, 1.41)	651	1.50 (1.29, 1.74)	171	1.36(1.07, 1.73)
Q4	1079	123	1.16 (0.88, 1.51)	709	1.85 (1.59, 2.15)	207	1.95(1.54, 2.47)
			<i>P for trend</i>				
			0.2472		<0.0001		<0.0001
Women							
Q1	1816	166	1.00	600	1.00	223	1.00
Q2	1866	148	1.02 (0.80, 1.29)	629	1.29 (1.12, 1.48)	162	0.96(0.77, 1.21)
Q3	1835	125	0.89 (0.69, 1.15)	687	1.51 (1.31, 1.73)	158	1.03(0.82, 1.31)
Q4	1634	109	0.94 (0.73, 1.23)	847	2.23 (1.94, 2.57)	215	1.85(1.15, 2.98)
			<i>P for trend</i>				
			0.4864		<0.0001		0.0067
All subjects							
Q1	3048	330	1.00	1162	1.00	385	1.00
Q2	3079	282	1.00 (0.84, 1.19)	1200	1.22 (1.11, 1.35)	363	1.03(0.87, 1.22)
Q3	2998	278	0.98 (0.82, 1.18)	1346	1.50 (1.36, 1.67)	302	1.18(1.00, 1.40)
Q4	2753	211	1.04 (0.86, 1.26)	1527	2.05 (1.85, 2.27)	433	1.88(1.60, 2.21)
			<i>P for trend</i>				
			0.2280		<0.0001		<0.0001
WC residuals							
Men							
Q1	1376	102	1.00	531	1.00	111	1.00
Q2	1232	131	1.34 (1.02, 1.78)	601	1.23 (1.06, 1.42)	155	1.41(1.07, 1.84)
Q3	1130	148	1.39 (0.70, 2.77)	644	1.39 (1.20, 1.62)	197	1.73(1.33, 2.25)
Q4	989	172	1.75 (1.33, 2.30)	696	1.57 (1.35, 1.82)	262	2.25(1.74, 2.90)
			<i>P for trend</i>				
			<0.0001		<0.0001		<0.0001
Women							
Q1	2019	80	1.00	598	1.00	108	1.00
Q2	1935	102	1.17 (0.86, 1.59)	651	1.04 (0.91, 1.18)	117	0.94(0.71, 1.25)
Q3	1708	172	2.04 (1.54, 2.70)	732	1.14 (0.99, 1.30)	194	1.40(1.08, 1.82)
Q4	1489	194	2.37 (1.78, 3.15)	782	1.13 (0.98, 1.30)	339	2.06(1.26, 3.38)
			<i>P for trend</i>				
			<0.0001		0.0216		<0.0001
All subjects							
Q1	3453	161	1.00	1109	1.00	203	1.00
Q2	3192	260	1.26 (0.99, 1.60)	1211	1.12 (1.01, 1.23)	260	1.16(0.82, 1.62)
Q3	2838	301	1.66 (1.16, 2.36)	1373	1.25 (1.13, 1.38)	412	1.55(1.29, 1.87)
Q4	2395	379	2.03 (1.66, 2.47)	1542	1.34 (1.09, 1.64)	608	2.18(1.83, 2.61)
			<i>P for trend</i>				
			0.0001		0.0021		<0.0001

Missing value excluded from the analysis.

OR: Adjusted for age (continuous variable), education (no formal education, primary school, middle school, high school, colleague or above, dummy variables), per capita income (<1000, 1000-2999, 3000-5000 and >5000 RMB Yuan / month, dummy variables), resident site (urban/rural area), family history of type 2 diabetes (yes/no), smoking (ever/never), alcohol drinking (ever/never), regular exercise (never/ever), phase of study (first /second survey); Additionally adjusted for sex (male/female) for all subjects.

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4 Table 4. Joint effect of general obesity and central obesity on type 2 diabetes among Chinese adults
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BMI	WC: Lower			WC: Higher			OR (95%CI) for hypertension		OR (95%CI) for type 2 diabetes	
	No. of subjects	Hypertension N (%)	Diabetes N (%)	No. of subjects	Hypertension N (%)	Diabetes N (%)	WC: Lower	WC: Higher	WC: Lower	WC: Higher
Men										
<18.5	212	36	20	16	10	6	0.61(0.42, 0.89)	3.68(1.28, 10.59)	1.02(0.62, 1.67)	3.77(1.13, 12.56)
18.5-23.9	3034	767	296	679	249	111	1.00	1.56(0.94, 2.57)	1.00	1.48(1.15, 1.90)
24.0-27.9	1010	356	134	2530	1179	483	1.61(1.13, 2.32)	2.38(1.78, 3.17)	1.46(1.16, 1.83)	1.85(1.16, 2.96)
≥28.0	36	20	4	960	580	224	3.91(1.95, 7.82)	4.67(3.97, 5.49)	1.71(0.55, 5.37)	2.60(2.12, 3.18)
<i>P for interaction</i>							0.0711		0.0933	
Women										
<18.5	313	51	19	8	2	1	0.68(0.49, 0.94)	0.85(0.16, 4.51)	0.93(0.56, 1.54)	2.45(0.22, 26.72)
18.5-23.9	4323	821	265	974	314	165	1.00	1.48(1.26, 1.75)	1.00	2.36(1.89, 2.94)
24.0-27.9	1330	384	93	2724	1102	437	1.84(1.59, 2.14)	2.21(1.97, 2.49)	1.19(0.92, 1.53)	2.14(1.81, 2.54)
≥28.0	81	32	9	1467	815	317	3.10(1.93, 5.00)	4.33(3.77, 4.96)	2.14(1.01, 4.52)	3.08(2.56, 3.71)
<i>P for interaction</i>							0.3524		0.4011	
Total										
<18.5	525	87	39	24	12	7	0.65(0.51, 0.83)	2.25(0.85, 5.93)	0.97(0.68, 1.39)	3.45(1.18, 10.12)
18.5-23.9	7357	1588	561	1653	563	276	1.00	1.52(1.25, 1.85)	1.00	1.88(1.42, 2.49)
24.0-27.9	2340	740	227	5254	2281	920	1.74(1.50, 2.03)	2.31(2.03, 2.62)	1.33(1.12, 1.58)	1.99(1.62, 2.45)
≥28.0	117	5	13	2427	1395	541	3.34(2.26, 4.94)	4.46(4.02, 4.96)	2.00(1.07, 3.74)	2.85(2.49, 3.27)
<i>P for interaction</i>							0.0562		0.0798	

37 2 Higher WC defined as ≥ 85 cm for men and ≥ 80 cm for women

38 3 OR: Adjusted for age (continuous variable), education (no formal education, primary school, middle school, high school, colleague or above, dummy variables), per capita
39 4 income (<1000, 1000-2999, 3000-5000 and >5000 RMB Yuan / month, dummy variables), resident site (urban/rural area), family history of type 2 diabetes (yes/no),
40 5 smoking (ever/never), alcohol drinking (ever/never), regular exercise (never/ever), and phase of study (first /second survey).

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1 **Increased Waist Circumference and Prevalence of Type 2 Diabetes and Hypertension in**
2 **Chinese Adults: Two Population-based Cross-sectional Surveys in Shanghai, China**

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44 **Abstract:**

45 **Objective:** To evaluate the changes in body mass index (BMI) and waist circumference (WC)
46 and their associations with the prevalence of hypertension and type 2 diabetes (T2DM) in Chinese
47 adults.

48 **Design:** Two consecutive population-based cross-sectional surveys.

49 **Setting:** A total of 12 districts and 7 counties in Shanghai, China.

50 **Participants:** 12,329 randomly selected participants of the survey in 2002-2003, and 7,423
51 randomly selected participants of the survey in 2009. All subjects were residents of Shanghai aged
52 35-74 years old.

53 **Outcome measures:** Measured BMI and WC. Previously-diagnosed and newly-identified
54 hypertension and T2DM by measured blood pressure, fasting and post-load glucose.

55 **Results:** While the participants of the two surveys were comparable in BMI in each age group,
56 the participants of the 2009 survey had significantly larger WC than those of the 2002-03 survey,
57 with an annual percentage change (APC) being higher among subjects aged 45-49 years old in both
58 men and women. The increase in prevalence of T2DM was observed in all age groups and also
59 appeared more evident in subjects aged 45-49 years old. The prevalence of hypertension was
60 observed to increase more rapidly in elderly men and middle-aged women. Obesity, both overt and
61 central, was associated with the risk of the two diseases, but BMI was more strongly linked to
62 hypertension while WC appeared more evidently related with T2DM.

63 **Conclusion:** The prevalence of central obesity and related chronic diseases has been
64 increasing in Shanghai, China. **Our findings provide useful information for the projection of**
65 **growing burden of T2DM and hypertension in Chinese adults.**

66
67 **Keywords:** type 2 diabetes; hypertension; prevalence; body mass index; waist circumference

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Article summary

Article focus

- The shift in BMI and WC among Chinese adults over past one decade.
- The contribution of changes in overall and central obesity to the increasing burden of chronic disease in China.

Key messages

- The WC increased in Chinese adults over the decade spanning 2002-2009, while BMI did not change over the same period.
- BMI was more strongly linked to hypertension while WC appeared more evidently related with T2DM in Chinese adults.
- Our findings provide useful information for the projection of a more rapidly growing burden of T2DM than hypertension in Chinese adults.

Strengths and limitations of this study

- The strengths of this study include the strict process of multistage sampling in adult population of Shanghai, anthropometric measurement according to a standardized protocol and fasting and postprandial blood glucose tests for the participants.
- The nature of the cross-sectional study design limits our ability to directly evaluate the influence of overall and central obesity as well as the change of their prevalence on the risk of hypertension and T2DM.
- The differences in several demographic characteristics between the participants of the two surveys indicate the possibility of selection bias.

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71 Introduction

72 A rising worldwide prevalence of chronic disease, manifested primarily as hypertension and
73 type 2 diabetes (T2DM), has been well documented [1-4]. In Chinese aged 15-74 years old, the
74 prevalence of hypertension increased from 5.11% in 1959, 7.73% in 1979 [5] and 13.58% in 1991[6]
75 to 17.65% in 2002 [7]. The prevalence of T2DM tripled between 1980 (about 1.0%) and 1996
76 (3.2%) [8 9], and reached 9.7% in 2008 among adults at 20 years old or above [10]. It is estimated
77 that over 92 million people in China have T2DM. This represents approximately half of the world's
78 diabetic population, and places China at the "global epicenter of the diabetes epidemic" [4].

79 Both hypertension and T2DM are associated with obesity [11 12]. Obesity is often measured
80 by body mass index (BMI). Across the entire range of BMI, the risk of hypertension and T2DM
81 increases, making a higher BMI a strong predictor of both hypertension and T2DM [4 12-14].
82 However, a significant proportion of Asian adults diagnosed with T2DM are with the normal BMI,
83 ie.18.5-25.0 kg/m² [15 16]. BMI is a general indicator of overt obesity, but does not give
84 information about the distribution of obesity. Central obesity, often assessed via waist
85 circumference (WC), is also strongly correlated with T2DM in both European and Asian adults [11
86 17]. While changes in BMI have been well documented in China over past several decades [2 18],
87 changes in WC, and thus central obesity, are not well described.

88 In this study, we took advantage of the data from population based cross-sectional surveys
89 conducted in Shanghai in 2002-03 and in 2009. We used the data from the two surveys to evaluate
90 correlations between shifts in BMI and WC with the prevalence of hypertension and T2DM in
91 Chinese adults. Our results may help to better understand the contribution of overall obesity and
92 central obesity in the increasing burden of chronic disease in China.

93 Materials and Methods

94 Study Participants

95 A representative sample of the general population was randomly selected through a multistage
96 sampling process in the 2002-03 survey. Firstly, 4 districts and 2 counties were randomly selected

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2 97 from a total of 12 districts and 7 counties in Shanghai, China. And then, 1-2 sub-districts or towns
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4 98 were randomly selected from each selected district or county. Next, 1-2 communities or villages,
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6 99 usually 1,000-2,000 residents for each, were randomly selected from each selected sub-district or
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8 100 town. Finally, eligible subjects (permanent residents of Shanghai, 15-74 years old and having been
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10 101 in the city for at least 5 years) were randomly selected from the selected communities and villages
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12 102 and were invited for participation. Pregnant women, individuals with type I diabetes, and physically
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14 103 or mentally disabled persons were excluded from the participation. During the period of May
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16 104 2002-October 2003, a total of 17,526 eligible subjects were recruited, and 14,401 (82.17%)
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18 105 participated the survey.

21 106 The 2009 survey used the similar sampling method except that only 7 communities and
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23 107 villages were randomly selected in the third stage of sampling. The inclusion and exclusion criteria
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25 108 of the 2009 survey were also similar to those for the 2002-03 survey, except that only those at the
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27 109 age of 35-74 years old were eligible for the 2009 survey. Among 7,627 eligible adults contacted
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29 110 during the period of May-July 2009, 7,414 (97.21%) were interviewed and donated blood samples.

32 111 To make the two surveys comparable, we excluded 1,071 subjects younger than 35 years from
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34 112 the 2002-03 survey. After further excluding subjects with missing information, the final analysis
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36 113 included 5,050 men and 7,279 women in the 2002-03 survey and 3,461 men and 3,962 women in
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38 114 the 2009 survey. The Institutional Review Board at Shanghai Municipal Center of Disease Control
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40 115 and Prevention approved the study. Informed consent was obtained from each participant before
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42 116 data collection.

46 117 **Data Collection**

48 118 A similar survey approach was followed by the two investigations. In both surveys,
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50 119 information on demographic and socioeconomic factors, diagnosis of diabetes, tobacco and alcohol
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52 120 use, physical activity and family history of diabetes was collected by trained interviewers with a
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54 121 structured questionnaire at community clinics located in the residential areas of the participants.

56 122 At the interview, each participant's blood pressure, body weight, standing height, and waist

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2 123 circumference (WC) were measured by trained staff. Blood pressure was measured on the right arm
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4 124 in the sitting position using standard mercury sphygmomanometer after at least 5 minutes of rest.
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6 125 The first and fifth Korotkoff sounds were recorded. Body weight and height were recorded while
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8 126 the subject was in light clothing and without shoes. Body weight was measured with electronic
9
10 127 scales to the nearest 0.1 kg. Body height was measured to the nearest 0.1 cm by using a stadiometer.
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12 128 WC, recorded to the nearest 0.1 cm, was taken with a cloth tape and was measured on bare skin at
13
14 129 the midline between the lower border of the ribs and the iliac crest in the horizontal plane after a
15
16 130 normal expiration. Two measurements were taken and the mean of the replicates was used in the
17
18 131 following analyses. Body mass index (BMI) was calculated as weight in kilograms divided by
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20 132 height in meters squared (kg/m^2) using the direct measurements.
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24 133 **Laboratory Measurements**

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26 134 After at least 10 hours of overnight fasting, 1-1.5 ml venous blood specimen was collected in a
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28 135 vacuum tube containing sodium fluoride. All participants with no history of diabetes and having a
29
30 136 fasting plasma glucose level of < 7.0 mmol per liter (mmol/l) were then asked to have an oral
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32 137 glucose-tolerance test (OGTT). Blood samples were drawn at 0 and 120 minutes after a standard 75
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34 138 gram glucose load. Plasma glucose was measured with Glucose oxidase-peroxidase (GOD-PAP)
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36 139 method.
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39 140 **Diagnosis of T2DM and Hypertension**

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41 141 Previously diagnosed T2DM and hypertension was identified by a positive response from the
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43 142 participant to the question of “Have you ever diagnosed with T2DM/hypertension by a doctor?” and
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45 143 confirmed by medical records in which prescriptions of anti-hypertensive or hypoglycemic
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47 144 medications were presented. The consistent rate was 100%. For those who had a negative response,
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49 145 the T2DM was diagnosed with measured glucose level by using the 1999 World Health
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51 146 Organization diagnostic criteria [Department of Noncommunicable Disease Surveillance. Definition,
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53 147 diagnosis and classification of diabetes mellitus and its complications: report of a WHO
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55 148 consultation. Part 1. Diagnosis and classification of diabetes mellitus. Geneva: World Health
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2 149 Organization, 1999. (Accessed July 5, 2010, at
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4 150 http://www.staff.ncl.ac.uk/philip.home/who_dmg.pdf.)] and hypertension referred to the subjects
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6 151 with measured systolic blood pressure (SBP) \geq 140 mmHg or diastolic blood pressure (DBP) \geq 90
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8 152 mmHg and confirmed by clinical visits. Total T2DM and hypertension included both previously
9
10 153 diagnosed and newly-diagnosed patients. 42.7% (1,110 of 2,598) diabetic patients and 10.3% (694
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12 154 of 6,735) hypertensive patients were newly-diagnosed in the two surveys.

