Observational Study

Journal of INTERNATIONAL MEDICAL RESEARCH

Journal of International Medical Research
2025, Vol. 53(6) 1–11

DOI: 10.1177/03000605251348229
journals.sagepub.com/home/imr
Sage

Association between long-term changes in obesity-related anthropometric indicators and the risk of type 2 diabetes mellitus in the older population

Xiaomin Xu[1], Lirong Li[1], Fengmei Chen[2] and Zhirong Guo[3]

Abstract

Objective: To investigate the association of long-term changes in body mass index, waist circumference, and waist-to-height ratio with the risk of type 2 diabetes mellitus in the older population.

Methods: We conducted a prospective cohort study in Jiangsu Province, China. Data from 593 participants who were aged ≥60 years were analyzed. The hazard ratios and 95% confidence intervals were estimated using the Cox proportional hazards model.

Results: Over a median follow-up period of 5.08 years, 70 participants (11.80%) developed type 2 diabetes mellitus. Compared with participants with persistently normal body mass index, waist circumference, and waist-to-height ratio, those in whom these parameters changed from normal to abnormal and those in whom these parameters were persistently abnormal had a significantly higher risk of type 2 diabetes mellitus, with adjusted hazard ratios of 2.11 (95% confidence interval: 1.05–4.26) and 2.37 (95% confidence interval: 1.21–4.63) for body mass index, 2.75 (95% confidence interval: 1.16–6.51) and 2.32 (95% confidence interval: 1.29–4.16) for waist circumference, and 2.24 (95% confidence interval: 1.14–5.91) and 4.11 (95% confidence interval: 2.21–7.68) for waist-to-height ratio, respectively.

[1]Department of Clinical Medicine, Suzhou Vocational Health College, China
[2]Department of Public Health, Suzhou Vocational Health College, China
[3]Department of Epidemiology, School of Public Health, Soochow University, China

Corresponding author:
Fengmei Chen, Department of Public Health, Suzhou Vocational Health College, Suzhou, 215009 Jiangsu, China, No. 28 Kehua Road, High-tech Zone, Suzhou City, Jiangsu Province, China.
Email: fmChen06@163.com

Conclusion: Long-term changes in obesity-related anthropometric indicators are strongly associated with the risk of type 2 diabetes mellitus in the older population.

Keywords
Obesity, body mass index, waist circumference, waist-to-height ratio, type 2 diabetes mellitus, older population

Date received: 4 February 2025; accepted: 21 May 2025

Introduction

Diabetes is a leading cause of disability and premature death, affecting people regardless of nation of residence, age, and sex.[1] In 2021, the prevalence of diabetes was 10.5% worldwide (536.6 million), and by 2045, it is expected to increase to 12.2% (783.2 million).[2] The prevalence of diabetes in China has significantly increased over the past few decades, rising from less than 1% in the 1980s to 12.4% in 2018.[3] China is one of the fastest-aging countries in the world.[4] According to data from the seventh national census in China, people aged ≥60 years constituted 18.7% (260.4 million) of the overall population in 2020. Thirty percent of them had diabetes (78.13 million, with over 95% of them having type 2 diabetes mellitus (T2DM)). Complications caused by poor blood glucose control are the main risk factors that threaten healthy survival of older adults. Therefore, one of the main initiatives of Healthy China (2019–2030) has been the prevention and treatment of diabetes.[5]

