

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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2 Chinese Adults: Two Population-based Cross-sectional Surveys in Shanghai, China 3 Ye Ruan, MD, PhD¹, Miao Mo, MD², Lisa Joss-Moore, PhD³, Yan Yun Li, MD¹, Qun Di Yang, 4 MD, MPH¹, Liang Shi, MD¹, Hua Zhang, MD², Rui Li, MD^{1*}, Wang Hong Xu, MD, PhD^{2*} 5 6 **AFILIATIONS:** 7 ¹ Department of Diabetes Prevention and Control, Shanghai Municipal Center for Disease Control 8 and Prevention, 1380 Zhong Shan Xi Road, Shanghai, 200336, People's Republic of China 9 ² Department of Epidemiology, School of Public Health, Fudan University; Key Laboratory of 0 1 Public Health Safety, Ministry of Education (Fudan University), 138 Yi Xue Yuan Road, Shanghai, 2 200032, People's Republic of China ι Lak ³ Division of Neonatology, University of Utah, Salt Lake City, Utah 84108, USA 3 4 5 Correspondence to: 6 Wang Hong Xu, MD, Ph.D, Associate professor 7 8 Department of Epidemiology 9 School of Public Health 0 Fudan University 138 Yi Xue Yuan Road 1 Shanghai 200032 2 P. R. China 3 4 Tel: 86-21-54237679 Fax: 86-21-54237334 5 6 Email: wanghong.xu@fudan.edu.cn

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

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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Introduction 71 A rising worldwide prevalence of chronic disease, manifested primarily as hypertension and 72 type 2 diabetes (T2DM), has been well documented [1-4]. In Chinese aged 15-74 years old, the 73 prevalence of hypertension increased from 5.11% in 1959, 7.73% in 1979 [5] and 13.58% in 1991[6] 74 75 to 17.65% in 2002 [7]. The prevalence of T2DM tripled between 1980 (about 1.0%) and 1996 (3.2%) [89], and reached 9.7% in 2008 among adults at 20 years old or above [10]. It is estimated 76 77 that over 92 million people in China have T2DM. This represents approximately half of the world's diabetic population, and places China at the "global epicenter of the diabetes epidemic" [4]. 78 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]. However, a significant proportion of Asian adults diagnosed with T2DM are with the normal BMI, 82 ie.18.5-25.0 kg/m² [15 16]. BMI is a general indicator of overt obesity, but does not give 83 84 information about the distribution of obesity. Central obesity, often assessed via waist circumference (WC), is also strongly correlated with T2DM in both European and Asian adults [11] 85 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 conducted in Shanghai in 2002-03 and in 2009. We used the data from the two surveys to evaluate 89 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

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

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from a total of 12 districts and 7 counties in Shanghai, China. And then, 1-2 sub-districts or towns were randomly selected from each selected district or county. Next, 1-2 communities or villages, usually 1,000-2,000 residents for each, were randomly selected from each selected sub-district or town. Finally, eligible subjects (permanent residents of Shanghai, 15-74 years old and having been in the city for at least 5 years) were randomly selected from the selected communities and villages and were invited for participation. Pregnant women, individuals with type I diabetes, and physically or mentally disabled persons were excluded from the participation. During the period of May 2002-October 2003, a total of 17,526 eligible subjects were recruited, and 14,401 (82.17%) participated the survey. The 2009 survey used the similar sampling method except that only 7 communities and

villages were randomly selected in the third stage of sampling. The inclusion and exclusion criteria of the 2009 survey were also similar to those for the 2002-03 survey, except that only those at the age of 35-74 years old were eligible for the 2009 survey. Among 7,627 eligible adults contacted during the period of May-July 2009, 7,414 (97.21%) were interviewed and donated blood samples. To make the two surveys comparable, we excluded 1,071 subjects younger than 35 years from the 2002-03 survey. After further excluding subjects with missing information, the final analysis included 5,050 men and 7,279 women in the 2002-03 survey and 3,461 men and 3,962 women in the 2009 survey. The Institutional Review Board at Shanghai Municipal Center of Disease Control and Prevention approved the study. Informed consent was obtained from each participant before data collection.

117 Data Collection

A similar survey approach was followed by the two investigations. In both surveys, information on demographic and socioeconomic factors, diagnosis of diabetes, tobacco and alcohol use, physical activity and family history of diabetes was collected by trained interviewers with a structured questionnaire at community clinics located in the residential areas of the participants. At the interview, each participant's blood pressure, body weight, standing height, and waist

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circumference (WC) were measured by trained staff. Blood pressure was measured on the right arm in the sitting position using standard mercury sphygmomanometer after at least 5 minutes of rest. The first and fifth Korotkoff sounds were recorded. Body weight and height were recorded while the subject was in light clothing and without shoes. Body weight was measured with electronic scales to the nearest 0.1 kg. Body height was measured to the nearest 0.1 cm by using a stadiometer. WC, recorded to the nearest 0.1 cm, was taken with a cloth tape and was measured on bare skin at the midline between the lower border of the ribs and the iliac crest in the horizontal plane after a normal expiration. Two measurements were taken and the mean of the replicates was used in the following analyses. Body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared (kg/m^2) using the direct measurements.

133 Laboratory Measurements

After at least 10 hours of overnight fasting, 1-1.5 ml venous blood specimen was collected in a vacuum tube containing sodium fluoride. All participants with no history of diabetes and having a fasting plasma glucose level of < 7.0 mmol per liter (mmol/l) were then asked to have an oral glucose-tolerance test (OGTT). Blood samples were drawn at 0 and 120 minutes after a standard 75 gram glucose load. Plasma glucose was measured with Glucose oxidase-peroxidase (GOD-PAP) method.

140 Diagnosis of T2DM and Hypertension

Previously diagnosed T2DM and hypertension was identified by a positive response from the participant to the question of "Have you ever diagnosed with T2DM/hypertension by a doctor?" and confirmed by medical records in which prescriptions of anti-hypertensive or hypoglycemic medications were presented. The consistent rate was 100%. For those who had a negative response, the T2DM was diagnosed with measured glucose level by using the 1999 World Health Organization diagnostic criteria [Department of Noncommunicable Disease Surveillance. Definition, diagnosis and classification of diabetes mellitus and its complications: report of a WHO consultation. Part 1. Diagnosis and classification of diabetes mellitus. Geneva: World Health

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149 Organization, 1999. (Accessed July 5, 2010, at_

150 <u>http://www.staff.ncl.ac.uk/philip.home/who_dmg.pdf.</u>] and hypertension referred to the subjects 151 with measured systolic blood pressure (SBP) \geq 140 mmHg or diastolic blood pressure (DBP) \geq 90 152 mmHg and confirmed by clinical visits. Total T2DM and hypertension included both previously 153 diagnosed and newly-diagnosed patients. 42.7% (1,110 of 2,598) diabetic patients and 10.3% (694 154 of 6,735) hypertensive patients were newly-diagnosed in the two surveys.

155 Statistical Analysis

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

Results

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

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of education, higher level of income per capita, more prior history of T2DM, higher frequency of
alcohol drinking and lower frequency of leisure time activity, and were more likely to have a family
history of diabetes.

Figure 1 shows the shapes of the BMI and WC distribution curves among men and women changed over the period of the two surveys. After adjusting for age, education, per capita income, resident site, smoking, drinking, regular exercise, and family history of T2DM, the curves of BMI were almost overlapped in both men and women. However, the WC curves for men and women were shifted to the right between 2002-03 and 2009, with the mean WC increasing from 83.6 to 85.3 cm for men and from 78.4 to 80.6 cm for women.

As presented in table 2, the prevalence of obesity, both overall and central, increased with increasing age groups. While the prevalence of overall obesity (BMI $\geq 28 \text{ kg/m}^2$) did not changed between two surveys (all P values > 0.05), the prevalence of central obesity were significantly higher in 2009 survey in each age group (all P values < 0.001). A more pronounced increase in prevalence of central obesity and T2DM was observed among subjects aged 45-49 years old in both men and women; whereas the change in prevalence of hypertension between two surveys appeared more evident in older men and younger women over the period. Using the World Health Organization (WHO) criteria for obesity did not change the results substantially (data not shown in the tables).

BMI and WC were highly correlated with each other, with a correlation coefficient of 0.77 (P <(0.0001) among men and (0.78) ($P \le 0.0001$) among women after adjusting for age. Therefore, the residual method was used to test the potential respective non-linear relationships of BMI and WC with the risk of T2DM and hypertension (Figure 2). The dose-response analysis likewise showed a statistically significant increased risk of T2DM at high level of WC and a significant elevated risk of hypertension at high level of BMI in both men and women after adjusting for age, education, per capita income, resident site, smoking, drinking, regular exercise, family history of T2DM and phase of surveys, with P values for non-linear relationship tests < 0.05. No significant relationship was

observed between BMI and T2DM in men and between WC and hypertension in women. As shown in table 3, in both sexes, BMI adjusted for WC (residuals) appeared more strongly associated with hypertension while WC adjusted for BMI (residuals) was more evidently related with T2DM. Comparing with the lowest quartile of BMI residuals, the risk of hypertension increased 85% (95%CI: 1.59-2.15) in men and 1.23-fold (95%CI: 1.94-2.57) in women, whereas the risk of T2DM did not increase significantly in both sexes. On the other hand, the ORs of the highest versus the lowest quartile WC residuals for T2DM were 1.75 (95%CI: 1.33-2.30) in men 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 1.13 (95%CI: 0.98-1.30) in women for hypertension.

We further evaluated the potential joint effect of BMI and WC on T2DM and hypertension (table 4). The participants were classified into normal weight (BMI 18.5-23.9 kg/m²), overweight $(24.0-27.9 \text{ kg/m}^2)$, or obese ($\geq 28 \text{ kg/m}^2$) based on data from Chinese adults, and were defined as with normal or increased WC using sex-specific cut-offs (85 cm in men and 80 cm in women) [19]. The risk of T2DM and hypertension increased across groups defined by BMI and WC, with the highest risk observed among men with the lowest BMI but a higher WC, and among those with the highest BMI and a higher WC for hypertension. However, no significant interaction was observed between BMI and WC (all *P* values for interaction tests > 0.05).

Discussion

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

225 Chinese adults have lower rates of overweight and obesity than their Western counterparts 226 using the WHO criteria (BMI \ge 25 kg/m² for overweight and BMI \ge 30 kg/m² for obesity) [15 16]. Page 11 of 26

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1 2	227	Nevertheless, increasing trends of BMI in Chinese adults have been well documented [18 20]. In
3 4 5	228	two national nutritional surveys undertaken in 1982 and 1992 in China, the prevalence of
5 6 7	229	overweight/obesity (BMI \ge 25 kg/m ²) in subjects 20-70 years of age was 10% and 15%,
8 9	230	respectively. Between 1992 and 2002, the combined prevalence of overweight and obesity increased
10 11	231	from 14.6 to 21.8% [21]. Interestingly, the increase in BMI among Chinese adults has slowed down
12 13	232	during past decades [2]. In this study, we did not observe an increase in BMI and prevalence of
14 15 16	233	obesity defined by the Chinese obesity standards or by WHO criteria (data not shown). Instead, we
17 18	234	observed a significant increase in WC, a measure of central obesity between surveys. Our
19 20	235	observation of increased WC in Chinese adults, without a concomitant increase in BMI, represents
21 22	236	an increasing burden of central obesity in this population. The increase in central obesity indicates
23 24	237	an upward trend in body fat percentages in the population who have been previously observed with
25 26 27	238	higher body fat percentages compared to other ethnic people with the same BMI [22 23].
28 29	239	Both epidemic of overall and central obesity parallel a continuously increasing prevalence of
30 31	240	hypertension and T2DM in China [21]. Several studies indicate that overall obesity (BMI) is more
32 33	241	strongly associated with hypertension, while central obesity (WC) is more strongly associated with
34 35 26	242	T2DM [17 24-26]. The rationale for these associations is based on the notion that central obesity
36 37 38	243	reflects specific accumulation of visceral adipose tissue. Excess visceral adipose tissue is
39 40	244	metabolically unfavorable due to productions of free fatty acids and inflammatory mediators.
41 42	245	Overall obesity, on the other hand, represents a greater overall physiologic strain and effects
43 44	246	vascular and cardiac parameters more significantly. In this study, we observed a significant increase
45 46	247	in prevalence of T2DM regardless of gender or age groups, which was more pronounced than the
47 48 49	248	change in the prevalence of hypertension during the period of 2002-03 and 2009. We also observed
50 51	249	a closer association of central obesity with the prevalence of T2DM than with the prevalence of
52 53	250	hypertension. These results support the notion that central obesity in particular is a stronger risk
54 55	251	factor for T2DM than for hypertension in Chinese adults. Due to the cross-sectional design,
56 57	252	however, our study was unable to make a causal inference.
58 59		

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. However, there are several strengths, including the strict process of multistage sampling in adult population in Shanghai, anthropometric measurement according to a standardized protocol and fasting and postprandial blood glucose tests for the participants.

