BMC Public Health

RESEARCH

Open Access

The correlation between healthy lifestyle habits and all-cause and cardiovascular mortality in Guangxi

Lan-Xian Mai[1,2,3,4†], Ying Liu[1,3,4,5†], Hong Wen[1,3,4*] and Zhi-Yu Zeng[1,2,3,4*]

Abstract

Background Adherence to healthy lifestyle habits has become a mainstream approach for lessening the burden of cardiovascular disease (CVD) during initial prevention efforts. The purpose of this study was to investigate the prevalence of four healthy lifestyle habits, the associated factors, and their impact on all-cause and cardiovascular mortality among residents of Guangxi Zhuang Autonomous Region.

Methods From 2015 to 2019, individuals between the ages of 35 and 75 from Guangxi Zhuang Autonomous Region were recruited through the ChinaHeart Million Person Project. Our study examined four healthy lifestyle habits: not smoking, no or moderate amounts of alcohol, sufficient leisure time physical activity (LTPA) and a balanced diet.

Results Out of the 19,969 individuals involved, the majority, 77.3% did not smoke, while 96.7% had limited alcohol intake, 24.5% engaged in sufficient LTPA, 5.5% followed a balanced diet, and merely 1.7% adhered to all four healthy lifestyle habits. Participants who were women, older, nonfarmers, living in cities, with a high income or level of education, or had hypertension or diabetes were more likely to follow all four healthy lifestyle habits ($p < 0.001$). People who followed the three healthy lifestyle habits had reduced chances of death from all cause (HR 0.34[95% CI:0.15,0.76]) and cardiovascular-related death (HR 0.23 [95% CI: 0.07, 0.68]) ($p < 0.01$) over a median period of 3.5 years.

Conclusions In Guangxi Province, the level of adherence to healthy lifestyle habits is very minimal. Therefore, population-specific health promotion strategies are urgently needed.

Keywords Healthy lifestyle habits, Mortality, Health promotion, Guangxi

†Lan-Xian Mai and Ying Liu share the first authorship.

*Correspondence:
Hong Wen
Wenhong120@126.com
Zhi-Yu Zeng
zengzhiyu@gxmu.edu.cn
[1]The First Affiliated Hospital of Guangxi Medical University, No.6 Shuangyong Road, Nanning 530021, China
[2]School of Information and Management, Guangxi Medical University, No.22 Shuangyong Road, Nanning 530021, China
[3]Guangxi Key Laboratory of Precision Medicine in Cardio-Cerebrovascular Diseases Control and Prevention, Nanning, China
[4]Guangxi Clinical Research Center for Cardio-Cerebrovascular Diseases, Nanning, China
[5]School of Public Administration, Guangxi University, No.100 East University Road, Nanning 530004, China

Introduction

China has a substantial population burden of cardiovascular risk factors, with only 0.2% of Chinese adults achieving ideal cardiovascular health [1]. CVD has become the primary disease that threatens the health of Chinese residents, leading in mortality rates across both urban and rural populations and represent a critical issue in the nation's public health landscape [2]. Currently, the prevalence of CVD in China is on the rise, it is estimated that there are currently 330 million people with CVD, and a turning point for the decline in cardiovascular health burden has not yet occurred [2]. Furthermore, In 2021, the proportion of the population in China aged 65 and above was 14.2%. It is projected that by 2050, the population aged 65 and above in China will reach 395 million, equivalent to 1.2 times the current population of the United States [3], it will further exacerbate this burden on China's health care system. The World Bank reports that without the adoption of impactful management strategies, a sharp surge in the prevalence of cardiovascular cases is anticipated between the years 2010 to 2030. The hospitalization rates for CVD in China have experienced significant increase over the past three decades. Although several diagnostic and treatment technologies for CVD have reached or approached global standards, it is important to recognize that substantial progress only in the areas of detection and therapeutic methods will not sufficiently reduce the impact of CVD in China. Instead, efforts should focus on improving major modifiable risk factors as part of current strategies for preventing CVD [4].

Prior studies have consistently shown that adopting a lifestyle with low-risk habits positively influences the initial avoidance of chronic diseases and promotes long-term health [5], including nonsmoking, a healthy diet, adequate physical activity and maintaining an optimal body weight, which may offer greater efficacy in mitigating the likelihood of cardiovascular ailments, diabetes, and cancer than relying on a single element [6–8]. A multi-national longitudinal investigation has shown that maintaining a health-conscious lifestyle is linked to a lower frequency and death rate from cancer in general, along with a diminished risk for specific cancer forms among those with diabetes [9]. Individuals who followed the most wholesome lifestyles experienced relative reductions of 55%, 58%, and 62% in overall mortality, mortality attributed to CVD, and the onset of CVD, respectively, compared to those adhering to the least healthful lifestyles [10]. In addition, the China Kadoorie Biobank (CKB) study showed that at age 30, males who adopt a low-risk lifestyle live 8.8 years longer than men who do not adopt a low-risk lifestyle, and females live 8.1 years longer, which is mainly due to lower death rate from long-term respiratory system disorders, malignancies and long-term respiratory system disorders [11].

The Guangxi Zhuang Autonomous Region is a region with a large population of ethnic minorities and is economically disadvantaged. In the year 2016, non-communicable diseases were the leading contributors to mortality in Guangxi, constituting 80% of all deaths. Specifically, cardiovascular conditions, cancer, and cardiovascular-related diseases were identified as the primary determinants of mortality in the region [12]. In the past, surveys on the health behaviour of Guangxi residents were limited to the analysis of a single or isolated healthy lifestyle [13, 14] or the exploration of national health literacy [15]. To date, there has been no relevant discussion on the situation of Guangxi residents adhering to a comprehensive healthy lifestyle habits and its association with all-cause death and cardiovascular-related death. To fill this study gap, we conducted a broad-based cohort study in Guangxi. The goal was to assess the prevalence of four healthy lifestyle habits: not smoking, no or moderate amounts of alcohol, sufficient LTPA and a balanced diet among residents in Guangxi and to assess the degree of clustering and the existence of dependencies with personal characteristics. Additionally, we aimed to further explore whether there are correlations between the four healthy lifestyles and the risks of all-cause and cardiovascular mortality.

Methods

Study design and participants

The ChinaHEART is a government-backed initiative focused on screening and managing individuals at high-risk of CVD. The project plan was released in January 2016 [16]. Briefly, the project sampled 8 sites (Nanning, Wuming District, Hengzhou District, Liuzhou, Liujiang District, Qinzhou, Baize and Hezhou), including 3 rural areas and 5 urban areas. Residents age ranges from 35 to 75 years, who had been residents of the area for a minimum of six months and in the previous year were invited to take part in this study. Participants enrolled in the study with project ID numbers 1, 3, 5, or 7 were selected at random to represent the entire group and provide in-depth information on CVD.

Approval for the study protocol was granted by the Ethics Committees of Fuwai Hospital in Beijing, China (Approval No. 2014–574). Written informed consent was obtained from all enrolled participants.