Overweight and obesity have grown to be serious public health concerns in China.[6] According to the most recent National Physical Fitness Monitoring Bulletin, based on the Chinese criteria, the prevalence of overweight and obesity was 41.7% and 16.7%, respectively, in individuals aged ≥60 years in 2020. Body mass index (BMI) has been used to assess general obesity, while waist circumference (WC) and waist-to-height ratio (WHtR) are used to identify abdominal obesity in populations.[7,8] Some studies have indicated that when assessing the impact of excess fat, long-term changes in weight/WC may be better indicators than baseline BMI/WC.[9,10] A prospective cohort study conducted in the UK demonstrated that over a mean follow-up period of 12 years, participants with weight gain >10% had a 1.61-fold higher risk of T2DM than those with stable weight, while those with weight loss ≥4% were at a lower risk.[11] A recent 10-year prospective cohort study conducted in Southwest China found that changes in weight and WC were both significantly associated with an increased risk of T2DM. Compared to participants with stable WC from baseline to follow-up, those with WC gain ≥9 cm had a 1.61-fold increased risk of T2DM, while those with WC loss >3 cm had a 30% decreased risk.[12] However, throughout a 3-year follow-up period, Biggs et al.[13] found no association of weight loss with a lower risk of T2DM. Tatsumi et al.[14] similarly found that WC loss was not associated with a decreased risk of T2DM. These studies, however, did not examine the effects of long-term changes in WHtR on the risk of diabetes and did not focus on the older population. Additionally, there may be racial and ethnic differences in the relationship between changes in obesity-related anthropometric indicators and the risk of T2DM.[15]

Therefore, based on the Prevention of Metabolic Syndrome and Multi-metabolic Disorders in Jiangsu Province of China, we investigated the relationship of long-term changes in BMI, WC, and WHtR with the risk of T2DM in individuals aged ≥60 years in China.

Methods

Study design and participants

The data used in this study were collected from a prospective cohort study called the Prevention of Metabolic Syndrome and Multi-metabolic Disorders in Jiangsu Province of China. Previous reports have revealed the study's thorough design.[16,17] The baseline survey was carried out from 2000 to 2004 on 5888 participants aged 35–74 years. During the final follow-up survey that was conducted from 2006 to 2008, 4582 participants from the baseline cohort who had been followed up for at least 5 years were contacted again. Finally, 4083 participants completed the final follow-up survey. The following were the inclusion criteria for this study: (a) age ≥60 years at baseline; (b) absence of diabetes, cardiovascular disease, and cancer; (c) BMI $\geq$18.5 kg/m^2; and (d) completion of the survey from baseline to final follow-up.

The reporting of this study conforms to the Strengthening the Reporting of Observational studies in Epidemiology (STROBE) statement.[18] No identifiable patient information was used in the study, and all participant details were completely de-identified before the analyses. This study was carried out in accordance with the Helsinki Declaration of 1975, as revised in 2024. Ethical approval was obtained from the Institutional Review Board of Suzhou Vocational Health College (Approval Number: SWYXLL202209, 8/12/2022, Suzhou, Jiangsu, China). Before data collection, an informed consent form was signed by each participant.

Data collection

General and clinical information of the participants was collected at baseline and at the time of follow-up. Face-to-face interviews were conducted by professional investigators using a standardized questionnaire to collect general information about age, sex, smoking pattern, alcohol consumption, diet style, physical activity, and family history of diabetes. Clinical information, including laboratory examinations, anthropometric measurements, and self-reported disease history, was obtained from the participants. Blood samples were obtained from the participants to test their fasting plasma glucose (FPG) level after an 8-h fast. A fully automated electronic blood pressure monitor was used to measure the participants' blood pressure in the right arm. Before having their blood pressure measured, the participants were required to sit still and rest in a quiet place for at least 10 min. Blood pressure was measured twice, separated by approximately 1 min. A third measurement of blood pressure was taken when the two measurements differed by more than 5 mmHg. The final result was the average value of the measurements. The participants were asked to remove their shoes and wear light clothing for the measurement of height and weight. Their height and weight were recorded to the closest 0.1 cm and 0.1 kg, respectively. BMI was calculated by dividing the weight in kilograms by the square of height in meters. WC was measured at the midpoint of the distance between the lowest coastal ridge and the upper border of the iliac crest to the closest 0.1 cm. By dividing the WC by height, the WHtR was determined. The cutoff values of WC for abdominal obesity were 90 cm in men and 80 cm in women. BMI $\geq$24 kg/m^2 indicated overweight and general obesity; a WHtR

>0.5 indicated abdominal obesity.[19] The participants were divided into four groups for further analyses based on the changes in their parameters (BMI/WC/WHtR) at baseline and the final follow-up. The changes were categorized as follows: persistently normal (normal BMI/WC/WHtR at baseline and final follow-up), abnormal to normal (abnormal BMI/WC/WHtR at baseline and normal BMI/WC/WHtR at final follow-up), normal to abnormal (normal BMI/WC/WHtR at baseline and abnormal BMI/WC/WHtR at final follow-up), and persistently abnormal (abnormal BMI/WC/WHtR at baseline and final follow-up).