260 Conclusions

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

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269 Footnotes

Contributors YR and MM contributed to data collection, data analysis and draft of the paper. 271 YR, YYL, QDY, and LS contributed to data collection and quality control. LJM contributed to 272 revision of the paper. HZ contributed to data clean and analysis. RL and WHX contributed to study 273 design, statistical analysis and revision of the paper. All authors contributed to the interpretation of 274 data and revision of the manuscript. All authors approved the final version.

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- Figure 2. Non-linear dose-response relationship of BMI and WC with hypertension and T2DM
- among participants of the two population-based surveys

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		1 st su	rvey	2 ⁿ	^d survey	P-value bei	ween surveys
	Characteristics	Men	Women	Men	Women	In mon	In more of
		(N=5,050)	(N=7,279)	(N=3,461)	(N=3,962)	In men	In women
_	Age (yrs., mean \pm 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		
	Colleague 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

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



	No. of st			l Obesity	APC	Centra	al obesity	APC		rtension	APC	Type 2 c		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	9.1.
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	<i>3.78</i>	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

Table 2. Prevalence of obesity, hypertension and type 2 diabetes in participants of the two population-based surveys by age groups in Shanghai, China	,	Table 2. Prevalence of obesity,	hypertension and type 2 d	iabetes in participants of the	e two population-based s	surveys by age groups in Shanghai, China	
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^a adjusted for sex according to the distribution in the first survey.

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

Shanghai, China

	No. of subjects with	Тур	e 2 diabetes only	Hy	Hypertension only		Both	
	neither diseases	Ν	OR (95%CI)	Ν	OR (95%CI)	Ν	OR (95%CI)	
BMI resid	uals		· ·					
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)	
	P for trend		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)	
-	P for trend		0.4864		< 0.0001		0.0067	
All subject	cts							
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)	
	P for trend		0.2280		<0.0001		<0.0001	
WC residu	uals							
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)	
	P for trend		<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)	
	P for trend		<0.0001		0.0216		<0.0001	
All subject								
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</i> for trend		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.

		WC: Lower			WC: Higher		OR (95%CI) fo	or hypertension	OR (95%CI) fo	or type 2 diabetes
BMI	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)
					P fo	r interaction	0.0	711	0.0	933
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)
					P fo	r interaction	0.3.	524	0.4	011
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)
					P fo	r interaction	0.0	562	0.0	798

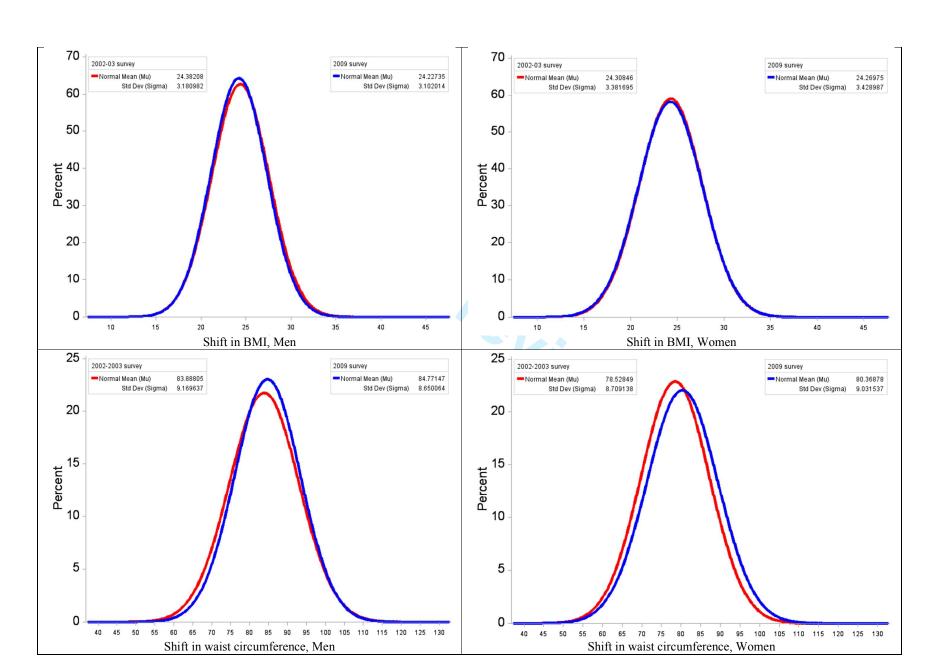
Higher WC defined as ≥ 85 cm for men and ≥ 80 cm for women

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),

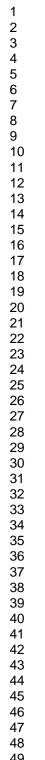
smoking (ever/never), alcohol drinking (ever/never), regular exercise (never/ever), and phase of study (first /second survey).

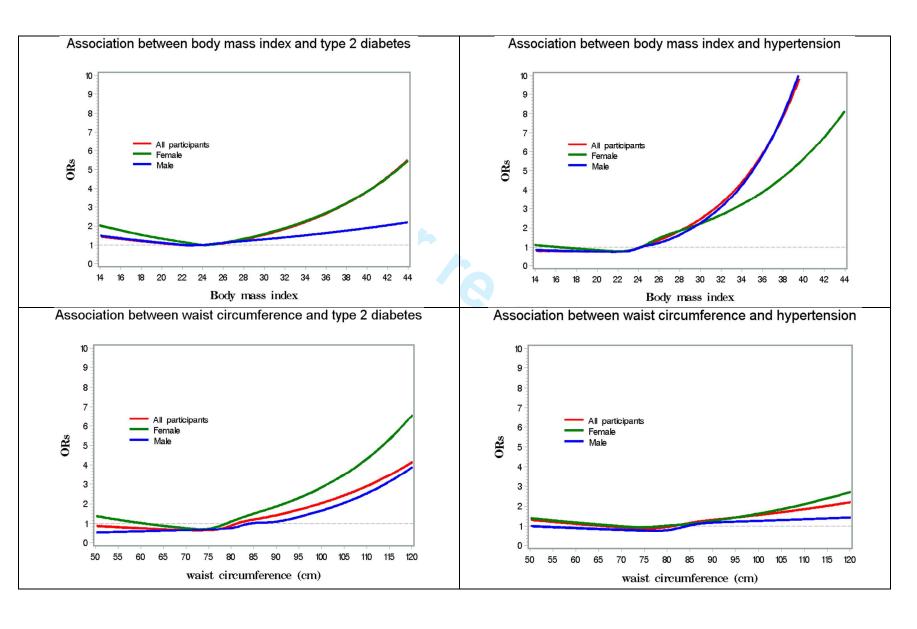
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	Item No	Recommendation	Results of check
Title and abstract	1	(<i>a</i>) Indicate the study's design with a commonly used term in the title or the abstract	We have indicated that the study was based on two population-based cross- sectional surveys 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	(<i>a</i>) 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	(<i>a</i>) Describe all statistical methods, including those used to control for confounding	Line 155-169
		(b) Describe any methods used to	Line 166-167

STROBE Statement—Checklist of items that should be included in reports	of cross-sectional studies
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		examine subgroups and interactions	
		(c) Explain how missing data were	There were very few missing data in
		addressed	this study. Please see footnote of the
			Table 3
		(<i>d</i>) If applicable, describe analytical	
		methods taking account of sampling	
		strategy	
		(<u>e</u>) Describe any sensitivity analyses	No
Results			
Participants	13*	(a) Report numbers of individuals at	Line 95-105
i un nonpunito		each stage of study—eg numbers	
		potentially eligible, examined for	
		eligibility, confirmed eligible,	
		included in the study, completing	
		follow-up, and analysed	
		(b) Give reasons for non-participation	No information
		at each stage	
		(c) Consider use of a flow diagram	No
Descriptive data	14*	(a) Give characteristics of study	Line 172-177, and Table 1
Descriptive data	14	participants (eg demographic,	Line 172-177, and Table 1
		clinical, social) and information on	
		exposures and potential confounders	
		(b) Indicate number of participants	Yes, we provide number of subjects
		with missing data for each variable of	for each variable of interest (Please
		interest	see tables)
Outcome data	15*	Report numbers of outcome events or	Yes (Please see tables)
Outcome data	15	summary measures	res (riease see tables)
Main results	16	(<i>a</i>) Give unadjusted estimates and, if	No. Due to the large table, we presen
Main results	10	applicable, confounder-adjusted	only adjusted ORs
		estimates and their precision (eg,	only adjusted OKS
		95% confidence interval). Make clear	
		which confounders were adjusted for	
		and why they were included	
			Veg (Plage geg table 4)
		(<i>b</i>) Report category boundaries when continuous variables were	Yes (Please see table 4)
		categorized	NA
		(<i>c</i>) If relevant, consider translating estimates of relative risk into absolute	NA
041	17	risk for a meaningful time period	Line 210 217
Other analyses	17	Report other analyses done—eg	Line 210-217
		analyses of subgroups and	
		interactions, and sensitivity analyses	
Discussion		1	
Key results	18	Summarise key results with reference	Line 219-224
		to study objectives	
Limitations	19	Discuss limitations of the study,	Line 253-259
		taking into account sources of	

		potential bias or imprecision. Discuss	
		both direction and magnitude of any	
		potential bias	
Interpretation	20	Give a cautious overall interpretation	Line 251-252
_		of results considering objectives,	
		limitations, multiplicity of analyses,	
		results from similar studies, and other	
		relevant evidence	
Generalisability	21	Discuss the generalisability (external	Line 263-264
·		validity) of the study results	
Other information			
Funding	22	Give the source of funding and the	Line 275-280
C .		role of the funders for the present	
		study and, if applicable, for the	
		original study on which the present	
		article is based	
*Give information separate	ly for expose	d and unexposed groups	
Give information separate	Ty for expose	a and unexposed groups.	
Note: An Explanation and	Elaboration (article discusses each checklist item and g	rives methodological background and
•		ting. The STROBE checklist is best used	
		licine at http://www.plosmedicine.org/, A	
		gy at http://www.epidem.com/). Informa	
	-		tion on the STROBE Initiative is
available at www.strobe-sta	atement.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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Keywords:	Hypertension < CARDIOLOGY, General diabetes < DIABETES & ENDOCRINOLOGY, EPIDEMIOLOGY, PUBLIC HEALTH

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Increased Waist Circumference and Prevalence of Type 2 Diabetes and Hypertension in Chinese Adults: Two Population-based Cross-sectional Surveys in Shanghai, China Ye Ruan, MD, PhD¹, Miao Mo, MD², Lisa Joss-Moore, PhD³, Yan Yun Li, MD¹, Qun Di Yang, MD, MPH¹, Liang Shi, MD¹, Hua Zhang, MD², Rui Li, MD^{1*}, Wang Hong Xu, MD, PhD^{2*} **AFILIATIONS:** ¹ Department of Diabetes Prevention and Control, Shanghai Municipal Center for Disease Control and Prevention, 1380 Zhong Shan Xi Road, Shanghai, 200336, People's Republic of China ² Department of Epidemiology, School of Public Health, Fudan University; Key Laboratory of Public Health Safety, Ministry of Education (Fudan University), 138 Yi Xue Yuan Road, Shanghai, 200032, People's Republic of China . Lake ³ Division of Neonatology, University of Utah, Salt Lake City, Utah 84108, USA Correspondence to: Wang Hong Xu, MD, Ph.D, Associate professor Department of Epidemiology School of Public Health Fudan University 138 Yi Xue Yuan Road Shanghai 200032 P. R. China Tel: 86-21-54237679 Fax: 86-21-54237334