From the Cox regression analysis, to prevent reverse causality and enhance the internal validity of our study, we omitted participants with a self-reported history of CVD (n=689). The participant recruitment and screening process is presented in Fig. 1.

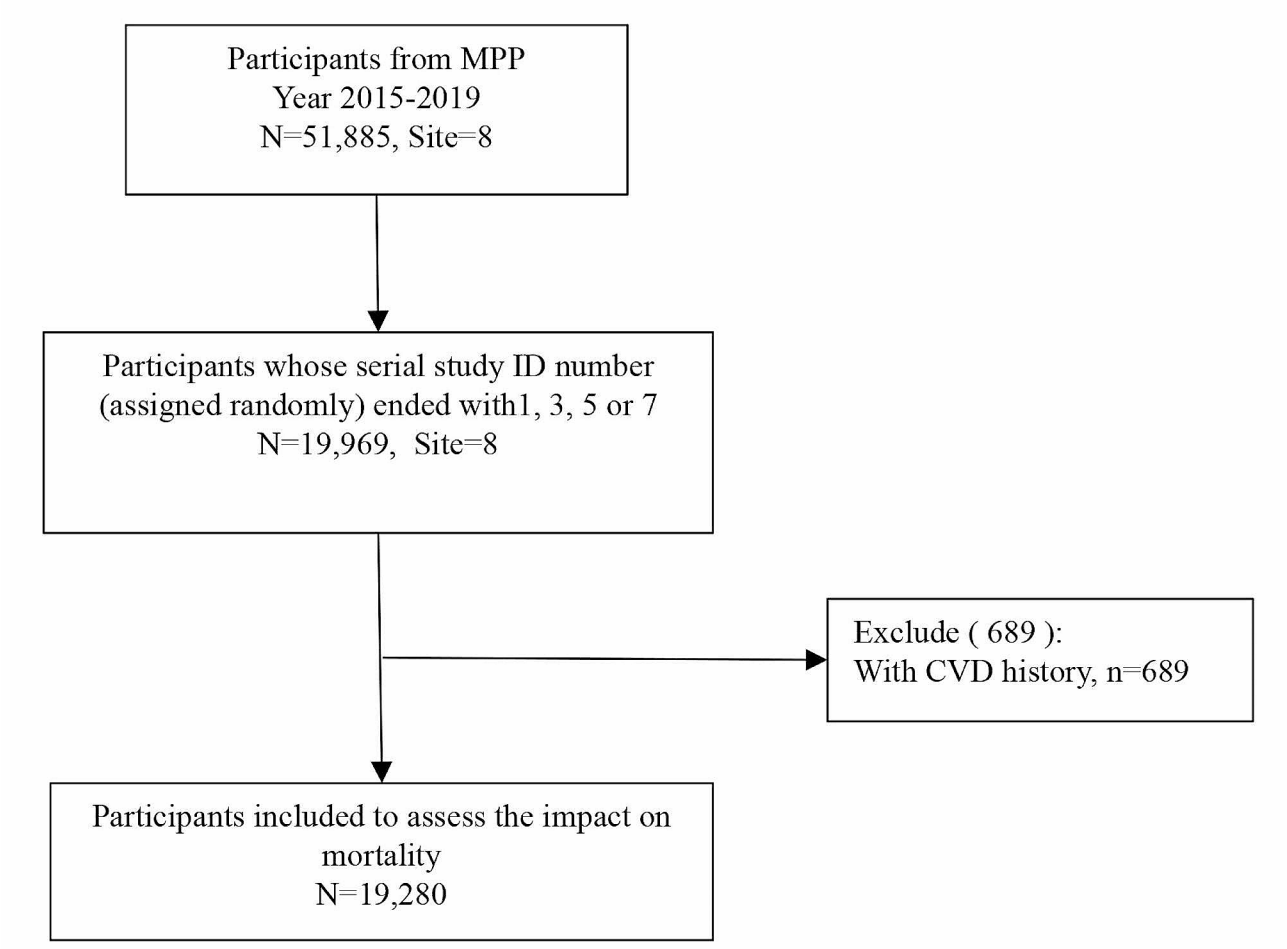

Fig. 1 The flowchart of the study population selection. MPP: The Million Persons Project in China focuses on evaluating cardiac events with a patient-centered approach; CVD: Cardiovascular disease

Data collection and variables

The project used standardized face-to-face electronic questionnaires to collect data about four healthy lifestyle habits, including smoking, alcohol consumption, LTPA and diet. We briefly asked about participants' smoking status, whether they were never, former, or current smokers. Those with a smoking history were also asked about their smoking habit, such as how often they smoked, what type of cigarettes they used, and how much tobacco they consumed daily. Former smokers were also questioned regarding the reasons behind their decision to stop smoking. In terms of drinking, participants were inquired about how often they consumed alcohol (never, monthly or less, 2–4 times a month, 2–3 times a week, or over 4 times a week). Former drinkers were asked about their typical alcohol consumption on a regular drinking day, which was used to calculate the average daily alcohol intake. LTPA was measured based on the common forms of physical activity at various levels of intensity (such as swimming, jogging, or high-intensity aerobic workouts; playing sports, walking, doing gymnastics, folk dancing, Tai-chi, Qigong, or other activities considered moderate-intensity), as well as the frequency and duration of exercise per week. A survey measuring the frequency of consumption in 12 food categories over the previous year was conducted using a qualitative food frequency questionnaire. The survey provided five choices for how often each food category was consumed, including daily, 1–3 times per week, 1–3 times per month, and rarely or never. A digital questionnaire equipped with real-time data validation checks was utilized to safeguard the accuracy and comprehensiveness of the collected interview information.

The healthy lifestyle habits category in terms of smoking was described as individuals who were nonsmokers (those who had never smoked or had quit smoking) [17]. The group of individuals with no or moderate amounts of alcohol (either never drinkers or those who consumed no more than 25 g [for males] or 15 g [for females] per day on average [18]). Participants in the sufficient LTPA

category engaged in a minimum of 150 min of moderate-intensity aerobic exercise or 75 min of vigorous-intensity aerobic exercise each week; additionally, the acceptable diet group (score≥4) followed the Chinese dietary recommendations and findings from prior research [18–21]. The balanced diet score was calculated based on the weekly consumption of six food groups, consisting of daily consumption of fresh fruits, fresh veggies, whole grains, fish and other sea creatures at least once a week, legumes and legume products at least four times a week, and restricting red meat intake to fewer than seven days per week. Individuals meeting the requirements for each nutritional group were assigned a score of 1; those who did not meet the criteria received a score of 0, resulting in a total healthy eating score of 6. The healthy group was defined as those with a score≥4 [19, 20].

Information regarding the sociodemographic characteristics of the participants, such as gender, age, job, level of education, income, marital status, and health insurance status, in addition to urban living conditions and medical history, including self-reported conditions like high blood pressure, diabetes, and cardiovascular events such as myocardial or stroke, was gathered through electronic surveys.

