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Income-related inequities of adult obesity and central obesity in China: evidence from the China Health and Nutrition Survey 1997–2011

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ABSTRACT

Objectives The aim of this study was to analyse the status regarding inequities in adult obesity and central obesity in China. Thus, income-related inequality for both diseases and the underlying factors were examined.

Methods and design The China Health and Nutrition Survey (CHNS)—conducted from 1997 to 2011—included 128 307 participants; in this study, 79 566 individuals classified as obese and 65 250 regarded as suffering from central obesity according to the CHNS were analysed. A body mass index greater than 27 was considered indicative of obesity; men and women with a waist circumference of more than 102 cm and 80 cm, respectively, were considered as suffering from central obesity. The concentration index was employed to analyse inequality in adult obesity and central obesity. The decomposition of this index based on a probit model was used to calculate the horizontal inequality index.

Results The prevalence of adult obesity increased from 8.34% in 1997 to 17.74% in 2011, and that of central obesity increased from 6.52% in 1997 to 16.79% in 2011. The horizontal inequality index for adult obesity decreased from 0.1377 in 1997 to 0.0164 in 2011; for central obesity, it decreased from 0.0806 in 1997 to −0.0193 in 2011. The main causes of inequality for both diseases are, among others, economic status, marital status and educational attainment.

Conclusions From 1997 to 2011, the prevalence of adult obesity and central obesity increased annually. The pro-rich inequalities in both adult and central obesity decreased from 1997 to 2011. The inequality in central obesity was more prominent in the low-income group in 2011. Future policies may need to address obesity reduction among the poor.

INTRODUCTION

Adult obesity is a common risk factor for type 2 diabetes, hypertension, hyperlipidaemia, malignant tumours and other chronic diseases. It increases the prevalence of chronic diseases and mortality,[1] and it adds to the global disease burden.[2] In 2010, 3.4 million deaths and 3.8% of disability-adjusted life-years in the world were attributed to obesity.[3] The problem of obesity is becoming more serious in low-income and middle-income countries, whereas the rate of increase in the incidence of obesity seems to have slowed down in recent years in some developed countries.[4] With rapid economic growth in China, the obesity problem has become more noticeable. The prevalence of overweight adults over age 18 increased from 14.6% in 1992 to 45.4% in 2011 in China, and the prevalence of obesity increased from 5.2% to 15.1% (nearly tripled).[5] As reported, China has the largest population of obese people in the world.[6]

The prevalence of obesity also varies within countries.[7] According to a previous study, the prevalence of obesity in rural populations was higher than that in urban populations. Moreover, populations with obese people who live in underdeveloped areas have increased more than those in populations living in developed areas.[8] These differences have attracted attention to the inequality of obesity. Societal structures may affect the unequal distribution of obesity. Previous studies have confirmed that in affluent countries and regions, populations with a lower

Strengths and limitations of this study

► The data used in this study were part of a temporal series encompassing more than 14 years.
► Calculation of the concentration index and decomposition of the concentration index were performed to analyse inequalities in adult obesity and central obesity and the underlying factors.
► Horizontal inequities in both adult and central obesity have been studied in this article; avoidable factors were excluded and unavoidable factors were emphasised. In this study, the prevalence and inequalities in adult and central obesity were compared.
► This is a descriptive research, not a causal research.

socioeconomic status (SES) are more likely to be overweight, but the inverse is true in low-income countries.[9] Researchers consider that disadvantages in wealth, power and prestige cause disadvantages in health protection, which could be responsible for the unequal prevalence of obesity. A study examining the relationship between SES and obesity in the Nordic region showed that social inequality still exists, although the Nordic region is relatively affluent.[10] Corresponding to this finding, other studies conducted in the USA also suggest that a higher obesity prevalence is associated with a lower SES.[11] It is uncommon to find that people with low SES or economically disadvantaged situations have a higher probability of obesity in high-income countries.[12] However, the trend in low-income or most low-income and middle-income countries tends to be different. Higher obesity prevalence is associated with higher SES in impoverished nations.[13] A previous study in China found that young people with a higher SES had higher body mass indices (BMIs) and higher odds of obesity.[14] In many low-income and middle-income countries, obesity is regarded as an epidemic that mainly affects the rich; with the rapid development of the economy and society, obesity is gradually becoming more concentrated among the poor.[15] Children and adults from lower income households are less likely to be obese in low-income and middle-income countries, which is opposite the situation in high-income countries.[16] Corresponding to this mechanism, researchers found that with the growing gross domestic product (GDP) in low-income and middle-income countries, the positive correlation between SES and obesity is gradually transformed into a negative correlation; namely, the inequality situation is changing with the country's economic growth.[17]

Inequality is a growing problem in China. According to a report from the World Bank, only 53 countries' Gini coefficients were higher than China's (out of 154 countries).[18] The prevalence of the inequality of obesity in China needs to be addressed. With the rapid economic development in China, not only is obesity's prevalence becoming more severe, but the prevalence of the inequality of obesity may also change. On one hand, when the country was economically poor, people with low income levels faced food scarcity, which could protect them against obesity; on the contrary, as the country gradually became wealthy, after a certain economic level, the lack of food was no longer common in society and people with a high-income levels are more conscious about healthy lifestyles. It is difficult for the poor to obtain expensive, low-energy, dense foods like fruits and vegetables.[19] Furthermore, epidemiological studies have documented that central obesity measured by waist circumference could reflect central fat distribution compared with obesity measured by BMI.[20] However, whether the income-related inequality of these two measures would be different has not been fully revealed. In this study, we assessed the inequality in Chinese adult obesity, measured by BMI, and central obesity, measured by waist circumference, using China Health and Nutrition Survey (CHNS) data from 1997 to 2011. Using data from a series of years in China, we could analyse how inequality has changed in China with the country's economic growth in the past decades.

