Healthy lifestyle and life expectancy at age 30 years in the Chinese population: an observational study

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Summary

Background The improvement of life expectancy is one of the aims of the Healthy China 2030 blueprint. We aimed to investigate the extent to which healthy lifestyles are associated with life expectancy in Chinese adults.

Methods We used the prospective China Kadoorie Biobank (CKB) study to examine the relative risk of mortality associated with individual and combined lifestyle factors (never smoking or quitting not for illness, no excessive alcohol use, being physically active, healthy eating habits, and healthy body shape). Participants with coronary heart disease, stroke, cancer, or missing values for body-mass index were excluded. For analysis of chronic respiratory diseases, participants with chronic obstructive pulmonary disease or asthma were excluded. We estimated the national prevalence of lifestyle factors using data from the China Nutrition and Health Surveillance (CNHS; 2015) and derived mortality rates from the Global Burden of Diseases, Injuries, and Risk Factors Study (2015). All three data sources were combined to estimate the life expectancy of individuals at age 30 years following different levels of lifestyle factors by using the life table method. The cause-specific decomposition of the life expectancy differences was analysed using Arriaga's method.

Findings After the exclusion of CKB participants with coronary heart disease, stroke, cancer, or missing BMI data at baseline, 487 209 were included in the primary analysis. Participants with COPD or asthma at baseline were additionally excluded for chronic respiratory disease-related analysis, leaving 451 233 participants with data available for analysis. Data from 171 127 adults aged 30–84 years from the CNHS 2015 were used to estimate the sex-specific and age-specific prevalence of lifestyle-related factors. There were 42 496 deaths documented over a median follow-up of 11·1 years (IQR 10·2–12·1) in CKB. The adjusted hazard ratios (aHRs) of participants adopting five versus 0–1 low-risk factors was 0·38 (95% CI 0·34–0·43) for all-cause mortality, aHR 0·37 (0·30–0·46) for cardiovascular disease mortality, aHR 0·47 (0·39–0·56) for cancer mortality, and aHR 0·30 (0·14–0·64) for chronic respiratory disease mortality. The life expectancy at age 30 years for individuals with 0–1 low-risk factors was on average 41·7 years (95% CI 41·5–42·0) for men and 47·3 years (46·6–48·0) for women. For individuals with all five low-risk factors, the life expectancy at age 30 was 50·5 years (95% CI 48·5–52·4) for men and 55·4 years (53·5–57·4) for women; meaning a difference of 8·8 years (95% CI 6·8–10·7) for men and 8·1 years (6·5–9·9) for women. The estimated extended life expectancy for men and women was mainly attributable to reduced death from cardiovascular disease (2·4 years [27% of the total extended life expectancy] for men and 3·7 years [46%] for women), cancer (2·6 years [30%] for men and 0·9 years [11%] for women), and chronic respiratory disease (0·6 years [7%] for men and 1·2 years [15%] for women).

Interpretation Our findings suggest that increasing the adoption of these five healthy lifestyle factors through public health interventions could be associated with substantial gains in life expectancy in the Chinese population.

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Introduction

Traditional lifestyle-related risk factors, including smoking, excess drinking, physical inactivity, poor dietary habits, and obesity, have been associated with increased risk of death, especially from chronic diseases.[1,2] The widespread prevalence of these risk factors has caused a great burden of disease (such as cardiovascular disease, cancer, and chronic respiratory diseases) worldwide,[3] with no exception to China.[4] Life expectancy as an absolute quantitative measure is more intuitive than indicators such as relative risk and absolute lifetime risk and has become a common metric for establishing public health priorities.