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

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/m ² [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

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

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from a total of 12 districts and 7 counties in Shanghai, China. And then, 1-2 sub-districts or towns were randomly selected from each selected district or county. Next, 1-2 communities or villages, usually 1,000-2,000 residents for each, were randomly selected from each selected sub-district or town. Finally, eligible subjects (permanent residents of Shanghai, 15-74 years old and having been in the city for at least 5 years) were randomly selected from the selected communities and villages and were invited for participation. Pregnant women, individuals with type I diabetes, and physically or mentally disabled persons were excluded from the participation. During the period of May 2002-October 2003, a total of 17,526 eligible subjects were recruited, and 14,401 (82.17%) participated the survey. The 2009 survey used the similar sampling method except that only 7 communities and

villages were randomly selected in the third stage of sampling. The inclusion and exclusion criteria of the 2009 survey were also similar to those for the 2002-03 survey, except that only those at the age of 35-74 years old were eligible for the 2009 survey. Among 7,627 eligible adults contacted during the period of May-July 2009, 7,414 (97.21%) were interviewed and donated blood samples. To make the two surveys comparable, we excluded 1,071 subjects younger than 35 years from the 2002-03 survey. After further excluding subjects with missing information, the final analysis included 5,050 men and 7,279 women in the 2002-03 survey and 3,461 men and 3,962 women in the 2009 survey. The Institutional Review Board at Shanghai Municipal Center of Disease Control and Prevention approved the study. Informed consent was obtained from each participant before data collection.

117 Data Collection

A similar survey approach was followed by the two investigations. In both surveys, information on demographic and socioeconomic factors, diagnosis of diabetes, tobacco and alcohol use, physical activity and family history of diabetes was collected by trained interviewers with a structured questionnaire at community clinics located in the residential areas of the participants. At the interview, each participant's blood pressure, body weight, standing height, and waist

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circumference (WC) were measured by trained staff. Blood pressure was measured on the right arm in the sitting position using standard mercury sphygmomanometer after at least 5 minutes of rest. The first and fifth Korotkoff sounds were recorded. Body weight and height were recorded while the subject was in light clothing and without shoes. Body weight was measured with electronic scales to the nearest 0.1 kg. Body height was measured to the nearest 0.1 cm by using a stadiometer. WC, recorded to the nearest 0.1 cm, was taken with a cloth tape and was measured on bare skin at the midline between the lower border of the ribs and the iliac crest in the horizontal plane after a normal expiration. Two measurements were taken and the mean of the replicates was used in the following analyses. Body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared (kg/m^2) using the direct measurements.

133 Laboratory Measurements

After at least 10 hours of overnight fasting, 1-1.5 ml venous blood specimen was collected in a vacuum tube containing sodium fluoride. All participants with no history of diabetes and having a fasting plasma glucose level of < 7.0 mmol per liter (mmol/l) were then asked to have an oral glucose-tolerance test (OGTT). Blood samples were drawn at 0 and 120 minutes after a standard 75 gram glucose load. Plasma glucose was measured with Glucose oxidase-peroxidase (GOD-PAP) method.

Diagnosis of T2DM and Hypertension

Previously diagnosed T2DM and hypertension was identified by a positive response from the participant to the question of "Have you ever diagnosed with T2DM/hypertension by a doctor?" and confirmed by medical records in which prescriptions of anti-hypertensive or hypoglycemic medications were presented. The consistent rate was 100%. For those who had a negative response, the T2DM was diagnosed with measured glucose level by using the 1999 World Health Organization diagnostic criteria [Department of Noncommunicable Disease Surveillance. Definition, diagnosis and classification of diabetes mellitus and its complications: report of a WHO consultation. Part 1. Diagnosis and classification of diabetes mellitus. Geneva: World Health

149 Organization, 1999. (Accessed July 5, 2010, at_

150http://www.staff.ncl.ac.uk/philip.home/who_dmg.pdf.] and hypertension referred to the subjects151with measured systolic blood pressure (SBP) \geq 140 mmHg or diastolic blood pressure (DBP) \geq 90152mmHg and confirmed by clinical visits. Total T2DM and hypertension included both previously153diagnosed and newly-diagnosed patients. 42.7% (1,110 of 2,598) diabetic patients and 10.3% (694154of 6,735) hypertensive patients were newly-diagnosed in the two surveys.

155 Statistical Analysis

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

Results

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

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of education, higher level of income per capita, more prior history of T2DM, higher frequency of
alcohol drinking and lower frequency of leisure time activity, and were more likely to have a family
history of diabetes.

Figure 1 shows the shapes of the BMI and WC distribution curves among men and women changed over the period of the two surveys. After adjusting for age, education, per capita income, resident site, smoking, drinking, regular exercise, and family history of T2DM, the curves of BMI were almost overlapped in both men and women. However, the WC curves for men and women were shifted to the right between 2002-03 and 2009, with the mean WC increasing from 83.6 to 85.3 cm for men and from 78.4 to 80.6 cm for women.

As presented in table 2, the prevalence of obesity, both overall and central, increased with increasing age groups. While the prevalence of overall obesity (BMI $\geq 28 \text{ kg/m}^2$) did not changed between two surveys (all P values > 0.05), the prevalence of central obesity were significantly higher in 2009 survey in each age group (all P values < 0.001). A more pronounced increase in prevalence of central obesity and T2DM was observed among subjects aged 45-49 years old in both men and women; whereas the change in prevalence of hypertension between two surveys appeared more evident in older men and younger women over the period. Using the World Health Organization (WHO) criteria for obesity did not change the results substantially (data not shown in the tables).

BMI and WC were highly correlated with each other, with a correlation coefficient of 0.77 (P <(0.0001) among men and (0.78) ($P \le 0.0001$) among women after adjusting for age. Therefore, the residual method was used to test the potential respective non-linear relationships of BMI and WC with the risk of T2DM and hypertension (Figure 2). The dose-response analysis likewise showed a statistically significant increased risk of T2DM at high level of WC and a significant elevated risk of hypertension at high level of BMI in both men and women after adjusting for age, education, per capita income, resident site, smoking, drinking, regular exercise, family history of T2DM and phase of surveys, with P values for non-linear relationship tests < 0.05. No significant relationship was

observed between BMI and T2DM in men and between WC and hypertension in women. As shown in table 3, in both sexes, BMI adjusted for WC (residuals) appeared more strongly associated with hypertension while WC adjusted for BMI (residuals) was more evidently related with T2DM. Comparing with the lowest quartile of BMI residuals, the risk of hypertension increased 85% (95%CI: 1.59-2.15) in men and 1.23-fold (95%CI: 1.94-2.57) in women, whereas the risk of T2DM did not increase significantly in both sexes. On the other hand, the ORs of the highest versus the lowest quartile WC residuals for T2DM were 1.75 (95%CI: 1.33-2.30) in men 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 1.13 (95%CI: 0.98-1.30) in women for hypertension.

We further evaluated the potential joint effect of BMI and WC on T2DM and hypertension (table 4). The participants were classified into normal weight (BMI 18.5-23.9 kg/m²), overweight $(24.0-27.9 \text{ kg/m}^2)$, or obese ($\geq 28 \text{ kg/m}^2$) based on data from Chinese adults, and were defined as with normal or increased WC using sex-specific cut-offs (85 cm in men and 80 cm in women) [19]. The risk of T2DM and hypertension increased across groups defined by BMI and WC, with the highest risk observed among men with the lowest BMI but a higher WC, and among those with the highest BMI and a higher WC for hypertension. However, no significant interaction was observed between BMI and WC (all *P* values for interaction tests > 0.05).

Discussion

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

225 Chinese adults have lower rates of overweight and obesity than their Western counterparts 226 using the WHO criteria (BMI \ge 25 kg/m² for overweight and BMI \ge 30 kg/m² for obesity) [15 16]. Page 11 of 46

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1 2	227	Nevertheless, increasing trends of BMI in Chinese adults have been well documented [18 20]. In
3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31	228	two national nutritional surveys undertaken in 1982 and 1992 in China, the prevalence of
	229	overweight/obesity (BMI \ge 25 kg/m ²) in subjects 20-70 years of age was 10% and 15%,
	230	respectively. Between 1992 and 2002, the combined prevalence of overweight and obesity increased
	231	from 14.6 to 21.8% [21]. Interestingly, the increase in BMI among Chinese adults has slowed down
	232	during past decades [2]. In this study, we did not observe an increase in BMI and prevalence of
	233	obesity defined by the Chinese obesity standards or by WHO criteria (data not shown). Instead, we
	234	observed a significant increase in WC, a measure of central obesity between surveys. Our
	235	observation of increased WC in Chinese adults, without a concomitant increase in BMI, represents
	236	an increasing burden of central obesity in this population. The increase in central obesity indicates
	237	an upward trend in body fat percentages in the population who have been previously observed with
	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
32 33	241	strongly associated with hypertension, while central obesity (WC) is more strongly associated with
34 35 36	242	T2DM [17 24-26]. The rationale for these associations is based on the notion that central obesity
37 38	243	reflects specific accumulation of visceral adipose tissue. Excess visceral adipose tissue is
39 40	244	metabolically unfavorable due to productions of free fatty acids and inflammatory mediators.
41 42	245	Overall obesity, on the other hand, represents a greater overall physiologic strain and effects
43 44 45	246	vascular and cardiac parameters more significantly. In this study, we observed a significant increase
45 46 47	247	in prevalence of T2DM regardless of gender or age groups, which was more pronounced than the
48 49	248	change in the prevalence of hypertension during the period of 2002-03 and 2009. We also observed
50 51	249	a closer association of central obesity with the prevalence of T2DM than with the prevalence of
52 53	250	hypertension. These results support the notion that central obesity in particular is a stronger risk
54 55 56	251	factor for T2DM than for hypertension in Chinese adults. Due to the cross-sectional design,
57 58 59	252	however, our study was unable to make a causal inference.

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 changes in general population over time. However, selection bias could not be excluded. However, there are several strengths, including the strict process of multistage sampling in adult population in Shanghai, anthropometric measurement according to a standardized protocol and fasting and postprandial blood glucose tests for the

260 participants.

Conclusions

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

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270 Footnotes

Contributors YR and MM contributed to data collection, data analysis and draft of the paper. 272 YR, YYL, QDY, and LS contributed to data collection and quality control. LJM contributed to 273 revision of the paper. HZ contributed to data clean and analysis. RL and WHX contributed to study 274 design, statistical analysis and revision of the paper. All authors contributed to the interpretation of 275 data and revision of the manuscript. All authors approved the final version.

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8 9	281	manuscript.
10 11	282	Conflict of Interest: None declared.
12 13 14 56 78 90 12 23 22 24 56 78 90 12 33 45 67 89 01 23 34 56 78 90 142 34 45 67 89 01 25 55 55 55 55 55 55 55 55 55 55 55 55	283	Conflict of Interest: None declared. Data sharing: No additional unpublished data.

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- Figure 2. Non-linear dose-response relationship of BMI and WC with hypertension and T2DM
- among participants of the two population-based surveys

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		1 st su	rvey	2 ⁿ	^d survey	P-value between surveys		
	Characteristics	Men	Women	Men	Women		I	
		(N=5,050)	(N=7,279)	(N=3,461)	(N=3,962)	In men	In women	
	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			
	Colleague 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	

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



		No. of subjects		Overall Obesity			al obesity	APC	Hypertension		APC			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	9.1.
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.