MATERIALS AND METHODS
Data sources
As mentioned previously, we used data from the CHNS for this study. The CHNS was designed as a longitudinal survey to explore a series of economic, sociological, demographic and health questions of interest to researchers.[21] Some key public health risk factors and health outcomes at the individual level were included in the surveys. The surveys were tracked every 2–4 years, as data regarding adult obesity were collected initially in 1989; a central obesity survey was conducted in 1993. The CHNS collected data covering 239 communities within nine of China's 31 provinces, including Beijing, Shanghai, Shandong, Jiangsu, Liaoning, Heilongjiang, Henan, Hubei, Hunan, Guangxi, Guizhou and Chongqing.[22] Methods using a multistage random cluster process were adopted in the sampling for each province. Data were examined from 1997, 2000, 2004, 2006, 2009 and 2011, referring to participants with data available for estimating obesity and central obesity. For adult obesity, there were 12 925, 13 600, 12 366, 11 798, 12 252 and 16 626 participants each survey year, respectively; for central obesity, there were 10 700, 11 554, 10 484, 9513, 9843 and 13 156 participants each year, respectively. In total, 79 566 obese individuals and 65 250 suffering from central obesity were selected based on a multistage cluster random sampling scheme in each province. The counties were stratified by income in each province, and a weighted sampling scheme was used to select four counties randomly. In each county, villages and towns were chosen randomly, as were urban and suburban neighbourhoods in each city.[23]

Variables
Dependent variables
Both adult obesity and central obesity were evaluated in this study. According to WHO, general obesity is defined as a BMI >30 kg/m^2.[24] In this study, adult obesity was defined as a BMI >27 kg/m^2 based on the criteria appropriate for the Chinese population recommended in previous studies.[25–28] When measuring their height, respondents took off their shoes and stood on a horizontal floor against the wall, with their feet facing forward and their heels against the wall. The back and head were in a straight state, and the line between the lower orbital margin and the superior edge of the auricle was in a horizontal state. In front of the eye, the H-angle plate was reduced slowly until the lower edge touched the head of the object, reading the calibration number and recording. To be considered accurate, height measurements had to be within 0.5 cm. When measuring weight, the weight metre was placed on a horizontal floor. Respondents were asked to take off their shoes and hats and wear only light clothing. They were also asked to remove items (such as

keys or wallets) from their pockets, weigh themselves and record their weight.[29]

Central obesity was defined as a waist circumference ≥102 for men and ≥88 for women, following ATP III criteria.[30] Respondents stood; their feet were separated 25–30 cm so that their weight was evenly distributed. The waist (horizontal girth) of each respondent was measured through the umbilical point.[18]

Independent variables

Based on previous studies on adult obesity and central obesity,[31 32] gender, age, residence, marital status, educational attainment, economic level, health insurance, smoking/drinking habits, tea consumption, activities and region were included as independent variables in our study. Age (in years) was categorised according to four groups: 18–30, 31–45, 46–60 and 61 and above. Residence was categorised as urban or rural and was decided by the question, 'Where do you live now, in an urban or rural area?'. Marital status was grouped by single, married and other status. Educational attainment was defined by a respondent's highest education level (ie, illiteracy, primary school, middle school, high school, or college and above). Economic level was measured by household income per capita, which was not adjusted for inflation or to the consumer price index (CPI).[33] Because the data in this study covered multiple periods, an unadjusted CPI would not have an impact on the results of the analysis. We used the natural logarithm of household income per capita, namely 'LNINCOME', in this study to represent economic level, which made the data easy to analyse. Lifestyle related to obesity included smoking/drinking habits, tea consumption and activity. Smoking and drinking habits were defined by the questions, 'Are you currently smoking?' and 'Are you currently drinking?'. Tea consumption was defined as the average of water and tea consumed per day. Activity was determined by the question, 'Are you currently involved in physical activities?'. Region were categorised as east, middle and west regions according to the State Statistical Bureau.

Data analysis
Concentration index
The concentration index has been considered a standard measure for evaluating the income-related inequality of health outcomes among populations.[33] The concentration index measures whether a specific health outcome is targeted towards high or low household income per capita and quantifies the extent to which a health outcome is clustered with the poor or rich. In this study, the concentration index was calculated as twice the area between the concentration curve and the line of equality (the 45° line).[34] The x-axis of the concentration curve was the living standard, such as income from the poorest to the richest, and the y-axis was the cumulative percentage of health variables. In this study, through the concentration curve, the cumulative percentage of health outcomes corresponding to every cumulative percentage for the

distribution of a living standard variable was displayed. When the concentration curve was below the line of equality, the value of the concentration index was positive, and accordingly, the health outcome was concentrated among the rich. When the concentration curve was above the line of equality inversely, the value of the concentration index was negative, and the health outcome was concentrated among the poor. If the concentration index equalled 0, there was no income-related inequality found in the distribution of health outcomes. In this study, we calculated the concentration index of adult obesity and central obesity each year. The 95% confidence interval helped us determine whether the change in concentration index was significant. If the 95% confidence intervals of 2 years did not overlap, the change in concentration index was regarded as significant. The following equation describes the method for calculating the concentration index:

$$C = \frac{2}{\mu}\mathrm{cov}\,(h, r)$$

where r represents the proportion of individual i in the sample sorted by income, h is the health variable (adult obesity and central obesity) and μ represents the average of the health variables.