Definition of T2DM

A diagnosis of T2DM was made for participants with an FPG level $\geq$7.0 mmol/L or those with a self-reported history of T2DM (using insulin or oral hypoglycemic medications).[20]

Statistical analyses

All statistical analyses were performed using the Statistical Package for Social Sciences (SPSS) 26.0 software (SPSS Inc., Chicago, USA). Continuous variables were summarized as means and standard deviations (SDs), and the differences between the groups were compared using Student's t-test or analysis of variance. Categorical variables were summarized as numbers and percentages, and the differences between the groups were compared using the chi-square test. The Cox proportional hazard model was used to assess the effect of different changes in BMI/WC/WHtR on the incidence of T2DM. The hazard ratios (HRs) and 95% confidence intervals (CIs) in two models were calculated. Model 1 was unadjusted, whereas Model 2 was adjusted for age, sex, smoking, alcohol consumption, diet style, physical activity, and family history of diabetes. Receiver operating characteristic (ROC) curves were created to compare the predictive values of BMI, WC, and WHtR for T2DM as measured by the area under the curve (AUC). The Youden index (sensitivity + specificity − 1) was used to determine the optimal cutoff point of each index. The Z test was used to compare the differences between two AUCs. A p-value of $<$0.05 was regarded as statistically significant.

Results

Characteristics of the participants and FPG at the final follow-up

In total, 593 participants (248 males and 345 females) were included in this study. Their mean (SD) age was 66.16 (5.02) years. Over a median follow-up period of 5.08 years, 70 participants (11.80%) developed T2DM. The incidence of T2DM was 15.73% (39 participants) in males and 8.99% (31 subjects) in females ($p = 0.012$). Table 1 shows the FPG levels at the final follow-up according to different characteristics. The FPG levels of the participants varied under four different change categories in BMI/WC/WHtR from baseline to final follow-up (all $p < 0.05$).

Associations of long-term changes in BMI/WC/WHtR with the risk of T2DM

Compared to participants with persistently normal BMI, those whose BMI changed from normal to abnormal and those with persistently abnormal BMI had a significantly higher risk of T2DM, with adjusted HRs of 2.11 (95% CI: 1.05–4.26) and 2.37 (95% CI: 1.21–4.63), respectively. Similarly, compared to participants with persistently normal WC, those whose WC changed from normal to abnormal and those with persistently abnormal WC had a 2.75-fold (95% CI: 1.16–6.51) and 2.32-fold (95% CI: 1.29–4.16) higher risk of T2DM,

Table 1. FPG at the final follow-up according to different characteristics.

