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Combined effect of healthy lifestyles and obesity on cardiometabolic risks in Chinese rural adults

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Abstract

Background Combined effect of healthy lifestyles and obesity on cardiometabolic risks were unclear in Chinese rural adults. We aimed to assess the above-mentioned issue.

Methods This study included 25,123 adults from baseline survey of Henan rural cohort study. We collected information regarding current not smoking, current not drinking, healthy diet, adequate exercise, and healthy sleep. We calculated the number of healthy lifestyle factors for each participant or used the latent class analysis to identify clustering classes of healthy lifestyle. Body mass index (BMI), waist circumference (WC), blood pressure, blood lipid, and fasting blood glucose were measured. Logistic models were applied to assess the combined associations of healthy lifestyles and obesity with cardiometabolic risks.

Results 3.8%, 45.8%, and 50.4% of all participants had 0–1, 2–3, and 4–5 healthy factors. The prevalence of obesity defined by BMI and WC was 17.1% and 38.1%, respectively. Compared with participants with obesity who met 0–1 healthy factor, those with obesity who met 4–5 healthy factors have a lower risk of hypertension (odds ratio [OR], 0.41; 95% confidence intervals [95%CI], 0.29–0.58) and dyslipidemia (OR, 0.49; 95%CI, 0.35–0.68) except hyperglycemia (OR, 0.87; 95%CI, 0.53–1.43). Irrespective of the healthy lifestyle scores, compared with participants with normal weight, those with obesity were at higher risk of hypertension, dyslipidemia and hyperglycemia. We obtained similar results when using the latent class analysis or WC to define obesity.

Conclusion Our findings indicated that healthy lifestyle did not entirely offset the obesity-related cardiometabolic risks although it brought some benefits.

Keywords Healthy lifestyle, Obesity, Hypertension, Dyslipidemia, Hyperglycemia

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Background

Obesity is an emerging public health crisis worldwide due to its high prevalence and heavy burden of disease [1, 2]. With the development of economy and the change of lifestyle, in China, the trend in the prevalence of obesity has increased during the past four decades [3]. It is well documented that obesity contributes to onset of hypertension, hyperglycemia, and hyperlipidemia [4]. Hypertension, hyperglycemia, and hyperlipidemia were not only common and frequently occurring diseases in China, but also is strongly related cardiovascular diseases (CVD) and premature death [5].

Given China has big population size, addressing obesity epidemic and its associated disease burden is urgent and necessary. Previous studies demonstrated that higher healthy lifestyle scores were associated with lower risk of CVD, type 2 diabetes (T2D), and multimorbidity in adults [6–9]. Based on the above-mentioned evidence, whether healthy lifestyle entirely offset the obesity-related adverse health risks (e.g. hypertension, hyperglycemia, and hyperlipidemia) was key evidence needed to make public health policy in China [3].

Recently, a more rapid increase was noted in the prevalence of overweight and obesity in Chinese rural areas than urban areas [3]. Consequently, based on Henan Rural Cohort Study which included large sample size of Chinese rural adults, we aimed to assess combined influence of obesity and healthy lifestyle on hypertension, hyperglycemia, and hyperlipidemia in Chinese rural adults [10, 11].

Methods

Study population

Henan Rural Cohort study was launched from July 2015 to September 2017 in five rural counties from different geographical regions of Henan province, China. Background, design, and implementation details of Henan Rural Cohort study were described elsewhere [12]. Briefly, a multistage, stratified cluster sampling method was used to select study subjects. All permanent residents in each administrative unit (rural village) from the selected communities of each rural county were recruited. A total of 39,259 adults aged 18–79 years were included in the study. The study was conducted in accordance with the Declaration of Helsinki. This study was approved by the ethics committee of the life sciences of Zhengzhou University. All of the participants provided signed informed consent.