155 **Statistical Analysis**

156 SAS software 9.2 was used for all the statistical analyses. Characteristics of the subgroups
157 were described using summary statistics (median, 25th and 75th percentile, frequencies, and
158 percentages) separately for men and women. The differences between two surveys were compared
159 using χ^2 test (category variables) and Wilcoxon tests (continuous variables). The annual percentage
160 changes (APC) in prevalence between two surveys were calculated as (prevalence in 2009 –
161 prevalence in 2002-03) / number of years using logarithms for each age group. Percentile curves
162 were constructed for BMI and WC values in the two surveys by gender using the LMS (lambda, mu,
163 sigma) method. Restricted cubic splines (RCS) were used to model a potential curvilinear
164 relationship of BMI and WC with hypertension and diabetes using the 5th, 25th, 75th and 95th
165 percentiles as fixed knots and the 50th percentile as the reference. Polynomial logistic regression
166 were used to estimate the odds ratios (OR) and 95% confidence intervals (95% CI) of BMI and WC
167 with T2DM and hypertension. Meta-analysis was applied to obtain the combined ORs and 95% CI
168 considering the potential heterogeneity of the populations in the two surveys. The residual method
169 was used to derive the independent effect of BMI and WC with each other in the models. *P* value
170 less than 0.05 was considered as a test of significance based on two sides.

171 **Results**

172 The male participants in two surveys were similar in age, resident site and cigarette smoking
173 while the females were comparable in cigarette smoking (*P* > 0.05) (Table 1). Compared to the
174 subjects in 2002-03 survey, the participants of 2009 survey, both men and women, had lower level

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2 175 of education, higher level of income per capita, more prior history of T2DM, higher frequency of
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4 176 alcohol drinking and lower frequency of leisure time activity, and were more likely to have a family
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6 177 history of diabetes.
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9 178 Figure 1 shows the shapes of the BMI and WC distribution curves among men and women
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11 179 changed over the period of the two surveys. After adjusting for age, education, per capita income,
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13 180 resident site, smoking, drinking, regular exercise, and family history of T2DM, the curves of BMI
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15 181 were almost overlapped in both men and women. However, the WC curves for men and women
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17 182 were shifted to the right between 2002-03 and 2009, with the mean WC increasing from 83.6 to
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19 183 85.3 cm for men and from 78.4 to 80.6 cm for women.
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22 184 As presented in table 2, the prevalence of obesity, both overall and central, increased with
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24 185 increasing age groups. While the prevalence of overall obesity ($BMI \geq 28 \text{ kg/m}^2$) did not changed
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26 186 between two surveys (all P values > 0.05), the prevalence of central obesity were significantly
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28 187 higher in 2009 survey in each age group (all P values < 0.001). A more pronounced increase in
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30 188 prevalence of central obesity and T2DM was observed among subjects aged 45-49 years old in both
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32 189 men and women; whereas the change in prevalence of hypertension between two surveys appeared
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34 190 more evident in older men and younger women over the period. Using the World Health
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36 191 Organization (WHO) criteria for obesity did not change the results substantially (data not shown in
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38 192 the tables).
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41 193 BMI and WC were highly correlated with each other, with a correlation coefficient of 0.77 ($P <$
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43 194 0.0001) among men and 0.78 ($P < 0.0001$) among women after adjusting for age. Therefore, the
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45 195 residual method was used to test the potential respective non-linear relationships of BMI and WC
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47 196 with the risk of T2DM and hypertension (Figure 2). The dose-response analysis likewise showed a
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49 197 statistically significant increased risk of T2DM at high level of WC and a significant elevated risk
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51 198 of hypertension at high level of BMI in both men and women after adjusting for age, education, per
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53 199 capita income, resident site, smoking, drinking, regular exercise, family history of T2DM and phase
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55 200 of surveys, with P values for non-linear relationship tests < 0.05 . No significant relationship was
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2 201 observed between BMI and T2DM in men and between WC and hypertension in women.

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4 202 As shown in table 3, in both sexes, BMI adjusted for WC (residuals) appeared more strongly
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6 203 associated with hypertension while WC adjusted for BMI (residuals) was more evidently related
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8 204 with T2DM. Comparing with the lowest quartile of BMI residuals, the risk of hypertension
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10 205 increased 85% (95%CI: 1.59-2.15) in men and 1.23-fold (95%CI: 1.94-2.57) in women, whereas
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12 206 the risk of T2DM did not increase significantly in both sexes. On the other hand, the ORs of the
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14 207 highest versus the lowest quartile WC residuals for T2DM were 1.75 (95%CI: 1.33-2.30) in men
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17 208 and 2.37 (95%CI: 1.78-3.15) in women, higher than the OR of 1.57 (95%CI: 1.35-1.82) in men and
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19 209 1.13 (95%CI: 0.98-1.30) in women for hypertension.

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21 210 We further evaluated the potential joint effect of BMI and WC on T2DM and hypertension
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23 211 (table 4). The participants were classified into normal weight (BMI 18.5-23.9 kg/m²), overweight
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25 212 (24.0-27.9 kg/m²), or obese (≥ 28 kg/m²) based on data from Chinese adults, and were defined as
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27 213 with normal or increased WC using sex-specific cut-offs (85 cm in men and 80 cm in women) [19].
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29 214 The risk of T2DM and hypertension increased across groups defined by BMI and WC, with the
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31 215 highest risk observed among men with the lowest BMI but a higher WC, and among those with the
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33 216 highest BMI and a higher WC for hypertension. However, no significant interaction was observed
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35 217 between BMI and WC (all *P* values for interaction tests > 0.05).

36 37 38 39 40 218 **Discussion**

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42 219 In this representative sample of the adult population in Shanghai, the largest city in China, we
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44 220 observed an increased prevalence of central obesity, hypertension and T2DM over the decade
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46 221 spanning 2002-2009. In contrast, BMI did not change over the same period. Our results present a
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48 222 snapshot of overt versus central obesity in the Chinese population and suggest that the epidemic of
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50 223 central obesity in this population, which has been more closely associated with the prevalence of
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52 224 T2DM, may lead to a more rapidly growing burden of T2DM in China.

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55 225 Chinese adults have lower rates of overweight and obesity than their Western counterparts
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57 226 using the WHO criteria (BMI ≥ 25 kg/m² for overweight and BMI ≥ 30 kg/m² for obesity) [15 16].
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2 227 Nevertheless, increasing trends of BMI in Chinese adults have been well documented [18 20]. In
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4 228 two national nutritional surveys undertaken in 1982 and 1992 in China, the prevalence of
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6 229 overweight/obesity ($\text{BMI} \geq 25 \text{ kg/m}^2$) in subjects 20-70 years of age was 10% and 15%,
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8 230 respectively. Between 1992 and 2002, the combined prevalence of overweight and obesity increased
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10 231 from 14.6 to 21.8% [21]. Interestingly, the increase in BMI among Chinese adults has slowed down
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12 232 during past decades [2]. In this study, we did not observe an increase in BMI and prevalence of
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14 233 obesity defined by the Chinese obesity standards or by WHO criteria (data not shown). Instead, we
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16 234 observed a significant increase in WC, a measure of central obesity between surveys. Our
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18 235 observation of increased WC in Chinese adults, without a concomitant increase in BMI, represents
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20 236 an increasing burden of central obesity in this population. The increase in central obesity indicates
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22 237 an upward trend in body fat percentages in the population who have been previously observed with
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24 238 higher body fat percentages compared to other ethnic people with the same BMI [22 23].

239 Both epidemic of overall and central obesity parallels a continuously increasing prevalence of
240 hypertension and T2DM in China [21]. Several studies indicate that overall obesity (BMI) is more
241 strongly associated with hypertension, while central obesity (WC) is more strongly associated with
242 T2DM [17 24-26]. The rationale for these associations is based on the notion that central obesity
243 reflects specific accumulation of visceral adipose tissue. Excess visceral adipose tissue is
244 metabolically unfavorable due to productions of free fatty acids and inflammatory mediators.
245 Overall obesity, on the other hand, represents a greater overall physiologic strain and effects
246 vascular and cardiac parameters more significantly. In this study, we observed a significant increase
247 in prevalence of T2DM regardless of gender or age groups, which was more pronounced than the
248 change in the prevalence of hypertension during the period of 2002-03 and 2009. We also observed
249 a closer association of central obesity with the prevalence of T2DM than with the prevalence of
250 hypertension. These results support the notion that central obesity in particular is a stronger risk
251 factor for T2DM than for hypertension in Chinese adults. Due to the cross-sectional design,
252 however, our study was unable to make a causal inference.

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2 253 The nature of the cross-sectional study design limits our ability to directly evaluate the
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4 254 influence of overall and central obesity as well as the change of their prevalence on the risk of
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6 255 hypertension and T2DM. The differences in several demographic characteristics between the
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8 256 participants of the two surveys indicate the changes in general population over time. However,
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10 257 selection bias could not be excluded. However, there are several strengths, including the strict
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12 258 process of multistage sampling in adult population in Shanghai, anthropometric measurement
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14 259 according to a standardized protocol and fasting and postprandial blood glucose tests for the
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16 260 participants.

261 Conclusions

262 In summary, this study describes the potential association of central obesity with an upward
263 trend of T2DM, implicating a more rapidly growing burden of T2DM than hypertension in Chinese
264 adults. The findings in Shanghai, the largest city and one of the most economically developed areas
265 in China, provide useful information for the projection of future trends in the whole country.

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270 Footnotes

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274 design, statistical analysis and revision of the paper. All authors contributed to the interpretation of
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8 281 manuscript.
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2 359 Figure 1. Shift in BMI and WC over the period of the two population-based surveys

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4 360 Figure 2. Non-linear dose-response relationship of BMI and WC with hypertension and T2DM

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6 361 among participants of the two population-based surveys

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363 Table 1. Characteristics of participants in two population-based surveys in Shanghai, China

Characteristics	1 st survey		2 nd survey		<i>P-value between surveys^a</i>	
	Men (N=5,050)	Women (N=7,279)	Men (N=3,461)	Women (N=3,962)	<i>In men</i>	<i>In women</i>
Age (yrs., mean ± SD)	54.8 ± 10.8	53.1 ± 10.3	54.7 ± 9.5	54.7 ± 9.1	0.55	<0.0001
Resident site (%)						
Urban	71.1	63.0	72.4	72.0		
Rural	29.0	37.0	27.7	28.0	0.19	<0.0001
Education (%)						
No formal education	4.1	18.4	3.2	9.5		
Primary school	18.2	23.0	14.7	17.7		
Middle school	35.3	31.1	45.7	45.2		
High school	27.6	22.6	27.6	23.8		
College or above	14.8	4.9	8.8	3.9	0.0025	<0.0001
Per capita income (yuan/mo.) (%)						
<1000	37.0	45.5	4.9	4.0		
1000-2999	38.3	38.4	41.8	46.7		
3000-5000	22.5	17.9	33.2	33.3		
>5000	2.2	1.3	20.0	16.0	<0.0001	<0.0001
Family history of type 2diabetes	12.3	13.1	16.4	19.0	<0.0001	<0.0001
Prevalence of type 2diabetes (%)	13.6	10.3	17.4	14.1	<0.0001	<0.0001
Prevalence of hypertension (%)	34.8	28.3	41.8	37.1	<0.0001	<0.0001
Cigarette smoking (%)	61.4	1.7	62.6	1.8	0.22	0.93
Alcohol drinking (%)	40.4	2.4	54.0	5.0	<0.0001	<0.0001
Leisure-time activity (%)	13.3	13.1	10.8	9.0	0.0009	<0.0001

364 ^a *P* for Wilcoxon tests or chi-square tests

Table 2. Prevalence of obesity, hypertension and type 2 diabetes in participants of the two population-based surveys by age groups in Shanghai, China

	No. of subjects		Overall Obesity			Central obesity			Hypertension			Type 2 diabetes		
	1 st survey	2 nd survey	1 st survey	2 nd survey	APC (%)	1 st survey	2 nd survey	APC (%)	1 st survey	2 nd survey	APC (%)	1 st survey	2 nd survey	APC (%)
Men														
Overall	5050	3461	11.7	11.9	0.21	46.3	53.8	2.35	34.8	41.8	2.87	13.6	17.4	3.78
Age-groups														
35-	414	230	10.5	9.1	-2.11	41.8	45.2	1.22	15.2	11.7	-3.92	4.6	5.7	3.25
40-	574	302	10.0	8.3	-2.83	41.8	47.00	1.85	22.5	21.9	-0.43	7.8	7.6	-0.44
45-	837	445	12.6	12.6	-0.04	44.0	53.7	3.12	25.3	31.0	3.16	7.8	13.7	9.13
50-	833	739	12.2	10.8	-1.76	44.1	53.8	3.12	33.1	40.3	3.07	12.7	18.3	5.72
55-	628	669	10.4	13.2	3.78	47.3	54.6	2.25	35.4	45.6	3.99	15.0	17.9	2.82
60-	507	513	10.5	15.4	6.18	48.7	56.1	2.19	44.6	51.7	2.29	15.6	20.1	3.98
65-	674	313	12.6	11.8	-0.99	51.4	61.0	2.67	49.4	59.4	2.88	20.8	26.2	3.64
70-	583	250	13.8	9.6	-5.40	51.1	54.0	0.85	50.9	65.2	3.87	24.2	25.6	0.88
Women														
Overall	7279	3962	13.8	13.8	0.02	41.7	54.2	4.10	28.3	37.1	4.28	10.3	14.1	4.84
Age-groups														
35-	615	251	7.5	7.2	-0.65	22.6	26.3	2.35	6.8	10.8	7.24	3.3	4.0	3.17
40-	1000	287	9.4	11.2	2.66	27.6	38.0	5.05	11.7	15.7	4.61	4.1	5.9	5.81
45-	1491	563	11.0	9.8	-1.82	32.3	42.6	4.38	19.3	23.5	3.03	5.8	8.7	6.32
50-	1309	866	15.1	14.1	-1.00	43.9	54.0	3.24	28.7	31.0	1.16	8.3	9.4	1.94
55-	838	818	15.7	13.6	-2.17	47.5	60.6	3.83	33.9	39.7	2.48	8.8	15.3	8.80
60-	610	585	19.2	18.1	-0.87	53.5	63.1	2.58	40.5	52.8	4.17	16.7	19.2	2.11
65-	799	327	18.0	18.4	0.28	59.0	66.1	1.76	48.4	59.3	3.17	23.7	27.8	2.54
70-	617	265	18.2	16.6	-1.36	60.2	68.7	2.05	51.4	64.5	3.57	21.4	27.2	3.75
All subjects														
Overall	12329	7423	13.0	12.9	-0.05	43.6	54.0	3.35	31.0	39.3	3.75	11.7	15.6	4.53
Age-groups ^a														
35-	1029	481	8.7	8.0	-1.04	30.3	33.9	2.39	10.2	11.2	1.49	3.8	4.7	3.63
40-	1574	589	9.6	10.1	0.11	32.7	41.3	4.14	15.6	17.9	2.92	5.5	6.5	3.41
45-	2328	1008	11.6	10.8	-0.77	36.5	46.6	4.16	21.5	26.2	3.46	6.5	10.5	8.22
50-	2142	1605	13.9	12.8	-1.53	44.0	53.9	3.19	30.4	34.6	0.90	10.0	12.8	4.69
55-	1466	1487	13.4	13.4	0.01	47.4	58.1	3.13	34.5	42.2	3.20	11.5	16.4	5.75
60-	1117	1098	15.2	16.9	1.59	51.3	59.9	2.39	42.4	52.3	3.29	16.2	19.6	2.96
65-	1473	640	15.6	15.4	-0.39	55.5	63.8	2.11	48.9	59.4	3.04	22.3	27.1	2.98
70-	1200	515	16.0	13.2	-2.94	55.8	61.5	1.52	51.2	64.9	3.71	22.8	26.4	2.32

^a adjusted for sex according to the distribution in the first survey.