Ascertainment of outcomes

The study assessed the subjects' survival status using the National Cause of Death Surveillance System and Cause of Death Registration and Reporting System operated by the Chinese CDC. The study utilized the International Classification of Diseases (ICD)-10 to code all events, with a focus on cardiovascular death (ICD-10: I01-I99) and all cause mortality outcomes. At the time of the analysis, mortality data were available through December 31, 2019. As a result, all subsequent observations in our research were concluded by this specific date or the date of passing, whichever came first.

Statistical analysis

The characteristics and prevalence of the four healthy lifestyle habits among all subjects were outlined with categorical data shown as frequencies and percentages, and continuous variables shown as P values or medians with interquartile ranges. When the P value was less than 0.05, it indicated a small difference between males and females as well as rural and urban residents. Linear trends were tested using the Mantel-Haynes test and simple linear regression.

The study utilized multivariate regression models to explore the connections between personal traits and compliance with four healthy lifestyle habits, including factors like gender, age, job, schooling, income, marital status, and health insurance, along with medical background such as self-reported high blood pressure or diabetes, as well as cardiovascular events like heart attacks or strokes. For each healthy lifestyle habit that was assessed, we simultaneously adjusted for the other three lifestyles in our model. In Table 3, the correlation of the four healthy lifestyle habits and personal characteristics is displayed. Fisher's Z-transformation was utilized to convert the diversity in correlation coefficients observed between rural and urban regions.

Cox proportional hazards models were utilized to calculate hazard ratios for cardiovascular-related death and all cause, adjusting for age and sex in multivariable models. The estimates were accompanied by 95% confidence intervals. The comprehensive model accounted for various demographic and socioeconomic factors, such as gender, age, job, schooling, yearly household earnings, marital status, and coverage under social health insurance. A sensitivity analysis was performed, excluding fatalities that happened during the initial six-month period. Additionally, a separate sensitivity analysis was carried out to omit participants who reported having hypertension or diabetes.

Statistical analyses were conducted using SAS 9.4 from SAS Institute in Kaili City, North Carolina, and R3.6.2 from Foundation for Statistical Computing in Vienna, Austria.

Results

Characteristics of participants and prevalence of healthy lifestyle habits

The study consisted of 19,969 individuals, with an average age of 55.3±9.9 years; 62% were women, 41.4% resided in rural regions, 34.3% had completed high school or higher education, 42.6% worked as farmers, 23.2% had a yearly household income exceeding 50,000 yuan, 95% were married, and 98.5% had medical insurance coverage. Out of all the individuals involved, 19.3% reported having hypertension or diabetes, while 3.5% had previously experienced cardiovascular disease (Table 1).

Based on data from the 2010 national census, adjusted for age and gender, the greatest level of adherence was seen in the group with no or moderate amounts of alcohol (96.7%), with nonsmokers coming in second (77.3%). Conversely, lower rates of compliance were noted for sufficient LTPA (24.5%) and a balanced diet (5.5%), as detailed in Table 2. Just 1.7% of the total participants followed all four healthy lifestyle habits.

Variations in adherence to healthy lifestyle habits

Women showed greater adherence to the four healthy lifestyle habits than men (all $p<0.001$). In terms of the three healthy lifestyles of non-smoker, sufficient LTPA, a balanced diet, after standardization, urban dwellers demonstrated a higher level of adherence than rural inhabitants (all $p<0.0001$); however, with no or moderate

Table 1 Participant characteristics by number of healthy lifestyle habits

	Total	Number of healthy lifestyle habits[a]					
		0	1	2	3	4	*P* for trend
Demographic and socioeconomic	19,969	269	2478	11,806	4983	433	
Men	7587 (38.0)	267 (99.3)	2435 (98.3)	3562 (30.2)	1225 (24.6)	98 (22.6)	<0.0001
Women	12,382 (62.0)	2 (0.7)	43 (1.7)	8244 (69.8)	3758 (75.4)	335 (77.4)	<0.0001
Age(year)	55.3 ± 9.9	56.8 ± 8.9	54 ± 9.9	54.8 ± 10	56.6 ± 9.5	57.6 ± 9.6	<0.0001
Rural	8271 (41.4)	179 (66.5)	1582 (63.8)	5913 (50.1)	581 (11.7)	16 (3.7)	<0.0001
Urban	11,698 (58.6)	90 (33.5)	896 (36.2)	5893 (49.9)	4402 (88.3)	417 (96.3)	<0.0001
Primary and below	6695 (33.5)	104 (38.7)	922 (37.2)	4691 (39.7)	935 (18.8)	43 (9.9)	<0.0001
junior high school	5998 (30.0)	95 (35.3)	902 (36.4)	3541 (30.0)	1363 (27.4)	97 (22.4)	<0.0001
High school	3933 (19.7)	38 (14.1)	353 (14.2)	1899 (16.1)	1488 (29.9)	155 (35.8)	<0.0001
College and above	2909 (14.6)	24 (8.9)	245 (9.9)	1418 (12.0)	1091 (21.9)	131 (30.3)	<0.0001
Farmer	8506 (42.6)	170 (63.2)	1558 (62.9)	6100 (51.7)	657 (13.2)	21 (4.8)	<0.0001
Nonfarmer	11,017 (55.2)	91 (33.8)	870 (35.1)	5449 (46.2)	4203 (84.3)	404 (93.3)	<0.0001
Annual income < 10,000 yuan	2469 (12.4)	21 (7.8)	297 (12.0)	1566 (13.3)	553 (11.1)	32 (7.4)	0.0271
Annual income 10,000–50,000 yuan	9442 (47.3)	156 (58.0)	1116 (45.0)	6004 (50.9)	2013 (40.4)	153 (35.3)	<0.0001
Annual income > 50,000	4637 (23.2)	60 (22.3)	550 (22.2)	2340 (19.8)	1505 (30.2)	182 (42.0)	<0.0001
Married	18,968 (95.0)	261 (97.0)	2399 (96.8)	11,259 (95.4)	4644 (93.2)	405 (93.5)	<0.0001
Social medical insurance	19,676 (98.5)	266 (98.9)	2458 (99.2)	11,647 (98.7)	4878 (97.9)	427 (98.6)	<0.0001
Hypertension or diabetes	3852 (19.3)	42 (15.6)	367 (14.8)	1997 (16.9)	1328 (26.7)	118 (27.3)	<0.0001
CVD history	689 (3.5)	11 (4.1)	79 (3.2)	349 (3.0)	236 (4.7)	14 (3.2)	0.0003

[a] Healthy lifestyle habits were defined as not smoking, no or moderate amounts of alcohol, sufficient leisure time physical activity and a balanced diet

Table 2 Participants' adherence to healthy lifestyle habits, overall, by gender and by urbanicity