Previous studies that have assessed the relationship between lifestyle and life expectancy were mainly done in North American and European populations, and these studies suggested that healthier lifestyles were associated with an increase in life expectancy of between 7·4 years

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See **Online** for appendix

Research in context

Evidence before this study

We searched PubMed, EMBASE, and Google Scholar for articles published from the inception of each database to Oct 31, 2021, using a combination of terms: ("life expectancy" OR "life span" OR "life time" OR "life years" OR "longevity") AND ("lifestyle" OR "smoking" OR "tobacco use" OR "alcohol" OR "physical activity" OR "diet" OR "BMI" OR "overweight" OR "obesity"). No restrictions were applied to study type or language. Relevant studies were also found by checking reference lists of identified articles. Available studies that assessed the relationship between lifestyle and life expectancy were mainly done in high-income countries and based on specific cohort populations, limiting the generalisability of the results to other countries, where the factors that influence health might differ.
The potential impact of healthy lifestyles on life expectancy at a population level in China remains unclear.

Added value of this study

The estimated life expectancy at age 30 years for individuals with five low-risk lifestyle factors was on average 8·8 years longer in men and 8·1 years longer in women than those with 0–1 low-risk factors. About two thirds of the extended life expectancy associated with adopting all five low-risk factors could be explained by the reduced death from cardiovascular disease, cancer, and chronic respiratory disease. To the best of our knowledge, this is the first study to quantify the association between combined lifestyle factors and life expectancy in China. The use of a large prospective cohort study of more than 500 000 Chinese people and a nationally representative survey of risk factors improved the representativeness of the findings for the national population.

Implications of all the available evidence

Our findings suggest that fostering a healthy lifestyle through population-wide public health interventions could be associated with substantial gains in life expectancy in the Chinese population. The findings of the study could encourage the government to commit to promoting a healthy lifestyle, in order to achieve the goal of increasing the average life expectancy, as outlined in the blueprint of Healthy China 2030. Further investigations are also needed to explore the effect of other factors on life expectancy, such as environmental hazards.

and 18·5 years.[5–7] Most of these studies were based on specific cohort populations; the results of such a study design only reflect the mortality of specific cohort populations over a follow-up period and caution should be maintained in generalising these results to national populations.

There are non-negligible differences between Chinese and European and American populations in economic and social development and determinants of health, such as genetics, lifestyle, and hazardous environmental exposures. However, only a few studies have evaluated the effect of individual lifestyle factors, such as smoking and alcohol intake, on the life expectancy of the Chinese population.[8–10] The effect of combined lifestyle behaviours on Chinese life expectancy remains unclear, and the evidence gaps need to be filled.

The blueprint of Healthy China 2030 set out the goal of increasing the average life expectancy of Chinese people at birth from 76·3 years in 2015 to 79 years in 2030. We aimed to evaluate the potential effects of individual and combined low-risk lifestyle factors on the life expectancy at age 30 years in the Chinese population.

Methods

Study design and participants

We combined three sources of data: (1) the China Kadoorie Biobank (CKB) study for the association between lifestyle factors and mortality; (2) the Global Burden of Diseases, Injuries, and Risk Factors Study (GBD, 2015) for population-based mortality rates; and (3) the China Nutrition and Health Surveillance (CNHS, 2015) for population-based prevalence of lifestyle factors (appendix p 27).

The CKB study is a nationwide population-based prospective cohort of more than 500 000 adults. Details of the study design have been previously described.[11] Briefly, 512 725 participants aged 30–79 years were recruited during 2004–08 from five urban and five rural areas geographically spread across China. Baseline survey and anthropometric measurements were undertaken by trained study staff. All participants signed informed consent forms. Ethical approval was obtained from the Ethics Review Committee of the Chinese Center for Disease Control and Prevention (CDC, Beijing, China) and the Oxford Tropical Research Ethics Committee, University of Oxford (Oxford, UK). In the present study, participants with coronary heart disease, stroke, or cancer at baseline were excluded, in addition to those with missing values for body-mass index (BMI). For analysis of chronic respiratory diseases, participants with chronic obstructive pulmonary disease (COPD) or asthma at baseline were excluded.