Table 3. Association of body size with hypertension and type 2 diabetes in two population-based surveys in Shanghai, China

	No. of subjects with neither diseases	Type 2 diabetes only		Hypertension only		Both	
		N	OR (95%CI)	N	OR (95%CI)	N	OR (95%CI)
BMI residuals							
Men							
Q1	1260	156	1.00	529	1.00	175	1.00
Q2	1224	142	0.99 (0.77, 1.27)	583	1.16 (1.00, 1.34)	172	1.11(0.87, 1.41)
Q3	1164	132	1.09 (0.84, 1.41)	651	1.50 (1.29, 1.74)	171	1.36(1.07, 1.73)
Q4	1079	123	1.16 (0.88, 1.51)	709	1.85 (1.59, 2.15)	207	1.95(1.54, 2.47)
	<i>P for trend</i>		0.2472	<i><0.0001</i>		<i><0.0001</i>	
Women							
Q1	1816	166	1.00	600	1.00	223	1.00
Q2	1866	148	1.02 (0.80, 1.29)	629	1.29 (1.12, 1.48)	162	0.96(0.77, 1.21)
Q3	1835	125	0.89 (0.69, 1.15)	687	1.51 (1.31, 1.73)	158	1.03(0.82, 1.31)
Q4	1634	109	0.94 (0.73, 1.23)	847	2.23 (1.94, 2.57)	215	1.85(1.15, 2.98)
	<i>P for trend</i>		0.4864	<i><0.0001</i>		0.0067	
All subjects							
Q1	3048	330	1.00	1162	1.00	385	1.00
Q2	3079	282	1.00 (0.84, 1.19)	1200	1.22 (1.11, 1.35)	363	1.03(0.87, 1.22)
Q3	2998	278	0.98 (0.82, 1.18)	1346	1.50 (1.36, 1.67)	302	1.18(1.00, 1.40)
Q4	2753	211	1.04 (0.86, 1.26)	1527	2.05 (1.85, 2.27)	433	1.88(1.60, 2.21)
	<i>P for trend</i>		0.2280	<i><0.0001</i>		<i><0.0001</i>	
WC residuals							
Men							
Q1	1376	102	1.00	531	1.00	111	1.00
Q2	1232	131	1.34 (1.02, 1.78)	601	1.23 (1.06, 1.42)	155	1.41(1.07, 1.84)
Q3	1130	148	1.39 (0.70, 2.77)	644	1.39 (1.20, 1.62)	197	1.73(1.33, 2.25)
Q4	989	172	1.75 (1.33, 2.30)	696	1.57 (1.35, 1.82)	262	2.25(1.74, 2.90)
	<i>P for trend</i>		<i><0.0001</i>	<i><0.0001</i>		<i><0.0001</i>	
Women							
Q1	2019	80	1.00	598	1.00	108	1.00
Q2	1935	102	1.17 (0.86, 1.59)	651	1.04 (0.91, 1.18)	117	0.94(0.71, 1.25)
Q3	1708	172	2.04 (1.54, 2.70)	732	1.14 (0.99, 1.30)	194	1.40(1.08, 1.82)
Q4	1489	194	2.37 (1.78, 3.15)	782	1.13 (0.98, 1.30)	339	2.06(1.26, 3.38)
	<i>P for trend</i>		<i><0.0001</i>	0.0216		<i><0.0001</i>	
All subjects							
Q1	3453	161	1.00	1109	1.00	203	1.00
Q2	3192	260	1.26 (0.99, 1.60)	1211	1.12 (1.01, 1.23)	260	1.16(0.82, 1.62)
Q3	2838	301	1.66 (1.16, 2.36)	1373	1.25 (1.13, 1.38)	412	1.55(1.29, 1.87)
Q4	2395	379	2.03 (1.66, 2.47)	1542	1.34 (1.09, 1.64)	608	2.18(1.83, 2.61)
	<i>P for trend</i>		0.0001	0.0021		<i><0.0001</i>	

Missing value excluded from the analysis.

OR: Adjusted for age (continuous variable), education (no formal education, primary school, middle school, high school, colleague or above, dummy variables), per capita income (<1000, 1000-2999, 3000-5000 and >5000 RMB Yuan / month, dummy variables), resident site (urban/rural area), family history of type 2 diabetes (yes/no), smoking (ever/never), alcohol drinking (ever/never), regular exercise (never/ever), phase of study (first /second survey); Additionally adjusted for sex (male/female) for all subjects.

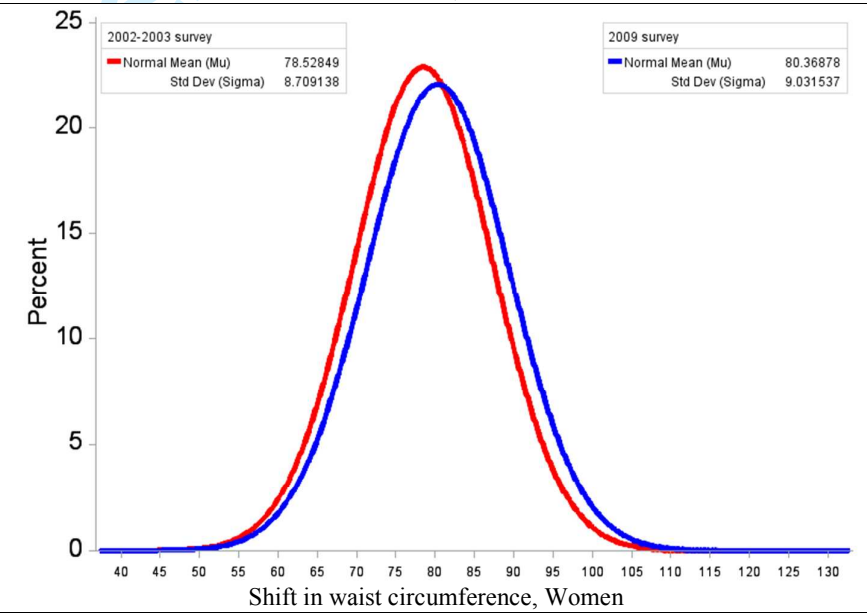
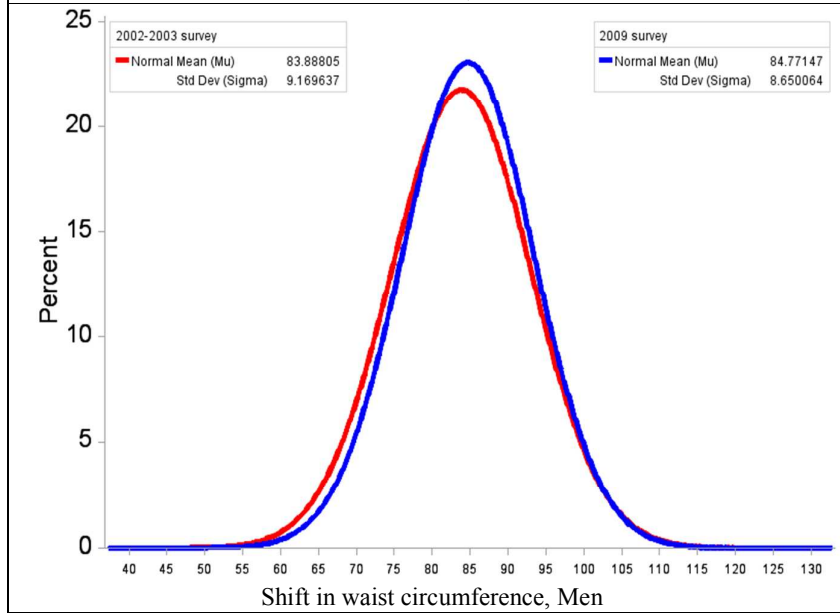
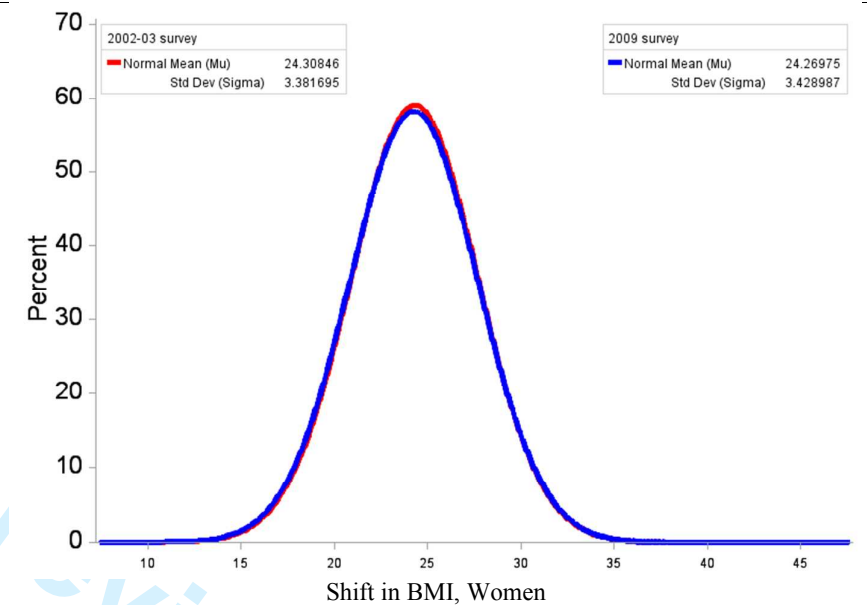
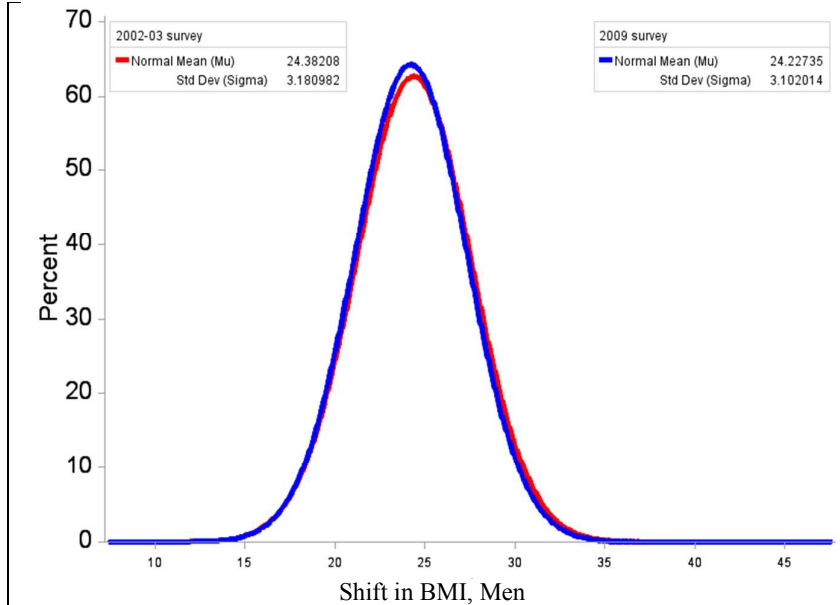
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4 Table 4. Joint effect of general obesity and central obesity on type 2 diabetes among Chinese adults

BMI	WC: Lower			WC: Higher			OR (95%CI) for hypertension		OR (95%CI) for type 2 diabetes	
	No. of subjects	Hypertension N (%)	Diabetes N (%)	No. of subjects	Hypertension N (%)	Diabetes N (%)	WC: Lower	WC: Higher	WC: Lower	WC: Higher
Men										
<18.5	212	36	20	16	10	6	0.61(0.42, 0.89)	3.68(1.28, 10.59)	1.02(0.62, 1.67)	3.77(1.13, 12.56)
18.5-23.9	3034	767	296	679	249	111	1.00	1.56(0.94, 2.57)	1.00	1.48(1.15, 1.90)
24.0-27.9	1010	356	134	2530	1179	483	1.61(1.13, 2.32)	2.38(1.78, 3.17)	1.46(1.16, 1.83)	1.85(1.16, 2.96)
≥28.0	36	20	4	960	580	224	3.91(1.95, 7.82)	4.67(3.97, 5.49)	1.71(0.55, 5.37)	2.60(2.12, 3.18)
<i>P for interaction</i>							0.0711		0.0933	
Women										
<18.5	313	51	19	8	2	1	0.68(0.49, 0.94)	0.85(0.16, 4.51)	0.93(0.56, 1.54)	2.45(0.22, 26.72)
18.5-23.9	4323	821	265	974	314	165	1.00	1.48(1.26, 1.75)	1.00	2.36(1.89, 2.94)
24.0-27.9	1330	384	93	2724	1102	437	1.84(1.59, 2.14)	2.21(1.97, 2.49)	1.19(0.92, 1.53)	2.14(1.81, 2.54)
≥28.0	81	32	9	1467	815	317	3.10(1.93, 5.00)	4.33(3.77, 4.96)	2.14(1.01, 4.52)	3.08(2.56, 3.71)
<i>P for interaction</i>							0.3524		0.4011	
Total										
<18.5	525	87	39	24	12	7	0.65(0.51, 0.83)	2.25(0.85, 5.93)	0.97(0.68, 1.39)	3.45(1.18, 10.12)
18.5-23.9	7357	1588	561	1653	563	276	1.00	1.52(1.25, 1.85)	1.00	1.88(1.42, 2.49)
24.0-27.9	2340	740	227	5254	2281	920	1.74(1.50, 2.03)	2.31(2.03, 2.62)	1.33(1.12, 1.58)	1.99(1.62, 2.45)
≥28.0	117	5	13	2427	1395	541	3.34(2.26, 4.94)	4.46(4.02, 4.96)	2.00(1.07, 3.74)	2.85(2.49, 3.27)
<i>P for interaction</i>							0.0562		0.0798	

2 Higher WC defined as ≥ 85 cm for men and ≥ 80 cm for women

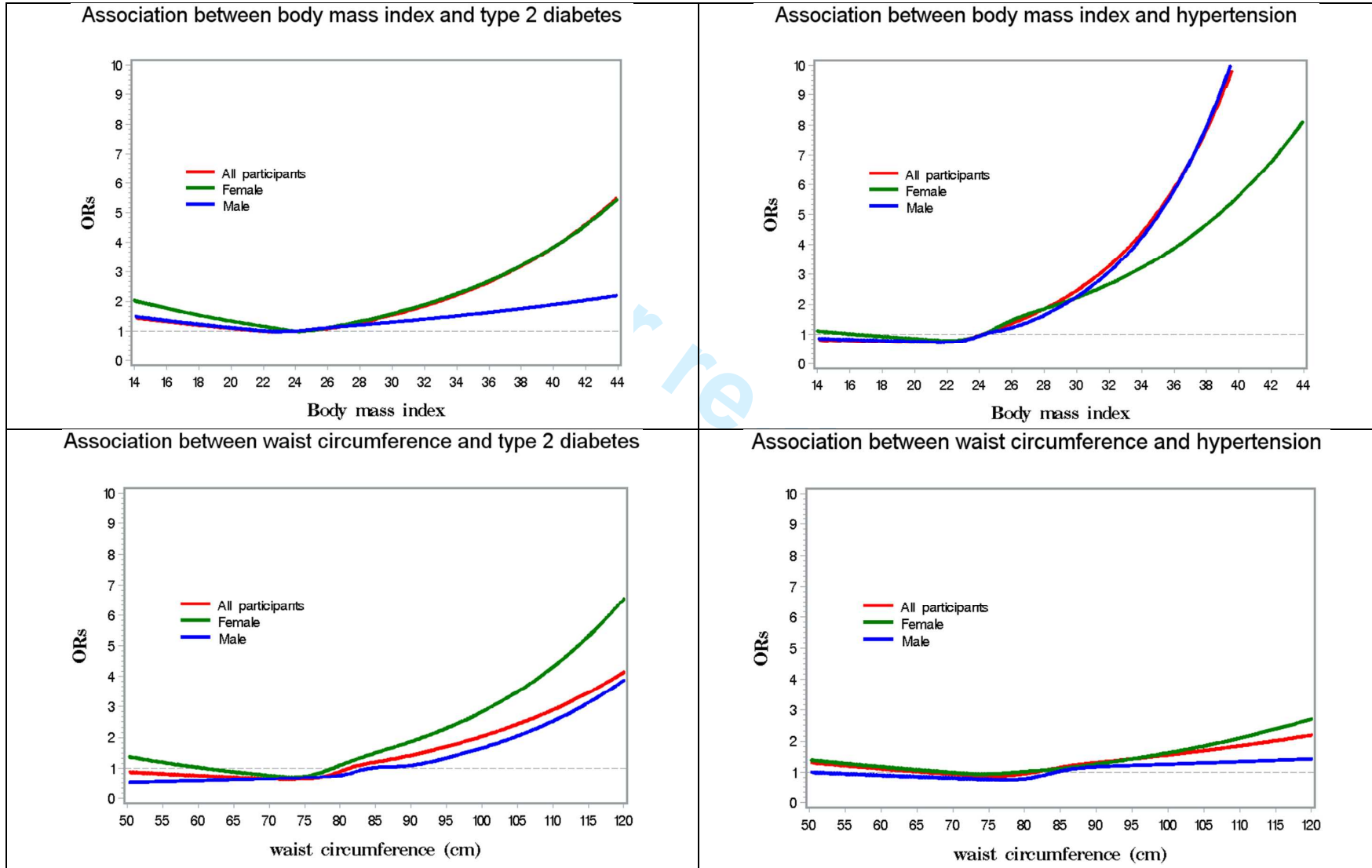
3 OR: Adjusted for age (continuous variable), education (no formal education, primary school, middle school, high school, colleague or above, dummy variables), per capita
4 income (<1000, 1000-2999, 3000-5000 and >5000 RMB Yuan / month, dummy variables), resident site (urban/rural area), family history of type 2 diabetes (yes/no),
5 smoking (ever/never), alcohol drinking (ever/never), regular exercise (never/ever), and phase of study (first /second survey).