	Overall	Women	Men	*P*(by gender)	Rural	Urban	*P* (by urbanicity)
	19,969	12,382	7587		8271	11,698	
Nonsmoking	16,627 (77.3)	12,351 (99.7)	4276 (55.6)	<0.0001	6470 (73.2)	10,157 (80.2)	<0.0001
No or moderate amounts of alcohol	19,378 (96.7)	12,324 (99.5)	7054 (94.0)	<0.0001	7980 (96.9)	11,398 (96.6)	<0.0001
Sufficient LTPA	5630 (24.5)	3710 (25.6)	1920 (23.4)	<0.0001	549 (6.4)	5081 (37.3)	<0.0001
Balanced diet	1136 (5.5)	760 (6.2)	376 (4.9)	0.0005	216 (2.7)	920 (7.5)	<0.0001
dietary score	1.7(1.1) 2(1, 2)	1.8(1) 2(1, 2)	1.7(1.2) 2(1, 2)	<0.0001	1.4(1) 1(1, 2)	2(1.1) 2(1, 3)	<0.0001
Eat fruit every day per week	5356 (26.3)	3618 (28.8)	1738 (23.9)	<0.0001	1101 (14.0)	4255 (35.0)	<0.0001
Eat vegetables every day per week	12,104 (59.9)	7623 (60.3)	4481 (59.6)	0.0004	4402 (52.4)	7702 (65.3)	<0.0001
Eat grain every day per week	1009 (5.1)	682 (5.7)	327 (4.5)	0.0002	285 (4.2)	724 (5.8)	<0.0001
Eat legumes > = 4 days per week	1917 (9.9)	1242 (10.5)	675 (9.2)	0.0083	451 (5.9)	1466 (12.7)	<0.0001
Eating fish > = 1 day per week	10,444 (53.1)	6598 (53.2)	3846 (53.0)	0.0004	2664 (33.1)	7780 (67.2)	<0.0001
Red meat < 7 days per week	3936 (19.2)	2368 (19.2)	1568 (19.1)	0.0078	2433 (28.5)	1503 (12.5)	<0.0001
0 heathy lifestyle behaviours	269 (1.4)	2 (0.0)	267 (2.8)	<0.0001	179 (1.7)	90 (1.2)	<0.0001
1 heathy lifestyle behaviours	2478 (17.4)	43 (0.4)	2435 (33.8)	<0.0001	1582 (24.4)	896 (12.4)	<0.0001
2 heathy lifestyle behaviours	11,806 (58.6)	8244 (70.5)	3562 (47.1)	<0.0001	5913 (67.0)	5893 (52.6)	<0.0001
3 heathy lifestyle behaviours	4983 (20.9)	3758 (26.7)	1225 (15.2)	<0.0001	581 (6.7)	4402 (30.9)	<0.0001
>=1 heathy lifestyle behaviours	19,700 (98.6)	12,380 (100)	7320 (97.2)	<0.0001	8092 (98.3)	11,608 (98.8)	<0.0001
>=2 heathy lifestyle behaviours	17,222 (81.2)	12,337 (99.6)	4885 (63.4)	<0.0001	6510 (73.9)	10,712 (86.4)	<0.0001
>=3 heathy lifestyle behaviours	5416 (22.6)	4093 (29.1)	1323 (16.3)	<0.0001	597 (6.9)	4819 (33.7)	<0.0001
4 heathy lifestyle behaviours	433 (1.7)	335 (2.4)	98 (1.1)	<0.0001	16 (0.2)	417 (2.8)	<0.0001

The frequencies in the table were based on rough counting numbers before standardization, whereas the percentages were standardized by age and sex using 2010 national census data

amounts of alcohol, rural residents had a greater rate of adherence than did urban residents ($p<0.0001$). Additionally, women had a higher balanced diet compared to men ($p<0.0001$), with a higher proportion of women consuming fruits, vegetables, and grains daily; beans at least 4 days a week; fish at least once a week; and red meat less than 7 days a week compared to men (all $p<0.05$). Urban residents had higher dietary scores compared to rural residents ($p<0.0001$), with higher daily consumption rates of fruits, vegetables, and grains, as

well as legumes at least 4 days a week, and fish at least 1 day a week (all $p<0.0001$). However, rural residents (28.5%) had greater percentages of people eating red meat<7 days weekly than did urban residents (12.5%) ($p<0.0001$). Women had a higher standardized adherence rate to two or more healthy lifestyle habits (99.6%) compared to men (63.4%) ($p<0.0001$), while urban residents had a higher standardized adherence rate to three or more healthy lifestyle habits (33.7%) compared to rural residents (6.9%) ($p<0.0001$) (Table 2) in relation to integrated healthy lifestyle habits.

Factors linked to four healthy lifestyle habits

The multivariate logistic regression analysis revealed that personal characteristics were linked to the four healthy lifestyle habits in various ways, with higher household income showing a negative connection to no or moderate amounts of alcohol and a balanced diet, but a positive correlation with adherence to the remaining two healthy behaviors. In general, women, older people, nonfarmers, individuals with higher levels of education, and urban dwellers were more inclined to adhere to all four healthy lifestyle habits ($p<0.0001$) (Table 3).

Table 3 Participants characteristics associated with adherence to four healthy lifestyle habits

	Nonsmoking	No or moderate amounts of alcohol	Sufficient LTPA	Balanced diet	Four healthy lifestyle habits
	ORs (95% CIs)	ORs 95 (CIs)	ORs 95(CIs)	ORs 95(CIs)	ORs 95 (CIs)
Sex					
Men	0.00(0.00,0.00)	0.10(0.07,0.14)	0.73(0.66,0.81)	0.89(0.75,1.06)	0.41(0.33,0.52)
Women	1	1	1	1	1
Age					
45–54	0.94(0.81,1.10)	0.65(0.47,0.89)	1.76(1.55,2.01)	0.98(0.80,1.21)	1.54(1.09,2.19)
55–64	1.15(0.98,1.36)	0.59(0.43,0.82)	2.64(2.31,3.02)	1.00(0.80,1.24)	2.15(1.52,3.05)
65–75	1.66(1.38,1.99)	0.69(0.49,0.99)	3.45(2.96,4.03)	1.17(0.91,1.49)	3.21(2.20,4.67)
35–44	1	1	1	1	1
Occupation					
Nonfarmer	1.12(0.93,1.34)	0.89(0.63,1.23)	2.52(2.18,2.90)	1.26(1.00,1.60)	2.67(1.57,4.52)
Farmer	1	1	1	1	1
Education					
College and above	1.47(1.19,1.82)	1.17(0.80,1.72)	2.61(2.23,3.06)	1.29(1.00,1.67)	3.42(2.31,5.05)
High school	1.16(0.95,1.40)	1.30(0.92,1.84)	1.89(1.65,2.17)	1.04(0.83,1.31)	2.26(1.57,3.26)
Middle school	0.98(0.85,1.14)	0.97(0.75,1.26)	1.49(1.31,1.70)	0.94(0.76,1.16)	1.62(1.12,2.35)
Primary school and below	1	1	1	1	1
Household income, yuan					
10,000–50,000	1.20(1.02,1.42)	0.84(0.62,1.14)	1.14(1.00,1.29)	1.01(0.82,1.25)	1.21(0.85,1.74)
>50,000	1.15(0.94,1.40)	0.77(0.53,1.13)	1.21(1.03,1.41)	0.78(0.60,1.01)	1.09(0.72,1.64)
<10,000	1	1	1	1	1
Marriage					
Yes	1.10(0.71,1.70)	1.65(0.91,2.98)	1.14(0.92,1.41)	1.14(0.80,1.61)	1.36(0.85,2.16)
No	1	1	1	1	1
Medical insurance					
Yes	1.57(0.75,3.26)	1.29(0.38,4.35)	0.92(0.59,1.44)	0.98(0.45,2.13)	1.23(0.34,4.45)
No	1	1	1	1	1
HTN/DM					
Yes	1.28(1.11,1.47)	0.98(0.77,1.24)	1.45(1.31,1.60)	0.93(0.78,1.10)	1.13(0.90,1.42)
No	1	1	1	1	1
CVD history					
Yes	0.80(0.62,1.03)	1.29(0.79,2.11)	1.40(1.14,1.72)	0.75(0.50,1.12)	0.77(0.45,1.33)
No	1	1	1	1	1
Residence					
Urban	1.21(0.62,2.35)	1.01(0.49,2.07)	6.59(2.83,15.3)	2.30(0.88,6.04)	6.72(2.66,17.0)
Rural	1	1	1	1	1