The CNHS (2015–17) was the latest cross-sectional survey with nationally and provincially representative samples from 302 survey sites of 31 provincial-level administrative divisions in mainland China. In this round of surveillance, the survey on adult chronic diseases and nutritional status was done in 2015. Participants were sampled using a stratified multistage cluster sampling design, with details published previously.[12] In the present study, data from adults aged 30–84 years from the CNHS 2015 were used to estimate the sex-specific and age-specific (every 5-years) prevalence of lifestyle-related factors. The Ethics Review Committee of the China CDC approved the survey. All participants had completed written informed consent forms.

Procedures

Baseline lifestyle-related factors and covariate information in CKB were assessed by interviewer-administered laptop-based questionnaires and physical measurements (body weight, height, and hip and waist circumference). The data entry system had built-in functions to avoid missing items and logic errors maximally. Details have been described in the appendix (p 2).

The data in CNHS were collected by face-to-face interviews with trained staff using well-designed questionnaires (appendix pp 3–7) and taking physical measurements. Questions about smoking status were the same as those in the CKB questionnaire, except that only the cigarettes were considered to calculate the daily smoking amount, whereas in the CKB study, hand-rolled cigarettes, pipes or water pipes, and cigars were also considered, and these data were converted to the equivalent numbers of cigarettes smoked per day. A food frequency questionnaire was used to collect the frequency and amount of various foods and alcoholic drinks consumed in the past 12 months. Physical activity was investigated with an adapted version of the International Physical Activity Questionnaire-long form, and the total amount of physical activity was calculated in a similar way to the CKB study (appendix p 8). Body weight, height, and waist circumference were measured by trained staff using well calibrated instruments.

The all-cause and cause-specific mortality rates, including from cardiovascular disease, cancer, and chronic respiratory disease (including COPD and asthma), of the Chinese population by sex and 5-year age groups (30–94 years) in 2015 were derived from the GBD study.

Five modifiable lifestyle factors that could define a low-risk lifestyle were included in this study based on previous studies and Dietary Guidelines for Chinese Residents: smoking, alcohol intake, physical activity, dietary habits, and body shape (a reflection of balance between energy intake and energy expenditure).[1,5,7,13]

Not smoking or quitting smoking for reasons other than illness was defined as low risk. Former smokers who had stopped smoking due to illness were excluded from the low-risk group to avoid biasing death risk upward. The low-risk group for alcohol intake included non-regular drinkers and daily light-to-moderate drinkers (<30 g of pure alcohol in men and <15 g in women per day).[1,5] Former drinkers were also excluded from the low-risk group to address the potential sick-quitter phenomenon (ie, cessation of alcohol consumption might result from disease onset and changes in health conditions).[14] However, such exclusion did not apply to the CNHS because its questionnaire did not ask about previous drinking habits. The low-risk group for physical activity included those who engaged in an age-specific (<50, 50–59, and ≥60 years) and sex-specific median or higher level of physical activity.[1] For dietary habits, we created a simple diet score by considering the following criteria: eating fresh vegetables daily, eating fresh fruits daily, eating red meat 1–6 days per week, eating legumes ≥4 days per week, and eating fish ≥1 day per week. For each criterion met, one point was scored; otherwise, 0. Thus, the diet score ranged from 0 to 5, with a score of 4 to 5 classified as the low-risk group.[1] Both general and central adiposity indicators were considered for body shape, with BMI of 18·5–27·9 kg/m² and waist circumference of <90 cm for men and <85 cm for women defined as low-risk,[15] which emphasises prevention of extremely high or low weight and abdominal obesity.

For more on **CKB questionnaires** see https://www.ckbiobank.org/

A simple low-risk lifestyle score was derived according to the number of low-risk lifestyle factors, ranging from 0 to 5, with higher scores indicating a healthier lifestyle. The vital status of each participant in CKB was identified through the National Disease Surveillance Points system, supplemented with the annual active follow-up. The underlying causes of death were coded using the 10th revision of the International Classification of Diseases.