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STROBE Statement—Checklist of items that should be included in reports of *cross-sectional studies*

	Item No	Recommendation	Results of check
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	We have indicated that the study was based on two population-based cross-sectional surveys in the title and the abstract
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	Line 53-62
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	Line 72-87
Objectives	3	State specific objectives, including any prespecified hypotheses	Line 89-92
Methods			
Study design	4	Present key elements of study design early in the paper	Line 95-104
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	Line 95-104
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants	Line 95-104
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	Line 117-153
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	Line 117-153
Bias	9	Describe any efforts to address potential sources of bias	Line 117-153
Study size	10	Explain how the study size was arrived at	NA
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	Line 155-169
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	Line 155-169
		(b) Describe any methods used to	Line 166-167

		examine subgroups and interactions	
		(c) Explain how missing data were addressed	There were very few missing data in this study. Please see footnote of the Table 3
		(d) If applicable, describe analytical methods taking account of sampling strategy	
		(e) Describe any sensitivity analyses	No
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Line 95-105
		(b) Give reasons for non-participation at each stage	No information
		(c) Consider use of a flow diagram	No
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Line 172-177, and Table 1
		(b) Indicate number of participants with missing data for each variable of interest	Yes, we provide number of subjects for each variable of interest (Please see tables)
Outcome data	15*	Report numbers of outcome events or summary measures	Yes (Please see tables)
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	No. Due to the large table, we present only adjusted ORs
		(b) Report category boundaries when continuous variables were categorized	Yes (Please see table 4)
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Line 210-217
Discussion			
Key results	18	Summarise key results with reference to study objectives	Line 219-224
Limitations	19	Discuss limitations of the study, taking into account sources of	Line 253-259

		potential bias or imprecision. Discuss both direction and magnitude of any potential bias	
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	Line 251-252
Generalisability	21	Discuss the generalisability (external validity) of the study results	Line 263-264
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	Line 275-280

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at www.strobe-statement.org.



**Increased Waist Circumference and Prevalence of Type 2
Diabetes and Hypertension in Chinese Adults: Two
Population-based Cross-sectional Surveys in Shanghai,
China**



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1 **Increased Waist Circumference and Prevalence of Type 2 Diabetes and Hypertension in**
2 **Chinese Adults: Two Population-based Cross-sectional Surveys in Shanghai, China**

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26 38 **RUNNING HEADER:** Obesity and prevalence of hypertension and T2DM in Chinese adults

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44 **Abstract:**

45 **Objective:** To evaluate the changes in body mass index (BMI) and waist circumference (WC)
46 and their associations with the prevalence of hypertension and type 2 diabetes (T2DM) in Chinese
47 adults.

48 **Design:** Two consecutive population-based cross-sectional surveys.

49 **Setting:** A total of 12 districts and 7 counties in Shanghai, China.

50 **Participants:** 12,329 randomly selected participants of the survey in 2002-2003, and 7,423
51 randomly selected participants of the survey in 2009. All subjects were residents of Shanghai aged
52 35-74 years old.

53 **Outcome measures:** Measured BMI and WC. Previously-diagnosed and newly-identified
54 hypertension and T2DM by measured blood pressure, fasting and post-load glucose.

55 **Results:** While the participants of the two surveys were comparable in BMI in each age group,
56 the participants of the 2009 survey had significantly larger WC than those of the 2002-03 survey,
57 with an annual percentage change (APC) being higher among subjects aged 45-49 years old in both
58 men and women. The increase in prevalence of T2DM was observed in all age groups and also
59 appeared more evident in subjects aged 45-49 years old. The prevalence of hypertension was
60 observed to increase more rapidly in elderly men and middle-aged women. Obesity, both overt and
61 central, was associated with the risk of the two diseases, but BMI was more strongly linked to
62 hypertension while WC appeared more evidently related with T2DM.

63 **Conclusion:** The prevalence of central obesity and related chronic diseases has been
64 increasing in Shanghai, China. Our findings provide useful information for the projection of
65 growing burden of T2DM and hypertension in Chinese adults.

66

67 **Keywords:** type 2 diabetes; hypertension; prevalence; body mass index; waist circumference

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Article summary

Article focus

- The shift in BMI and WC among Chinese adults over past one decade.
- The contribution of changes in overall and central obesity to the increasing burden of chronic disease in China.

Key messages

- The WC increased in Chinese adults over the decade spanning 2002-2009, while BMI did not change over the same period.
- BMI was more strongly linked to hypertension while WC appeared more evidently related with T2DM in Chinese adults.
- Our findings provide useful information for the projection of a growing burden of T2DM and hypertension in Chinese adults.

Strengths and limitations of this study

- The strengths of this study include the strict process of multistage sampling in adult population of Shanghai, anthropometric measurement according to a standardized protocol and fasting and postprandial blood glucose tests for the participants.
- The nature of the cross-sectional study design limits our ability to directly evaluate the influence of overall and central obesity as well as the change of their prevalence on the risk of hypertension and T2DM.
- The differences in several demographic characteristics between the participants of the two surveys indicate the possibility of selection bias.

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71 Introduction

72 A rising worldwide prevalence of chronic disease, manifested primarily as hypertension and
73 type 2 diabetes (T2DM), has been well documented [1-4]. In Chinese aged 15-74 years old, the
74 prevalence of hypertension increased from 5.11% in 1959, 7.73% in 1979 [5] and 13.58% in 1991[6]
75 to 17.65% in 2002 [7]. The prevalence of T2DM tripled between 1980 (about 1.0%) and 1996
76 (3.2%) [8 9], and reached 9.7% in 2008 among adults at 20 years old or above [10]. It is estimated
77 that over 92 million people in China have T2DM. This represents approximately half of the world's
78 diabetic population, and places China at the "global epicenter of the diabetes epidemic" [4].

79 Both hypertension and T2DM are associated with obesity [11 12]. Obesity is often measured
80 by body mass index (BMI). Across the entire range of BMI, the risk of hypertension and T2DM
81 increases, making a higher BMI a strong predictor of both hypertension and T2DM [4 12-14].
82 However, a significant proportion of Asian adults diagnosed with T2DM are with the normal BMI,
83 ie.18.5-25.0 kg/m² [15 16]. BMI is a general indicator of overt obesity, but does not give
84 information about the distribution of obesity. Central obesity, often assessed via waist
85 circumference (WC), is also strongly correlated with T2DM in both European and Asian adults [11
86 17]. While changes in BMI have been well documented in China over past several decades [2 18],
87 changes in WC, and thus central obesity, are not well described.

88 In this study, we took advantage of the data from population based cross-sectional surveys
89 conducted in Shanghai in 2002-03 and in 2009. We used the data from the two surveys to evaluate
90 correlations between shifts in BMI and WC with the prevalence of hypertension and T2DM in
91 Chinese adults. Our results may help to better understand the contribution of overall obesity and
92 central obesity in the increasing burden of chronic disease in China.

93 Materials and Methods

94 Study Participants

95 A representative sample of the general population was randomly selected through a multistage
96 sampling process in the 2002-03 survey. Firstly, 4 districts and 2 counties were randomly selected

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97 from a total of 12 districts and 7 counties in Shanghai, China. And then, 1-2 sub-districts or towns
98 were randomly selected from each selected district or county. Next, 1-2 communities or villages,
99 usually 1,000-2,000 residents for each, were randomly selected from each selected sub-district or
100 town. Finally, eligible subjects (permanent residents of Shanghai, 15-74 years old and having been
101 in the city for at least 5 years) were randomly selected from the selected communities and villages
102 and were invited for participation. Pregnant women, individuals with type I diabetes, and physically
103 or mentally disabled persons were excluded from the participation. During the period of May
104 2002-October 2003, a total of 17,526 eligible subjects were recruited, and 14,401 (82.17%)
105 participated the survey.

106 The 2009 survey used the similar sampling method except that only 7 communities and
107 villages were randomly selected in the third stage of sampling. The inclusion and exclusion criteria
108 of the 2009 survey were also similar to those for the 2002-03 survey, except that only those at the
109 age of 35-74 years old were eligible for the 2009 survey. Among 7,627 eligible adults contacted
110 during the period of May-July 2009, 7,414 (97.21%) were interviewed and donated blood samples.

111 To make the two surveys comparable, we excluded 1,071 subjects younger than 35 years from
112 the 2002-03 survey. After further excluding subjects with missing information, the final analysis
113 included 5,050 men and 7,279 women in the 2002-03 survey and 3,461 men and 3,962 women in
114 the 2009 survey. The Institutional Review Board at Shanghai Municipal Center of Disease Control
115 and Prevention approved the study. Informed consent was obtained from each participant before
116 data collection and laboratory measurements.

117 **Data Collection**

118 A similar survey approach was followed by the two investigations. In both surveys,
119 information on demographic and socioeconomic factors, diagnosis of diabetes, tobacco and alcohol
120 use, physical activity and family history of diabetes was collected by trained interviewers with a
121 structured questionnaire at community clinics located in the residential areas of the participants.

122 At the interview, each participant's blood pressure, body weight, standing height, and waist

1
2 123 circumference (WC) were measured by trained staff. Blood pressure was measured on the right arm
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4 124 in the sitting position using standard mercury sphygmomanometer after at least 5 minutes of rest.
5
6 125 The first and fifth Korotkoff sounds were recorded. Body weight and height were recorded while
7
8 126 the subject was in light clothing and without shoes. Body weight was measured with electronic
9
10 127 scales to the nearest 0.1 kg. Body height was measured to the nearest 0.1 cm by using a stadiometer.
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12 128 WC, recorded to the nearest 0.1 cm, was taken with a cloth tape and was measured on bare skin at
13
14 129 the midline between the lower border of the ribs and the iliac crest in the horizontal plane after a
15
16 130 normal expiration. Two measurements were taken and the mean of the replicates was used in the
17
18 131 following analyses. Body mass index (BMI) was calculated as weight in kilograms divided by
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20 132 height in meters squared (kg/m^2) using the direct measurements.
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24 133 **Laboratory Measurements**

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26 134 After at least 10 hours of overnight fasting, 1-1.5 ml venous blood specimen was collected in a
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28 135 vacuum tube containing sodium fluoride. All participants with no history of diabetes and having a
29
30 136 fasting plasma glucose level of < 7.0 mmol per liter (mmol/l) were then asked to have an oral
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32 137 glucose-tolerance test (OGTT). Blood samples were drawn at 0 and 120 minutes after a standard 75
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34 138 gram glucose load. Plasma glucose was measured with Glucose oxidase-peroxidase (GOD-PAP)
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36 139 method.
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39 140 **Diagnosis of T2DM and Hypertension**

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41 141 Previously diagnosed T2DM and hypertension was identified by a positive response from the
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43 142 participant to the question of “Have you ever diagnosed with T2DM/hypertension by a doctor?” and
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45 143 confirmed by medical records in which prescriptions of anti-hypertensive or hypoglycemic
46
47 144 medications were presented. The consistent rate was 100%. For those who had a negative response,
48
49 145 the T2DM was diagnosed with measured glucose level by using the 1999 World Health
50
51 146 Organization diagnostic criteria [Department of Noncommunicable Disease Surveillance. Definition,
52
53 147 diagnosis and classification of diabetes mellitus and its complications: report of a WHO
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55 148 consultation. Part 1. Diagnosis and classification of diabetes mellitus. Geneva: World Health
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2 149 Organization, 1999. (Accessed July 5, 2010, at
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4 150 http://www.staff.ncl.ac.uk/philip.home/who_dmg.pdf.)] and hypertension referred to the subjects
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6 151 with measured systolic blood pressure (SBP) \geq 140 mmHg or diastolic blood pressure (DBP) \geq 90
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8 152 mmHg and confirmed by clinical visits. Total T2DM and hypertension included both previously
9
10 153 diagnosed and newly-diagnosed patients. 42.7% (1,110 of 2,598) diabetic patients and 10.3% (694
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12 154 of 6,735) hypertensive patients were newly-diagnosed in the two surveys.

155 **Statistical Analysis**

156 SAS software 9.2 was used for all the statistical analyses. Characteristics of the subgroups
157 were described using summary statistics (median, 25th and 75th percentile, frequencies, and
158 percentages) separately for men and women. The differences between two surveys were compared
159 using χ^2 test (category variables) and Wilcoxon tests (continuous variables). The annual percentage
160 changes (APC) in prevalence between two surveys were calculated as (prevalence in 2009 –
161 prevalence in 2002-03) / number of years using logarithms for each age group. Percentile curves
162 were constructed for BMI and WC values in the two surveys by gender using the LMS (lambda, mu,
163 sigma) method. Restricted cubic splines (RCS) were used to model a potential curvilinear
164 relationship of BMI and WC with hypertension and diabetes using the 5th, 25th, 75th and 95th
165 percentiles as fixed knots and the 50th percentile as the reference. Polynomial logistic regression
166 were used to estimate the odds ratios (OR) and 95% confidence intervals (95% CI) of BMI and WC
167 with T2DM and hypertension. Meta-analysis was applied to obtain the combined ORs and 95% CI
168 considering the potential heterogeneity of the populations in the two surveys. The residual method
169 was used to derive the independent effect of BMI and WC with each other in the models. *P* value
170 less than 0.05 was considered as a test of significance based on two sides.

171 **Results**

172 The male participants in two studies were similar in age, resident site and cigarette smoking
173 while the female participants were comparable in cigarette smoking (*P* > 0.05) (Table 1). Compared
174 to the subjects in 2002-03 survey, the participants of 2009 survey, both men and women, had lower

1 175 level of education, higher level of income per capita, more prior history of T2DM, higher frequency
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4 176 of alcohol drinking and lower frequency of leisure time activity, and were more likely to have a
5
6 177 family history of diabetes.
7

8 178 Figure 1 shows the shapes of the BMI and WC distribution curves among men and women
9
10 179 changed over the period of the two surveys. After adjusting for age, education, per capita income,
11
12 180 resident site, smoking, drinking, regular exercise, and family history of T2DM, the curves of BMI
13
14 181 were almost overlapped in both men and women. However, the WC curves for men and women
15
16 182 were shifted to the right between 2002-03 and 2009, with the mean WC increasing from 83.6 to
17
18 183 85.3 cm for men and from 78.4 to 80.6 cm for women.
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20
21 184 As presented in table 2, the prevalence of obesity, both overall and central, increased with
22
23 185 increasing age groups. While the prevalence of overall obesity ($BMI \geq 28 \text{ kg/m}^2$) did not change
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25 186 between two surveys (all P values > 0.05), the prevalence of central obesity was significantly higher
26
27 187 in 2009 survey in each age group (all P values < 0.001). A more pronounced increase in the
28
29 188 prevalence of central obesity and T2DM was observed among subjects aged 45-49 years old in both
30
31 189 men and women; whereas the change in the prevalence of hypertension between two surveys
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33 190 appeared more evident in older men and younger women over the period. Using the World Health
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35 191 Organization (WHO) criteria for obesity did not change the results substantially (data not shown in
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37 192 the tables).
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41 193 BMI and WC were highly correlated with each other, with a correlation coefficient of 0.77 ($P <$
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43 194 0.0001) among men and 0.78 ($P < 0.0001$) among women after adjusting for age. Therefore, the
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45 195 residual method was used to test the potential respective non-linear relationships of BMI and WC
46
47 196 with the risk of T2DM and hypertension (Figure 2). The dose-response analysis likewise showed a
48
49 197 statistically significant increased risk of T2DM at high level of WC and a significant elevated risk
50
51 198 of hypertension at high level of BMI in both men and women after adjusting for age, education, per
52
53 199 capita income, resident site, smoking, alcohol consumption, regular exercise, family history of
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55 200 T2DM and phase of surveys, with P values for non-linear relationship tests < 0.05 . No significant
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2 201 relationship was observed between BMI and T2DM in men and between WC and hypertension in
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4 202 women.