Decomposition of the concentration index
The concentration index can be decomposed into the contributions of each variable. In the process employed in this study for decomposing the concentration index, independent variables were grouped into avoidable and unavoidable variables. The avoidable variables included those that could be avoided in obesity research, such as residence, marital status, economic level, insurance, smoking/drinking habits, tea consumption, activities and regions studied. The unavoidable factors were those that could not be avoided in our research, such as gender and age. To decompose concentration index into the contributions of these variables, the probit model was adopted. The equation follows:

$$y_i = \alpha^m + \sum \beta_j^m x_{ji} + \sum_k \gamma_k^m Z_{ki} + \mu_i$$

where y_i is the health outcome variable, x_{ji} is the unavoidable variable, γ_k is the avoidable variable, Z is the vector of control variables, β_j^m and γ_k^m refer to the partial effect and μ_i is the error term (including approximation errors).

By summing up the concentration indexes of all unavoidable factors, we could obtain the horizontal inequity index (HI). HI is related to the income-related equity of health variables and has the same attributes as concentration index. In this study, we obtained both the concentration index and HI for adult obesity and central obesity. The following equation shows how to extract HI from concentration index:

$$C = \sum_j \left(\beta_j^m \bar{x}_j / \mu \right) C_j + \sum_k \left(\gamma_k^m \bar{Z}_k / \mu \right) C_k + GC_\varepsilon / \mu$$

where C represents the concentration index of health variables, C_j represents the concentration index of x_j, C_k is the concentration index of z_k and GC_k is the concentration index of residual terms. This formula indicates that the concentration index of health variables is obtained by adding the weighted sum of avoidable variables and the concentration index of unavoidable variables. In other words, the HI can be measured by controlling the contribution of unavoidable variables.

RESULTS

Table 1 shows the definitions of variables and descriptive results in China from 1997 to 2011. As can be seen clearly from the table, the LNINCOME, the natural logarithm of household income per capita, increased from 8.07 in 1997 to 9.25 in 2011. In the total sample, over 50% each year were women. The insurance coverage rate increased from 26.53% in 1997 to 95.08% in 2011. The number of married adults was greater than that of single adults from 1997 to 2011. In the last 4 years, there were more people aged 46–60 than in other groups. The other descriptive results of our sample are presented in table 1.

As shown in figure 1, the prevalence of adult obesity and central obesity has been increasing annually. The prevalence of obesity in adults increased from 8.34% in 1997 to 17.74% in 2011. The prevalence of central obesity increased from 6.52% in 1997 to 16.79% in 2011. The gap between adult obesity and central adult obesity decreased. From figure 2, we can see that a deviation exists between equality in adult obesity and central obesity. However, the pro-rich inequality in the prevalence of adult obesity and central obesity has diminished similarly. In 2011, the prevalence of inequality in central obesity was pro-poor.

Tables 2 and 3 show the partial effect of each determinant on the probability of suffering from adult obesity and central obesity. Taking the results of 2011 as an example, people with higher income levels have a lower probability of suffering from adult obesity, which is consistent with the results for central obesity but not statistically significant. Compared with women, men have a lower probability of suffering from central obesity. Urban residents have a higher probability of suffering from both adult and central obesity compared with rural residents. People who have attained higher educational levels have a lower probability of adult obesity and central obesity compared with people who are illiterate. Compared with single people, married people are more likely to suffer from central obesity. Compared with those under age 30, the elderly have a higher probability of suffering from both adult and central obesity. Smokers are less likely to suffer from adult obesity compared with non-smokers, whereas those who drink alcohol have the opposite result. Compared with those from the eastern China, people from the middle and western China have a lower probability of suffering from adult and central obesity.

Tables 4 and 5 show the decomposition of inequality in adult obesity and central obesity. Taking the results of 2011 as an example, the inequality in adult obesity can be explained mainly by economic status (−53.90%), urban classification (52.94%), a college education or above (54.71%) and habitation in the western China (147.58%). The inequality in central obesity can be explained mainly by economic status (65.39%), male gender (41.16%), college education or above (55.79%) and habitation in the western China (−82.08%).

Table 6 shows the HI in adult and central obesity. The HI was computed by extracting the contribution of avoidable variables from the concentration index. The HIs of adult and central obesity have decreased over the years. In 2011, the HI of central obesity decreased to a level below 0.