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

Shanghai, China

	No. of subjects with	Typ N	e 2 diabetes only	Hy	pertension only	Both		
	neither diseases		OR (95%CI)	Ν	OR (95%CI)	Ν	OR (95%CI)	
BMI resid	luals							
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)	
	P for trend		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)	
,	P for trend		0.4864		<0.0001		0.0067	
All subje								
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)	
× ×	P for trend		0.2280		<0.0001		<0.0001	
	5							
WC resid	uals							
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)	
,	P for trend		<0.0001		<0.0001		<0.0001	
Women	v							
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)	
Q3 Q4	1489	194	2.37 (1.78, 3.15)	782	1.13 (0.98, 1.30)	339	2.06(1.26, 3.38)	
Ϋ́	<i>P</i> for trend	174	<0.0001	762	0.0216	557	<0.0001	
All subje			<0.0001		0.0210		<0.0001	
Q1	3453	161	1.00	1109	1.00	203	1.00	
Q1 Q2	3192	260	1.26 (0.99, 1.60)	1211	1.12 (1.01, 1.23)	260	1.16(0.82, 1.62)	
Q2 Q3	2838	301	1.66 (1.16, 2.36)	1373	1.12 (1.01, 1.23) 1.25 (1.13, 1.38)	412	1.55(1.29, 1.87)	
Q3 Q4	2395	379	2.03 (1.66, 2.47)	1575	1.23 (1.15, 1.58) 1.34 (1.09, 1.64)	608	2.18(1.83, 2.61)	
	(17)	.)/7	2.0.1 + .00.2.4/1	1.242	1.041.07.1.041	000	2.1011.02.2.01	

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.

		WC: Lower			WC: Higher		OR (95%CI) fo	or hypertension	OR (95%CI) for type 2 diabetes		
BMI	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)	
					P fo	r interaction	0.0	711	0.0	933	
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)	
					P fo	r interaction	0.3.	524	0.4	011	
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)	
					P fo	r interaction	0.0	562	0.0	798	

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

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), and phase of study (first /second survey).

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1 2	1	Increased Waist Circumference and Prevalence of Type 2 Diabetes and Hypertension in
3 4 5	2	Chinese Adults: Two Population-based Cross-sectional Surveys in Shanghai, China
5 6 7	3	
8 9	4	Ye Ruan, MD, PhD ¹ , Miao Mo, MD ² , Lisa Joss-Moore, PhD ³ , Yan Yun Li, MD ¹ , Qun Di Yang,
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3 of 46	BMJ Open
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 grou
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 bo
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 an
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	

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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2 3	71	Introduction
4 5	72	A rising worldwide prevalence of chronic disease, manifested primarily as hypertension and
6 7 8	73	type 2 diabetes (T2DM), has been well documented [1-4]. In Chinese aged 15-74 years old, the
9 10	74	prevalence of hypertension increased from 5.11% in 1959, 7.73% in 1979 [5] and 13.58% in 1991[6]
11 12	75	to 17.65% in 2002 [7]. The prevalence of T2DM tripled between 1980 (about 1.0%) and 1996
13 14	76	(3.2%) [8 9], and reached 9.7% in 2008 among adults at 20 years old or above [10]. It is estimated
15 16 17	77	that over 92 million people in China have T2DM. This represents approximately half of the world's
18 19	78	diabetic population, and places China at the "global epicenter of the diabetes epidemic" [4].
20 21	79	Both hypertension and T2DM are associated with obesity [11 12]. Obesity is often measured
22 23	80	by body mass index (BMI). Across the entire range of BMI, the risk of hypertension and T2DM
24 25 26 27 28	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,
29 30	83	ie.18.5-25.0 kg/m ² [15 16]. BMI is a general indicator of overt obesity, but does not give
31 32	84	information about the distribution of obesity. Central obesity, often assessed via waist
33 34	85	circumference (WC), is also strongly correlated with T2DM in both European and Asian adults [11
35 36 37	86	17]. While changes in BMI have been well documented in China over past several decades [2 18],
38 39	87	changes in WC, and thus central obesity, are not well described.
40 41	88	In this study, we took advantage of the data from population based cross-sectional surveys
42 43	89	conducted in Shanghai in 2002-03 and in 2009. We used the data from the two surveys to evaluate
44 45	90	correlations between shifts in BMI and WC with the prevalence of hypertension and T2DM in
46 47 48	91	Chinese adults. Our results may help to better understand the contribution of overall obesity and
49 50	92	central obesity in the increasing burden of chronic disease in China.
51 52 53	93	Materials and Methods

Study Participants

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

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

The 2009 survey used the similar sampling method except that only 7 communities and villages were randomly selected in the third stage of sampling. The inclusion and exclusion criteria of the 2009 survey were also similar to those for the 2002-03 survey, except that only those at the age of 35-74 years old were eligible for the 2009 survey. Among 7,627 eligible adults contacted during the period of May-July 2009, 7,414 (97.21%) were interviewed and donated blood samples. To make the two surveys comparable, we excluded 1,071 subjects younger than 35 years from the 2002-03 survey. After further excluding subjects with missing information, the final analysis included 5,050 men and 7,279 women in the 2002-03 survey and 3,461 men and 3,962 women in the 2009 survey. The Institutional Review Board at Shanghai Municipal Center of Disease Control and Prevention approved the study. Informed consent was obtained from each participant before data collection.

117 Data Collection

A similar survey approach was followed by the two investigations. In both surveys, information on demographic and socioeconomic factors, diagnosis of diabetes, tobacco and alcohol use, physical activity and family history of diabetes was collected by trained interviewers with a structured questionnaire at community clinics located in the residential areas of the participants. At the interview, each participant's blood pressure, body weight, standing height, and waist

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circumference (WC) were measured by trained staff. Blood pressure was measured on the right arm in the sitting position using standard mercury sphygmomanometer after at least 5 minutes of rest. The first and fifth Korotkoff sounds were recorded. Body weight and height were recorded while the subject was in light clothing and without shoes. Body weight was measured with electronic scales to the nearest 0.1 kg. Body height was measured to the nearest 0.1 cm by using a stadiometer. WC, recorded to the nearest 0.1 cm, was taken with a cloth tape and was measured on bare skin at the midline between the lower border of the ribs and the iliac crest in the horizontal plane after a normal expiration. Two measurements were taken and the mean of the replicates was used in the following analyses. Body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared (kg/m^2) using the direct measurements.

133 Laboratory Measurements

After at least 10 hours of overnight fasting, 1-1.5 ml venous blood specimen was collected in a vacuum tube containing sodium fluoride. All participants with no history of diabetes and having a fasting plasma glucose level of < 7.0 mmol per liter (mmol/l) were then asked to have an oral glucose-tolerance test (OGTT). Blood samples were drawn at 0 and 120 minutes after a standard 75 gram glucose load. Plasma glucose was measured with Glucose oxidase-peroxidase (GOD-PAP) method.

140 Diagnosis of T2DM and Hypertension

Previously diagnosed T2DM and hypertension was identified by a positive response from the participant to the question of "Have you ever diagnosed with T2DM/hypertension by a doctor?" and confirmed by medical records in which prescriptions of anti-hypertensive or hypoglycemic medications were presented. The consistent rate was 100%. For those who had a negative response, the T2DM was diagnosed with measured glucose level by using the 1999 World Health Organization diagnostic criteria [Department of Noncommunicable Disease Surveillance. Definition, diagnosis and classification of diabetes mellitus and its complications: report of a WHO consultation. Part 1. Diagnosis and classification of diabetes mellitus. Geneva: World Health

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149 Organization, 1999. (Accessed July 5, 2010, at_

150 <u>http://www.staff.ncl.ac.uk/philip.home/who_dmg.pdf.</u>] and hypertension referred to the subjects 151 with measured systolic blood pressure (SBP) \geq 140 mmHg or diastolic blood pressure (DBP) \geq 90 152 mmHg and confirmed by clinical visits. Total T2DM and hypertension included both previously 153 diagnosed and newly-diagnosed patients. 42.7% (1,110 of 2,598) diabetic patients and 10.3% (694 154 of 6,735) hypertensive patients were newly-diagnosed in the two surveys.

155 Statistical Analysis

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

Results

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

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of education, higher level of income per capita, more prior history of T2DM, higher frequency of
alcohol drinking and lower frequency of leisure time activity, and were more likely to have a family
history of diabetes.

Figure 1 shows the shapes of the BMI and WC distribution curves among men and women changed over the period of the two surveys. After adjusting for age, education, per capita income, resident site, smoking, drinking, regular exercise, and family history of T2DM, the curves of BMI were almost overlapped in both men and women. However, the WC curves for men and women were shifted to the right between 2002-03 and 2009, with the mean WC increasing from 83.6 to 85.3 cm for men and from 78.4 to 80.6 cm for women.

As presented in table 2, the prevalence of obesity, both overall and central, increased with increasing age groups. While the prevalence of overall obesity (BMI $\geq 28 \text{ kg/m}^2$) did not changed between two surveys (all P values > 0.05), the prevalence of central obesity were significantly higher in 2009 survey in each age group (all P values < 0.001). A more pronounced increase in prevalence of central obesity and T2DM was observed among subjects aged 45-49 years old in both men and women; whereas the change in prevalence of hypertension between two surveys appeared more evident in older men and younger women over the period. Using the World Health Organization (WHO) criteria for obesity did not change the results substantially (data not shown in the tables).

BMI and WC were highly correlated with each other, with a correlation coefficient of 0.77 (P <(0.0001) among men and (0.78) ($P \le 0.0001$) among women after adjusting for age. Therefore, the residual method was used to test the potential respective non-linear relationships of BMI and WC with the risk of T2DM and hypertension (Figure 2). The dose-response analysis likewise showed a statistically significant increased risk of T2DM at high level of WC and a significant elevated risk of hypertension at high level of BMI in both men and women after adjusting for age, education, per capita income, resident site, smoking, drinking, regular exercise, family history of T2DM and phase of surveys, with P values for non-linear relationship tests < 0.05. No significant relationship was

observed between BMI and T2DM in men and between WC and hypertension in women. As shown in table 3, in both sexes, BMI adjusted for WC (residuals) appeared more strongly associated with hypertension while WC adjusted for BMI (residuals) was more evidently related with T2DM. Comparing with the lowest quartile of BMI residuals, the risk of hypertension increased 85% (95%CI: 1.59-2.15) in men and 1.23-fold (95%CI: 1.94-2.57) in women, whereas the risk of T2DM did not increase significantly in both sexes. On the other hand, the ORs of the highest versus the lowest quartile WC residuals for T2DM were 1.75 (95%CI: 1.33-2.30) in men 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 1.13 (95%CI: 0.98-1.30) in women for hypertension.

We further evaluated the potential joint effect of BMI and WC on T2DM and hypertension (table 4). The participants were classified into normal weight (BMI 18.5-23.9 kg/m²), overweight $(24.0-27.9 \text{ kg/m}^2)$, or obese ($\geq 28 \text{ kg/m}^2$) based on data from Chinese adults, and were defined as with normal or increased WC using sex-specific cut-offs (85 cm in men and 80 cm in women) [19]. The risk of T2DM and hypertension increased across groups defined by BMI and WC, with the highest risk observed among men with the lowest BMI but a higher WC, and among those with the highest BMI and a higher WC for hypertension. However, no significant interaction was observed between BMI and WC (all *P* values for interaction tests > 0.05).

Discussion

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

225 Chinese adults have lower rates of overweight and obesity than their Western counterparts 226 using the WHO criteria (BMI \ge 25 kg/m² for overweight and BMI \ge 30 kg/m² for obesity) [15 16].