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6 203 As shown in table 3, in both sexes, BMI adjusted for WC (residuals) appeared more strongly
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8 204 associated with hypertension while WC adjusted for BMI (residuals) was more evidently related
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10 205 with T2DM. Comparing with the lowest quartile of BMI residuals, the risk of hypertension
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12 206 increased 85% (95%CI: 1.59-2.15) in men and 1.23-fold (95%CI: 1.94-2.57) in women, whereas
13
14 207 the risk of T2DM did not increase significantly in both sexes. On the other hand, the ORs of the
15
16 208 highest versus the lowest quartile WC residuals for T2DM were 1.75 (95%CI: 1.33-2.30) in men
17
18 209 and 2.37 (95%CI: 1.78-3.15) in women, higher than the OR of 1.57 (95%CI: 1.35-1.82) in men and
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20 210 1.13 (95%CI: 0.98-1.30) in women for hypertension.

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24 211 We further evaluated the potential joint effect of BMI and WC on T2DM and hypertension
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26 212 (table 4). The participants were classified into normal weight (BMI 18.5-23.9 kg/m²), overweight
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28 213 (24.0-27.9 kg/m²), or obese (≥ 28 kg/m²) based on data from Chinese adults, and were defined as
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30 214 with normal or increased WC using sex-specific cut-offs (85 cm in men and 80 cm in women) [19].
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32 215 The risk of T2DM and hypertension increased across groups defined by BMI and WC, with the
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34 216 highest risk observed among men with the lowest BMI but a higher WC, and among those with the
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36 217 highest BMI and a higher WC for hypertension. However, no significant interaction was observed
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38 218 between BMI and WC (all *P* values for interaction tests > 0.05).

39 40 41 42 219 **Discussion**

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45 220 In this representative sample of the adult population in Shanghai, the largest city in China, we
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47 221 observed an increased prevalence of central obesity, hypertension and T2DM over the decade
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49 222 spanning 2002-2009. In contrast, BMI did not change over the same period. Our results present a
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51 223 snapshot of overt versus central obesity in the Chinese population and suggest that the epidemic of
52
53 224 central obesity in this population, which has been more closely associated with the prevalence of
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55 225 T2DM, may lead to a more rapidly growing burden of T2DM in China.

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57 226 Chinese adults have lower rates of overweight and obesity than their Western counterparts
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1 227 using the WHO criteria (BMI ≥ 25 kg/m² for overweight and BMI ≥ 30 kg/m² for obesity) [15 16].
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4 228 Nevertheless, increasing trends of BMI in Chinese adults have been well documented [18 20]. In
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6 229 two national nutritional surveys undertaken in 1982 and 1992 in China, the prevalence of
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8 230 overweight/obesity (BMI ≥ 25 kg/m²) in subjects 20-70 years of age was 10% and 15%,
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10 231 respectively. Between 1992 and 2002, the combined prevalence of overweight and obesity increased
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12 232 from 14.6 to 21.8% [21]. Interestingly, the increase in BMI among Chinese adults has slowed down
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14 233 during past decades [2]. In this study, we did not observe an increase in BMI and prevalence of
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16 234 obesity defined by the Chinese obesity standards or by WHO criteria (data not shown). Instead, we
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18 235 observed a significant increase in WC, a measure of central obesity between surveys. Our
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20 236 observation of increased WC in Chinese adults, without a concomitant increase in BMI, represents
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22 237 an increasing burden of central obesity in this population. The increase in central obesity indicates
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24 238 an upward trend in body fat percentages in the population who have been previously observed with
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26 239 higher body fat percentages compared to other ethnic people with the same BMI [22 23].
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30 240 Both epidemics of overall and central obesity parallel a continuously increasing prevalence of
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32 241 hypertension and T2DM in China [21]. Several studies indicate that overall obesity (BMI) is more
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34 242 strongly associated with hypertension, while central obesity (WC) is more strongly associated with
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36 243 T2DM [17 24-26]. The rationale for these associations is based on the notion that central obesity
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38 244 reflects specific accumulation of visceral adipose tissue. Excess visceral adipose tissue is
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40 245 metabolically unfavorable due to productions of free fatty acids and inflammatory mediators.
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42 246 Overall obesity, on the other hand, represents a greater overall physiologic strain and effects
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44 247 vascular and cardiac parameters more significantly. In this study, we observed a significant increase
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46 248 in prevalence of T2DM regardless of gender or age groups, which was more pronounced than the
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48 249 change in the prevalence of hypertension during the period of 2002-03 and 2009. We also observed
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50 250 a closer association of central obesity with the prevalence of T2DM than with the prevalence of
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52 251 hypertension. These results support the notion that central obesity in particular is a stronger risk
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54 252 factor for T2DM than for hypertension in Chinese adults. Due to the cross-sectional design,
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2 253 however, our study was unable to make a causal inference.

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4 254 The nature of the cross-sectional study design limits our ability to directly evaluate the
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6 255 influence of overall and central obesity as well as the change of their prevalence on the risk of
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8 256 hypertension and T2DM. The differences in several demographic characteristics between the
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10 257 participants of the two surveys indicate the changes in general population over time. However,
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12 258 selection bias could not be excluded. There are several strengths in this study, including the strict
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14 259 process of multistage sampling in adult population in Shanghai, anthropometric measurement
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16 260 according to a standardized protocol and fasting and postprandial blood glucose tests for the
17
18 261 participants.
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20 21 22 262 **Conclusions**

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25 263 In summary, this study describes the potential association of central obesity with an upward
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27 264 trend of T2DM. Our findings provide useful information about the growing burden of type 2
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29 265 diabetes and hypertension in Chinese adults and suggest the need for further study in other rapidly
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31 266 changing populations in China.
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33 34 35 36 268 **Acknowledgements**

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40
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42
43 271 surveys and the healthcare workers in each community involved.
44

45 46 272 **Footnotes**

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48
49 273 **Contributors** YR and MM contributed to data collection, data analysis and draft of the paper.
50
51 274 YR, YYL, QDY, and LS contributed to data collection and quality control. LJM contributed to
52
53 275 revision of the paper. HZ contributed to data clean and analysis. RL and WHX contributed to study
54
55 276 design, statistical analysis and revision of the paper. All authors contributed to the interpretation of
56
57 277 data and revision of the manuscript. All authors approved the final version.
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11
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14
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16
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2 361 Figure 1. Shift in BMI and WC over the period of the two population-based surveys

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4 362 Figure 2. Non-linear dose-response relationship of BMI and WC with hypertension and T2DM

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365 Table 1. Characteristics of participants in two population-based surveys in Shanghai, China

Characteristics	1 st survey		2 nd survey		<i>P-value between surveys^a</i>	
	Men (N=5,050)	Women (N=7,279)	Men (N=3,461)	Women (N=3,962)	<i>In men</i>	<i>In women</i>
Age (yrs., mean ± SD)	54.8 ± 10.8	53.1 ± 10.3	54.7 ± 9.5	54.7 ± 9.1	0.55	<0.0001
Resident site (%)						
Urban	71.1	63.0	72.4	72.0		
Rural	29.0	37.0	27.7	28.0	0.19	<0.0001
Education (%)						
No formal education	4.1	18.4	3.2	9.5		
Primary school	18.2	23.0	14.7	17.7		
Middle school	35.3	31.1	45.7	45.2		
High school	27.6	22.6	27.6	23.8		
College or above	14.8	4.9	8.8	3.9	0.0025	<0.0001
Per capita income (yuan/mo.) (%)						
<1000	37.0	45.5	4.9	4.0		
1000-2999	38.3	38.4	41.8	46.7		
3000-5000	22.5	17.9	33.2	33.3		
>5000	2.2	1.3	20.0	16.0	<0.0001	<0.0001
Family history of type 2diabetes	12.3	13.1	16.4	19.0	<0.0001	<0.0001
Prevalence of type 2diabetes (%)	13.6	10.3	17.4	14.1	<0.0001	<0.0001
Prevalence of hypertension (%)	34.8	28.3	41.8	37.1	<0.0001	<0.0001
Cigarette smoking (%)	61.4	1.7	62.6	1.8	0.22	0.93
Alcohol drinking (%)	40.4	2.4	54.0	5.0	<0.0001	<0.0001
Leisure-time activity (%)	13.3	13.1	10.8	9.0	0.0009	<0.0001

366 ^a *P* for Wilcoxon tests or chi-square tests

Table 2. Prevalence of obesity, hypertension and type 2 diabetes in participants of the two population-based surveys by age groups in Shanghai, China

	No. of subjects		Overall Obesity			Central obesity			Hypertension			Type 2 diabetes		
	1 st survey	2 nd survey	1 st survey	2 nd survey	APC (%)	1 st survey	2 nd survey	APC (%)	1 st survey	2 nd survey	APC (%)	1 st survey	2 nd survey	APC (%)
Men														
Overall	5050	3461	11.7	11.9	0.21	46.3	53.8	2.35	34.8	41.8	2.87	13.6	17.4	3.78
Age-groups														
35-	414	230	10.5	9.1	-2.11	41.8	45.2	1.22	15.2	11.7	-3.92	4.6	5.7	3.25
40-	574	302	10.0	8.3	-2.83	41.8	47.00	1.85	22.5	21.9	-0.43	7.8	7.6	-0.44
45-	837	445	12.6	12.6	-0.04	44.0	53.7	3.12	25.3	31.0	3.16	7.8	13.7	9.13
50-	833	739	12.2	10.8	-1.76	44.1	53.8	3.12	33.1	40.3	3.07	12.7	18.3	5.72
55-	628	669	10.4	13.2	3.78	47.3	54.6	2.25	35.4	45.6	3.99	15.0	17.9	2.82
60-	507	513	10.5	15.4	6.18	48.7	56.1	2.19	44.6	51.7	2.29	15.6	20.1	3.98
65-	674	313	12.6	11.8	-0.99	51.4	61.0	2.67	49.4	59.4	2.88	20.8	26.2	3.64
70-	583	250	13.8	9.6	-5.40	51.1	54.0	0.85	50.9	65.2	3.87	24.2	25.6	0.88
Women														
Overall	7279	3962	13.8	13.8	0.02	41.7	54.2	4.10	28.3	37.1	4.28	10.3	14.1	4.84
Age-groups														
35-	615	251	7.5	7.2	-0.65	22.6	26.3	2.35	6.8	10.8	7.24	3.3	4.0	3.17
40-	1000	287	9.4	11.2	2.66	27.6	38.0	5.05	11.7	15.7	4.61	4.1	5.9	5.81
45-	1491	563	11.0	9.8	-1.82	32.3	42.6	4.38	19.3	23.5	3.03	5.8	8.7	6.32
50-	1309	866	15.1	14.1	-1.00	43.9	54.0	3.24	28.7	31.0	1.16	8.3	9.4	1.94
55-	838	818	15.7	13.6	-2.17	47.5	60.6	3.83	33.9	39.7	2.48	8.8	15.3	8.80
60-	610	585	19.2	18.1	-0.87	53.5	63.1	2.58	40.5	52.8	4.17	16.7	19.2	2.11
65-	799	327	18.0	18.4	0.28	59.0	66.1	1.76	48.4	59.3	3.17	23.7	27.8	2.54
70-	617	265	18.2	16.6	-1.36	60.2	68.7	2.05	51.4	64.5	3.57	21.4	27.2	3.75
All subjects														
Overall	12329	7423	13.0	12.9	-0.05	43.6	54.0	3.35	31.0	39.3	3.75	11.7	15.6	4.53
Age-groups ^a														
35-	1029	481	8.7	8.0	-1.04	30.3	33.9	2.39	10.2	11.2	1.49	3.8	4.7	3.63
40-	1574	589	9.6	10.1	0.11	32.7	41.3	4.14	15.6	17.9	2.92	5.5	6.5	3.41
45-	2328	1008	11.6	10.8	-0.77	36.5	46.6	4.16	21.5	26.2	3.46	6.5	10.5	8.22
50-	2142	1605	13.9	12.8	-1.53	44.0	53.9	3.19	30.4	34.6	0.90	10.0	12.8	4.69
55-	1466	1487	13.4	13.4	0.01	47.4	58.1	3.13	34.5	42.2	3.20	11.5	16.4	5.75
60-	1117	1098	15.2	16.9	1.59	51.3	59.9	2.39	42.4	52.3	3.29	16.2	19.6	2.96
65-	1473	640	15.6	15.4	-0.39	55.5	63.8	2.11	48.9	59.4	3.04	22.3	27.1	2.98
70-	1200	515	16.0	13.2	-2.94	55.8	61.5	1.52	51.2	64.9	3.71	22.8	26.4	2.32

^a adjusted for sex according to the distribution in the first survey.

Table 3. Association of body size with hypertension and type 2 diabetes in two population-based surveys in Shanghai, China

	No. of subjects with neither diseases	Type 2 diabetes only		Hypertension only		Both	
		N	OR (95%CI)	N	OR (95%CI)	N	OR (95%CI)
BMI residuals							
Men							
Q1	1260	156	1.00	529	1.00	175	1.00
Q2	1224	142	0.99 (0.77, 1.27)	583	1.16 (1.00, 1.34)	172	1.11(0.87, 1.41)
Q3	1164	132	1.09 (0.84, 1.41)	651	1.50 (1.29, 1.74)	171	1.36(1.07, 1.73)
Q4	1079	123	1.16 (0.88, 1.51)	709	1.85 (1.59, 2.15)	207	1.95(1.54, 2.47)
			<i>P for trend</i>				
			0.2472		<0.0001		<0.0001
Women							
Q1	1816	166	1.00	600	1.00	223	1.00
Q2	1866	148	1.02 (0.80, 1.29)	629	1.29 (1.12, 1.48)	162	0.96(0.77, 1.21)
Q3	1835	125	0.89 (0.69, 1.15)	687	1.51 (1.31, 1.73)	158	1.03(0.82, 1.31)
Q4	1634	109	0.94 (0.73, 1.23)	847	2.23 (1.94, 2.57)	215	1.85(1.15, 2.98)
			<i>P for trend</i>				
			0.4864		<0.0001		0.0067
All subjects							
Q1	3048	330	1.00	1162	1.00	385	1.00
Q2	3079	282	1.00 (0.84, 1.19)	1200	1.22 (1.11, 1.35)	363	1.03(0.87, 1.22)
Q3	2998	278	0.98 (0.82, 1.18)	1346	1.50 (1.36, 1.67)	302	1.18(1.00, 1.40)
Q4	2753	211	1.04 (0.86, 1.26)	1527	2.05 (1.85, 2.27)	433	1.88(1.60, 2.21)
			<i>P for trend</i>				
			0.2280		<0.0001		<0.0001
WC residuals							
Men							
Q1	1376	102	1.00	531	1.00	111	1.00
Q2	1232	131	1.34 (1.02, 1.78)	601	1.23 (1.06, 1.42)	155	1.41(1.07, 1.84)
Q3	1130	148	1.39 (0.70, 2.77)	644	1.39 (1.20, 1.62)	197	1.73(1.33, 2.25)
Q4	989	172	1.75 (1.33, 2.30)	696	1.57 (1.35, 1.82)	262	2.25(1.74, 2.90)
			<i>P for trend</i>				
			<0.0001		<0.0001		<0.0001
Women							
Q1	2019	80	1.00	598	1.00	108	1.00
Q2	1935	102	1.17 (0.86, 1.59)	651	1.04 (0.91, 1.18)	117	0.94(0.71, 1.25)
Q3	1708	172	2.04 (1.54, 2.70)	732	1.14 (0.99, 1.30)	194	1.40(1.08, 1.82)
Q4	1489	194	2.37 (1.78, 3.15)	782	1.13 (0.98, 1.30)	339	2.06(1.26, 3.38)
			<i>P for trend</i>				
			<0.0001		0.0216		<0.0001
All subjects							
Q1	3453	161	1.00	1109	1.00	203	1.00
Q2	3192	260	1.26 (0.99, 1.60)	1211	1.12 (1.01, 1.23)	260	1.16(0.82, 1.62)
Q3	2838	301	1.66 (1.16, 2.36)	1373	1.25 (1.13, 1.38)	412	1.55(1.29, 1.87)
Q4	2395	379	2.03 (1.66, 2.47)	1542	1.34 (1.09, 1.64)	608	2.18(1.83, 2.61)
			<i>P for trend</i>				
			0.0001		0.0021		<0.0001

Missing value excluded from the analysis.