The primary outcomes were all-cause mortality and cause-specific mortality, including cardiovascular disease (I00–I99), cancer (C00–C97), and chronic respiratory disease (including COPD [J41–J44] and asthma [J45–J46]), assessed in all participants.

Statistical analysis

In the analysis of CKB, person-years were counted from baseline until death, loss to follow-up, or Dec 31, 2017, whichever occurred first. Cox proportional hazards regression with an age timescale was used to calculate the hazard ratio (HR) and 95% CI for the relative risk of mortality outcomes with each lifestyle factor and the number of combined lifestyle factors. The Cox model was stratified jointly by ten study areas and age at baseline in a 5-year interval. For cause-specific mortality, we applied a regression model based on the proportional sub-distribution hazard proposed by Fine and Gray.[16]

For more on the **Global Burden of Disease 2015 study** see http://ghdx.healthdata.org/gbd-results-tool

Assuming that the observed association is causal, we calculated population-attributable risk percent (PAR%), which estimates the percentage of mortality that would have been prevented if all participants had been in the low-risk group. In these analyses, we coded low-risk lifestyle factors as a binary variable and compared participants with all five low-risk factors with all others, following a method advocated by Wacholder and colleagues.[17]

The statistical methods used for estimating years of life gained or lost associated with lifestyle factors are detailed in the appendix (pp 9–10). Due to the sex differences in life expectancy, we did all analyses for men and women separately. We used period life tables to calculate the life expectancy, applying 1-year age bands for age 30 up to 94 years, with the final age group encompassing those aged 95 years and older. The cumulative survival from age 30 years onwards was estimated for participants following different levels of low-risk lifestyle factors by applying sex-specific HRs for all-cause and cause-specific mortality from the CKB to the detailed mortality component from the GBD, combined with the prevalence of low-risk lifestyle factors from CNHS (2015).

By applying Arriaga's decomposition method,[18] we estimated the cause-specific contributions to the life expectancy difference between participants adopting all five and 0–1 low-risk lifestyle factors to determine which cause-specific mortality differences were major contributors to the total change in life expectancy (appendix p 11).

In the sensitivity analysis, we excluded CKB participants who died within the first 2 years of follow-up to minimise potential reverse causality. We also applied sex-specific and age-at-risk-specific HRs for all-cause mortality to the life expectancy analysis to account for potential non-linear increase of death hazard in older ages, in which participant age at risk was determined by splitting the follow-up time every 10 years.[19] The age-at-risk groups were 30–49, 50–59, 60–69, 70–79, and 80 years and older for men and 30–69, and 70 years and older for women, considering that few deaths occurred before the age of 70 and older than 80 years among women adopting 0–1 low-risk lifestyle factors (the reference group) in the CKB study. Considering the lag time between exposure and mortality outcome, we substituted the mortality data with the most recent data from 2019 (4-year lag).[6,20]

Subgroup analyses were done by the factors of residence (urban and rural), education level (no education and primary school, and middle school and higher), smoking status (men: never, former, and current; women: never and ever), body shape (underweight, neither general nor abdominal obesity, and either or both), and baseline disease status (neither hypertension nor diabetes, and either or both).

Considering the gradients in death risk according to different levels of each lifestyle factor, we further created an expanded low-risk lifestyle score. We graded the categories of each lifestyle factor from 1 (least healthy) to 5 (most healthy) according to the CKB findings of the association between lifestyle factors and all-cause mortality. The points across all five lifestyle factors were totalled, with the overall score ranging from 5 to 25.

All statistical analyses, unless otherwise stated, were done with Stata (version 15.0). The competing-risk analysis, calculation of PAR%, and computation of prevalence of lifestyle factors were done with SAS (version 9.4). The confidence interval for life expectancy was estimated using @RISK 8.1 (Palisade Corp, Ithaca, NY).[21] Graphs were plotted using R (version 4.0.3).

Role of the funding source

The funders had no role in the study design, data collection, data analysis, data interpretation, or writing of the report.