Characteristics	N	FPG (mmol/L)	
		Mean ± SD	p
Age (years)			
66.16 ± 5.02	593	4.91 ± 1.28	
Sex			0.376
Male	248	4.97 ± 1.53	
Female	345	4.87 ± 1.07	
Current smoking[a]			0.391
Yes	118	4.82 ± 1.56	
No	475	4.92 ± 1.25	
Alcohol consumption[b]			0.502
Yes	483	4.99 ± 1.49	
No	110	4.90 ± 1.28	
Physical activity[c]			0.115
Light	471	5.12 ± 1.68	
Medium	90	4.97 ± 1.21	
Heavy	32	4.76 ± 1.32	
Diet style[d]			0.475
High-fiber diet	122	4.90 ± 1.30	
Low-fiber diet	471	5.05 ± 0.98	
Family history of diabetes			0.221
Yes	35	5.12 ± 1.34	
No	558	4.86 ± 1.21	
Changes in BMI between baseline and final follow-up			0.002
Persistently normal	359	4.84 ± 1.63	
Abnormal to normal	50	4.81 ± 1.00	
Normal to abnormal	47	5.36 ± 1.30	
Persistently abnormal	137	5.38 ± 1.77	
Changes in WC between baseline and final follow-up			0.010
Persistently normal	433	4.88 ± 1.21	
Abnormal to normal	27	4.71 ± 1.11	
Normal to abnormal	47	5.20 ± 1.13	
Persistently abnormal	86	5.54 ± 2.46	
Changes in WHtR between baseline and final follow-up			0.011
Persistently normal	245	4.88 ± 1.21	
Abnormal to normal	49	4.84 ± 0.91	
Normal to abnormal	76	5.16 ± 1.13	
Persistently abnormal	223	5.32 ± 1.65	

FPG: fasting plasma glucose; BMI: body mass index; WC: waist circumference; WHtR: waist-to-height ratio; SD: standard deviation.
[a]Current smoking: smoking at least 100 cigarettes and continuing to smoke at the time of the interview.
[b]Alcohol consumption: drinking more than 12 times per year.
[c]Physical activity: light refers to work with a sitting position as the primary task; medium refers to work that requires standing and walking; heavy refers to work that relies mostly on walking or physical labor.
[d]Diet style: a high-fiber diet indicates higher than the standard for the dietary pyramid, and a low-fiber diet indicates lower than the standard.

respectively; compared to participants with persistently normal WHtR, those whose WHtR changed from normal to abnormal and those with persistently abnormal WHtR had a 2.24-fold (95% CI: 1.14–5.91) and 4.11-fold (95% CI: 2.21–7.68) higher risk of T2DM, respectively (Table 2).

ROC curve analysis of BMI, WC, and WHtR in predicting T2DM

Table 3 and Figure 1 show the AUCs and optimal cutoff points of BMI, WC, and WHtR in predicting T2DM. BMI (cutoff point: 25.3 kg/m^2), WC (cutoff point: 78.9 cm), and WHtR (cutoff point: 0.48) all demonstrated certain predictive values for T2DM. The AUC of WC (AUC = 0.688, 95% CI: 0.620–0.755) was the largest of them, followed by that of WHtR (AUC = 0.667, 95% CI: 0.598–0.736) and BMI (AUC = 0.626, 95% CI: 0.552–0.700).

Discussion

Based on a 5-year prospective cohort study conducted in Jiangsu Province of China, we found a significant relationship between the long-term changes in obesity-related anthropometric indicators and the risk of T2DM in the older population.

Overweight and obesity account for approximately 80%–90% of all T2DM cases and are important obstacles to the successful long-term management of T2DM.[21] A meta-analysis of 84 studies involving more than 2.69 million participants from 20 countries found that overweight/obesity is associated with a 1.24-fold higher risk of prediabetes, and overweight and obesity result in a 2.24-fold and 4.56-fold higher risk of T2DM, respectively.[22] Several studies have linked long-term changes in obesity-related anthropometric indicators with the risk of T2DM; however, their findings

Table 2. Associations of long-term changes in BMI, WC, and WHtR with the risk of T2DM.

	Cox proportional hazard model					
	Model 1			Model 2		
Variables (N)	HR	95% CI	p	HR	95% CI	p
Changes in BMI between baseline and final follow-up						
Persistently normal (359)	1			1		
Abnormal to normal (50)	1.91	0.86–4.25	0.351	1.28	0.58–3.17	0.551
Normal to abnormal (47)	2.49	1.25–5.39	0.015	2.11	1.05–4.26	0.036
Persistently abnormal (137)	3.39	1.98–5.79	<0.001	2.37	1.21–4.63	0.012
Changes in WC between baseline and final follow-up						
Persistently normal (433)	1			1		
Abnormal to normal (27)	1.34	0.56–5.38	0.129	1.75	0.75–3.87	0.141
Normal to abnormal (47)	2.52	1.21–5.25	0.014	2.75	1.16–6.51	0.016
Persistently abnormal (86)	2.95	1.61–5.41	<0.001	2.32	1.29–4.16	0.004
Changes in WHtR between baseline and final follow-up						
Persistently normal (245)	1			1		
Abnormal to normal (49)	1.99	0.59–5.05	0.244	1.13	0.49–2.61	0.770
Normal to abnormal (76)	2.48	1.08–6.28	0.012	2.24	1.14–5.91	0.017
Persistently abnormal (223)	5.67	2.99–10.76	<0.001	4.11	2.21–7.68	<0.001