For the current study, we excluded 9846 adults whose information on body mass index (BMI), healthy lifestyles, blood pressure, blood lipid, or fasting blood glucose was not available. We also excluded 3588 participants who were diagnosed with stroke, coronary heart disease, cancer, or kidney failure. We also excluded 24 participants who were non-Han nationality and 678 participants with underweight (BMI < 18.5 kg/m^2). Finally, 25,123 participants were eligible for the present study.

Healthy lifestyles assessment

Information on the lifestyles was collected using a questionnaire. Current not smoking was defined that participants never smoke at least one cigarette daily for more than half a year [13]. Current not drinking was defined that the participants never drank at least 12 times per year [13]. Physical activity was classified into low, moderate, and high levels based on International Physical Activity Questionnaire (IPAQ) [14]. Moderate or high levels was considered as adequate exercise. Pittsburgh Sleep Quality Index was used to evaluate overall sleep quality. Healthy sleep was defined as scores from Pittsburgh Sleep Quality Index ≤ 5 [15]. Participants provided information on food consumption frequency and quantity over the past year for dietary assessment. Healthy diet was defined that participants met at least 3 recommendations of the Chinese Dietary guidelines 2022 (consumption of vegetables ≥ 300 g/day, fruits ≥ 200 g/day, milk and other dairy products ≥ 300 ml/day, egg ≥ 42.857 g/day, red and white meat ≥ 42.857 g/day, and fish ≥ 42.857 g/day) [16].

Weight assessment

Height without shoes and weight with light clothing were measured. BMI was calculated as weight/height^2 (kg/m^2). The trained investigator used a nonelastic measuring tape to measure waist circumference (WC) at the level of 1.0 cm above the navel.

According to the reference values for Chinese adults, participants were classified into three groups based on BMI or WC: normal weight (BMI ≥ 18.5 kg/m^2 and < 24 kg/m^2), overweight (BMI ≥ 24 kg/m^2 and < 28 kg/m^2), and obesity (BMI ≥ 28 kg/m^2); normal weight (male: WC < 85 cm; female: WC < 80 cm), increased WC(male: WC ≥ 85 cm and < 90 cm; female: WC ≥ 80 cm and < 85 cm), and abdominal obesity (male: WC ≥ 90 cm; female: WC ≥ 85 cm) [17].

Outcome assessment

Blood pressure (BP) measuring instrument and process, blood sample collection, and biochemical indexes measurement (blood lipid and fasting blood glucose) were described in detail in the previous publications [12]. Hypertension was defined as systolic BP/diastolic BP ≥ 140/90 mm Hg or ever having taken antihypertensive drugs during the last two weeks in terms of the 2018 Chinese Guidelines for Prevention and Treatment of Hypertension [18]. Dyslipidemia was defined as total cholesterol (TC) ≥ 6.2 mmol/L, triglyceride (TG) ≥ 2.3mmol/L, high-density lipoprotein cholesterol

(HDL-C) < 1 mmol/L, low-density lipoprotein cholesterol (LDL-C) ≥ 4.1 mmol/L, or taking lipid-lowering drugs for the last two weeks according to the 2016 Chinese Guidelines for the Prevention and Treatment of Dyslipidemia in adults [19]. Hyperglycemia was defined as fasting blood glucose ≥ 7.0 mmol/l, or ever having taken antihyperglycemic medications in the last two weeks [20].

Covariates

Data on gender, age, marital status (married/cohabiting, widowed, divorced/separated, and single), education level (illiterate, primary school, middle school, high school, and university or higher), and per capita monthly income (< 500, 500–999, 1000–1999, 2000–2999, and ≥ 3000 RMB) were self-reported using a questionnaire.

Statistical analysis

We calculated the number of healthy lifestyle factors for each participant, which ranged 0 to 5. Participants were then classified into three groups: 0–1, 2–3, and 4–5 healthy lifestyle factors. Logistic models were used to assess the independent effect of weight status by BMI and healthy lifestyles scores on hypertension, dyslipidemia, and hyperglycemia, after adjusting for gender, age, marital status, education level, and per capita monthly income. In detail, weight status by BMI, healthy lifestyle score, and the above covariates were included in the Logistic model simultaneously. Hypertension, hyperlipidemia, and hyperglycemia were considered as dependent variables in three independent Logistic models. We repeated the above-mentioned analyses with an alternative weight status by WC.