DISCUSSION

The results of our study show that in the past decades, the prevalence of adult obesity and central adult obesity has increased, which is consistent with findings from the Working Group of Obesity, China and the WHO.[35] A previous study based on the CHNS found that obesity prevalence in China in 2002 was 5.6% using the same criteria as was used in our study, but the prevalence was found to be higher in this study (8.34% in 2000 and 10.54% in 2004). A reason for this difference might be that the lower prevalence was based on the entire population, and our sample contained only adults over age 18.[36] Other studies focused on central obesity also show an increase during the past decades in China, but the growth values are differ by study.[37] Notably, the prevalence of obesity was always higher than the prevalence of central obesity for each year in our study. Existing literature has documented that central obesity measured by waist circumference was better than the BMI for predicting cardiovascular diseases, as waist circumference could reflect central fat distribution.[38 39] Central obesity is ectopic fat accumulated in the abdomen, which may not be effectively measured with BMI.[40] With a given waist circumference value, obese people and people whose weight is within the normal range defined by the BMI have equivalent health risks.[41] Central obesity can occur in people with normal BMIs.

Economic level, gender, residence, insurance, education, marital status, age, smoking/drinking and region were found to be risk factors for adult obesity in our study. The prevalence of adult obesity and central obesity in women was higher than that in men. One reason might be that women have more fat cells than men, and oestrogen is associated with fat biosynthesis. In addition, women generally are less active than men; thus, their consumption of heat is less, making them prone to adult obesity.[42] Findings of this study also show that adults suffering from central obesity are mainly between 46 and 60 years of age. Previous studies have suggested that after middle age, the prevalence of adult obesity increases because of, among others, stress at work, a lack of exercise, unhealthy eating habits and increased social interaction.[40] Educational

Table 1 Definition of variables and description for adults in China 1997–2011

Variables	1997 N	1997 %	2000 N	2000 %	2004 N	2004 %	2006 N	2006 %	2009 N	2009 %	2011 N	2011 %
LNINCOME, mean (SE)	8.07	0.01	8.24	0.01	8.51	0.01	8.62	0.01	9.01	0.01	9.25	0.01
Gender												
Female*	4256	51.42	4798	52.21	4653	52.32	4581	52.76	4857	52.61	6555	53.06
Male	4021	48.58	4392	47.79	4240	47.68	4102	47.24	4375	47.39	5799	46.94
Urban												
Rural*	5700	68.5	6311	68.33	6173	68.91	6025	68.89	6400	68.88	7182	57.69
Urban	2621	31.5	2925	31.67	2785	31.09	2721	31.11	2892	31.12	5268	42.31
Health insurance												
No*	6053	73.47	6996	77.54	6455	72.41	4355	49.79	832	8.95	612	4.92
Yes	2186	26.53	2027	22.46	2459	27.59	4391	50.21	8460	91.05	11 838	95.08
Education attainment												
Illiteracy*	2335	28.97	2061	23.1	1885	21.09	2152	24.67	2112	22.76	2455	19.75
Primary school	1808	22.43	1991	22.31	2070	23.16	1569	17.99	1801	19.41	2029	16.32
Middle school	2354	29.21	2832	31.73	2801	31.33	2671	30.62	3084	33.23	3847	30.95
High school	1030	12.78	1205	13.5	1238	13.85	1223	14.02	1101	11.86	1640	13.19
College and above	532	6.6	835	9.36	945	10.57	1107	12.69	1183	12.75	2458	19.78
Marriage												
Single*	1142	13.84	1078	12.12	777	8.72	615	7.04	586	6.31	687	5.52
Married	6527	79.08	7182	80.72	7357	82.57	7328	83.89	7782	83.78	10 475	84.18
Else	585	7.09	637	7.16	776	8.71	792	9.07	921	9.91	1282	10.3
Age group												
18–30*	2100	25.24	1868	20.23	1261	14.08	1014	11.59	1072	11.54	1374	11.04
31–45	2811	33.78	3152	34.13	2782	31.06	2729	31.2	2663	28.66	3207	25.76
46–60	2041	24.53	2614	28.3	3011	33.61	2983	34.11	3228	34.74	4516	36.27
>60	1369	16.45	1602	17.35	1904	21.25	2020	23.1	2329	25.06	3353	26.93
Smoke												
No*	5603	67.73	6277	68.52	6057	67.74	6001	68.67	6388	68.77	8638	69.4
Yes	2670	32.27	2884	31.48	2884	32.26	2738	31.33	2901	31.23	3808	30.6
Drink												
No*	5202	63.53	5819	64.73	6007	67.19	5946	67.99	6229	67.06	8227	66.09
Yes	2986	36.47	3171	35.27	2933	32.81	2799	32.01	3060	32.94	4221	33.91

Continued

Table 1 Continued

Variables	1997 N	%	2000 N	%	2004 N	%	2006 N	%	2009 N	%	2011 N	%
Tea consumption, mean (SE)	0.62	0.01	0.67	0.01	0.64	0.01	1.91	0.02	2.13	0.02	2.24	0.01
Activity												
No*	7435	89.35	8438	91.36	8216	91.72	7964	91.06	8546	91.97	10 692	85.88
Yes	886	10.65	798	8.64	742	8.28	782	8.94	746	8.03	1758	14.12
Area												
East*	1120	15.28	1132	13.69	1059	13.24	982	12.75	1144	13.84	3426	30.01
Middle	3832	52.28	4967	60.06	4769	59.62	4561	59.23	5007	60.57	4840	42.4
West	2378	32.44	2171	26.25	2171	27.14	2158	28.02	2116	25.6	3150	27.59

LNINCOME means natural logarithm of per capital household income; tea consumption means the average of water and tea consumption per day, and LNINCOME and tea consumption are considered as continue variables. Dummy variables were generated for category variables in regression models.