The correlation between health outcomes and four healthy lifestyle habits

The analysis included 19,969 participants, with a median follow-up of 3.53 years (IQR 1.60–3.68). There was a total of 236 deaths from all cause and 95 deaths from cardiovascular-related. After considering healthy lifestyle habits, there was a significant, inverse, and linear relationship between the number of healthy lifestyle habits and the risk of all-cause and cardiovascular mortality ($p<0.05$). After adjusting for age and gender, people who followed three healthy lifestyle habits had significantly lower risks of death from all-cause mortality (HR 0.43 [95% CI: 0.19, 0.99]) and cardiovascular mortality (HR 0.28 [95% CI: 0.09, 0.87]) compared to those who did not follow any healthy habit ($p<0.05$) (Table 4).

Table 4 Hazard ratios for all-cause and cardiovascular mortality

	All-cause mortality		Cardiovascular mortality	
	HR (95% CI)	*P* value	HR (95% CI)	*P* value
Model 1: no adjustment				
Number of healthy lifestyle habits (reference = 0)				
1	0.98(0.44,2.14)	0.950	0.74(0.26,2.12)	0.571
2	0.48(0.22,1.02)	0.055	0.33(0.12,0.92)	0.034
3	0.34(0.15,0.76)	0.009	0.23(0.07,0.68)	0.008
4	0.36(0.11,1.24)	0.107	0.16(0.02,1.43)	0.101
Nonsmoking	0.47(0.36,0.63)	0.000	0.43(0.28,0.67)	0.000
No or moderate amounts of alcohol	0.64(0.36,1.14)	0.132	0.51(0.22,1.17)	0.112
Sufficient LTPA	0.74(0.54,1.00)	0.049	0.62(0.37,1.02)	0.062
Balanced diet	0.42(0.19,0.95)	0.037	0.35(0.09,1.41)	0.139
Model 2: adjusted for age and gender				
Number of healthy lifestyle habits (reference = 0)				
1	1.20(0.54,2.62)	0.656	0.91(0.32,2.63)	0.862
2	0.67(0.31,1.47)	0.317	0.46(0.16,1.31)	0.146
3	0.43(0.19,0.99)	0.047	0.28(0.09,0.87)	0.027
4	0.43(0.12,1.48)	0.180	0.18(0.02,1.64)	0.128
Nonsmoking	0.55(0.39,0.78)	0.001	0.49(0.29,0.84)	0.009
No or moderate amounts of alcohol	0.95(0.53,1.71)	0.863	0.77(0.33,1.79)	0.542
Sufficient LTPA	0.65(0.48,0.88)	0.005	0.54(0.32,0.89)	0.016
Balanced diet	0.44(0.19,0.99)	0.046	0.36(0.09,1.48)	0.157
Model 3: multivariable adjusted model				
Number of healthy lifestyle habits (reference = 0)				
1	1.61(0.64,4.08)	0.311	1.80(0.42,7.73)	0.431
2	1.00(0.40,2.51)	0.996	0.89(0.21,3.86)	0.881
3	1.02(0.38,2.75)	0.973	0.82(0.17,4.00)	0.811
4	1.32(0.33,5.22)	0.692	0.72(0.06,8.60)	0.793
Nonsmoking	0.65(0.45,0.95)	0.028	0.57(0.31,1.04)	0.066
No or moderate amounts of alcohol	1.18(0.61,2.26)	0.622	1.20(0.43,3.36)	0.728
Sufficient LTPA	1.15(0.77,1.72)	0.495	0.88(0.46,1.66)	0.685
Balanced diet	0.68(0.30,1.55)	0.365	0.56(0.14,2.32)	0.428

Model 3: adjusted for gender, age, occupation, education, household income, marital status, social medical insurance status, and urbanicity

A single healthy lifestyle habit Cox regression model showed evidence of a low risk of death for nonsmokers for all cause mortality (HR 0.55 [95% CI: 0.39, 0.78]) and cardiovascular-related death (HR 0.49 [95% CI: 0.29, 0.84]) after adjustments for age and gender. Nevertheless, when it came to no or moderate amounts of alcohol, there was no clear evidence of a lower risk of all cause (HR 1.18 [95% CI 0.61, 2.26]) or cardiovascular-related death (HR 1.20 [95% CI 0.43, 3.36]) after multivariable adjustment. The adjustments resulted in nearly identical HRs for cardiovascular mortality as for all-cause mortality.

Discussion

In this study, we analysed the healthy lifestyle habits of the residents in Guangxi Province by utilizing data collected through the ChinaHEART Program in Guangxi. We found that only 1 out of 58 residents in Guangxi adhered to all four healthy lifestyle habits, which was lower than the national average [22].

Among the four healthy lifestyle habits, balanced diet adherence was the lowest, followed by sufficient LTPA, which is consistent with other studies [1, 23, 24]; moreover, the low proportion of balanced diets was the main reason for the very low proportion of comprehensive healthy lifestyle habit adherence. The 2010 Global Burden of Disease Study revealed that joint dietary risks constituted 10% of the worldwide disease burden [25]. According to China's Pathway to Health in Ageing, it is proposed that overnutrition and undernutrition coexist in older Chinese adults [26]. The 2009 China Health and Nutrition Survey (CHNS) highlighted issues with diet quality and imbalances among senior adults, noting an overconsumption of grains, oils, and salt, alongside significant to severe insufficiencies in the intake of fish, vegetables, fruits, milk, and soy products [27]. The results of a previous survey on healthy lifestyles of the whole population in Guangxi's chronic disease demonstration area showed that balanced diets were associated with the highest rate of knowledge of healthy lifestyles [13], thus suggesting that although the knowledge rate of healthy diets was high, the rate of healthy dietary behaviours was too low. Additionally, the timing of the survey administration in this research may have been connected to the brief interval preceding the initiation of the chronic disease demonstration project in Guangxi (2011). The CKB

study indicated that overall physical activity (including work-related, commuting, household, and leisure-time activities) influences the trajectory of cardiometabolic disease development, thereby implying a broad health benefit associated with engaging in physical activity [28]. Furthermore, individuals who were not very active during most of their adult years but started being more physically active in their late adulthood (ages 40–61) experienced reduced risks of all-cause mortality, as well as lower rates of cardiovascular-related and cancer-related deaths [29]. This indicates that beginning physical activity in midlife can still be beneficial. Therefore, physical activity counselling should be a routine part of health care visits [17].