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1 2	227	Nevertheless, increasing trends of BMI in Chinese adults have been well documented [18 20]. In
3 4	228	two national nutritional surveys undertaken in 1982 and 1992 in China, the prevalence of
5 6 7	229	overweight/obesity (BMI \ge 25 kg/m ²) in subjects 20-70 years of age was 10% and 15%,
7 8 9	230	respectively. Between 1992 and 2002, the combined prevalence of overweight and obesity increased
10 11	231	from 14.6 to 21.8% [21]. Interestingly, the increase in BMI among Chinese adults has slowed down
12 13	232	during past decades [2]. In this study, we did not observe an increase in BMI and prevalence of
14 15	233	obesity defined by the Chinese obesity standards or by WHO criteria (data not shown). Instead, we
16 17 18	234	observed a significant increase in WC, a measure of central obesity between surveys. Our
19 20	235	observation of increased WC in Chinese adults, without a concomitant increase in BMI, represents
21 22	236	an increasing burden of central obesity in this population. The increase in central obesity indicates
23 24	237	an upward trend in body fat percentages in the population who have been previously observed with
25 26 27	238	higher body fat percentages compared to other ethnic people with the same BMI [22 23].
28 29	239	Both epidemic of overall and central obesity parallels a continuously increasing prevalence of
30 31	240	hypertension and T2DM in China [21]. Several studies indicate that overall obesity (BMI) is more
32 33	241	strongly associated with hypertension, while central obesity (WC) is more strongly associated with
34 35 36	242	T2DM [17 24-26]. The rationale for these associations is based on the notion that central obesity
37 38	243	reflects specific accumulation of visceral adipose tissue. Excess visceral adipose tissue is
39 40	244	metabolically unfavorable due to productions of free fatty acids and inflammatory mediators.
41 42	245	Overall obesity, on the other hand, represents a greater overall physiologic strain and effects
43 44 45	246	vascular and cardiac parameters more significantly. In this study, we observed a significant increase
45 46 47	247	in prevalence of T2DM regardless of gender or age groups, which was more pronounced than the
48 49	248	change in the prevalence of hypertension during the period of 2002-03 and 2009. We also observed
50 51	249	a closer association of central obesity with the prevalence of T2DM than with the prevalence of
52 53	250	hypertension. These results support the notion that central obesity in particular is a stronger risk
54 55 56	251	factor for T2DM than for hypertension in Chinese adults. Due to the cross-sectional design,
57 58 59	252	however, our study was unable to make a causal inference.
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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 changes in general population over time. However, selection bias could not be excluded. However, there are several strengths, including the strict process of multistage sampling in adult population in Shanghai, anthropometric measurement according to a standardized protocol and fasting and postprandial blood glucose tests for the participants.

Conclusions

In summary, this study describes the potential association of central obesity with an upward trend of T2DM, implicating a more rapidly growing burden of T2DM than hypertension in Chinese adults. The findings in Shanghai, the largest city and one of the most economically developed areas 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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- Figure 2. Non-linear dose-response relationship of BMI and WC with hypertension and T2DM
- among participants of the two population-based surveys

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		1 st su	rvey	2 ⁿ	^d survey	P-value bei	ween surveys
	Characteristics	Men (N=5,050)	Women (N=7,279)	Men (N=3,461)	Women (N=3,962)	In men	In women
-	Age (yrs., mean \pm 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		
	Colleague 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

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



	No. of s			l Obesity	APC	Centra	al obesity	APC		rtension	APC		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	<i>3.78</i>
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

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

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

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

Shanghai, China

	No. of subjects with	Тур	e 2 diabetes only	Hy	pertension only		Both
	neither diseases	Ν	OR (95%CI)	Ν	OR (95%CI)	Ν	OR (95%CI)
BMI resid	uals		· ·				
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)
	P for trend		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)
	P for trend		0.4864		< 0.0001		0.0067
All subject	cts						
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)
	P for trend		0.2280		<0.0001		< 0.0001
WC residu	uals						
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)
	P for trend		<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)
,	P for trend		<0.0001		0.0216		<0.0001
All subject							
Q1 J	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)
	P for trend		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.

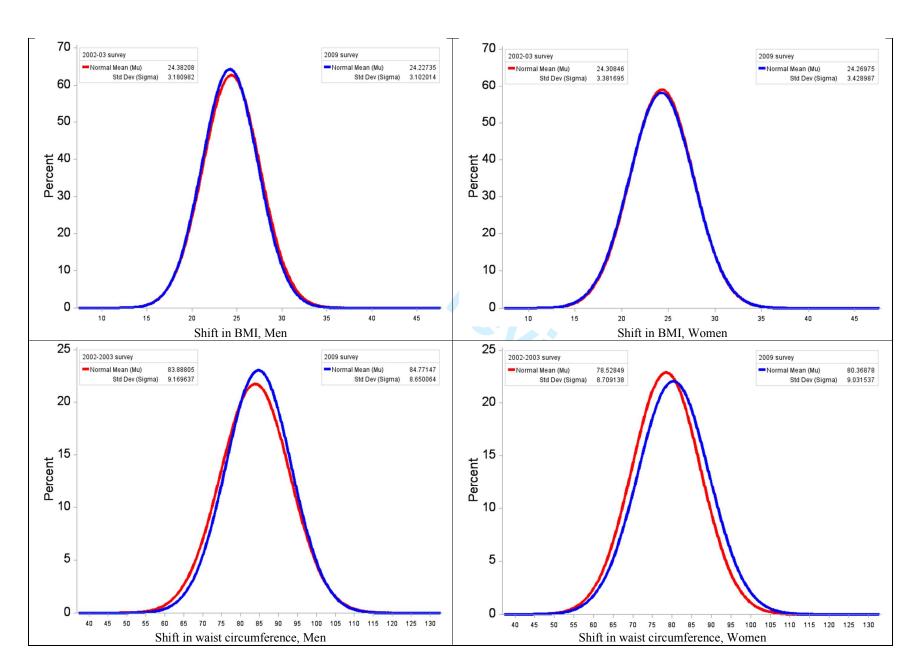
	WC: Lower			WC: Higher			OR (95%CI) fo	or hypertension	OR (95%CI) for type 2 diabetes		
BMI	No. of subjects	Hypertension N (%)	Diabetes N (%)	No. of subjects	Hypertension N (%)	Diabetes N (%)	WC: Lower	WC: Higher	WC: Lower	WC: Higher	
Men											
<18.5	212	36	20	16	10	6	0.61(0.42, 0.89)	3.68(1.28, 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)	
Women					P fo	r interaction	0.0	711	0.0	933	
<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)	
					P fo	r interaction	0.3.	524	0.4	011	
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)	
					P fo	r interaction	0.0.	562	0.0	798	

2 Higher WC defined as ≥ 85 cm for men and ≥ 80 cm for women 3 OR: Adjusted for age (continuous variable), education (no forma

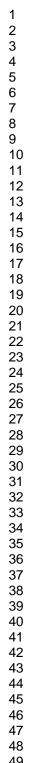
 OR: Adjusted for age (continuous variable), education (no formal education, primary school, middle school, high school, colleague or above, dummy variables), per capita income (<1000, 1000-2999, 3000-5000 and >5000 RMB Yuan / month, dummy variables), resident site (urban/rural area), family history of type 2 diabetes (yes/no),

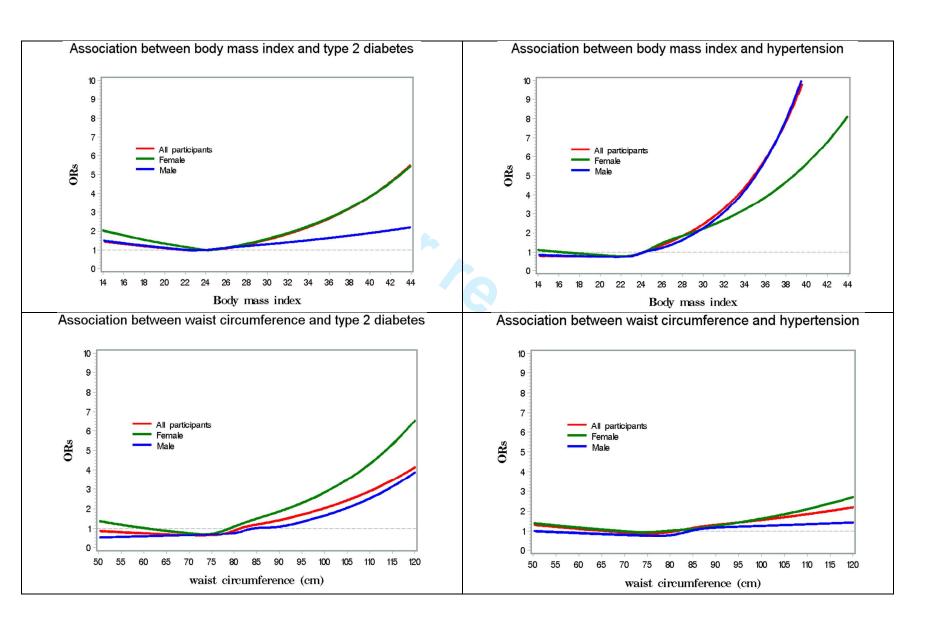
income (<1000, 1000-2999, 3000-5000 and >5000 RMB Yuan / month, dummy variables), resident site (urban/rural area), far
 smoking (ever/never), alcohol drinking (ever/never), regular exercise (never/ever), and phase of study (first /second survey).





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	Item No	Recommendation	Results of check		
Title and abstract	1	(<i>a</i>) Indicate the study's design with a commonly used term in the title or	We have indicated that the study was based on two population-based cross-		
		the abstract	sectional surveys in the title and the abstract		
		(b) Provide in the abstract an	Line 53-62		
		informative and balanced summary of	Line 55-62		
		what was done and what was found			
		what was done and what was found			
Introduction					
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	Line 72-87		
Objectives	3	State specific objectives, including	Line 89-92		
Objectives	3		Line 89-92		
		any prespecified hypotheses			
Methods					
Study design	4	Present key elements of study design early in the paper	Line 95-104		
Setting	5	Describe the setting, locations, and	Line 95-104		
C		relevant dates, including periods of			
		recruitment, exposure, follow-up, and			
		data collection			
Participants	6	(a) Give the eligibility criteria, and	Line 95-104		
1 articipants	0	the sources and methods of selection	Line 95-104		
V	7	of participants	Line 117 152		
Variables	/	Clearly define all outcomes,	Line 117-153		
		exposures, predictors, potential			
		confounders, and effect modifiers.			
	0.1	Give diagnostic criteria, if applicable	· · · · · · · · · · · · · · · · · · ·		
Data sources/ measurement	8*	For each variable of interest, give	Line 117-153		
		sources of data and details of			
		methods of assessment			
		(measurement). Describe			
		comparability of assessment methods			
		if there is more than one group			
Bias	9	Describe any efforts to address	Line 117-153		
		potential sources of bias			
Study size	10	Explain how the study size was	NA		
		arrived at			
Quantitative variables	11	Explain how quantitative variables	Line 155-169		
		were handled in the analyses. If			
		applicable, describe which groupings			
		were chosen and why			
Statistical methods	12	(<i>a</i>) Describe all statistical methods,	Line 155-169		
		including those used to control for			
		confounding			
		comounding			

		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
		(<i>d</i>) If applicable, describe analytical methods taking account of sampling strategy	
		(e) Describe any sensitivity analyses	No
Results	1		
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	Yes, we provide number of subjects for each variable of interest (Please
Outcome data	15*	interest	see tables) Yes (Please see tables)
		Report numbers of outcome events or summary measures	
Main results	16	 (<i>a</i>) 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 preser 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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Primary Subject Heading :	Epidemiology
Secondary Subject Heading:	Epidemiology, Public health, Cardiovascular medicine, Diabetes and endocrinology
Keywords:	Hypertension < CARDIOLOGY, General diabetes < DIABETES & ENDOCRINOLOGY, EPIDEMIOLOGY, PUBLIC HEALTH