To assess the combined effect of weight status by BMI and healthy lifestyles scores on hypertension, dyslipidemia, and hyperglycemia, participants were then classified into nine groups: participants with obesity who met 0–1, 2–3, and 4–5 healthy lifestyle factors; participants with overweight who met 0–1, 2–3, and 4–5 healthy lifestyle factors; participants with normal weight who met 0–1, 2–3, and 4–5 healthy lifestyle factors. Multivariable-adjusted Logistic models were also used to investigate the aforementioned issue. We also repeated those analyses with an alternative weight status by WC.

We also used the latent class analysis to identify clustering classes of healthy lifestyle. Latent class analysis is a statistical method to classify individuals into latent groups on the basis of a set of categorical variables [21, 22]. To identify the best model, we used two class to start the analysis and added further classes. The fit indicators included G^2, Akaike information criterion (AIC), Bayesian information criteria (BIC), consistent AIC (CAIC), and adjusted BIC [21, 22]. We chose best model based on the lower fit indicators, and simplicity and interpretability of model [21, 22]. Lower fit indicators suggested a particular model was preferable based on the data fitting. Model simplicity required the less numbers of latent classes. Model interpretability indicated that each class should be distinguishable from the others and the meaningful label could be assigned to each class. Then, we also used the above-mentioned analytic strategy to evaluate the combined effect of weight status and clustering classes of healthy lifestyle on hypertension, dyslipidemia, and hyperglycemia.

We considered overadjustment of covariates and did not believe that such problems existed. First, sample size were large and there were only five covariates (gender, age, marital status, education level, and per capita monthly income). Second, generally, odds ratio regarding the association of exposure with outcome did not change significantly with and without adjustment for those five covariates based on the above-mentioned Logistic models. Third, the results after adjustment for those five covariates based on the above-mentioned Logistic models were consistent with the objective reality. Additionally, we checked the multicollinearity based on Variance Inflation Factor (VIF) in all Logistic models. We found the VIF for any tested variables in all Logistic models less than 5, indicating there was no multicollinearity.

SAS version 9.4 (SAS Institute, Cary, California, USA) and R version 4.3.2 were used to perform statistical analyses. Two-sided P values < 0.05 were considered statistically significant.

Results

25,123 participants (male: 40.5%; mean age: 54.4 years) were included in the current study. Table 1 presents the characteristics of all participants. 3.8%, 45.8%, and 50.4% of all participants had 0–1, 2–3, and 4–5 healthy factors. The prevalence of obesity defined by BMI and WC was 17.1% and 38.1%, respectively. The prevalence of hypertension, hyperglycemia, and dyslipidemia was 29.8%, 8.0% and 35.6%, respectively.

Table S1 describes the independent effect of weight status and healthy lifestyles scores on hypertension, dyslipidemia, and hyperglycemia. Compared with the participants with normal weight by BMI, those with obesity were more likely to have hypertension, dyslipidemia, and hyperglycemia [all $Ps < 0.001$]. Compared with the participants with 0–1 healthy factor, those with 4–5 healthy factors were at lower risk of hypertension and dyslipidemia [all $Ps < 0.001$] except hyperglycemia [$P = 0.290$]. We observed the similar result when using WC to define abdominal obesity.