OR: Adjusted for age (continuous variable), education (no formal education, primary school, middle school, high school, colleague or above, dummy variables), per capita income (<1000, 1000-2999, 3000-5000 and >5000 RMB Yuan / month, dummy variables), resident site (urban/rural area), family history of type 2 diabetes (yes/no), smoking (ever/never), alcohol drinking (ever/never), regular exercise (never/ever), phase of study (first /second survey); Additionally adjusted for sex (male/female) for all subjects.

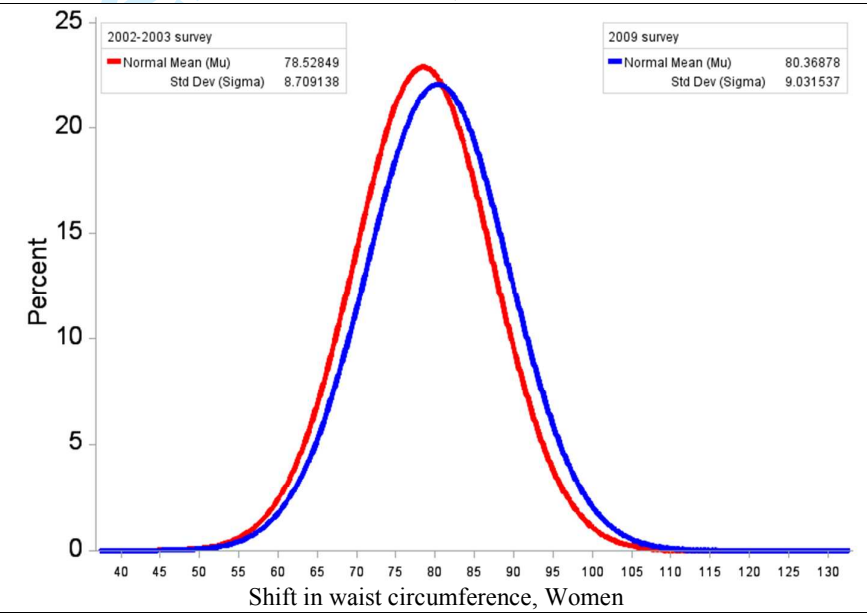
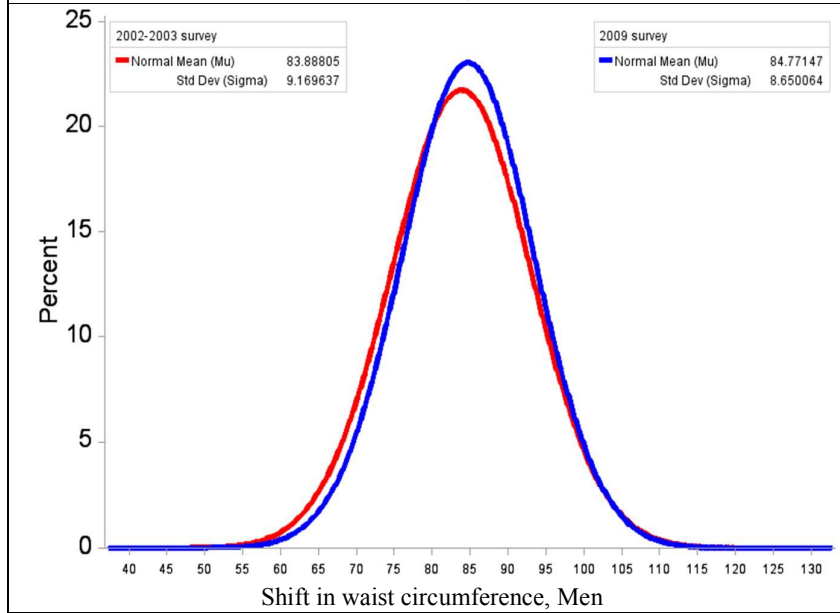
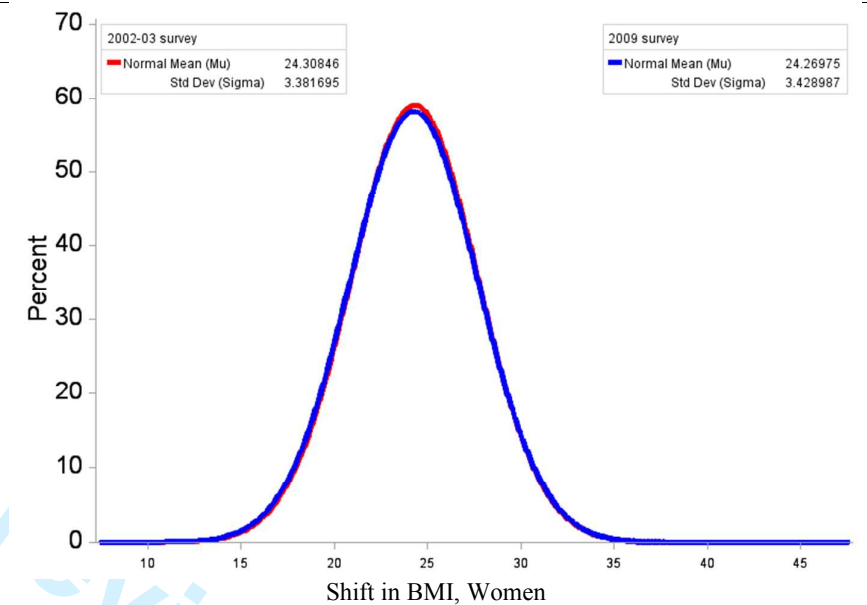
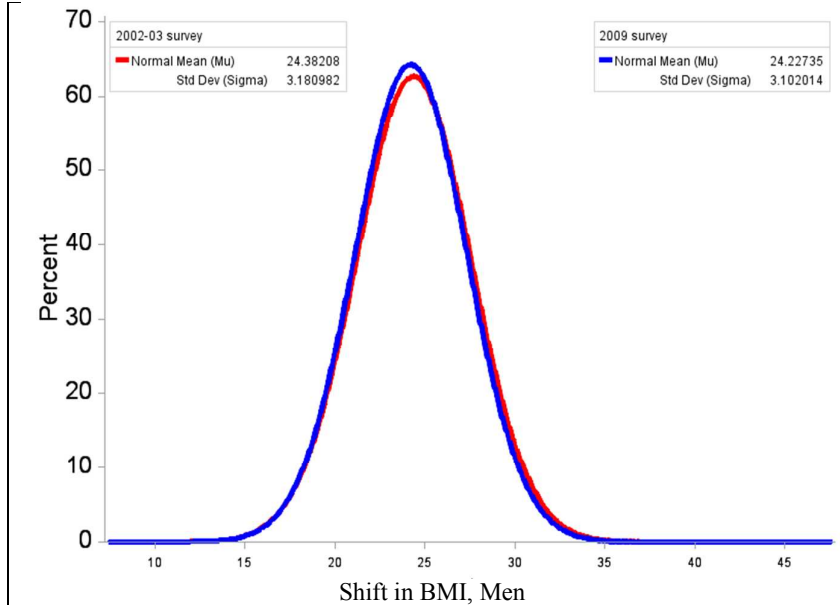
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4 Table 4. Joint effect of general obesity and central obesity on type 2 diabetes among Chinese adults

BMI	WC: Lower			WC: Higher			OR (95%CI) for hypertension		OR (95%CI) for type 2 diabetes	
	No. of subjects	Hypertension N (%)	Diabetes N (%)	No. of subjects	Hypertension N (%)	Diabetes N (%)	WC: Lower	WC: Higher	WC: Lower	WC: Higher
Men										
<18.5	212	36	20	16	10	6	0.61(0.42, 0.89)	3.68(1.28, 10.59)	1.02(0.62, 1.67)	3.77(1.13, 12.56)
18.5-23.9	3034	767	296	679	249	111	1.00	1.56(0.94, 2.57)	1.00	1.48(1.15, 1.90)
24.0-27.9	1010	356	134	2530	1179	483	1.61(1.13, 2.32)	2.38(1.78, 3.17)	1.46(1.16, 1.83)	1.85(1.16, 2.96)
≥28.0	36	20	4	960	580	224	3.91(1.95, 7.82)	4.67(3.97, 5.49)	1.71(0.55, 5.37)	2.60(2.12, 3.18)
<i>P for interaction</i>							0.0711		0.0933	
Women										
<18.5	313	51	19	8	2	1	0.68(0.49, 0.94)	0.85(0.16, 4.51)	0.93(0.56, 1.54)	2.45(0.22, 26.72)
18.5-23.9	4323	821	265	974	314	165	1.00	1.48(1.26, 1.75)	1.00	2.36(1.89, 2.94)
24.0-27.9	1330	384	93	2724	1102	437	1.84(1.59, 2.14)	2.21(1.97, 2.49)	1.19(0.92, 1.53)	2.14(1.81, 2.54)
≥28.0	81	32	9	1467	815	317	3.10(1.93, 5.00)	4.33(3.77, 4.96)	2.14(1.01, 4.52)	3.08(2.56, 3.71)
<i>P for interaction</i>							0.3524		0.4011	
Total										
<18.5	525	87	39	24	12	7	0.65(0.51, 0.83)	2.25(0.85, 5.93)	0.97(0.68, 1.39)	3.45(1.18, 10.12)
18.5-23.9	7357	1588	561	1653	563	276	1.00	1.52(1.25, 1.85)	1.00	1.88(1.42, 2.49)
24.0-27.9	2340	740	227	5254	2281	920	1.74(1.50, 2.03)	2.31(2.03, 2.62)	1.33(1.12, 1.58)	1.99(1.62, 2.45)
≥28.0	117	5	13	2427	1395	541	3.34(2.26, 4.94)	4.46(4.02, 4.96)	2.00(1.07, 3.74)	2.85(2.49, 3.27)
<i>P for interaction</i>							0.0562		0.0798	

2 Higher WC defined as ≥ 85 cm for men and ≥ 80 cm for women

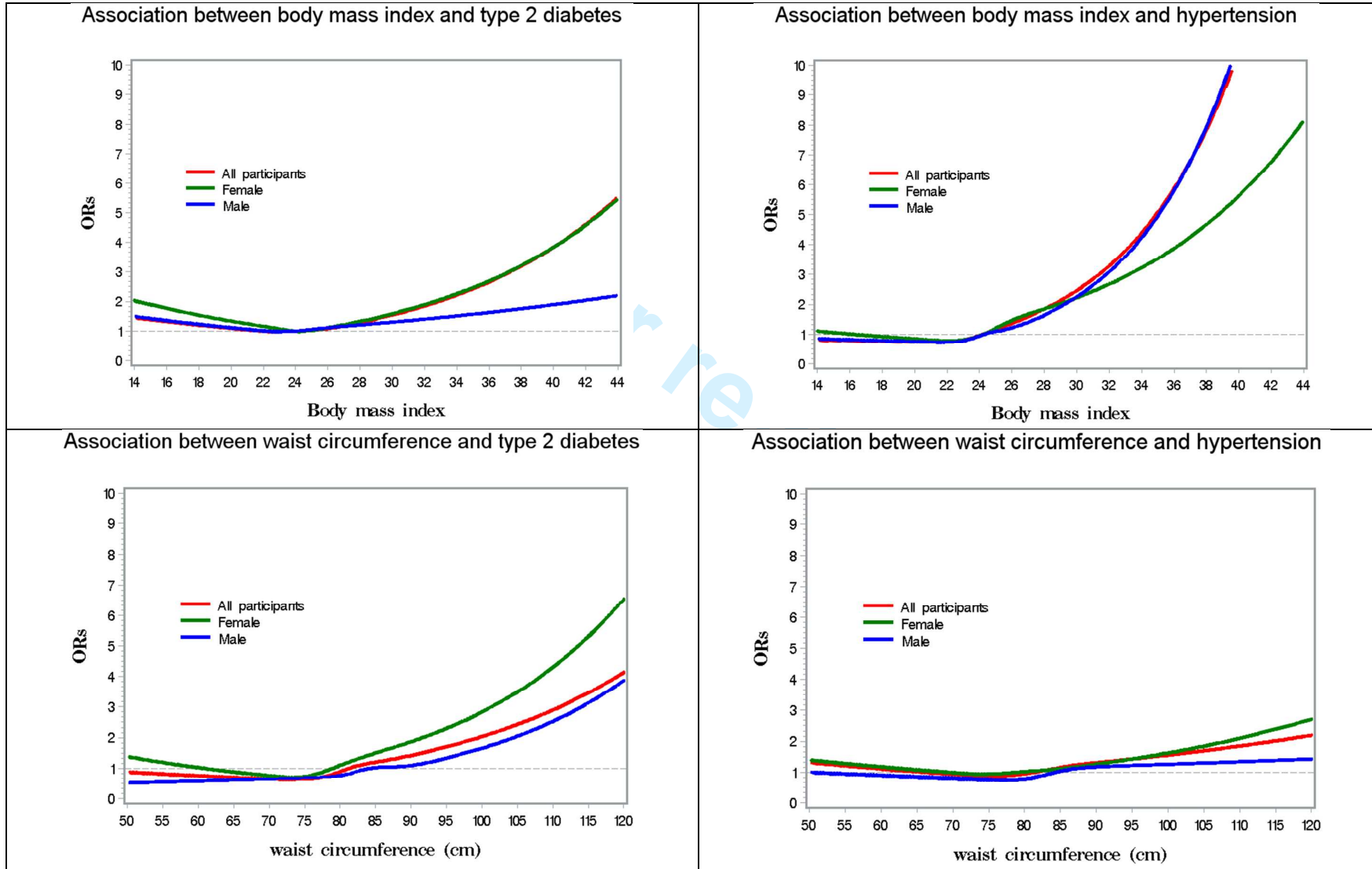
3 OR: Adjusted for age (continuous variable), education (no formal education, primary school, middle school, high school, colleague or above, dummy variables), per capita
4 income (<1000, 1000-2999, 3000-5000 and >5000 RMB Yuan / month, dummy variables), resident site (urban/rural area), family history of type 2 diabetes (yes/no),
5 smoking (ever/never), alcohol drinking (ever/never), regular exercise (never/ever), and phase of study (first /second survey).

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STROBE Statement—Checklist of items that should be included in reports of *cross-sectional studies*

	Item No	Recommendation	Results of check
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	We have indicated that the study was based on two population-based cross-sectional surveys in the title and the abstract
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	Line 53-62
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	Line 72-87
Objectives	3	State specific objectives, including any prespecified hypotheses	Line 89-92
Methods			
Study design	4	Present key elements of study design early in the paper	Line 95-104
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	Line 95-104
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants	Line 95-104
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	Line 117-153
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	Line 117-153
Bias	9	Describe any efforts to address potential sources of bias	Line 117-153
Study size	10	Explain how the study size was arrived at	NA
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	Line 155-169
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	Line 155-169
		(b) Describe any methods used to	Line 166-167

		examine subgroups and interactions	
		(c) Explain how missing data were addressed	There were very few missing data in this study. Please see footnote of the Table 3
		(d) If applicable, describe analytical methods taking account of sampling strategy	
		(e) Describe any sensitivity analyses	No
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Line 95-105
		(b) Give reasons for non-participation at each stage	No information
		(c) Consider use of a flow diagram	No
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Line 172-177, and Table 1
		(b) Indicate number of participants with missing data for each variable of interest	Yes, we provide number of subjects for each variable of interest (Please see tables)
Outcome data	15*	Report numbers of outcome events or summary measures	Yes (Please see tables)
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	No. Due to the large table, we present only adjusted ORs
		(b) Report category boundaries when continuous variables were categorized	Yes (Please see table 4)
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Line 210-217
Discussion			
Key results	18	Summarise key results with reference to study objectives	Line 219-224
Limitations	19	Discuss limitations of the study, taking into account sources of	Line 253-259

		potential bias or imprecision. Discuss both direction and magnitude of any potential bias	
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	Line 251-252
Generalisability	21	Discuss the generalisability (external validity) of the study results	Line 263-264
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	Line 275-280

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at www.strobe-statement.org.

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1 **Increased Waist Circumference and Prevalence of Type 2 Diabetes and Hypertension in**
2 **Chinese Adults: Two Population-based Cross-sectional Surveys in Shanghai, China**

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26 38 **RUNNING HEADER:** Obesity and prevalence of hypertension and T2DM in Chinese adults

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30 40 **Word Count:**

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32 41 Abstract: 249

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34 42 Text: 2,658

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44 **Abstract:**

45 **Objective:** To evaluate the changes in body mass index (BMI) and waist circumference (WC)
46 and their associations with the prevalence of hypertension and type 2 diabetes (T2DM) in Chinese
47 adults.