*Reference levels; mean and SE were calculated for continuous variables and observations (N) and percentage (%) was used for category variables.
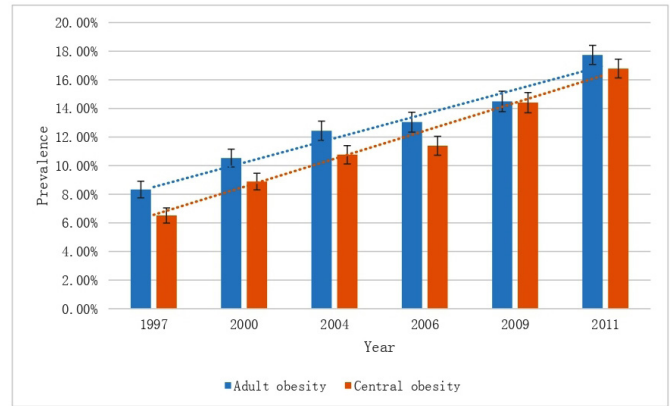

Figure 1 Prevalence of adult obesity and central obesity in China 1997–2011.

attainment is also an important factor in the incidence of central obesity. The prevalence of central obesity in the population with low educational levels was higher than that in the population with high educational levels, which could be attributed to a general lack of knowledge and awareness of health in the former, as well as the lack of attention paid by the less educated population to the adult obesity problem. An explanation may be that people with higher educational levels have greater access and the ability to gather health-related information, a greater perception of the risks of certain lifestyle choices and better self-control than those with less education.[43]

The concentration index suggests that skewness pertaining to the prevalence of inequality for both adult and central obesity decreased from 1997 to 2011. At the beginning of the study, both the concentration index and HI for adult and central obesity were positive, indicating a prevalence primarily among the rich. However, the pro-rich prevalence weakened over time; that is to say, the obese population has grown, and most of the newly obese people are poor. In 2011, the concentration index and HI for central obesity fell below zero; the decline was dramatic. Our finding that adult obesity was concentrated among the rich is in line with results of previous studies in China and other low-income and middle-income countries.[15 40] Health outcomes have an intense relationship
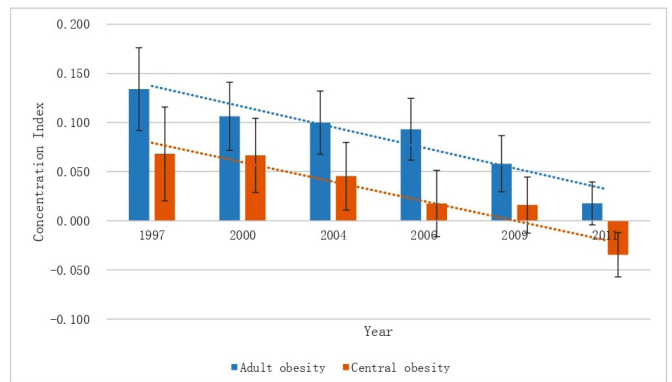

Figure 2 Inequality of adult obesity and central obesity in China 1997–2011.

Table 2 Partial effect of each determinant on the probability of adult obesity in China 1997–2011

Obesity	1997 dy/dx	SE	2000 dy/dx	SE	2004 dy/dx	SE	2006 dy/dx	SE	2009 dy/dx	SE	2011 dy/dx	SE
LNINCOME	0.0128***	0.0037	0.0042	0.0037	0.0128***	0.0039	0.0114***	0.0038	0.0065*	0.0039	-0.0031	0.0037
Male	-0.0125	0.0077	-0.0155*	0.0092	-0.0088	0.0099	0.0053	0.0103	0.0086	0.0105	0.0010	0.0099
Urban	0.0582***	0.0081	0.0518***	0.0088	0.0376***	0.0092	0.0397***	0.0095	0.0337***	0.0094	0.0227***	0.0085
Health insurance	0.0203***	0.0077	0.0374***	0.0102	0.0060	0.0095	0.0052	0.0079	-0.0115	0.0139	-0.0176	0.0175
Primary school	0.0028	0.0083	-0.0073	0.0099	-0.0052	0.0108	0.0024	0.0120	0.0126	0.0125	0.0168	0.0128
Middle school	-0.0036	0.0086	-0.0034	0.0105	-0.0095	0.0113	0.0064	0.0119	0.0077	0.0119	0.0199*	0.0120
High school	-0.0174*	0.0091	-0.0212*	0.0114	-0.0361***	0.0117	-0.0343**	0.0123	-0.0248*	0.0137	-0.0256*	0.0135
College and above	-0.0146	0.0106	-0.0364***	0.0108	-0.0293**	0.0131	-0.0323**	0.0133	-0.0320**	0.0139	-0.0231	0.0138
Married	0.0398***	0.0086	0.0281**	0.0110	0.0339**	0.0149	0.0571***	0.0171	0.0453**	0.0187	0.0166	0.0192
Else	0.0409**	0.0242	0.0028	0.0194	0.0071	0.0232	0.0430	0.0335	0.0504*	0.0314	0.0347	0.0259
31–45	0.0217**	0.0100	0.0300***	0.0118	0.0603***	0.0166	0.0326*	0.0185	0.0455***	0.0183	0.0254	0.0159
46–60	0.0486***	0.0129	0.0446***	0.0135	0.0727***	0.0171	0.0621***	0.0198	0.0593***	0.0184	0.0589***	0.0162
>60	0.0664***	0.0179	0.0446***	0.0173	0.0879***	0.0217	0.0619***	0.0231	0.0492**	0.0205	0.0319*	0.0174
Smoke	-0.0154**	0.0072	-0.0177**	0.0085	-0.0340***	0.0092	-0.0395***	0.0095	-0.0356***	0.0097	-0.0192*	0.0099
Drink	0.0045	0.0072	0.0117	0.0087	0.0159*	0.0096	0.0056	0.0099	-0.0027	0.0098	0.0158*	0.0092
Tea	0.0030	0.0025	0.0026	0.0028	0.0021	0.0028	0.0060**	0.0023	-0.0001	0.0026	0.0025	0.0023
Activity	0.0005	0.0087	-0.0035	0.0113	0.0210	0.0141	0.0171	0.0140	0.0104	0.0146	-0.0136	0.0103
Middle	-0.0023	0.0076	0.0131	0.0094	0.0191*	0.0108	0.0175	0.0108	0.0053	0.0108	-0.0273***	0.0087
West	-0.0524***	0.0070	-0.0552***	0.0089	-0.0649***	0.0105	-0.0619***	0.0108	-0.0672***	0.0106	-0.0866***	0.0085