Figure 1 and Table S2 shows the combined effect of weight status by BMI and healthy lifestyles scores on hypertension, dyslipidemia, and hyperglycemia. Compared with participants with obesity who met 0–1 healthy factor, those with obesity who met 4–5 healthy

Table 1 Characteristics of all participants

	All participants (*N* = 25123)
Male, n (%)	10,184 (40.5%)
Age, years	54.4 ± 12.4
Marital status	
Married/cohabiting, n (%)	22,831 (90.9%)
Widowed, n (%)	1742 (6.9%)
Divorced/separated, n (%)	135 (0.5%)
Single, n (%)	415 (1.7%)
Education level	
Illiterate, n (%)	3882 (15.5%)
Primary school, n (%)	6746 (26.9%)
Middle school, n (%)	10,060 (40.0%)
High school, n (%)	3502 (13.9%)
University or higher, n (%)	933 (3.7%)
Per capita monthly income	
<500 RMB, n (%)	8778 (34.9%)
500–999 RMB, n (%)	7974 (31.7%)
1000–1999 RMB, n (%)	6071 (24.2%)
2000–2999 RMB, n (%)	1496 (6.0%)
≥3000 RMB, n (%)	804 (3.2%)
Current non-smoker, n (%)	19,913 (79.3%)
Current non-drinker, n (%)	20,481 (81.5%)
Healthy diet, n (%)	8090 (32.2%)
Adequate exercise, n (%)	17,349 (69.1%)
Healthy sleep, n (%)	20,092 (80.0%)
Number of healthy lifestyles	
0–1	963 (3.8%)
2–3	11,507 (45.8%)
4–5	12,653 (50.4%)
BMI, kg/ m^2	24.9 ± 3.4
Weight status by BMI	
Normal weight, n (%)	10,863 (43.2%)
Overweight, n (%)	9961 (39.7%)
Obesity, n (%)	4299 (17.1%)
Waist circumference, cm	84.0 ± 10.1
Weight status by WC	
Normal weight, n (%)	10,767 (42.9%)
Increased WC, n (%)	4776 (19.0%)
Abdominal obesity, n (%)	9580 (38.1%)
SBP, mmHg	125.0 ± 19.6
DBP, mmHg	77.4 ± 11.6
Hypertension, n (%)	7475 (29.8%)
Fasting blood glucose, mmol/L	5.5 ± 1.4
Hyperglycemia, n (%)	2011 (8.0%)
TC, mmol/L	4.9 ± 1.0
TG, mmol/L	1.7 ± 1.1
HDL-C, mmol/L	1.3 ± 0.3
LDL-C, mmol/L	2.9 ± 0.8
Dyslipidemia, n (%)	8949 (35.6%)

DBP, diastolic blood pressure; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; SBP, systolic blood pressure; TC, total cholesterol; TG, triglyceride; WC, waist circumference; BMI, body mass index. Data were shown as mean ± SD for continuous variables and number (percentage) for categorical variables

factors have a lower risk of hypertension (OR, 0.41; 95%CI, 0.29–0.58) and dyslipidemia (OR, 0.49; 95%CI, 0.35–0.68) except hyperglycemia (OR, 0.87; 95%CI, 0.53–1.43). Of particular interest, irrespective of the healthy lifestyle scores, compared with participants with normal weight, those with obesity were at higher risk of hypertension, dyslipidemia and hyperglycemia, on the basis of nonoverlapping of the 95% confidence intervals of OR. We repeated analyses with an alternative weight status by WC and observed the similar results (Table S3).

Table S4 provides the fit indicators of latent class analysis. We chose a model with three clustering classes based on the lower BIC, CAIC, and adjusted BIC. The model with three clustering classes also had simplicity and interpretability. The model with three classes clearly shows a distinction in the healthy lifestyle (Table S5). The classes were named "least healthy factors" ($n = 7213$, 28.7%),"moderate healthy factors" ($n = 12343$, 49.1%), and "most healthy factors" ($n = 5567$, 22.2%). We repeated analyses when using latent class analysis to identify clustering classes of healthy lifestyle and obtained the similar results (Table 2). We also observed the similar results when further using WC to define abdominal obesity (Table S6).

Discussion

In this study, compared with participants with obesity who met 0–1 healthy factor, those with obesity who met 4–5 healthy factors have a lower risk of hypertension and dyslipidemia except hyperglycemia. However, irrespective of the healthy lifestyle scores, compared with participants with normal weight, those with obesity were at higher risk of hypertension, dyslipidemia and hyperglycemia. We obtained similar results when using the latent class analysis to classify healthy lifestyle or WC to define obesity.