48 **Design:** Two consecutive population-based cross-sectional surveys.

49 **Setting:** A total of 12 districts and 7 counties in Shanghai, China.

50 **Participants:** 12,329 randomly selected participants of the survey in 2002-2003, and 7,423
51 randomly selected participants of the survey in 2009. All subjects were residents of Shanghai aged
52 35-74 years old.

53 **Outcome measures:** Measured BMI and WC. Previously-diagnosed and newly-identified
54 hypertension and T2DM by measured blood pressure, fasting and post-load glucose.

55 **Results:** While the participants of the two surveys were comparable in BMI in each age group,
56 the participants of the 2009 survey had significantly larger WC than those of the 2002-03 survey,
57 with an annual percentage change (APC) being higher among subjects aged 45-49 years old in both
58 men and women. The increase in prevalence of T2DM was observed in all age groups and also
59 appeared more evident in subjects aged 45-49 years old. The prevalence of hypertension was
60 observed to increase more rapidly in elderly men and middle-aged women. Obesity, both overt and
61 central, was associated with the risk of the two diseases, but BMI was more strongly linked to
62 hypertension while WC appeared more evidently related with T2DM.

63 **Conclusion:** The prevalence of central obesity and related chronic diseases has been
64 increasing in Shanghai, China. Our findings provide useful information for the projection of
65 growing burden of T2DM and hypertension in Chinese adults.

66

67 **Keywords:** type 2 diabetes; hypertension; prevalence; body mass index; waist circumference

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Article summary

Article focus

- The shift in BMI and WC among Chinese adults over past one decade.
- The contribution of changes in overall and central obesity to the increasing burden of chronic disease in China.

Key messages

- The WC increased in Chinese adults over the decade spanning 2002-2009, while BMI did not change over the same period.
- BMI was more strongly linked to hypertension while WC appeared more evidently related with T2DM in Chinese adults.
- Our findings provide useful information for the projection of a growing burden of T2DM and hypertension in Chinese adults.

Strengths and limitations of this study

- The strengths of this study include the strict process of multistage sampling in adult population of Shanghai, anthropometric measurement according to a standardized protocol and fasting and postprandial blood glucose tests for the participants.
- The nature of the cross-sectional study design limits our ability to directly evaluate the influence of overall and central obesity as well as the change of their prevalence on the risk of hypertension and T2DM.
- The differences in several demographic characteristics between the participants of the two surveys indicate the possibility of selection bias.

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71 Introduction

72 A rising worldwide prevalence of chronic disease, manifested primarily as hypertension and
73 type 2 diabetes (T2DM), has been well documented [1-4]. In Chinese aged 15-74 years old, the
74 prevalence of hypertension increased from 5.11% in 1959, 7.73% in 1979 [5] and 13.58% in 1991[6]
75 to 17.65% in 2002 [7]. The prevalence of T2DM tripled between 1980 (about 1.0%) and 1996
76 (3.2%) [8 9], and reached 9.7% in 2008 among adults at 20 years old or above [10]. It is estimated
77 that over 92 million people in China have T2DM. This represents approximately half of the world's
78 diabetic population, and places China at the "global epicenter of the diabetes epidemic" [4].

79 Both hypertension and T2DM are associated with obesity [11 12]. Obesity is often measured
80 by body mass index (BMI). Across the entire range of BMI, the risk of hypertension and T2DM
81 increases, making a higher BMI a strong predictor of both hypertension and T2DM [4 12-14].
82 However, a significant proportion of Asian adults diagnosed with T2DM are with the normal BMI,
83 ie.18.5-25.0 kg/m² [15 16]. BMI is a general indicator of overt obesity, but does not give
84 information about the distribution of obesity. Central obesity, often assessed via waist
85 circumference (WC), is also strongly correlated with T2DM in both European and Asian adults [11
86 17]. While changes in BMI have been well documented in China over past several decades [2 18],
87 changes in WC, and thus central obesity, are not well described.

88 In this study, we took advantage of the data from population based cross-sectional surveys
89 conducted in Shanghai in 2002-03 and in 2009. We used the data from the two surveys to evaluate
90 correlations between shifts in BMI and WC with the prevalence of hypertension and T2DM in
91 Chinese adults. Our results may help to better understand the contribution of overall obesity and
92 central obesity in the increasing burden of chronic disease in China.

93 Materials and Methods

94 Study Participants

95 A representative sample of the general population was randomly selected through a multistage
96 sampling process in the 2002-03 survey. Firstly, 4 districts and 2 counties were randomly selected

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2 97 from a total of 12 districts and 7 counties in Shanghai, China. And then, 1-2 sub-districts or towns
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4 98 were randomly selected from each selected district or county. Next, 1-2 communities or villages,
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6 99 usually 1,000-2,000 residents for each, were randomly selected from each selected sub-district or
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8 100 town. Finally, eligible subjects (permanent residents of Shanghai, 15-74 years old and having been
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10 101 in the city for at least 5 years) were randomly selected from the selected communities and villages
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12 102 and were invited for participation. Pregnant women, individuals with type I diabetes, and physically
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14 103 or mentally disabled persons were excluded from the participation. During the period of May
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16 104 2002-October 2003, a total of 17,526 eligible subjects were recruited, and 14,401 (82.17%)
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18 105 participated the survey.

21 106 The 2009 survey used the similar sampling method except that only 7 communities and
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23 107 villages were randomly selected in the third stage of sampling. The inclusion and exclusion criteria
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25 108 of the 2009 survey were also similar to those for the 2002-03 survey, except that only those at the
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27 109 age of 35-74 years old were eligible for the 2009 survey. Among 7,627 eligible adults contacted
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29 110 during the period of May-July 2009, 7,414 (97.21%) were interviewed and donated blood samples.

32 111 To make the two surveys comparable, we excluded 1,071 subjects younger than 35 years from
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34 112 the 2002-03 survey. After further excluding subjects with missing information, the final analysis
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36 113 included 5,050 men and 7,279 women in the 2002-03 survey and 3,461 men and 3,962 women in
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38 114 the 2009 survey. The Institutional Review Board at Shanghai Municipal Center of Disease Control
39
40 115 and Prevention approved the study. **Informed consent was obtained from each participant before**
41
42 116 **data collection and laboratory measurements.**

46 117 **Data Collection**

48 118 A similar survey approach was followed by the two investigations. In both surveys,
49
50 119 information on demographic and socioeconomic factors, diagnosis of diabetes, tobacco and alcohol
51
52 120 use, physical activity and family history of diabetes was collected by trained interviewers with a
53
54 121 structured questionnaire at community clinics located in the residential areas of the participants.

56 122 At the interview, each participant's blood pressure, body weight, standing height, and waist

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2 123 circumference (WC) were measured by trained staff. Blood pressure was measured on the right arm
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4 124 in the sitting position using standard mercury sphygmomanometer after at least 5 minutes of rest.
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6 125 The first and fifth Korotkoff sounds were recorded. Body weight and height were recorded while
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8 126 the subject was in light clothing and without shoes. Body weight was measured with electronic
9
10 127 scales to the nearest 0.1 kg. Body height was measured to the nearest 0.1 cm by using a stadiometer.
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12 128 WC, recorded to the nearest 0.1 cm, was taken with a cloth tape and was measured on bare skin at
13
14 129 the midline between the lower border of the ribs and the iliac crest in the horizontal plane after a
15
16 130 normal expiration. Two measurements were taken and the mean of the replicates was used in the
17
18 131 following analyses. Body mass index (BMI) was calculated as weight in kilograms divided by
19
20 132 height in meters squared (kg/m^2) using the direct measurements.
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24 133 **Laboratory Measurements**

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26 134 After at least 10 hours of overnight fasting, 1-1.5 ml venous blood specimen was collected in a
27
28 135 vacuum tube containing sodium fluoride. All participants with no history of diabetes and having a
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30 136 fasting plasma glucose level of < 7.0 mmol per liter (mmol/l) were then asked to have an oral
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32 137 glucose-tolerance test (OGTT). Blood samples were drawn at 0 and 120 minutes after a standard 75
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34 138 gram glucose load. Plasma glucose was measured with Glucose oxidase-peroxidase (GOD-PAP)
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36 139 method.
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39 140 **Diagnosis of T2DM and Hypertension**

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41 141 Previously diagnosed T2DM and hypertension was identified by a positive response from the
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43 142 participant to the question of “Have you ever diagnosed with T2DM/hypertension by a doctor?” and
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45 143 confirmed by medical records in which prescriptions of anti-hypertensive or hypoglycemic
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47 144 medications were presented. The consistent rate was 100%. For those who had a negative response,
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49 145 the T2DM was diagnosed with measured glucose level by using the 1999 World Health
50
51 146 Organization diagnostic criteria [Department of Noncommunicable Disease Surveillance. Definition,
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53 147 diagnosis and classification of diabetes mellitus and its complications: report of a WHO
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55 148 consultation. Part 1. Diagnosis and classification of diabetes mellitus. Geneva: World Health
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2 149 Organization, 1999. (Accessed July 5, 2010, at_
3
4 150 http://www.staff.ncl.ac.uk/philip.home/who_dmg.pdf.)] and hypertension referred to the subjects
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6 151 with measured systolic blood pressure (SBP) \geq 140 mmHg or diastolic blood pressure (DBP) \geq 90
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8 152 mmHg and confirmed by clinical visits. Total T2DM and hypertension included both previously
9
10 153 diagnosed and newly-diagnosed patients. 42.7% (1,110 of 2,598) diabetic patients and 10.3% (694
11
12 154 of 6,735) hypertensive patients were newly-diagnosed in the two surveys.

155 **Statistical Analysis**

156 SAS software 9.2 was used for all the statistical analyses. Characteristics of the subgroups
157 were described using summary statistics (median, 25th and 75th percentile, frequencies, and
158 percentages) separately for men and women. The differences between two surveys were compared
159 using χ^2 test (category variables) and Wilcoxon tests (continuous variables). The annual percentage
160 changes (APC) in prevalence between two surveys were calculated as (prevalence in 2009 –
161 prevalence in 2002-03) / number of years using logarithms for each age group. Percentile curves
162 were constructed for BMI and WC values in the two surveys by gender using the LMS (lambda, mu,
163 sigma) method. Restricted cubic splines (RCS) were used to model a potential curvilinear
164 relationship of BMI and WC with hypertension and diabetes using the 5th, 25th, 75th and 95th
165 percentiles as fixed knots and the 50th percentile as the reference. Polynomial logistic regression
166 were used to estimate the odds ratios (OR) and 95% confidence intervals (95% CI) of BMI and WC
167 with T2DM and hypertension. Meta-analysis was applied to obtain the combined ORs and 95% CI
168 considering the potential heterogeneity of the populations in the two surveys. The residual method
169 was used to derive the independent effect of BMI and WC with each other in the models. *P* value
170 less than 0.05 was considered as a test of significance based on two sides.

171 **Results**

172 The male participants in two studies were similar in age, resident site and cigarette smoking
173 while the female participants were comparable in cigarette smoking ($P > 0.05$) (Table 1). Compared
174 to the subjects in 2002-03 survey, the participants of 2009 survey, both men and women, had lower

1
2 175 level of education, higher level of income per capita, more prior history of T2DM, higher frequency
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4 176 of alcohol drinking and lower frequency of leisure time activity, and were more likely to have a
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6 177 family history of diabetes.
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8
9 178 Figure 1 shows the shapes of the BMI and WC distribution curves among men and women
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11 179 changed over the period of the two surveys. After adjusting for age, education, per capita income,
12
13 180 resident site, smoking, drinking, regular exercise, and family history of T2DM, the curves of BMI
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15 181 were almost overlapped in both men and women. However, the WC curves for men and women
16
17 182 were shifted to the right between 2002-03 and 2009, with the mean WC increasing from 83.6 to
18
19 183 85.3 cm for men and from 78.4 to 80.6 cm for women.
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22 184 As presented in table 2, the prevalence of obesity, both overall and central, increased with
23
24 185 increasing age groups. While the prevalence of overall obesity (BMI ≥ 28 kg/m²) **did not change**
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26 186 between two surveys (all *P* values > 0.05), the prevalence of central obesity **was** significantly higher
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28 187 in 2009 survey in each age group (all *P* values < 0.001). A more pronounced increase in **the**
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30 188 prevalence of central obesity and T2DM was observed among subjects aged 45-49 years old in both
31
32 189 men and women; whereas the change in **the** prevalence of hypertension between two surveys
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34 190 appeared more evident in older men and younger women over the period. Using the World Health
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36 191 Organization (WHO) criteria for obesity did not change the results substantially (data not shown in
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38 192 the tables).
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42 193 BMI and WC were highly correlated with each other, with a correlation coefficient of 0.77 (*P* <
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44 194 0.0001) among men and 0.78 (*P* < 0.0001) among women after adjusting for age. Therefore, the
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46 195 residual method was used to test the potential respective non-linear relationships of BMI and WC
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48 196 with the risk of T2DM and hypertension (Figure 2). The dose-response analysis likewise showed a
49
50 197 statistically significant increased risk of T2DM at high level of WC and a significant elevated risk
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52 198 of hypertension at high level of BMI in both men and women after adjusting for age, education, per
53
54 199 capita income, resident site, smoking, **alcohol consumption**, regular exercise, family history of
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56 200 T2DM and phase of surveys, with *P* values for non-linear relationship tests < 0.05. No significant
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2 201 relationship was observed between BMI and T2DM in men and between WC and hypertension in
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4 202 women.

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6 203 As shown in table 3, in both sexes, BMI adjusted for WC (residuals) appeared more strongly
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8 204 associated with hypertension while WC adjusted for BMI (residuals) was more evidently related
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10 205 with T2DM. Comparing with the lowest quartile of BMI residuals, the risk of hypertension
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12 206 increased 85% (95%CI: 1.59-2.15) in men and 1.23-fold (95%CI: 1.94-2.57) in women, whereas
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14 207 the risk of T2DM did not increase significantly in both sexes. On the other hand, the ORs of the
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16 208 highest versus the lowest quartile WC residuals for T2DM were 1.75 (95%CI: 1.33-2.30) in men
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18 209 and 2.37 (95%CI: 1.78-3.15) in women, higher than the OR of 1.57 (95%CI: 1.35-1.82) in men and
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20 210 1.13 (95%CI: 0.98-1.30) in women for hypertension.

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24 211 We further evaluated the potential joint effect of BMI and WC on T2DM and hypertension
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26 212 (table 4). The participants were classified into normal weight (BMI 18.5-23.9 kg/m²), overweight
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28 213 (24.0-27.9 kg/m²), or obese (≥ 28 kg/m²) based on data from Chinese adults, and were defined as
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30 214 with normal or increased WC using sex-specific cut-offs (85 cm in men and 80 cm in women) [19].
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32 215 The risk of T2DM and hypertension increased across groups defined by BMI and WC, with the
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34 216 highest risk observed among men with the lowest BMI but a higher WC, and among those with the
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36 217 highest BMI and a higher WC for hypertension. However, no significant interaction was observed
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38 218 between BMI and WC (all *P* values for interaction tests > 0.05).

39 40 41 42 219 **Discussion**

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45 220 In this representative sample of the adult population in Shanghai, the largest city in China, we
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47 221 observed an increased prevalence of central obesity, hypertension and T2DM over the decade
48
49 222 spanning 2002-2009. In contrast, BMI did not change over the same period. Our results present a
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51 223 snapshot of overt versus central obesity in the Chinese population and suggest that the epidemic of
52
53 224 central obesity in this population, which has been more closely associated with the prevalence of
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55 225 T2DM, may lead to a more rapidly growing burden of T2DM in China.

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57 226 Chinese adults have lower rates of overweight and obesity than their Western counterparts
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1 227 using the WHO criteria (BMI ≥ 25 kg/m² for overweight and BMI ≥ 30 kg/m² for obesity) [15 16].
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4 228 Nevertheless, increasing trends of BMI in Chinese adults have been well documented [18 20]. In
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6 229 two national nutritional surveys undertaken in 1982 and 1992 in China, the prevalence of
7
8 230 overweight/obesity (BMI ≥ 25 kg/m²) in subjects 20-70 years of age was 10% and 15%,
9
10 231 respectively. Between 1992 and 2002, the combined prevalence of overweight and obesity increased
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12 232 from 14.6 to 21.8% [21]. Interestingly, the increase in BMI among Chinese adults has slowed down
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14 233 during past decades [2]. In this study, we did not observe an increase in BMI and prevalence of
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16 234 obesity defined by the Chinese obesity standards or by WHO criteria (data not shown). Instead, we
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18 235 observed a significant increase in WC, a measure of central obesity between surveys. Our
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20 236 observation of increased WC in Chinese adults, without a concomitant increase in BMI, represents
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22 237 an increasing burden of central obesity in this population. The increase in central obesity indicates
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24 238 an upward trend in body fat percentages in the population who have been previously observed with
25
26 239 higher body fat percentages compared to other ethnic people with the same BMI [22 23].