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Increased Waist Circumference and Prevalence of Type 2 Diabetes and Hypertension in Chinese Adults: Two Population-based Cross-sectional Surveys in Shanghai, China Ye Ruan, MD, PhD¹, Miao Mo, MD², Lisa Joss-Moore, PhD³, Yan Yun Li, MD¹, Qun Di Yang, MD, MPH¹, Liang Shi, MD¹, Hua Zhang, MD², Rui Li, MD^{1*}, Wang Hong Xu, MD, PhD^{2*} **AFILIATIONS:** ¹ Department of Diabetes Prevention and Control, Shanghai Municipal Center for Disease Control and Prevention, 1380 Zhong Shan Xi Road, Shanghai, 200336, People's Republic of China ² Department of Epidemiology, School of Public Health, Fudan University; Key Laboratory of Public Health Safety, Ministry of Education (Fudan University), 138 Yi Xue Yuan Road, Shanghai, 200032, People's Republic of China . Lake ³ Division of Neonatology, University of Utah, Salt Lake City, Utah 84108, USA Correspondence to: Wang Hong Xu, MD, Ph.D, Associate professor Department of Epidemiology School of Public Health Fudan University 138 Yi Xue Yuan Road Shanghai 200032 P. R. China Tel: 86-21-54237679 Fax: 86-21-54237334

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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 focus

Article summary

- 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/m ² [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

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

from a total of 12 districts and 7 counties in Shanghai, China. And then, 1-2 sub-districts or towns were randomly selected from each selected district or county. Next, 1-2 communities or villages, usually 1,000-2,000 residents for each, were randomly selected from each selected sub-district or town. Finally, eligible subjects (permanent residents of Shanghai, 15-74 years old and having been in the city for at least 5 years) were randomly selected from the selected communities and villages and were invited for participation. Pregnant women, individuals with type I diabetes, and physically or mentally disabled persons were excluded from the participation. During the period of May 2002-October 2003, a total of 17,526 eligible subjects were recruited, and 14,401 (82.17%) participated the survey. The 2009 survey used the similar sampling method except that only 7 communities and 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

age of 35-74 years old were eligible for the 2009 survey. Among 7,627 eligible adults contacted

during the period of May-July 2009, 7,414 (97.21%) were interviewed and donated blood samples.
To make the two surveys comparable, we excluded 1,071 subjects younger than 35 years from
the 2002-03 survey. After further excluding subjects with missing information, the final analysis
included 5,050 men and 7,279 women in the 2002-03 survey and 3,461 men and 3,962 women in
the 2009 survey. The Institutional Review Board at Shanghai Municipal Center of Disease Control
and Prevention approved the study. Informed consent was obtained from each participant before

116 data collection and laboratory measurements.

117 Data Collection

A similar survey approach was followed by the two investigations. In both surveys, information on demographic and socioeconomic factors, diagnosis of diabetes, tobacco and alcohol use, physical activity and family history of diabetes was collected by trained interviewers with a structured questionnaire at community clinics located in the residential areas of the participants. At the interview, each participant's blood pressure, body weight, standing height, and waist

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circumference (WC) were measured by trained staff. Blood pressure was measured on the right arm in the sitting position using standard mercury sphygmomanometer after at least 5 minutes of rest. The first and fifth Korotkoff sounds were recorded. Body weight and height were recorded while the subject was in light clothing and without shoes. Body weight was measured with electronic scales to the nearest 0.1 kg. Body height was measured to the nearest 0.1 cm by using a stadiometer. WC, recorded to the nearest 0.1 cm, was taken with a cloth tape and was measured on bare skin at the midline between the lower border of the ribs and the iliac crest in the horizontal plane after a normal expiration. Two measurements were taken and the mean of the replicates was used in the following analyses. Body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared (kg/m^2) using the direct measurements.

133 Laboratory Measurements

After at least 10 hours of overnight fasting, 1-1.5 ml venous blood specimen was collected in a vacuum tube containing sodium fluoride. All participants with no history of diabetes and having a fasting plasma glucose level of < 7.0 mmol per liter (mmol/l) were then asked to have an oral glucose-tolerance test (OGTT). Blood samples were drawn at 0 and 120 minutes after a standard 75 gram glucose load. Plasma glucose was measured with Glucose oxidase-peroxidase (GOD-PAP) method.

140 Diagnosis of T2DM and Hypertension

Previously diagnosed T2DM and hypertension was identified by a positive response from the participant to the question of "Have you ever diagnosed with T2DM/hypertension by a doctor?" and confirmed by medical records in which prescriptions of anti-hypertensive or hypoglycemic medications were presented. The consistent rate was 100%. For those who had a negative response, the T2DM was diagnosed with measured glucose level by using the 1999 World Health Organization diagnostic criteria [Department of Noncommunicable Disease Surveillance. Definition, diagnosis and classification of diabetes mellitus and its complications: report of a WHO consultation. Part 1. Diagnosis and classification of diabetes mellitus. Geneva: World Health

149 Organization, 1999. (Accessed July 5, 2010, at_

150http://www.staff.ncl.ac.uk/philip.home/who_dmg.pdf.)] and hypertension referred to the subjects151with measured systolic blood pressure (SBP) \geq 140 mmHg or diastolic blood pressure (DBP) \geq 90152mmHg and confirmed by clinical visits. Total T2DM and hypertension included both previously153diagnosed and newly-diagnosed patients. 42.7% (1,110 of 2,598) diabetic patients and 10.3% (694154of 6,735) hypertensive patients were newly-diagnosed in the two surveys.

155 Statistical Analysis

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

Results

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

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level of education, higher level of income per capita, more prior history of T2DM, higher frequency
of alcohol drinking and lower frequency of leisure time activity, and were more likely to have a
family history of diabetes.

Figure 1 shows the shapes of the BMI and WC distribution curves among men and women changed over the period of the two surveys. After adjusting for age, education, per capita income, resident site, smoking, drinking, regular exercise, and family history of T2DM, the curves of BMI were almost overlapped in both men and women. However, the WC curves for men and women were shifted to the right between 2002-03 and 2009, with the mean WC increasing from 83.6 to 85.3 cm for men and from 78.4 to 80.6 cm for women.

As presented in table 2, the prevalence of obesity, both overall and central, increased with increasing age groups. While the prevalence of overall obesity (BMI $\ge 28 \text{ kg/m}^2$) did not change between two surveys (all P values > 0.05), the prevalence of central obesity was significantly higher in 2009 survey in each age group (all P values < 0.001). A more pronounced increase in the prevalence of central obesity and T2DM was observed among subjects aged 45-49 years old in both men and women; whereas the change in the prevalence of hypertension between two surveys appeared more evident in older men and younger women over the period. Using the World Health Organization (WHO) criteria for obesity did not change the results substantially (data not shown in the tables).

BMI and WC were highly correlated with each other, with a correlation coefficient of 0.77 (P <(0.0001) among men and (0.78) ($P \le 0.0001$) among women after adjusting for age. Therefore, the residual method was used to test the potential respective non-linear relationships of BMI and WC with the risk of T2DM and hypertension (Figure 2). The dose-response analysis likewise showed a statistically significant increased risk of T2DM at high level of WC and a significant elevated risk of hypertension at high level of BMI in both men and women after adjusting for age, education, per capita income, resident site, smoking, alcohol consumption, regular exercise, family history of T2DM and phase of surveys, with P values for non-linear relationship tests < 0.05. No significant

relationship was observed between BMI and T2DM in men and between WC and hypertension in women. As shown in table 3, in both sexes, BMI adjusted for WC (residuals) appeared more strongly associated with hypertension while WC adjusted for BMI (residuals) was more evidently related with T2DM. Comparing with the lowest quartile of BMI residuals, the risk of hypertension increased 85% (95%CI: 1.59-2.15) in men and 1.23-fold (95%CI: 1.94-2.57) in women, whereas the risk of T2DM did not increase significantly in both sexes. On the other hand, the ORs of the highest versus the lowest quartile WC residuals for T2DM were 1.75 (95%CI: 1.33-2.30) in men 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 1.13 (95%CI: 0.98-1.30) in women for hypertension. We further evaluated the potential joint effect of BMI and WC on T2DM and hypertension (table 4). The participants were classified into normal weight (BMI 18.5-23.9 kg/m²), overweight $(24.0-27.9 \text{ kg/m}^2)$, or obese ($\geq 28 \text{ kg/m}^2$) based on data from Chinese adults, and were defined as with normal or increased WC using sex-specific cut-offs (85 cm in men and 80 cm in women) [19]. The risk of T2DM and hypertension increased across groups defined by BMI and WC, with the highest risk observed among men with the lowest BMI but a higher WC, and among those with the highest BMI and a higher WC for hypertension. However, no significant interaction was observed between BMI and WC (all *P* values for interaction tests > 0.05).

Discussion

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

8 <u>226</u>

Chinese adults have lower rates of overweight and obesity than their Western counterparts

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227	using the WHO criteria (BMI \ge 25 kg/m ² for overweight and BMI \ge 30 kg/m ² for obesity) [15 16].
228	Nevertheless, increasing trends of BMI in Chinese adults have been well documented [18 20]. In
229	two national nutritional surveys undertaken in 1982 and 1992 in China, the prevalence of
230	overweight/obesity (BMI \ge 25 kg/m ²) in subjects 20-70 years of age was 10% and 15%,
231	respectively. Between 1992 and 2002, the combined prevalence of overweight and obesity increased
232	from 14.6 to 21.8% [21]. Interestingly, the increase in BMI among Chinese adults has slowed down
233	during past decades [2]. In this study, we did not observe an increase in BMI and prevalence of
234	obesity defined by the Chinese obesity standards or by WHO criteria (data not shown). Instead, we
235	observed a significant increase in WC, a measure of central obesity between surveys. Our
236	observation of increased WC in Chinese adults, without a concomitant increase in BMI, represents
237	an increasing burden of central obesity in this population. The increase in central obesity indicates
238	an upward trend in body fat percentages in the population who have been previously observed with
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,

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

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 changes in general population over time. However, selection bias could not be excluded. There are several strengths in this study, including the strict process of multistage sampling in adult population in Shanghai, anthropometric measurement according to a standardized protocol and fasting and postprandial blood glucose tests for the participants.

Conclusions

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

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272 Footnotes

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$\begin{array}{c} 16\\ 17\\ 18\\ 19\\ 20\\ 21\\ 22\\ 23\\ 24\\ 25\\ 26\\ 27\\ 28\\ 29\\ 30\\ 31\\ 32\\ 33\\ 45\\ 36\\ 37\\ 38\\ 940\\ 41\\ 243\\ 445\\ 46\\ 78\\ 95\\ 51\\ 53\\ 54\\ 55\\ 56\\ 57\\ 58\\ 59\\ \end{array}$	285	Conflict of Interest: None declared.

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 Figure 2. Non-linear dose-response relationship of BMI and WC with hypertension and T2DM
- among participants of the two population-based surveys

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		1 st su	rvey	2 ⁿ	^d survey	P-value between surveys		
	Characteristics	Men	Women	Men	Women	T		
		(N=5,050)	(N=7,279)	(N=3,461)	(N=3,962)	In men	In women	
-	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			
	Colleague 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	

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



	No. of s			l Obesity	APC	Centra	al obesity	APC		rtension	APC		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.

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

Shanghai, China

	No. of subjects with		e 2 diabetes only	Hy	pertension only		Both		
	neither diseases	Ν	OR (95%CI)	Ν	OR (95%CI)	Ν	OR (95%CI)		
BMI resid	luals								
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)		
	P for trend		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)		
	P for trend		0.4864		<0.0001		0.0067		
All subje									
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)		
	P for trend		0.2280		<0.0001		<0.0001		
	v								
WC residu	uals								
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)		
	P for trend		<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)		
Ϋ́	<i>P</i> for trend	171	<0.0001	702	0.0216	557	<0.0001		
All subje			0.0001		0.0210		0.0001		
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)		
Q2 Q3	2838	301	1.66 (1.16, 2.36)	1373	1.12 (1.01, 1.25)	412	1.55(1.29, 1.87)		
Q3 Q4	2395	379	2.03 (1.66, 2.47)	1542	1.34 (1.09, 1.64)	608	2.18(1.83, 2.61)		
~ 7	<i>P</i> for trend	517	0.0001	1074	0.0021	000	<0.0001		

Missing value excluded from the analysis.