This study showed that the healthy lifestyle reduced the risk of hypertension and dyslipidemia in adults with obesity. Nurses' Health Study and Health Professionals Follow-up Study further pointed out that higher healthy lifestyle scores were related to lower risk for all-cause mortality in each category of BMI (18.5–22.4, 22.5–24.9, 25-29.9, ≥30) [23]. Our findings were partly supported by other publications, which founded that higher healthy lifestyle scores were associated with lower risk for CVD and T2D among adults with cancer, all-cause and cancer mortality and macrovascular and microvascular complications among adults with diabetes, and longer life in adults with multimorbidity [8, 24, 25]. Potential mechanism may explain our findings. Healthy lifestyles affect cardiometabolic health mainly by reduced insulin resistance, oxidative stress, inflammatory reaction, vascular endothelial function and structure damage, and vascular

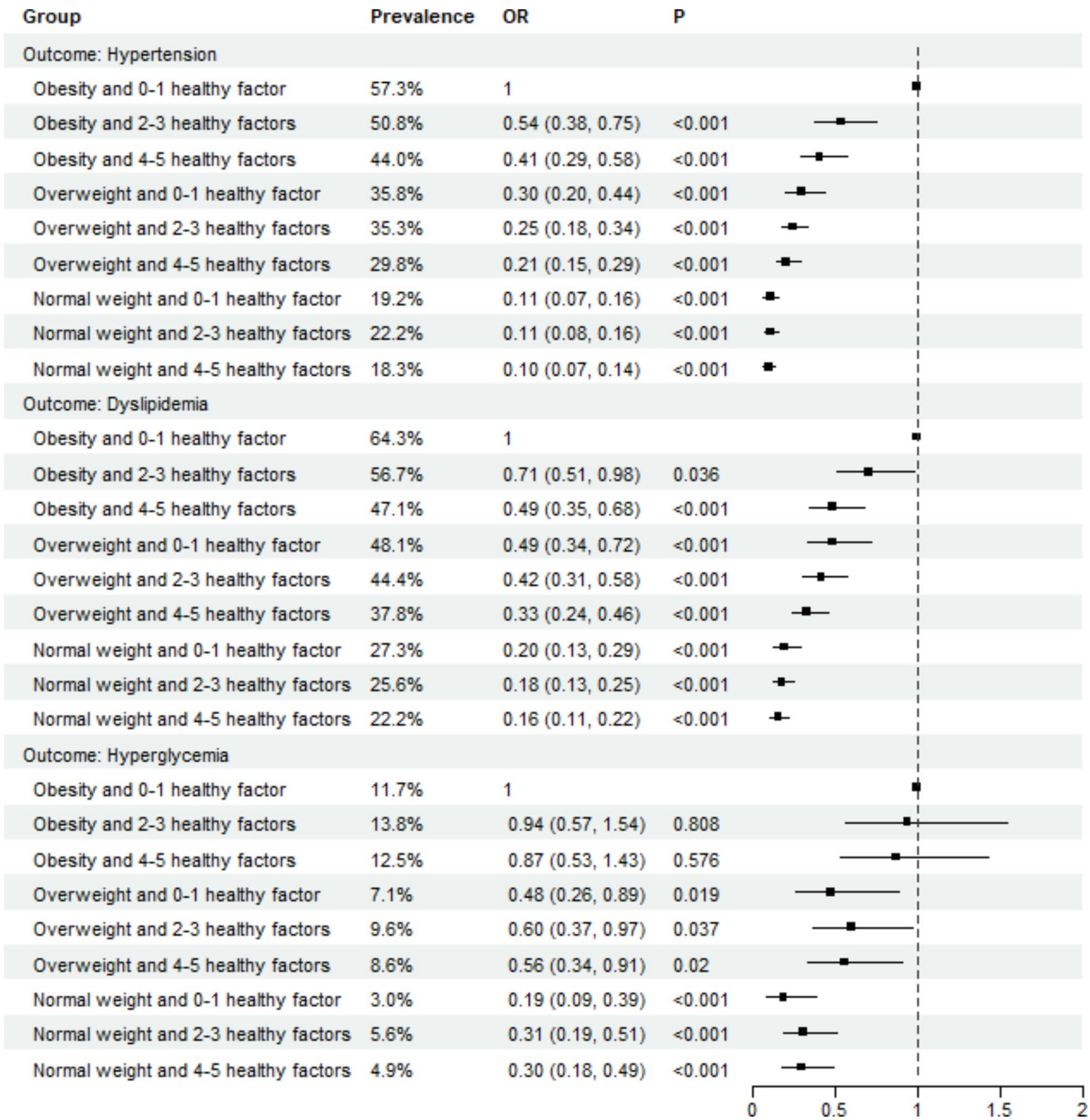

Fig. 1 Combined effect of weight status by BMI and healthy lifestyles on outcomes

hardness, and improvements in lipid lipoprotein profiles [23, 26].

Our study indicated that the healthy lifestyle partly reduced rather than entirely offset the obesity-related cardiometabolic risks. Two cohort studies from UK Biobank also reported that healthy lifestyles were not sufficient to attenuate the obesity-related adverse health risk [26, 27]. On the contrary, weight loss was effective despite difficult [28]. Consequently, weight loss was the key measure to control the obesity-related adverse health risk.