BMI: body mass index; WC: waist circumference; WHtR: waist-to-height ratio; T2DM: type 2 diabetes mellitus; HR: hazard ratio; CI: confidence interval.
Model 1: unadjusted.
Model 2: adjusted for age, sex, smoking, alcohol consumption, diet style, physical activity, and family history of diabetes.

Table 3. AUCs and optimal cutoff points of BMI, WC, and WHtR in predicting T2DM.

Parameters	AUC (95% CI)	Cutoff point	Youden index	Sensitivity	Specificity
BMI	0.626 (0.552–0.700)	25.3	0.226	0.400	0.826
WC	0.688 (0.620–0.755)*	78.9	0.367	0.757	0.610
WHtR	0.667 (0.598–0.736)	0.48	0.298	0.814	0.484

AUC: area under the curve; BMI: body mass index; WC: waist circumference; WHtR: waist-to-height ratio; T2DM: type 2 diabetes mellitus; CI: confidence interval.
*: $Z = 1.991$, $p = 0.046$, compared to BMI.

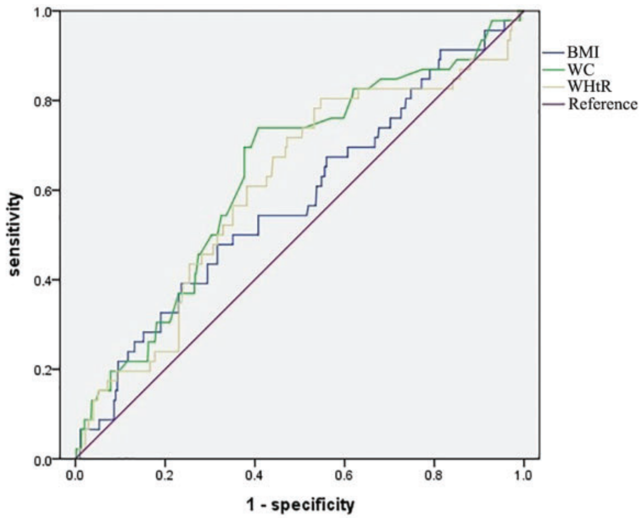

Figure 1. ROC curves of BMI, WC, and WHtR in predicting T2DM. ROC: receiver operating characteristic; BMI: body mass index; WC: waist circumference; WHtR: waist-to-height ratio; T2DM: type 2 diabetes mellitus.

are inconsistent.[11–14] In the current study, compared to participants with persistently normal BMI/WC/WHtR, those whose BMI/WC/WHtR changed from normal to abnormal had a significantly increased risk of T2DM, consistent with previous studies.[11,12] These findings confirm that changes in obesity-related anthropometric indicators are significant predictors of T2DM. The underlying mechanism could be that the changes in BMI, WC, and WHtR reflect an increase in adipose tissue, which is associated with increased cytokine production and insulin resistance.[23] Furthermore, we found that participants with persistently abnormal BMI/WC/WHtR had a significantly higher risk of T2DM than those with persistently normal BMI/WC/WHtR. Fan et al.[24] found that even overweight or obese individuals with stable weight had a higher risk of T2DM than normal-weight individuals. Thus, maintaining weight or WC alone is insufficient to lower the risk of diabetes in overweight or obese individuals; however, a significant, sustained, and deliberate reduction in weight or WC may be beneficial.[25]