Men, younger people, farmers, people with a low education level and rural residents had lower adherence rates to the four healthy lifestyle habits. Principal risk factors for men encompassed tobacco use and high alcohol intake, while the increased adherence to healthful lifestyles among older individuals might be attributed to sufficient engagement in LTPA. Higher education is likely to enhance the well-being and quality of life for seniors. The findings from eight synchronized groups in various countries, including the US, UK, Spain, Europe, Australia, Japan, Korea, and Mexico, which are part of the Healthy Ageing Trajectories Study, indicate that initial educational experiences can significantly impact the health and capabilities of seniors [30]. Research on the impact of educational inequality on mortality indicates that individuals who have achieved higher levels of education tend to adopt healthier lifestyles [31]. China's urban–rural education inequality and urban–rural development imbalance problems have led to the low educational attainment of farmers and rural residents. Data from the UK Biobank revealed that individuals with lower socioeconomic positions and poor lifestyle choices faced the greatest threats from death and heart disease [32], thus emphasizing the critical need for lifestyle improvements to mitigate health issues, particularly for those in lower socioeconomic groups.

Prior research has indicated that adopting a comprehensive healthy lifestyle in Chinese communities may yield similar health advantages as seen in Western communities. A meta-analysis including fifteen longitudinal investigations of Western subjects (n=531,804 participants) with an average observation period of approximately 13.24 years demonstrated a decline in the relative risk of mortality for each additional healthy lifestyle element incorporated, thus indicating that embracing a minimum of four healthy lifestyle factors could lead to a 66% reduction in the likelihood of all-cause mortality [33]. Another meta-analysis demonstrated a significant dose–response effect between adherence to a healthy lifestyle and CVD risk [34]. Moreover, CKB et al. reported that participants who followed a combination of multiple health lifestyle habits had a much lower total mortality risk [19]. Our study did not find a significant association between moderate alcohol intake and the risk of all-cause mortality, which differs from the results of the CKB. The inverse relationship could be attributed to the brief duration of the follow-up [22] or the possibility of reverse causation. Nevertheless, the strong correlation between various healthy lifestyle habits and health outcomes was notable. A strong negative correlation was found between the number of healthy lifestyle habits and the likelihood of mortality. These results align with prior investigations [7, 19] and could be associated with the pattern of adopting multiple healthy lifestyle habits.

Strengths and limitation of this study

This study is the first large-scale epidemiologic survey in Guangxi, with findings that could impact policies related to the prevention and control of chronic diseases in the region. Special focus should be placed on vulnerable groups, such as individuals with limited education and income or those residing in rural areas, in addition to health promotion initiatives aimed at the overall adult population in Guangxi. In Guangxi, a region with lower economic levels, health promotion strategies should be customized to fit the local economic conditions and prioritize addressing prevalent health issues. Furthermore, the lack of adherence to the Chinese Dietary Guidelines for Adequate Physical Activity or Diet by many people indicates that implementing integrated health interventions, such as diet and exercise counselling, could be a more effective approach to enhancing the overall population's commitment to healthy lifestyle habits.

However, due to the fact that lifestyle habits were self-reported, recall bias was unavoidable, despite the use of a standardized questionnaire. Furthermore, this research assessed solely the occurrence of various food groups, without considering the specific kinds and serving sizes, and failed to account for total caloric consumption. Secondly, despite incorporating the majority of demographic and socioeconomic factors into the multivariate analysis, the possibility of reverse causality and remaining confounding influenced by unmeasured or unidentified elements cannot be entirely dismissed. Furthermore, even though the NMMS and vital registration cover both urban and rural regions in Guangxi, some death records may still be missing, particularly in rural areas, despite efforts to register them after validation by local household registration bureaus. The brief monitoring of the participants could have resulted in a small underestimation of the potential influence of healthy habits on death rates. Fourth, the study population was not determined on the basis of a randomized sampling design, which may lead to misestimating regional averages and may lead to

spurious associations [35]. Fifth, our study population was restricted to adults aged between 35 and 75 years. We recognize that the non-communicable diseases are affecting even younger populations; therefore the exclusion of this demography may limit the generalizability of our findings to the broader population. We propose that future research should consider extending the lower age limit to 18 years or younger, allowing for a more comprehensive understanding of lifestyle factors across a wider age spectrum and their impact on health outcomes. This study focused on four healthy lifestyle habits, but future research should delve deeper into other habits like sedentary habits, mental well-being, and lack of sleep.

Conclusions

Residents aged 35–75 in Guangxi are not meeting the desired level of healthy lifestyle behaviors. Key lifestyle factors like unbalanced diet and inadequate LTPA are outstanding problems that require targeted health intervention and guidance. Furthermore, variations exist among demographic categories like sex, age, and urban versus rural regions, emphasizing the importance of prioritizing targeted health education and promotion strategies in public health policy.

Abbreviations

CVD	Cardiovascular Diseases
LTPA	Leisure Time Physical Activity
ChinaHEART	China Health Evaluation and Risk Reduction through Nationwide Teamwork
China PEACE MPP	China Patient Centred Evaluative Assessment of Cardiac Events Million Persons Project
CDC	Centers for Disease Control and Prevention
ICD-10	International Classification of Diseases 10th edition
IQR	Interquartile Range
SMD	Standardized Mean Differences
MI	Myocardial Infarction
OR	Odds Ratio
HR	Hazard Ratio
CI	Confidence Interval

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12889-024-19718-w.

Supplementary Material 1

Acknowledgements

The authors would like to thank all the staff members who participated in this investigation for all their work in the design, implementation, data collection, analysis, and reporting of this study.

Author contributions

ZY Z, and WH: conceptualization, visualization; WH, LX M, LY: investigation, data collection. ML and LY: data analysis, writing, original draft preparation, methodology, software, and reviewing. All authors contributed to the article and approved the submitted version.

Funding

Funding for this project was provided by the Ministry of Finance of China and National Health and Family Planning Commission, the Guangxi Key Laboratory of Precision Medicine in Cardio-cerebrovascular Diseases Control and Prevention (22-035-18), Guangxi Clinical Research Center for Cardio-Cerebrovascular Diseases (AD17129014) and Guangxi Medical High-level Backbone Talents "139" Program (G201901006).

Data availability

The authors declare that all data supporting the findings of this study are available within the article and its supplementary information files.