dy/dx means partial effects of each variable and evaluated at sample means.
*p<0.1, **p<0.05, ***p<0.01.

Table 3 Partial effect of each determinant on the probability of adult central obesity in China 1997–2011

Metabolic	1997		2000		2004		2006		2009		2011	
	dy/dx	SE	dy/dx	SE	dy/dx	SE	dy/dx	SE	dy/dx	Std.	dy/dx	SE
LNINCOME	0.0037*	0.0022	0.0031	0.0024	0.0053*	0.0029	0.0027	0.0029	0.0035	0.0033	−0.0070**	0.0033
Male	−0.0721***	0.0072	−0.0972***	0.0082	−0.1431***	0.0097	−0.1236***	0.0093	−0.1726***	0.0102	−0.1893***	0.0094
Urban	0.0359***	0.0058	0.0314***	0.0061	0.0187***	0.0070	0.0271***	0.0074	0.0260***	0.0082	0.0205***	0.0076
Health insurance	0.0038	0.0045	−0.0030	0.0057	−0.0033	0.0072	0.0031	0.0060	−0.0021	0.0116	−0.0098	0.0157
Primary school	0.0057	0.0051	−0.0037	0.0058	−0.0017	0.0076	0.0009	0.0084	0.0026	0.0096	−0.0079	0.0102
Middle school	−0.0054	0.0050	−0.0092	0.0062	−0.0189***	0.0078	−0.0126	0.0082	−0.0146	0.0092	−0.0108	0.0098
High school	−0.0084	0.0057	−0.0167**	0.0067	−0.0319***	0.0080	−0.0209**	0.0091	−0.0554***	0.0087	−0.0438***	0.0105
College and above	−0.0052	0.0068	−0.0100	0.0078	−0.0357***	0.0080	−0.0388***	0.0082	−0.0506***	0.0096	−0.0436***	0.0110
Married	0.0243***	0.0049	0.0373***	0.0060	0.0036	0.0140	0.0318*	0.0147	0.0511***	0.0162	0.0418**	0.0171
Else	0.0362**	0.0198	0.0356**	0.0211	−0.0164	0.0141	0.0264	0.0277	0.0631**	0.0346	0.0578**	0.0285
31–45	0.0024	0.0059	0.0170**	0.0087	0.0278**	0.0132	0.0031	0.0140	0.0081	0.0149	0.0020	0.0141
46–60	0.0395***	0.0099	0.0630***	0.0124	0.0706***	0.0151	0.0624***	0.0173	0.0596***	0.0166	0.0707***	0.0154
>60	0.0784***	0.0173	0.1099***	0.0206	0.1225***	0.0226	0.1010***	0.0237	0.0920***	0.0207	0.0892***	0.0181
Smoke	−0.0051	0.0055	−0.0076	0.0067	−0.0014	0.0092	−0.0127	0.0091	−0.0149	0.0103	−0.0073	0.0106
Drink	−0.0017	0.0048	−0.0051	0.0060	0.0083	0.0084	−0.0101	0.0083	0.0072	0.0096	0.0005	0.0088
Tea	0.0006	0.0017	0.0059***	0.0018	0.0036	0.0022	0.0001	0.0024	−0.0007	0.0025	0.0025	0.0021
Activity	−0.0043	0.0053	0.0042	0.0088	0.0136	0.0116	0.0121	0.0113	−0.0059	0.0123	−0.0109	0.0093
Middle	0.0017	0.0048	0.0125**	0.0062	0.0070	0.0085	0.0207**	0.0081	0.0115	0.0092	−0.0170**	0.0078
West	−0.0193***	0.0046	−0.0180***	0.0076	−0.0471***	0.0062	−0.0418***	0.0080	−0.0579***	0.0087	−0.0890***	0.0072

dy/dx means partial effects of each variable and evaluated at sample means.
*p<0.1, **p<0.05, ***p<0.01.