Whether WC or WHtR is a better predictor of T2DM remains debatable. The results of a systematic review of 78 studies and a meta-analysis of 15 studies showed that WC and WHtR are both better predictors of diabetes than BMI.[26,27] The Guangzhou Biobank Cohort Study (GBCS) found that abdominal obesity was more strongly associated with incident diabetes than general obesity.[28] In line with the GBCS findings, our results showed that WC was a superior predictor of T2DM than BMI in our study population (aged ≥60 years) ($p < 0.05$). This could be because WC is more closely associated with visceral fat distribution, which is strongly linked to insulin resistance. Excess visceral fat leads to visceral fat inflammation, a major contributor to the development of insulin resistance and T2DM.[29] A large prospective cohort study based on the Women's Health Initiative found that WC had the strongest association out of all the assessed parameters with the risk of diabetes in postmenopausal women of all racial and ethnic groups, especially Asian women.[15] However, the WC threshold is not uniformly defined, and it should be established based on ethnic and racial backgrounds.[30] According to previous studies, the optimal range of WC in Chinese adults is 85–90 cm for men and 80–85 cm for women.[31,32] In a study of 44,048 Chinese participants, the optimal cutoff point of WC for hyperglycemia was 80.4 cm, with a sensitivity of 60% and a specificity of 46%.[33] Our study suggested that the optimal cutoff point of WC for predicting T2DM was 78.9 cm, with a sensitivity of 75.7% and a specificity of 61.0%. A large-scale cross-sectional study of 13,275 Han adults showed that the optimal cutoff points of WC for hyperglycemia were 90.5 and 78.5 cm in men and women, respectively.[8] The reason for the slight discrepancy in the cutoff points may be the difference between demographic characteristics and diagnostic criteria.

To the best of our knowledge, this is the first report on the association of long-term changes in BMI, WC, and WHtR with the risk of T2DM in older adults (age ≥60 years) in China. We used data from the Prevention of Metabolic Syndrome and Multi-metabolic Disorders in Jiangsu Province of China; thus, our study had a long follow-up period and relatively low follow-up loss of participants; further, the data we used were obtained through standardized measurements rather than self-reported by the participants, making the results of this study more reliable. However, this study has certain limitations. First, the FPG levels and associated medical history were used to diagnose new-onset T2DM, which may have underestimated the incidence of T2DM. Second, we merged overweight and general obesity into a category called "abnormal BMI" because of the relatively low prevalence of obesity (based on BMI values) at baseline and follow-up. As a result, our study was unable to differentiate between the effects of overweight and obesity on the risk of T2DM in the study population. Third, we adjusted for the primary confounding factors in the statistical analyses, there may still be some confounding factors that were not considered in this study and may have affected the results. The application of the findings is limited to older populations. Further large-scale prospective studies and meta-analyses are needed to investigate the potential differences between different populations and more comprehensively determine the relationship between long-term changes in various obesity-related anthropometric indicators and the risk of T2DM.

Conclusion

Long-term changes in obesity-related anthropometric indicators, from normal to abnormal and persistently abnormal, are strongly associated with an increased risk of T2DM in older individuals. Prevention of overweight and obesity may reduce the incidence of T2DM, and efforts should be made to improve older adults' knowledge about importance and methods of weight control and WC reduction.

Acknowledgements

This study used data from the Prevention of Metabolic Syndrome and Multi-metabolic Disorders in Jiangsu Province of China. We thank all the participants and staff of the study.

Author contributions

Fengmei Chen and Zhirong Guo designed the study and contributed the original data. Xiaomin Xu conducted the statistical analyses and prepared the initial draft of the manuscript. Lirong Li conducted the literature review and helped in writing the manuscript. The final version of the manuscript has been read and approved by all authors.

Data availability statement

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Declaration of conflicting interests

The authors declare that there is no conflict of interest.