240 Both **epidemics** of overall and central obesity parallel a continuously increasing prevalence of
241 hypertension and T2DM in China [21]. Several studies indicate that overall obesity (BMI) is more
242 strongly associated with hypertension, while central obesity (WC) is more strongly associated with
243 T2DM [17 24-26]. The rationale for these associations is based on the notion that central obesity
244 reflects specific accumulation of visceral adipose tissue. Excess visceral adipose tissue is
245 metabolically unfavorable due to productions of free fatty acids and inflammatory mediators.
246 Overall obesity, on the other hand, represents a greater overall physiologic strain and effects
247 vascular and cardiac parameters more significantly. In this study, we observed a significant increase
248 in prevalence of T2DM regardless of gender or age groups, which was more pronounced than the
249 change in the prevalence of hypertension during the period of 2002-03 and 2009. We also observed
250 a closer association of central obesity with the prevalence of T2DM than with the prevalence of
251 hypertension. These results support the notion that central obesity in particular is a stronger risk
252 factor for T2DM than for hypertension in Chinese adults. Due to the cross-sectional design,

1
2 253 however, our study was unable to make a causal inference.

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4 254 The nature of the cross-sectional study design limits our ability to directly evaluate the
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6 255 influence of overall and central obesity as well as the change of their prevalence on the risk of
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8 256 hypertension and T2DM. The differences in several demographic characteristics between the
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10 257 participants of the two surveys indicate the changes in general population over time. However,
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12 258 selection bias could not be excluded. There are several strengths in this study, including the strict
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14 259 process of multistage sampling in adult population in Shanghai, anthropometric measurement
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16 260 according to a standardized protocol and fasting and postprandial blood glucose tests for the
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18 261 participants.
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22 262 **Conclusions**

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25 263 In summary, this study describes the potential association of central obesity with an upward
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27 264 trend of T2DM. **Our findings provide useful information about the growing burden of type 2**
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29 265 **diabetes and hypertension in Chinese adults and suggest the need for further study in other rapidly**
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31 266 **changing populations in China.**
32

36 268 **Acknowledgements**

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39 269 We thank Dr. Xiao-ou Shu and Dr. Hui Cai of Vanderbilt University for their contributions in
40
41 270 study design and data analysis. The authors thank the study participants of the two cross-sectional
42
43 271 surveys and the healthcare workers in each community involved.
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46 272 **Footnotes**

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1 361 Figure 1. Shift in BMI and WC over the period of the two population-based surveys

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3 362 Figure 2. Non-linear dose-response relationship of BMI and WC with hypertension and T2DM

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365 Table 1. Characteristics of participants in two population-based surveys in Shanghai, China

Characteristics	1 st survey		2 nd survey		<i>P-value between surveys^a</i>	
	Men (N=5,050)	Women (N=7,279)	Men (N=3,461)	Women (N=3,962)	<i>In men</i>	<i>In women</i>
Age (yrs., mean ± SD)	54.8 ± 10.8	53.1 ± 10.3	54.7 ± 9.5	54.7 ± 9.1	0.55	<0.0001
Resident site (%)						
Urban	71.1	63.0	72.4	72.0		
Rural	29.0	37.0	27.7	28.0	0.19	<0.0001
Education (%)						
No formal education	4.1	18.4	3.2	9.5		
Primary school	18.2	23.0	14.7	17.7		
Middle school	35.3	31.1	45.7	45.2		
High school	27.6	22.6	27.6	23.8		
College or above	14.8	4.9	8.8	3.9	0.0025	<0.0001
Per capita income (yuan/mo.) (%)						
<1000	37.0	45.5	4.9	4.0		
1000-2999	38.3	38.4	41.8	46.7		
3000-5000	22.5	17.9	33.2	33.3		
>5000	2.2	1.3	20.0	16.0	<0.0001	<0.0001
Family history of type 2diabetes	12.3	13.1	16.4	19.0	<0.0001	<0.0001
Prevalence of type 2diabetes (%)	13.6	10.3	17.4	14.1	<0.0001	<0.0001
Prevalence of hypertension (%)	34.8	28.3	41.8	37.1	<0.0001	<0.0001
Cigarette smoking (%)	61.4	1.7	62.6	1.8	0.22	0.93
Alcohol drinking (%)	40.4	2.4	54.0	5.0	<0.0001	<0.0001
Leisure-time activity (%)	13.3	13.1	10.8	9.0	0.0009	<0.0001

366 ^a *P* for Wilcoxon tests or chi-square tests

Table 2. Prevalence of obesity, hypertension and type 2 diabetes in participants of the two population-based surveys by age groups in Shanghai, China

	No. of subjects		Overall Obesity		APC	Central obesity		APC	Hypertension		APC	Type 2 diabetes		APC
	1 st survey	2 nd survey	1 st survey	2 nd survey	(%)	1 st survey	2 nd survey	(%)	1 st survey	2 nd survey	(%)	1 st survey	2 nd survey	(%)
Men														
Overall	5050	3461	11.7	11.9	0.21	46.3	53.8	2.35	34.8	41.8	2.87	13.6	17.4	3.78
Age-groups														
35-	414	230	10.5	9.1	-2.11	41.8	45.2	1.22	15.2	11.7	-3.92	4.6	5.7	3.25
40-	574	302	10.0	8.3	-2.83	41.8	47.00	1.85	22.5	21.9	-0.43	7.8	7.6	-0.44
45-	837	445	12.6	12.6	-0.04	44.0	53.7	3.12	25.3	31.0	3.16	7.8	13.7	9.13
50-	833	739	12.2	10.8	-1.76	44.1	53.8	3.12	33.1	40.3	3.07	12.7	18.3	5.72
55-	628	669	10.4	13.2	3.78	47.3	54.6	2.25	35.4	45.6	3.99	15.0	17.9	2.82
60-	507	513	10.5	15.4	6.18	48.7	56.1	2.19	44.6	51.7	2.29	15.6	20.1	3.98
65-	674	313	12.6	11.8	-0.99	51.4	61.0	2.67	49.4	59.4	2.88	20.8	26.2	3.64
70-	583	250	13.8	9.6	-5.40	51.1	54.0	0.85	50.9	65.2	3.87	24.2	25.6	0.88
Women														
Overall	7279	3962	13.8	13.8	0.02	41.7	54.2	4.10	28.3	37.1	4.28	10.3	14.1	4.84
Age-groups														
35-	615	251	7.5	7.2	-0.65	22.6	26.3	2.35	6.8	10.8	7.24	3.3	4.0	3.17
40-	1000	287	9.4	11.2	2.66	27.6	38.0	5.05	11.7	15.7	4.61	4.1	5.9	5.81
45-	1491	563	11.0	9.8	-1.82	32.3	42.6	4.38	19.3	23.5	3.03	5.8	8.7	6.32
50-	1309	866	15.1	14.1	-1.00	43.9	54.0	3.24	28.7	31.0	1.16	8.3	9.4	1.94
55-	838	818	15.7	13.6	-2.17	47.5	60.6	3.83	33.9	39.7	2.48	8.8	15.3	8.80
60-	610	585	19.2	18.1	-0.87	53.5	63.1	2.58	40.5	52.8	4.17	16.7	19.2	2.11
65-	799	327	18.0	18.4	0.28	59.0	66.1	1.76	48.4	59.3	3.17	23.7	27.8	2.54
70-	617	265	18.2	16.6	-1.36	60.2	68.7	2.05	51.4	64.5	3.57	21.4	27.2	3.75
All subjects														
Overall	12329	7423	13.0	12.9	-0.05	43.6	54.0	3.35	31.0	39.3	3.75	11.7	15.6	4.53
Age-groups ^a														
35-	1029	481	8.7	8.0	-1.04	30.3	33.9	2.39	10.2	11.2	1.49	3.8	4.7	3.63
40-	1574	589	9.6	10.1	0.11	32.7	41.3	4.14	15.6	17.9	2.92	5.5	6.5	3.41
45-	2328	1008	11.6	10.8	-0.77	36.5	46.6	4.16	21.5	26.2	3.46	6.5	10.5	8.22
50-	2142	1605	13.9	12.8	-1.53	44.0	53.9	3.19	30.4	34.6	0.90	10.0	12.8	4.69
55-	1466	1487	13.4	13.4	0.01	47.4	58.1	3.13	34.5	42.2	3.20	11.5	16.4	5.75
60-	1117	1098	15.2	16.9	1.59	51.3	59.9	2.39	42.4	52.3	3.29	16.2	19.6	2.96
65-	1473	640	15.6	15.4	-0.39	55.5	63.8	2.11	48.9	59.4	3.04	22.3	27.1	2.98
70-	1200	515	16.0	13.2	-2.94	55.8	61.5	1.52	51.2	64.9	3.71	22.8	26.4	2.32

^a adjusted for sex according to the distribution in the first survey.

Table 3. Association of body size with hypertension and type 2 diabetes in two population-based surveys in Shanghai, China

	No. of subjects with neither diseases	Type 2 diabetes only		Hypertension only		Both	
		N	OR (95%CI)	N	OR (95%CI)	N	OR (95%CI)
BMI residuals							
Men							
Q1	1260	156	1.00	529	1.00	175	1.00
Q2	1224	142	0.99 (0.77, 1.27)	583	1.16 (1.00, 1.34)	172	1.11(0.87, 1.41)
Q3	1164	132	1.09 (0.84, 1.41)	651	1.50 (1.29, 1.74)	171	1.36(1.07, 1.73)
Q4	1079	123	1.16 (0.88, 1.51)	709	1.85 (1.59, 2.15)	207	1.95(1.54, 2.47)
			<i>P for trend</i>				
			0.2472		<0.0001		<0.0001
Women							
Q1	1816	166	1.00	600	1.00	223	1.00
Q2	1866	148	1.02 (0.80, 1.29)	629	1.29 (1.12, 1.48)	162	0.96(0.77, 1.21)
Q3	1835	125	0.89 (0.69, 1.15)	687	1.51 (1.31, 1.73)	158	1.03(0.82, 1.31)
Q4	1634	109	0.94 (0.73, 1.23)	847	2.23 (1.94, 2.57)	215	1.85(1.15, 2.98)
			<i>P for trend</i>				
			0.4864		<0.0001		0.0067
All subjects							
Q1	3048	330	1.00	1162	1.00	385	1.00
Q2	3079	282	1.00 (0.84, 1.19)	1200	1.22 (1.11, 1.35)	363	1.03(0.87, 1.22)
Q3	2998	278	0.98 (0.82, 1.18)	1346	1.50 (1.36, 1.67)	302	1.18(1.00, 1.40)
Q4	2753	211	1.04 (0.86, 1.26)	1527	2.05 (1.85, 2.27)	433	1.88(1.60, 2.21)
			<i>P for trend</i>				
			0.2280		<0.0001		<0.0001
WC residuals							
Men							
Q1	1376	102	1.00	531	1.00	111	1.00
Q2	1232	131	1.34 (1.02, 1.78)	601	1.23 (1.06, 1.42)	155	1.41(1.07, 1.84)
Q3	1130	148	1.39 (0.70, 2.77)	644	1.39 (1.20, 1.62)	197	1.73(1.33, 2.25)
Q4	989	172	1.75 (1.33, 2.30)	696	1.57 (1.35, 1.82)	262	2.25(1.74, 2.90)
			<i>P for trend</i>				
			<0.0001		<0.0001		<0.0001
Women							
Q1	2019	80	1.00	598	1.00	108	1.00
Q2	1935	102	1.17 (0.86, 1.59)	651	1.04 (0.91, 1.18)	117	0.94(0.71, 1.25)
Q3	1708	172	2.04 (1.54, 2.70)	732	1.14 (0.99, 1.30)	194	1.40(1.08, 1.82)
Q4	1489	194	2.37 (1.78, 3.15)	782	1.13 (0.98, 1.30)	339	2.06(1.26, 3.38)
			<i>P for trend</i>				
			<0.0001		0.0216		<0.0001
All subjects							
Q1	3453	161	1.00	1109	1.00	203	1.00
Q2	3192	260	1.26 (0.99, 1.60)	1211	1.12 (1.01, 1.23)	260	1.16(0.82, 1.62)
Q3	2838	301	1.66 (1.16, 2.36)	1373	1.25 (1.13, 1.38)	412	1.55(1.29, 1.87)
Q4	2395	379	2.03 (1.66, 2.47)	1542	1.34 (1.09, 1.64)	608	2.18(1.83, 2.61)
			<i>P for trend</i>				
			0.0001		0.0021		<0.0001

Missing value excluded from the analysis.

OR: Adjusted for age (continuous variable), education (no formal education, primary school, middle school, high school, colleague or above, dummy variables), per capita income (<1000, 1000-2999, 3000-5000 and >5000 RMB Yuan / month, dummy variables), resident site (urban/rural area), family history of type 2 diabetes (yes/no), smoking (ever/never), alcohol drinking (ever/never), regular exercise (never/ever), phase of study (first /second survey); Additionally adjusted for sex (male/female) for all subjects.

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4 Table 4. Joint effect of general obesity and central obesity on type 2 diabetes among Chinese adults

BMI	WC: Lower			WC: Higher			OR (95%CI) for hypertension		OR (95%CI) for type 2 diabetes	
	No. of subjects	Hypertension N (%)	Diabetes N (%)	No. of subjects	Hypertension N (%)	Diabetes N (%)	WC: Lower	WC: Higher	WC: Lower	WC: Higher
Men										
<18.5	212	36	20	16	10	6	0.61(0.42, 0.89)	3.68(1.28, 10.59)	1.02(0.62, 1.67)	3.77(1.13, 12.56)
18.5-23.9	3034	767	296	679	249	111	1.00	1.56(0.94, 2.57)	1.00	1.48(1.15, 1.90)
24.0-27.9	1010	356	134	2530	1179	483	1.61(1.13, 2.32)	2.38(1.78, 3.17)	1.46(1.16, 1.83)	1.85(1.16, 2.96)
≥28.0	36	20	4	960	580	224	3.91(1.95, 7.82)	4.67(3.97, 5.49)	1.71(0.55, 5.37)	2.60(2.12, 3.18)
<i>P for interaction</i>							0.0711		0.0933	
Women										
<18.5	313	51	19	8	2	1	0.68(0.49, 0.94)	0.85(0.16, 4.51)	0.93(0.56, 1.54)	2.45(0.22, 26.72)
18.5-23.9	4323	821	265	974	314	165	1.00	1.48(1.26, 1.75)	1.00	2.36(1.89, 2.94)
24.0-27.9	1330	384	93	2724	1102	437	1.84(1.59, 2.14)	2.21(1.97, 2.49)	1.19(0.92, 1.53)	2.14(1.81, 2.54)
≥28.0	81	32	9	1467	815	317	3.10(1.93, 5.00)	4.33(3.77, 4.96)	2.14(1.01, 4.52)	3.08(2.56, 3.71)
<i>P for interaction</i>							0.3524		0.4011	
Total										
<18.5	525	87	39	24	12	7	0.65(0.51, 0.83)	2.25(0.85, 5.93)	0.97(0.68, 1.39)	3.45(1.18, 10.12)
18.5-23.9	7357	1588	561	1653	563	276	1.00	1.52(1.25, 1.85)	1.00	1.88(1.42, 2.49)
24.0-27.9	2340	740	227	5254	2281	920	1.74(1.50, 2.03)	2.31(2.03, 2.62)	1.33(1.12, 1.58)	1.99(1.62, 2.45)
≥28.0	117	5	13	2427	1395	541	3.34(2.26, 4.94)	4.46(4.02, 4.96)	2.00(1.07, 3.74)	2.85(2.49, 3.27)
<i>P for interaction</i>							0.0562		0.0798	

2 Higher WC defined as ≥ 85 cm for men and ≥ 80 cm for women

3 OR: Adjusted for age (continuous variable), education (no formal education, primary school, middle school, high school, colleague or above, dummy variables), per capita
4 income (<1000, 1000-2999, 3000-5000 and >5000 RMB Yuan / month, dummy variables), resident site (urban/rural area), family history of type 2 diabetes (yes/no),
5 smoking (ever/never), alcohol drinking (ever/never), regular exercise (never/ever), and phase of study (first /second survey).