Table 4 Decomposition of inequality of adult obesity in China 1997–2011

Obesity	1997 Cont.	1997 %	2000 Cont.	2000 %	2004 Cont.	2004 %	2006 Cont.	2006 %	2009 Cont.	2009 %	2011 Cont.	2011 %
LNINCOME	0.0704	53.45	0.0212	19.95	0.0568	57.08	0.0506	54.63	0.0247	42.68	−0.0095	−53.90
Male	−0.0001	−0.11	−0.0002	−0.21	−0.0004	−0.45	0.0004	0.47	0.0006	1.05	0.0001	0.40
Urban	0.0293	22.29	0.0274	25.73	0.0171	17.20	0.0169	18.22	0.0128	22.05	0.0094	52.94
Health insurance	0.0180	13.68	0.0325	30.60	0.0048	4.84	0.0029	3.13	−0.0009	−1.51	−0.0008	−4.61
Primary school	−0.0005	−0.36	0.0012	1.12	0.0010	1.03	−0.0004	−0.41	−0.0017	−2.96	−0.0023	−12.99
Middle school	−0.0005	−0.34	0.0003	0.25	0.0009	0.93	−0.0003	−0.37	−0.0004	−0.77	−0.0013	−7.50
High school	−0.0047	−3.57	−0.0050	−4.70	−0.0060	−6.08	−0.0055	−5.91	−0.0036	−6.15	−0.0021	−11.68
College and above	−0.0042	−3.16	−0.0139	−13.10	−0.0121	−12.20	−0.0143	−15.43	−0.0111	−19.20	−0.0097	−54.71
Married	0.0009	0.68	0.0022	2.11	0.0024	2.39	0.0036	3.92	0.0036	6.19	0.0010	5.69
Else	−0.0033	−2.49	−0.0002	−0.22	−0.0006	−0.57	−0.0037	−4.02	−0.0044	−7.66	−0.0031	−17.34
31–45	0.0009	0.69	0.0005	0.48	−0.0003	−0.30	0.0006	0.61	−0.0017	−2.86	−0.0003	−1.64
46–60	0.0102	7.74	0.0076	7.19	0.0041	4.12	0.0035	3.78	0.0054	9.34	0.0033	18.39
>60	−0.0147	−11.13	−0.0044	−4.13	−0.0024	−2.38	−0.0050	−5.44	−0.0020	−3.47	−0.0017	−9.78
Smoke	0.0021	1.60	0.0020	1.84	0.0000	−0.03	−0.0015	−1.64	0.0008	1.38	0.0003	1.61
Drink	0.0004	0.31	0.0015	1.41	0.0019	1.89	0.0008	0.81	−0.0004	−0.68	0.0019	10.88
Tea	0.0014	1.05	0.0012	1.16	0.0010	0.98	0.0051	5.53	−0.0001	−0.15	0.0012	7.00
Activity	0.0001	0.11	−0.0006	−0.54	0.0043	4.30	0.0041	4.40	0.0018	3.15	−0.0032	−17.83
Middle	0.0005	0.37	−0.0040	−3.80	−0.0016	−1.62	0.0004	0.46	0.0000	−0.07	0.0040	22.42
West	0.0147	11.19	0.0068	6.43	0.0220	22.14	0.0170	18.40	0.0180	31.09	0.0261	147.58

Cont. means contribution to concentration index; % means the percentage of contribution to concentration index.