Compared with previous studies, this study had added value. First, facing a more rapid increase trend in overweight and obesity, less medical service resources, lower coverage by health care systems, lower income levels in Chinese rural areas than urban areas, it is urgent to adopt effective intervention measures to reduce obesity and its related burden in Chinese rural adults [3, 12]. We used Henan Rural Cohort study to confirm the importance of

Table 2 Combined effect of weight status by BMI and healthy lifestyles clustering classes based on latent class analysis on hypertension, dyslipidemia, and hyperglycemia

	Hypertension*			**Dyslipidemia***			**Hyperglycemia***		
	Prevalence	OR (95%CI)	*P*	Prevalence	OR (95%CI)	*P*	Prevalence	OR (95%CI)	*P*
Obesity and least healthy factors (*n* = 1161)	48.6%	Ref		61.6%	Ref		12.2%	Ref	
Obesity and moderate healthy factors (*n* = 2254)	49.6%	0.75 (0.63–0.88)	< 0.001	49.6%	0.59 (0.50–0.69)	< 0.001	14.1%	0.94 (0.74–1.20)	0.612
Obesity and most healthy factors (*n* = 884)	42.3%	0.63 (0.52–0.77)	< 0.001	47.4%	0.55 (0.46–0.67)	< 0.001	11.8%	0.85 (0.63–1.14)	0.268
Overweight and least healthy factors (*n* = 2788)	32.0%	0.39 (0.33–0.45)	< 0.001	44.5%	0.48 (0.42–0.55)	< 0.001	8.0%	0.54 (0.43–0.68)	< 0.001
Overweight and moderate healthy factors (*n* = 4894)	34.8%	0.37 (0.32–0.44)	< 0.001	40.8%	0.41 (0.35–0.47)	< 0.001	9.9%	0.62 (0.50–0.78)	< 0.001
Overweight and most healthy factors (*n* = 2279)	28.0%	0.32 (0.27–0.38)	< 0.001	37.7%	0.37 (0.32–0.44)	< 0.001	8.0%	0.56 (0.44–0.73)	< 0.001
Normal weight and least healthy factors (*n* = 3264)	18.1%	0.15 (0.12–0.17)	< 0.001	23.6%	0.18 (0.16–0.21)	< 0.001	4.1%	0.24 (0.19–0.31)	< 0.001
Normal weight and moderate healthy factors (*n* = 5195)	23.7%	0.20 (0.17–0.24)	< 0.001	25.3%	0.20 (0.17–0.23)	< 0.001	6.1%	0.36 (0.28–0.45)	< 0.001
Normal weight and most healthy factors (*n* = 2404)	15.2%	0.14 (0.12–0.17)	< 0.001	21.5%	0.17 (0.14–0.20)	< 0.001	4.3%	0.30 (0.22–0.39)	< 0.001