Funding

This work was supported by the Suzhou Basic Research Program (Medical Application Basic Research) Project (SKYD2023098), the Science and Technology Innovation Team of Suzhou Vocational Health College (SZWZYTD202202), the Medical Research Project of Jiangsu Commission of Health (Ym2023056), the Research Project of Suzhou Vocational Health College (SZWZY202203), and Jiangsu Province Engineering Research Center of Development and Translation of Key Technologies for Chronic Disease Prevention and Control.

ORCID iD

Fengmei Chen https://orcid.org/0009-0000-4454-3881

References

1. Wang B, Fu Y, Tan X, et al. Assessing the impact of type 2 diabetes on mortality and life expectancy according to the number of risk factor targets achieved: an observational study. *BMC Med* 2024; 22: 114.
2. Sun H, Saeedi P, Karuranga S, et al. IDF diabetes atlas: global, regional and country-level diabetes prevalence estimates for 2021 and projections for 2045. *Diabetes Res Clin Pract* 2022; 183: 109119.
3. Wang L, Peng W, Zhao Z, et al. Prevalence and treatment of diabetes in China, 2013–2018. *JAMA* 2021; 326: 2498–2506.
4. Hao X, Yang Y, Gao X, et al. Evaluating the effectiveness of the health management program for the elderly on health-related quality of life among elderly people in China: findings from the China Health and Retirement Longitudinal Study. *Int J Environ Res Public Health* 2019; 16: 113.
5. Chinese Elderly Type 2 Diabetes Prevention and Treatment of Clinical Guidelines Writing Group, Geriatric Endocrinology and Metabolism Branch of Chinese Geriatric Society, Geriatric Endocrinology and Metabolism Branch of Chinese Geriatric Health Care Society, et al. [Clinical guidelines for prevention and treatment of type 2 diabetes mellitus in the elderly in China (2022 edition)]. *Zhonghua Nei ke za Zhi* 2022; 61: 12–50.
6. Pan XF, Wang L and Pan A. Epidemiology and determinants of obesity in China. *Lancet Diabetes Endocrinol* 2021; 9: 373–392.
7. Ortega FB, Sui X, Lavie CJ, et al. Body mass index, the most widely used but also widely criticized index: would a criterion standard measure of total body fat be a better predictor of cardiovascular disease mortality? *Mayo Clin Proc* 2016; 91: 443–455.
8. Dong J, Ni YQ, Chu X, et al. Association between the abdominal obesity anthropometric indicators and metabolic disorders in a Chinese population. *Public Health* 2016; 131: 3–10.
9. Wang Y, Li F, Chu C, et al. Early life body mass index trajectories and albuminuria in