Table 5 Decomposition of inequality of adult central obesity in China 1997–2011

Metabolic	1997		2000		2004		2006		2009		2011	
	Cont.	%	Cont.	%	Cont.	%	Cont.	%	Cont.	%	Cont.	%
LNINCOME	0.0258	38.84	0.0184	27.63	0.0269	59.51	0.0136	78.18	0.0135	83.92	−0.0226	65.39
Male	−0.0010	−1.55	−0.0016	−2.46	−0.0083	−18.43	−0.0116	−66.34	−0.0122	−76.30	−0.0142	41.16
Urban	0.0231	34.76	0.0196	29.50	0.0098	21.66	0.0132	75.83	0.0099	61.70	0.0090	−25.91
Health insurance	0.0043	6.47	−0.0031	−4.64	−0.0030	−6.69	0.0020	11.50	−0.0002	−1.01	−0.0005	1.38
Primary school	−0.0012	−1.87	0.0007	1.06	0.0004	0.87	−0.0002	−0.99	−0.0004	−2.20	0.0012	−3.33
Middle school	−0.0009	−1.32	0.0008	1.25	0.0021	4.70	0.0008	4.36	0.0008	5.26	0.0008	−2.20
High school	−0.0029	−4.39	−0.0047	−7.03	−0.0062	−13.62	−0.0038	−21.97	−0.0080	−49.99	−0.0037	10.81
College and above	−0.0019	−2.82	−0.0045	−6.83	−0.0171	−37.73	−0.0196	−112.76	−0.0177	−110.12	−0.0193	55.79
Married	0.0007	1.05	0.0035	5.28	0.0003	0.64	0.0023	13.28	0.0041	25.31	0.0027	−7.76
Else	−0.0037	−5.59	−0.0036	−5.34	0.0015	3.35	−0.0026	−15.05	−0.0056	−34.74	−0.0054	15.62
31–45	0.0001	0.19	0.0003	0.52	−0.0002	−0.35	0.0001	0.36	−0.0003	−1.86	0.0000	0.07
46–60	0.0106	15.89	0.0128	19.25	0.0046	10.15	0.0040	23.11	0.0055	34.07	0.0041	−11.94
>60	−0.0221	−33.23	−0.0128	−19.28	−0.0038	−8.41	−0.0094	−54.09	−0.0038	−23.58	−0.0051	14.78
Smoke	0.0009	1.33	0.0010	1.49	0.0000	0.00	−0.0006	−3.22	0.0003	2.10	0.0001	−0.33
Drink	−0.0002	−0.29	−0.0008	−1.17	0.0011	2.52	−0.0016	−8.92	0.0011	6.62	0.0001	−0.17
Tea	0.0003	0.48	0.0033	5.03	0.0019	4.23	0.0001	0.84	−0.0005	−3.09	0.0013	−3.69
Activity	−0.0015	−2.29	0.0008	1.22	0.0032	7.07	0.0033	18.97	−0.0010	−6.53	−0.0027	7.72
Middle	−0.0005	−0.70	−0.0045	−6.82	−0.0007	−1.51	0.0006	3.31	−0.0001	−0.54	0.0026	−7.56
West	0.0069	10.43	0.0026	3.96	0.0185	40.80	0.0132	75.51	0.0156	97.30	0.0284	−82.08

Cont. means contribution to concentration index; % means the percentage of contribution to concentration index.

Table 6 Horizontal inequity in adult obesity and central obesity in China 1997–2011

	1997	2000	2004	2006	2009	2011
Adult obesity						
Concentration index	0.1340	0.1063	0.0999	0.0931	0.0580	0.0177
Unavoidable	−0.0037	0.0035	0.0010	−0.0005	0.0023	0.0013
HI	0.1377	0.1028	0.0989	0.0936	0.0556	0.0164
Central obesity						
Concentration index	0.0681	0.0665	0.0454	0.0176	0.0160	−0.0345
Unavoidable	−0.0124	−0.0013	−0.0077	−0.0169	−0.0109	−0.0152
HI	0.0806	0.0679	0.0531	0.0345	0.0269	−0.0193

HI, horizontal inequity index.

with economic levels. Several studies in high-income countries have emphasised that a higher economic status could reduce the risk of obesity.[44][45] However, in low-income and middle-income countries, due to food scarcity, the prevalence of obesity is more concentrated among the rich because they have more access to fat, sugar and convenient transportation. The lifestyle of the rich in these areas is typically sedentary and characterised by high caloric intake/diets, though the majority of the population—the poor—struggle for adequate food. Obesity is regarded as a 'rich disease'. Our study verified this finding. However, China has experienced significant economic growth since the last century. Since its reform and opening up, China has made rapid progress in many fields, especially economically. It has become the largest developing country in the world. The GDP per capita was $781 in 1997, rising to $5432 in 2011. As the economy and residents' income levels have improved, social changes and economic development have taken place. Consequently, residents' lifestyles have changed significantly. People are gradually seeking healthier lifestyles, and the rich have more opportunities than the poor to obtain healthy foods (vegetables and fruits). Moreover, disadvantaged groups in the economy are regarded as having limited literacy skills and health knowledge.[46] Less access to healthy foods and health education/skills by the poor results in the increasing obesity prevalence among the poor. Skewness towards the rich has decreased. Income-related inequity gradually has approached that of high-income countries. The concentration index has continued to fall, with the value turning negative in 2011.

Limitations of this study include the following. First, records with much missing data were deleted at the time of data screening, though this action did not affect the results of the final analysis. Second, data collected were from nine of the 31 provinces; however, they covered the eastern, central and western parts of China, so the generalisation of the results for the entire country was appropriate. Third, only factors affecting adult and central obesity were identified in this study; the causal relationship was not explored, though it is expected to be validated and studied in future research. Moreover, only part of the influencing factors could be analysed in the study because several determinants of adult and central obesity were not included in the analysis. Finally, smokers and drinkers were defined as having used any quantity of cigarettes or alcoholic beverages, so we can only draw differences between drinkers and non-drinkers and smokers and non-smokers. More specific and in-depth research is needed in the future.

CONCLUSIONS

From 1997 to 2011, the prevalence of adult and central obesity has been increasing annually. The pro-rich inequality for both decreased from 1997 to 2011; inequality in central obesity was observed to be more prominent in the low-income group in 2011. Future policies may need to focus more on obesity reduction among the poor.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not required.

Ethics approval Patients and the public were not involved. Participants were not involved in developing the research questions or planning the study. All study procedures were approved by the Health Science Center Ethics Committee at Xi'an Jiaotong University, Shaanxi, China (approval number: 2015-644).

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Data availability statement Data are available in a public, open access repository. The database is available upon reasonable request from the URL: https://www.cpc.unc.edu/projects/china/

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