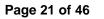
OR: Adjusted for age (continuous variable), education (no formal education, primary school, middle school, high school, colleague or above, dummy variables), per capita income (<1000, 1000-2999, 3000-5000 and >5000 RMB Yuan / month, dummy variables), resident site (urban/rural area), family history of 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.

	WC: Lower				WC: Higher		OR (95%CI) fo	or hypertension	OR (95%CI) for type 2 diabetes		
BMI	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)	
					P fo	r interaction	0.0	711	0.0	933	
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)	
					P fo	r interaction	0.3.	524	0.4	011	
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)	
					P fo	r interaction	0.0	562	0.0	798	

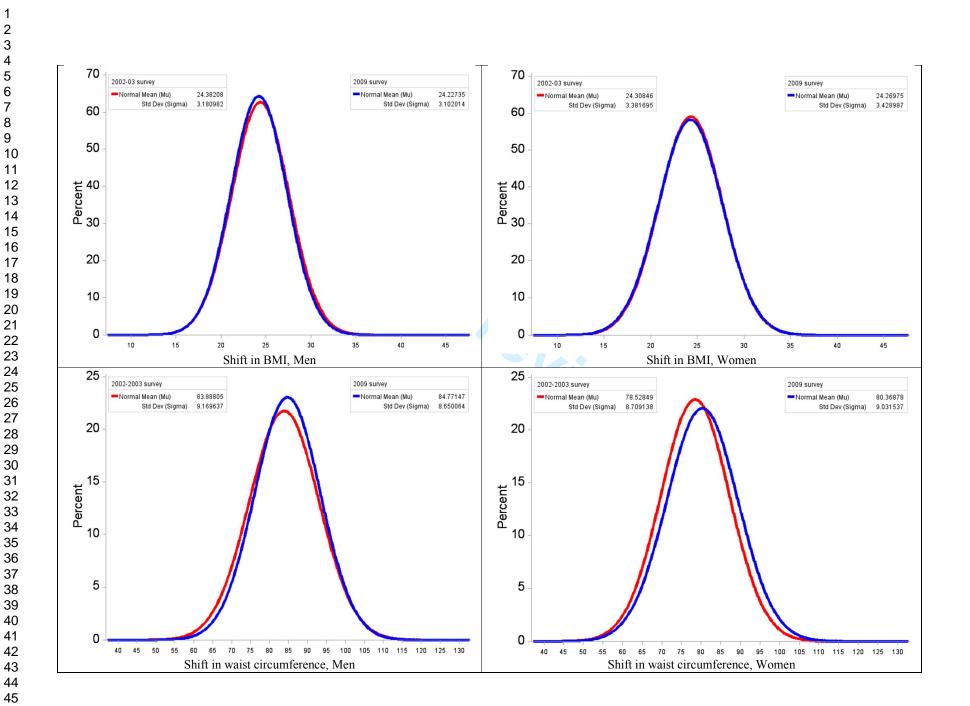
Higher WC defined as ≥ 85 cm for men and ≥ 80 cm for women

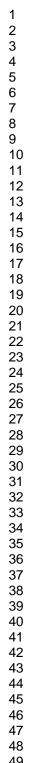
 OR: Adjusted for age (continuous variable), education (no formal education, primary school, middle school, high school, colleague or above, dummy variables), per capita income (<1000, 1000-2999, 3000-5000 and >5000 RMB Yuan / month, dummy variables), resident site (urban/rural area), family history of type 2 diabetes (yes/no),

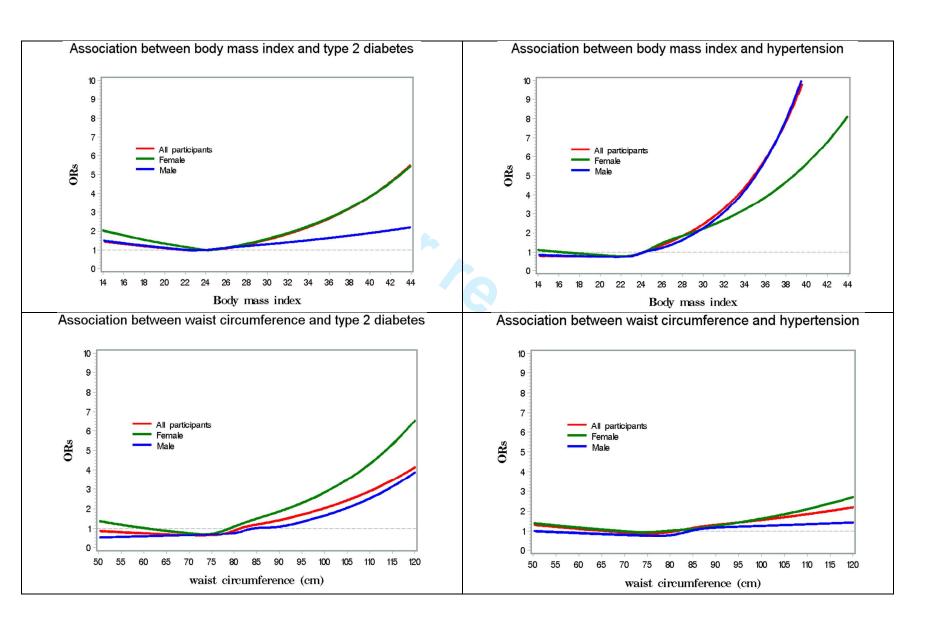
smoking (ever/never), alcohol drinking (ever/never), regular exercise (never/ever), and phase of study (first /second survey).



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 For Deer review only

	Item No	Recommendation	Results of check
Title and abstract	1	(<i>a</i>) Indicate the study's design with a	We have indicated that the study was
		commonly used term in the title or	based on two population-based cross-
		the abstract	sectional surveys in the title and the
			abstract
		(b) Provide in the abstract an	Line 53-62
		informative and balanced summary of	Ene 33-02
		what was done and what was found	
		what was done and what was found	
Introduction			
Background/rationale	2	Explain the scientific background and	Line 72-87
		rationale for the investigation being	
		reported	
Objectives	3	State specific objectives, including	Line 89-92
		any prespecified hypotheses	
Methods			
Study design	4	Present key elements of study design	Line 95-104
		early in the paper	
Setting	5	Describe the setting, locations, and	Line 95-104
betting	5	relevant dates, including periods of	
		recruitment, exposure, follow-up, and	
		data collection	
D	(1. 05.104
Participants	6	(a) Give the eligibility criteria, and	Line 95-104
		the sources and methods of selection	
		of participants	
Variables	7	Clearly define all outcomes,	Line 117-153
		exposures, predictors, potential	
		confounders, and effect modifiers.	
		Give diagnostic criteria, if applicable	
Data sources/ measurement	8*	For each variable of interest, give	Line 117-153
		sources of data and details of	
		methods of assessment	
		(measurement). Describe	
		comparability of assessment methods	
		if there is more than one group	
Bias	9	Describe any efforts to address	Line 117-153
		potential sources of bias	
Study size	10	Explain how the study size was	NA
		arrived at	
Quantitative variables	11	Explain how quantitative variables	Line 155-169
Zuminanive variables	11	were handled in the analyses. If	Line 155-107
		applicable, describe which groupings	
	10	were chosen and why	1. 155.160
Statistical methods	12	(a) Describe all statistical methods,	Line 155-169
		including those used to control for	
		confounding	
		(b) Describe any methods used to	Line 166-167

		examine subgroups and interactions	
		(c) Explain how missing data were	There were very few missing data in
		addressed	this study. Please see footnote of the
			Table 3
		(<i>d</i>) If applicable, describe analytical	
		methods taking account of sampling	
		strategy	
		(<u>e</u>) Describe any sensitivity analyses	No
Results			
Participants	13*	(a) Report numbers of individuals at	Line 95-105
		each stage of study—eg numbers	
		potentially eligible, examined for	
		eligibility, confirmed eligible,	
		included in the study, completing	
		follow-up, and analysed	
		(b) Give reasons for non-participation	No information
		at each stage	
		(c) Consider use of a flow diagram	No
Descriptive data	14*	(a) Give characteristics of study	Line 172-177, and Table 1
Descriptive data	14	participants (eg demographic,	Line 172-177, and Table 1
		clinical, social) and information on	
		exposures and potential confounders	
		(b) Indicate number of participants	Yes, we provide number of subjects
			for each variable of interest (Please
		with missing data for each variable of interest	see tables)
Outcome data	15*	Report numbers of outcome events or	Yes (Please see tables)
Outcome data	15	summary measures	res (riease see tables)
Main results	16	(<i>a</i>) Give unadjusted estimates and, if	No. Due to the large table, we presen
Ivialii results	10	applicable, confounder-adjusted	only adjusted ORs
		estimates and their precision (eg,	only adjusted OKS
		95% confidence interval). Make clear	
		which confounders were adjusted for	
		and why they were included	
		(b) Report category boundaries when	Yes (Please see table 4)
		continuous variables were	res (riease see table 4)
		categorized	
		(c) If relevant, consider translating	NA
		estimates of relative risk into absolute	NA
Other analyzag	17	risk for a meaningful time period Report other analyses done—eg	Line 210-217
Other analyses	17	analyses of subgroups and	Line 210-21/
		interactions, and sensitivity analyses	
Discussion			
Key results	18	Summarise key results with reference	Line 219-224
		to study objectives	
Limitations	19	Discuss limitations of the study,	Line 253-259
		taking into account sources of	

		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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2	1	Increased Waist Circumference and Prevalence of Type 2 Diabetes and Hypertension in
3 4	2	Chinese Adults: Two Population-based Cross-sectional Surveys in Shanghai, China
5 6	3	
7 8 9	4	Ye Ruan, MD, PhD ¹ , Miao Mo, MD ² , Lisa Joss-Moore, PhD ³ , Yan Yun Li, MD ¹ , Qun Di Yang,
10 11	5	MD, MPH ¹ , Liang Shi, MD ¹ , Hua Zhang, MD ² , Rui Li, MD ^{1*} , Wang Hong Xu, MD, PhD ^{2*}
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14 15 16	7	AFILIATIONS:
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34 35 36	16	Correspondence to: Wang Hong Xu, MD, Ph.D, Associate professor
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57 58 59 60	26	Email: wanghong.xu@fudan.edu.cn

2	27	
3 4 5	28	or
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23 24 25	37	
26 27	38	RUNNING HEADER : Obesity and prevalence of hypertension and T2DM in Chinese adults
28 29	39	
30 31 22	40	Word Count:
32 33 34	41	Abstract: 249
35 36	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

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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2 3	71	Introduction
4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19	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].
20 21	79	Both hypertension and T2DM are associated with obesity [11 12]. Obesity is often measured
22 23 24 25 26 27 28 29 30 31 32 33 34 35 36	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/m ² [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],
37 38 39	87	changes in WC, and thus central obesity, are not well described.
40 41	88	In this study, we took advantage of the data from population based cross-sectional surveys
42 43	89	conducted in Shanghai in 2002-03 and in 2009. We used the data from the two surveys to evaluate
44 45	90	correlations between shifts in BMI and WC with the prevalence of hypertension and T2DM in
46 47	91	Chinese adults. Our results may help to better understand the contribution of overall obesity and
48 49 50	92	central obesity in the increasing burden of chronic disease in China.
50 51 52		
52 53	93	Materials and Methods

Study Participants

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

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

The 2009 survey used the similar sampling method except that only 7 communities and villages were randomly selected in the third stage of sampling. The inclusion and exclusion criteria of the 2009 survey were also similar to those for the 2002-03 survey, except that only those at the age of 35-74 years old were eligible for the 2009 survey. Among 7,627 eligible adults contacted during the period of May-July 2009, 7,414 (97.21%) were interviewed and donated blood samples. To make the two surveys comparable, we excluded 1,071 subjects younger than 35 years from the 2002-03 survey. After further excluding subjects with missing information, the final analysis included 5,050 men and 7,279 women in the 2002-03 survey and 3,461 men and 3,962 women in the 2009 survey. The Institutional Review Board at Shanghai Municipal Center of Disease Control and Prevention approved the study. Informed consent was obtained from each participant before data collection and laboratory measurements.