* Adjusted for gender, age, marital status, education level, and per capita monthly income

OR, odds ratio; CI, confidence interval; BMI, body mass index

adopting healthy lifestyles in addressing the obesity epidemic in Chinese rural areas. Similarly, healthy lifestyles were especially recommended and strengthened implementation in national "Healthy China 2030 Plan" [29]. Second, previous study evaluated and classified healthy lifestyle based on a composite score, which is simple and easily understood [6–9, 23–27]. However, the characteristics of each group are not clear. We used latent class analysis to identify clustering classes of healthy lifestyle and better characterized each group by high (> 0.7) probabilities of each of healthy lifestyle (Table S5) [21, 22]. Three clustering classes were identified: least healthy factors (main adherence to healthy sleep), moderate healthy factors (main adherence to current non-smoker, current non-drinker, and healthy sleep), and most healthy factors (adherence to 5 healthy lifestyle factors) (Table S5). Third, previous study only used BMI to evaluated weight status [23, 26, 27]. Given abdominal obesity epidemic by WC in Chinese adults and its high relation to cardiometabolic risks, we also used WC to evaluated weight status [30]. We obtained the similar results when using latent class analysis to classify healthy lifestyle or using WC to define abdominal obesity, which supported the stability of the results.

With obesity epidemic in the Chinese adults, this study had important public health implications. On the one hand, this study highlighted the importance of adopting a healthy lifestyle to reduce the burden of obesity in adults with obesity. On the other hand, this study supported that maintaining a healthy weight yield significant benefits for adults with normal weight. Consequently, in making public policies, priority should be given to primary prevention for obesity, which indicated that adopting measures aimed to prevent the population-level obesity epidemic. In clinical settings, for adults with obesity, weight loss was considered as the main target. Weight loss requires a multidimensional approach, which included lifestyle modification, taking medication, and bariatric surgery.

The strength of this study included large sample size and high quality data. Our study has also several limitations. First, causality between obesity, healthy lifestyles, and cardiometabolic risks could not be verified because the baseline survey is a cross-sectional design. Second, information about healthy lifestyles was self-reported, which may introduce the bias. Third, this study did not include Chinese urban adults. Fourth, some potential confounders, which we did not take into account and could not collect, may affect our results. Fifth, we did not perform a stratified analysis by gender, because there were too few participants in some categories. For example, the number of female participants with obesity who met 0–1 healthy lifestyle factors were five. Future studies with larger sample sizes which can be used to conduct sex-stratified analysis are needed to confirm our findings. Finally, this study did not include participants with underweight due to small number.

Conclusions

In conclusion, our study indicated that healthy lifestyle did not entirely offset the obesity-related cardiometabolic risks although it brought some benefits. Thus, our findings underscore the importance of primary prevention for obesity in Chinese rural adults.

Abbreviations

BMI	body mass index
WC	waist circumference
IPAQ	International Physical Activity Questionnaire
BP	blood pressure
TC	total cholesterol
TG	triglyceride
HDL-C	high-density lipoprotein cholesterol
LDL-C	low-density lipoprotein cholesterol

Supplementary Information

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Supplementary Material 1

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Author contributions
HF, XZ, CW, and CH conceptualized and designed the study; HF carried out the initial analyses, drafted the initial manuscript and reviewed and revised the manuscript; XZ, CW, and CH critically reviewed and revised the manuscript. All authors read and approved the final manuscript as submitted.

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Data availability
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
The study was conducted in accordance with the Declaration of Helsinki. This study was approved by the ethics committee of the life sciences of Zhengzhou University. All of the participants provided signed informed consent.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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