Declarations

Ethics approval and consent to participate

The project protocol was approved by the central ethics committee at Fuwai Hospital, Beijing, China (Approval No. 2014–574). Written informed consent was obtained from all enrolled participants.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

Received: 12 April 2024 / Accepted: 7 August 2024
Published online: 15 August 2024

References

1. Bi Y, Jiang Y, He J, Xu Y, Wang L, Xu M, Zhang M, Li Y, Wang T, Dai M, Lu J, Li M, Chen CS, Lai S, Wang W, Wang L, Ning G. Status of cardiovascular health in Chinese adults. J Am Coll Cardiol. 2015;65(10):1013–25.
2. Shengshou H. Overview of the China Cardiovascular Health and Disease Report 2022. China Cardiovasc Disease Res. 2023;21(07):577–600.
3. UN Department of Economic and Social Affairs Population Division. World Population Prospects. 2022. https://population.un.org/wpp/ (accessed July 14, 2022).
4. China Cardiovascular Disease Prevention Guidelines Writing Group. Editorial Board of Chinese Journal of Cardiovascular Disease. Chinese guidelines for cardiovascular disease prevention (2017). Chin J Cardiovasc Disease. 2018;46(1):10–25.
5. Chiuve SE, Rexrode KM, Spiegelman D, Logroscino G, Manson JE, Rimm EB. Primary prevention of stroke by healthy lifestyle. Circulation. 2008;118(9):947–54.
6. Han H, Cao Y, Feng C, Zheng Y, Dhana K, Zhu S, Shang C, Yuan C, Zong G. Association of a healthy lifestyle with all-cause and cause-specific mortality among individuals with type 2 diabetes: a prospective study in UK Biobank. Diabetes Care. 2022;45(2):319–29.
7. Li Y, Pan A, Wang DD, Liu X, Dhana K, Franco OH, Kaptoge S, Di Angelantonio E, Stampfer M, Willett WC, Hu FB. Impact of healthy lifestyle factors on life expectancies in the US Population. Circulation. 2018;138(4):345–55.
8. Li Y, Schoufour J, Wang DD, Dhana K, Pan A, Liu X, Song M, Liu G, Shin HJ, Sun Q, Al-Shaar L, Wang M, Rimm EB, Hertzmark E, Stampfer MJ, Willett WC, Franco OH, Hu FB. Healthy lifestyle and life expectancy free of cancer, cardiovascular disease, and type 2 diabetes: prospective cohort study. BMJ. 2020;368:l6669.
9. Zhang YB, Pan XF, Lu Q, Wang YX, Geng TT, Zhou YF, Liao LM, Tu ZZ, Chen JX, Xia PF, Wang Y, Wan ZZ, Guo KQ, Yang K, Yang HD, Chen SH, Wang GD, Han X, Wang YX, Yu D, He MA, Zhang XM, Liu LG, Wu T, Wu SL, Liu G, Pan A. Associations of combined healthy lifestyles with cancer morbidity and mortality among individuals with diabetes: results from five cohort studies in the USA, the UK and China. Diabetologia. 2022;65(12):2044–55.
10. Zhang YB, Pan XF, Chen J, Cao A, Xia L, Zhang Y, Wang J, Li H, Liu G, Pan A. Combined lifestyle factors, all-cause mortality and cardiovascular disease: a systematic review and meta-analysis of prospective cohort studies. J Epidemiol Community Health. 2021;75(1):92–9.
11. Sun Q, Yu D, Fan J, Yu C, Guo Y, Pei P, Yang L, Chen Y, Du H, Yang X, Sansome S, Wang Y, Zhao W, Chen J, Chen Z, Zhao L, Lv J, Li L. Healthy lifestyle and life expectancy at age 30 years in the Chinese population: an observational study. Lancet Public Health. 2022;7(12):e994–1004.
12. Wei Huiyan. Analysis of death characteristics and disease burden of major chronic diseases among Guangxi residents in 2016 [D.]2018.
13. Hong LShui-yingY, Jun M, Hong-lei CEN, Wei-Jiang LU. Evaluation on the effect of national healthy lifestyle action in the demonstration area of