117 Data Collection

A similar survey approach was followed by the two investigations. In both surveys, information on demographic and socioeconomic factors, diagnosis of diabetes, tobacco and alcohol use, physical activity and family history of diabetes was collected by trained interviewers with a structured questionnaire at community clinics located in the residential areas of the participants. At the interview, each participant's blood pressure, body weight, standing height, and waist

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circumference (WC) were measured by trained staff. Blood pressure was measured on the right arm in the sitting position using standard mercury sphygmomanometer after at least 5 minutes of rest. The first and fifth Korotkoff sounds were recorded. Body weight and height were recorded while the subject was in light clothing and without shoes. Body weight was measured with electronic scales to the nearest 0.1 kg. Body height was measured to the nearest 0.1 cm by using a stadiometer. WC, recorded to the nearest 0.1 cm, was taken with a cloth tape and was measured on bare skin at the midline between the lower border of the ribs and the iliac crest in the horizontal plane after a normal expiration. Two measurements were taken and the mean of the replicates was used in the following analyses. Body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared (kg/m^2) using the direct measurements.

133 Laboratory Measurements

After at least 10 hours of overnight fasting, 1-1.5 ml venous blood specimen was collected in a vacuum tube containing sodium fluoride. All participants with no history of diabetes and having a fasting plasma glucose level of < 7.0 mmol per liter (mmol/l) were then asked to have an oral glucose-tolerance test (OGTT). Blood samples were drawn at 0 and 120 minutes after a standard 75 gram glucose load. Plasma glucose was measured with Glucose oxidase-peroxidase (GOD-PAP) method.

140 Diagnosis of T2DM and Hypertension

Previously diagnosed T2DM and hypertension was identified by a positive response from the participant to the question of "Have you ever diagnosed with T2DM/hypertension by a doctor?" and confirmed by medical records in which prescriptions of anti-hypertensive or hypoglycemic medications were presented. The consistent rate was 100%. For those who had a negative response, the T2DM was diagnosed with measured glucose level by using the 1999 World Health Organization diagnostic criteria [Department of Noncommunicable Disease Surveillance. Definition, diagnosis and classification of diabetes mellitus and its complications: report of a WHO consultation. Part 1. Diagnosis and classification of diabetes mellitus. Geneva: World Health

149 Organization, 1999. (Accessed July 5, 2010, at_

150http://www.staff.ncl.ac.uk/philip.home/who_dmg.pdf] and hypertension referred to the subjects151with measured systolic blood pressure (SBP) \geq 140 mmHg or diastolic blood pressure (DBP) \geq 90152mmHg and confirmed by clinical visits. Total T2DM and hypertension included both previously153diagnosed and newly-diagnosed patients. 42.7% (1,110 of 2,598) diabetic patients and 10.3% (694154of 6,735) hypertensive patients were newly-diagnosed in the two surveys.

155 Statistical Analysis

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

Results

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

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level of education, higher level of income per capita, more prior history of T2DM, higher frequency
of alcohol drinking and lower frequency of leisure time activity, and were more likely to have a
family history of diabetes.

Figure 1 shows the shapes of the BMI and WC distribution curves among men and women changed over the period of the two surveys. After adjusting for age, education, per capita income, resident site, smoking, drinking, regular exercise, and family history of T2DM, the curves of BMI were almost overlapped in both men and women. However, the WC curves for men and women were shifted to the right between 2002-03 and 2009, with the mean WC increasing from 83.6 to 85.3 cm for men and from 78.4 to 80.6 cm for women.

As presented in table 2, the prevalence of obesity, both overall and central, increased with increasing age groups. While the prevalence of overall obesity (BMI $\ge 28 \text{ kg/m}^2$) did not change between two surveys (all P values > 0.05), the prevalence of central obesity was significantly higher in 2009 survey in each age group (all P values < 0.001). A more pronounced increase in the prevalence of central obesity and T2DM was observed among subjects aged 45-49 years old in both men and women; whereas the change in the prevalence of hypertension between two surveys appeared more evident in older men and younger women over the period. Using the World Health Organization (WHO) criteria for obesity did not change the results substantially (data not shown in the tables).

BMI and WC were highly correlated with each other, with a correlation coefficient of 0.77 (P <(0.0001) among men and (0.78) ($P \le 0.0001$) among women after adjusting for age. Therefore, the residual method was used to test the potential respective non-linear relationships of BMI and WC with the risk of T2DM and hypertension (Figure 2). The dose-response analysis likewise showed a statistically significant increased risk of T2DM at high level of WC and a significant elevated risk of hypertension at high level of BMI in both men and women after adjusting for age, education, per capita income, resident site, smoking, alcohol consumption, regular exercise, family history of T2DM and phase of surveys, with P values for non-linear relationship tests < 0.05. No significant

relationship was observed between BMI and T2DM in men and between WC and hypertension in women. As shown in table 3, in both sexes, BMI adjusted for WC (residuals) appeared more strongly associated with hypertension while WC adjusted for BMI (residuals) was more evidently related with T2DM. Comparing with the lowest quartile of BMI residuals, the risk of hypertension increased 85% (95%CI: 1.59-2.15) in men and 1.23-fold (95%CI: 1.94-2.57) in women, whereas the risk of T2DM did not increase significantly in both sexes. On the other hand, the ORs of the highest versus the lowest quartile WC residuals for T2DM were 1.75 (95%CI: 1.33-2.30) in men 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 1.13 (95%CI: 0.98-1.30) in women for hypertension. We further evaluated the potential joint effect of BMI and WC on T2DM and hypertension (table 4). The participants were classified into normal weight (BMI 18.5-23.9 kg/m²), overweight $(24.0-27.9 \text{ kg/m}^2)$, or obese ($\geq 28 \text{ kg/m}^2$) based on data from Chinese adults, and were defined as with normal or increased WC using sex-specific cut-offs (85 cm in men and 80 cm in women) [19]. The risk of T2DM and hypertension increased across groups defined by BMI and WC, with the highest risk observed among men with the lowest BMI but a higher WC, and among those with the highest BMI and a higher WC for hypertension. However, no significant interaction was observed between BMI and WC (all *P* values for interaction tests > 0.05).

Discussion

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

8 <u>226</u>

Chinese adults have lower rates of overweight and obesity than their Western counterparts

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227	using the WHO criteria (BMI \ge 25 kg/m ² for overweight and BMI \ge 30 kg/m ² for obesity) [15 16].
228	Nevertheless, increasing trends of BMI in Chinese adults have been well documented [18 20]. In
229	two national nutritional surveys undertaken in 1982 and 1992 in China, the prevalence of
230	overweight/obesity (BMI \ge 25 kg/m ²) in subjects 20-70 years of age was 10% and 15%,
231	respectively. Between 1992 and 2002, the combined prevalence of overweight and obesity increased
232	from 14.6 to 21.8% [21]. Interestingly, the increase in BMI among Chinese adults has slowed down
233	during past decades [2]. In this study, we did not observe an increase in BMI and prevalence of
234	obesity defined by the Chinese obesity standards or by WHO criteria (data not shown). Instead, we
235	observed a significant increase in WC, a measure of central obesity between surveys. Our
236	observation of increased WC in Chinese adults, without a concomitant increase in BMI, represents
237	an increasing burden of central obesity in this population. The increase in central obesity indicates
238	an upward trend in body fat percentages in the population who have been previously observed with
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	
244	reflects specific accumulation of visceral adipose tissue. Excess visceral adipose tissue is
244 245	reflects specific accumulation of visceral adipose tissue. Excess visceral adipose tissue is metabolically unfavorable due to productions of free fatty acids and inflammatory mediators.
245	metabolically unfavorable due to productions of free fatty acids and inflammatory mediators.
245 246	metabolically unfavorable due to productions of free fatty acids and inflammatory mediators. Overall obesity, on the other hand, represents a greater overall physiologic strain and effects
245 246 247	metabolically unfavorable due to productions of free fatty acids and inflammatory mediators. Overall obesity, on the other hand, represents a greater overall physiologic strain and effects vascular and cardiac parameters more significantly. In this study, we observed a significant increase
245 246 247 248	metabolically unfavorable due to productions of free fatty acids and inflammatory mediators. Overall obesity, on the other hand, represents a greater overall physiologic strain and effects vascular and cardiac parameters more significantly. In this study, we observed a significant increase in prevalence of T2DM regardless of gender or age groups, which was more pronounced than the
245 246 247 248 249	metabolically unfavorable due to productions of free fatty acids and inflammatory mediators. Overall obesity, on the other hand, represents a greater overall physiologic strain and effects vascular and cardiac parameters more significantly. In this study, we observed a significant increase in prevalence of T2DM regardless of gender or age groups, which was more pronounced than the change in the prevalence of hypertension during the period of 2002-03 and 2009. We also observed
 245 246 247 248 249 250 	metabolically unfavorable due to productions of free fatty acids and inflammatory mediators. Overall obesity, on the other hand, represents a greater overall physiologic strain and effects vascular and cardiac parameters more significantly. In this study, we observed a significant increase in prevalence of T2DM regardless of gender or age groups, which was more pronounced than the change in the prevalence of hypertension during the period of 2002-03 and 2009. We also observed a closer association of central obesity with the prevalence of T2DM than with the prevalence of

however, our study was unable to make a causal inference. 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 changes in general population over time. However, selection bias could not be excluded. There are several strengths in this study, including the strict process of multistage sampling in adult population in Shanghai, anthropometric measurement according to a standardized protocol and fasting and postprandial blood glucose tests for the participants. Conclusions

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

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272 Footnotes

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17 17 18 19 20 21 22 3 24 25 26 27 28 9 0 31 23 34 35 37 38 9 40 41 23 44 56 7 28 9 0 31 23 34 35 37 89 40 41 24 34 45 67 56 7 55 57 55 57 58 59	285	Conflict of Interest: None declared.

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 population-based surveys

 Figure 2. Non-linear dose-response relationship of BMI and WC with hypertension and T2DM
- among participants of the two population-based surveys

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		1 st su	rvey	2 ⁿ	^d survey	P-value between surveys		
	Characteristics	Men (N=5,050)	Women (N=7,279)	Men (N=3,461)	Women (N=3,962)	In men	In women	
	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			
	Colleague 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	^{<i>a</i>} <i>P</i> for Wilcoxon tests or chi-square	e tests		C	2			

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



	No. of subjects			l Obesity			al obesity	APC	Hypertension		APC			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

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

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

Shanghai, China

	No. of subjects with	Тур	e 2 diabetes only	Hy	pertension only	Both		
	neither diseases	Ν	OR (95%CI)	Ν	OR (95%CI)	Ν	OR (95%CI)	
BMI resid	uals							
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)	
	P for trend		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)	
-	P for trend		0.4864		< 0.0001		0.0067	
All subject	cts							
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)	
	P for trend		0.2280		<0.0001		<0.0001	
	·							
WC residu	uals							
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)	
-	P for trend		<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)	
$\tilde{Q3}$	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</i> for trend	171	<0.0001	, 02	0.0216	557	<0.0001	
All subject			0.0001		0.0210		0.0001	
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)	
Q2 Q3	2838	301	1.66 (1.16, 2.36)	1373	1.12 (1.01, 1.23)	412	1.55(1.29, 1.87)	
Q3 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</i> for trend	517	0.0001	1012	0.0021	000	<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.

		WC: Lower		WC: Higher			OR (95%CI) fo	or hypertension	OR (95%CI) for type 2 diabetes		
BMI	No. of	Hypertension	Diabetes	No. of	Hypertension	Diabetes	WC: Lower	WC: Higher	WC: Lower	WC: Higher	
	subjects	N (%)	N (%)	subjects	N (%)	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)	
					P fo	r interaction	0.0	711	0.0	933	
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)	
					P fo	r interaction	0.3	524	0.4	011	
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)	
					P fo	r interaction	0.0	562	0.0	798	

2 Higher WC defined as \geq 85 cm for men and \geq 80 cm for women 3 OR: Adjusted for age (continuous variable), education (no forma

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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