midlife: a 30-year prospective cohort study. *EClinicalMedicine* 2022; 48: 101420.
10. Zheng Y, Manson JE, Yuan C, et al. Associations of weight gain from early to middle adulthood with major health outcomes later in life. *JAMA* 2017; 318: 255–269.
11. Wannamethee SG and Shaper AG. Weight change and duration of overweight and obesity in the incidence of type 2 diabetes. *Diabetes Care* 1999; 22: 1266–1272.
12. Chen Y, Wang Y, Xu K, et al. Adiposity and long-term adiposity change are associated with incident diabetes: a prospective cohort study in southwest China. *Int J Environ Res Public Health* 2021; 18: 11481.
13. Biggs ML, Mukamal KJ, Luchsinger JA, et al. Association between adiposity in midlife and older age and risk of diabetes in older adults. *JAMA* 2010; 303: 2504–2512.
14. Tatsumi Y, Watanabe M, Nakai M, et al. Changes in waist circumference and the incidence of type 2 diabetes in community-dwelling men and women: the Suita study. *J Epidemiol* 2015; 25: 489–495.
15. Luo J, Hendryx M, Laddu D, et al. Racial and ethnic differences in anthropometric measures as risk factors for diabetes. *Diabetes Care* 2019; 42: 126–133.
16. Luo WS, Chen F, Ji JM, et al. Interaction of tobacco smoking and alcohol consumption with obesity on cardiovascular disease in a Chinese cohort. *Coron Artery Dis* 2020; 31: 372–377.
17. Liu SJ, Guo ZR, Hu XS, et al. Risks for type-2 diabetes associated with the metabolic syndrome and the interaction between impaired fasting glucose and other components of metabolic syndrome the study from Jiangsu, China of 5 years follow-up. *Diabetes Res Clin Pract* 2008; 81: 117–123.
18. Von Elm E, Altman DG, Egger M; STROBE Initiative, et al. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *Ann Intern Med* 2007; 147: 573–577.
19. Ashwell M and Gibson S. A proposal for a primary screening tool: 'keep your waist circumference to less than half your height'. *BMC Med* 2014; 12: 207.
20. Jia W, Weng J, Zhu D; Chinese Diabetes Society, et al. Standards of medical care for type 2 diabetes in China 2019. *Diabetes Metab Res Rev* 2019; 35: e3158.
21. Astrup A and Finer N. Redefining type 2 diabetes: 'diabesity' or 'obesity dependent diabetes mellitus'? *Obes Rev* 2000; 1: 57–59.
22. Yu HJ, Ho M, Liu X, et al. Association of weight status and the risks of diabetes in adults: A systematic review and meta-analysis of prospective cohort studies. *Int J Obes (Lond)* 2022; 46: 1101–1113.
23. McLaughlin T, Lamendola C, Liu A, et al. Preferential fat deposition in subcutaneous versus visceral depots is associated with insulin sensitivity. *J Clin Endocrinol Metab* 2011; 96: E1756–E1760.
24. Fan Y, Wang R, Ding L, et al. Waist circumference and its changes are more strongly associated with the risk of type 2 diabetes than body mass index and changes in body weight in Chinese adults. *J Nutr* 2020; 150: 1259–1265.
25. Sjöström CD, Lissner L, Wedel H, et al. Reduction in incidence of diabetes, hypertension and lipid disturbances after intentional weight loss induced by bariatric surgery: the SOS Intervention Study. *Obes Res* 1999; 7: 477–484.
26. Browning LM, Hsieh SD and Ashwell M. A systematic review of waist-to-height ratio as a screening tool for the prediction of cardiovascular disease and diabetes: 0·5 could be a suitable global boundary value. *Nutr Res Rev* 2010; 23: 247–269.
27. Kodama S, Horikawa C, Fujihara K, et al. Comparisons of the strength of associations with future type 2 diabetes risk among anthropometric obesity indicators, including waist-to-height ratio: a meta-analysis. *Am J Epidemiol* 2012; 176: 959–969.
28. Xu L, Lam TH, Jiang CQ, et al. Adiposity and incident diabetes within 4 years of follow-up: the Guangzhou Biobank Cohort Study. *Diabet Med* 2017; 34: 1400–1406.
29. Burhans MS, Hagman DK, Kuzma JN, et al. Contribution of adipose tissue inflammation to the development of type 2 diabetes mellitus. *Compr Physiol* 2019; 9: 1–58.
30. Misra A, Wasir JS and Vikram NK. Waist circumference criteria for the diagnosis of

abdominal obesity are not applicable uniformly to all populations and ethnic groups. *Nutrition* 2005; 21: 969–976.
31. Zhou BF; Cooperative Meta-Analysis Group of the Working Group on Obesity in China. Predictive values of body mass index and waist circumference for risk factors of certain related diseases in Chinese adults–study on optimal cut-off points of body mass index and waist circumference in Chinese adults. *Biomed Environ Sci* 2002; 15: 83–96.
32. Bao Y, Lu J, Wang C, et al. Optimal waist circumference cutoffs for abdominal obesity in Chinese. *Atherosclerosis* 2008; 201: 378–384.
33. Liu J, Tse LA, Liu Z; PURE (Prospective Urban Rural Epidemiology) study in China, et al. Predictive values of anthropometric measurements for cardiometabolic risk factors and cardiovascular diseases among 44 048 Chinese. *J Am Heart Assoc* 2019; 8: e010870.