comprehensive prevention and control of chronic diseases in Guangxi. Chronic Disease Prev Control China. 2017;25(02):104–8.
14. Shuiying L, Weijiang L. Evaluation of effect of national healthy lifestyle action in Guangxi. Appl Prev Med. 2023;29(03):133–8.
15. He Qiuping TANG, Chi C, Yanping GUO, Liangyong HUANG, Zhenlei. Study on the relationship between health literacy level and health status of ethnic minority residents in Nanning, Guangxi. Chin Health Educ. 2020;36(10):933–7.
16. Lu J, Xuan S, Downing NS, Wu C, Li L, Krumholz HM, Jiang L. Protocol for the China PEACE (patient-centered evaluative Assessment of Cardiac events) million persons Project pilot. BMJ Open. 2016;6(1):e010200.
17. Arnett DK, Khera A, Blumenthal RS. 2019 ACC/AHA Guideline on the primary Prevention of Cardiovascular Disease: part 1, lifestyle and behavioral factors. JAMA Cardiol. 2019;4(10):1043–4.
18. Society CN. The Chinese dietary guidelines. Beijing People's Medical Publishing House; 2016.
19. Zhu N, Yu C, Guo Y, Bian Z, Han Y, Yang L, Chen Y, Du H, Li H, Liu F, Chen J, Chen Z, Lv J, Li L. Adherence to a healthy lifestyle and all-cause and cause-specific mortality in Chinese adults: a 10-year prospective study of 0.5 million people. Int J Behav Nutr Phys Act. 2019;16(1):98.
20. Lv J, Yu C, Guo Y, Bian Z, Yang L, Chen Y, Tang X, Zhang W, Qian Y, Huang Y, Wang X, Chen J, Chen Z, Qi L, Li L. Adherence to healthy Lifestyle and Cardiovascular diseases in the Chinese Population. J Am Coll Cardiol. 2017;69(9):1116–25.
21. Van Horn L, Carson JA, Appel LJ, Burke LE, Economos C, Karmally W, Lancaster K, Lichtenstein AH, Johnson RK, Thomas RJ, Vos M, Wylie-Rosett J, Kris-Etherton P. Recommended Dietary Pattern to achieve adherence to the American Heart Association/American College of Cardiology (AHA/ACC) guidelines: A Scientific Statement from the American Heart Association. Circulation. 2016;134(22):e505–29.
22. Zhang X, Lu J, Wu C, Cui J, Wu Y, Hu A, Li J, Li X. Healthy lifestyle behaviours and all-cause and cardiovascular mortality among 0.9 million Chinese adults. Int J Behav Nutr Phys Act. 2021;18(1):162.
23. Xingyi HAn-yiZ, Yue W, Ziyu G, Yichun T. Li Xi. Healthy lifestyle adherence among middle-aged people in four communities. China Circulation J. 2022;37(05):513–8.
24. Pan Zirui S, Zhongming W, Jinbo Q, Yu S, Jian, Cui LAN, Jinyi ZHOU, Ming WU, Ran TAO. Analysis of the status quo of healthy lifestyle in 22083 high-risk population of cardiovascular disease in Jiangsu Province. Chin J Disease Control. 2021;25(08):948–54.
25. Lim SS, Vos T, Flaxman AD, Danaei G, Shibuya K, Adair-Rohani H, Amann M, Anderson HR, Andrews KG, Aryee M, Atkinson C, Bacchus LJ, Bahalim AN, Balakrishnan K, Balmes J, Barker-Collo S, Baxter A, Bell ML, Blore JD, Blyth F, Bonner C, Borges G, Bourne R, Boussinesq M, Brauer M, Brooks P, Bruce NG, Brunekreef B, Bryan-Hancock C, Bucello C, Buchbinder R, Bull F, Burnett RT, Byers TE, Calabria B, Carapetis J, Carnahan E, Chafe Z, Charlson F, Chen H, Chen JS, Cheng AT, Child JC, Cohen A, Colson KE, Cowie BC, Darby S, Darling S, Davis A, Degenhardt L, Dentener F, Des Jarlais DC, Devries K, Dherani M, Ding EL, Dorsey ER, Driscoll T, Edmond K, Ali SE, Engell RE, Erwin PJ, Fahimi S, Falder G, Farzadfar F, Ferrari A, Finucane MM, Flaxman S, Fowkes FG, Freedman G, Freeman MK, Gakidou E, Ghosh S, Giovannucci E, Gmel G, Graham K, Grainger R, Grant B, Gunnell D, Gutierrez HR, Hall W, Hoek HW, Hogan A, Hosgood HD 3rd, Hoy D, Hu H, Hubbell BJ, Hutchings SJ, Ibeanusi SE, Jacklyn GL, Jasrasaria R, Jonas JB, Kan H, Kanis JA, Kassebaum N, Kawakami N, Khang YH, Khatibzadeh S, Khoo JP, Kok C, Laden F, Lalloo R, Lan Q, Lathlean T, Leasher JL, Leigh J, Li Y, Lin JK, Lipshultz SE, London S, Lozano R, Lu Y, Mak J, Malekzadeh R, Mallinger L, Marcenes W, March L, Marks R, Martin R, McGale P, McGrath J, Mehta S, Mensah GA, Merriman TR, Micha R, Michaud C, Mishra V, Mohd Hanafiah K, Mokdad AA, Morawska L, Mozaffarian D, Murphy T, Naghavi M, Neal B, Nelson PK, Nolla JM, Norman R, Olives C, Omer SB, Orchard J, Osborne R, Ostro B, Page A, Pandey KD, Parry CD, Passmore E, Patra J, Pearce N, Pelizzari PM, Petzold M, Phillips MR, Pope D, Pope CA 3rd, Powles J, Rao M, Razavi H, Rehfuess EA, Rehm JT, Ritz B, Rivara FP, Roberts T, Robinson C, Rodriguez-Portales JA, Romieu I, Room R, Rosenfeld LC, Roy A, Rushton L, Salomon JA, Sampson U, Sanchez-Riera L, Sanman E, Sapkota A, Seedat S, Shi P, Shield K, Shivakoti R, Singh GM, Sleet DA, Smith E, Smith KR, Stapelberg NJ, Steenland K, Stöckl H, Stovner LJ, Straif K, Straney L, Thurston GD, Tran JH, Van Dingenen R, van Donkelaar A, Veerman JL, Vijayakumar L, Weintraub R, Weissman MM, White RA, Whiteford H, Wiersma ST, Wilkinson JD, Williams HC, Williams W, Wilson N, Woolf AD, Yip P, Zielinski JM, Lopez AD, Murray CJ, Ezzati M, AlMazroa MA, Memish ZA. A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010. Lancet. 2012;380(9859):2224-60.
26. Chen X, Giles J, Yao Y, Yip W, Meng Q, Berkman L, Chen H, Chen X, Feng J, Feng Z, Glinskaya E, Gong J, Hu P, Kan H, Lei X, Liu X, Steptoe A, Wang G, Wang H, Wang H, Wang X, Wang Y, Yang L, Zhang L, Zhang Q, Wu J, Wu Z, Strauss J, Smith J, Zhao Y. The path to healthy ageing in China: a Peking University-Lancet Commission. Lancet. 2022;400(10367):1967–2006.
27. Xu X, Hall J, Byles J, Shi Z. Assessing dietary quality of older Chinese people using the Chinese Diet Balance Index (DBI). PLoS ONE. 2015;10(3):e0121618.
28. Han Y, Hu Y, Yu C, Guo Y, Pei P, Yang L, Chen Y, Du H, Sun D, Pang Y, Chen N, Clarke R, Chen J, Chen Z, Li L, Lv J. Lifestyle, cardiometabolic disease, and multimorbidity in a prospective Chinese study. Eur Heart J. 2021;42(34):3374–84.
29. Saint-Maurice PF, Coughlan D, Kelly SP, Keadle SK, Cook MB, Carlson SA, Fulton JE, Matthews CE. Association of Leisure-Time Physical Activity across the Adult Life Course with all-cause and cause-specific mortality. JAMA Netw Open. 2019;2(3):e190355.
30. Wu YT, Daskalopoulou C, Muniz Terrera G, Sanchez Niubo A, Rodríguez-Artalejo F, Ayuso-Mateos JL, Bobak M, Caballero FF, de la Fuente J, de la Torre-Luque A, García-Esquinas E, Haro JM, Koskinen S, Koupil I, Leonardi M, Pajak A, Panagiotakos D, Stefler D, Tobias-Adamczyk B, Prince M, Prina AM. Education and wealth inequalities in healthy ageing in eight harmonised cohorts in the ATHLOS consortium: a population-based study. Lancet Public Health. 2020;5(7):e386–94.
31. Lu J, Wu C, Zhang X, Yang Y, Cui J, Xu W, Song L, Yang H, He W, Zhang Y, Li J, Li X. Educational inequalities in mortality and their mediators among generations across four decades: nationwide, population based, prospective cohort study based on the ChinaHEART project. BMJ. 2023;382:e073749.
32. Zhang YB, Chen C, Pan XF, Guo J, Li Y, Franco OH, Liu G, Pan A. Associations of healthy lifestyle and socioeconomic status with mortality and incident cardiovascular disease: two prospective cohort studies. BMJ. 2021;373:n604.
33. Loef M, Walach H. The combined effects of healthy lifestyle behaviors on all cause mortality: a systematic review and meta-analysis. Prev Med. 2012;55(3):163–70.
34. Barbaresko J, Rienks J, Nöthlings U. Lifestyle indices and Cardiovascular Disease Risk: a Meta-analysis. Am J Prev Med. 2018;55(4):555–64.
35. Munafò MR, Tilling K, Taylor AE, Evans DM, Davey Smith G. Collider scope: when selection bias can substantially influence observed associations. Int J Epidemiol. 2018;47(1):226–35.

Publisher's Note