Results

In the present study, 15 472 CKB participants with coronary heart disease, 8884 with stroke, and 2578 with cancer at baseline were excluded, in addition to two people with missing values for BMI. After these exclusions, a total of 487 209 participants were included in the primary analysis. Reasons for exclusion were not mutually exclusive, with 1406 participants meeting multiple exclusion criteria. For analysis of chronic respiratory diseases, 37 057 participants with COPD and 2528 with asthma at baseline were excluded, and 451 233 participants were included in the final analysis. Baseline COPD was ascertained on the basis of self-reported clinical diagnosis of chronic bronchitis or emphysema and onsite pulmonary function test.[22] Other medical histories relied on self-reported clinical diagnoses. In the present study, we used up to 171 127 adults aged 30–84 years from the CNHS 2015 to estimate the sex-specific and age-specific (every 5-years) prevalence of lifestyle-related factors (appendix p 13).

The baseline mean age of the included 487 209 CKB participants was 51·5 years (SD 10·5); 199 238 (40·9%) were men and 287 971 (59·1%) were women, and 277 062 (56·9%) resided in rural areas. A total of 331 104 (68·0%) participants had at least three low-risk lifestyle factors, 135 305 (27·8%) had at least four, and 9767 (2·0%) had all five. Female participants, those of younger age, those with a higher education, and those residing in urban areas were more likely to adopt a low-risk lifestyle (appendix pp 14–15).

In CNHS, the mean age of the eligible 171 127 participants was 54·5 years (SD 12·3); 80 650 (47·1%) were men and 90 477 (52·9%) were women, and 101 707 (59·4%) resided in rural areas. Among the 67 798 participants used for lifestyle combination analysis, 46 559 (68·7%) adopted at least three low-risk lifestyle factors, 19 128 (28·2%) adopted four, and 2178 (3·2%) participants adopted all five low-risk lifestyle factors. The subset of participants used for lifestyle combination analysis shared similar characteristics with the total group of 171 127 eligible participants.

During a median follow-up of 11·1 years (IQR 10·2–12·1; 5·3 million person-years), the CKB study documented 42 496 deaths, including 16 257 deaths from cardiovascular disease, 14 069 deaths from cancer, and 3332 deaths from chronic respiratory disease. After excluding participants with prevalent COPD and asthma at baseline, 1449 deaths from chronic respiratory disease occurred among the remaining 451 233 participants. In the multivariable-adjusted model, smoking was associated with an increased risk of all-cause mortality, and being physically active and following healthy dietary habits were

	All causes			Cardiovascular diseases			Cancer		
	Deaths	Deaths per 1000 person-years	HR (95% CI)	Deaths	Deaths per 1000 person-years	HR (95% CI)	Deaths	Deaths per 1000 person-years	HR (95% CI)
Smoking*									
Never	21 819	6·0	1 (ref)	8899	2·5	1 (ref)	6838	1·9	1 (ref)
Former	1929	12·8	1·11 (1·06–1·17)	707	4·7	1·04 (0·96–1·13)	655	4·4	1·15 (1·06–1·26)
Current (number of cigarettes or equivalents per day)									
1–9	4832	16·5	1·30 (1·25–1·35)	2010	6·9	1·27 (1·20–1·35)	1411	4·8	1·34 (1·25–1·43)
10–19	4968	12·1	1·26 (1·21–1·31)	1797	4·4	1·20 (1·13–1·27)	1699	4·1	1·39 (1·30–1·48)
≥20	8948	10·9	1·38 (1·34–1·43)	2844	3·5	1·28 (1·21–1·35)	3466	4·2	1·59 (1·50–1·69)
Alcohol intake†									
Less than daily	33 334	7·2	1·08 (0·97–1·21)	13 331	2·9	1·12 (0·93–1·34)	10 559	2·3	0·96 (0·80–1·15)
Former	3410	18·0	1·42 (1·27–1·59)	1185	6·3	1·37 (1·14–1·65)	1067	5·6	1·22 (1·01–1·47)
Current daily (g of pure alcohol per day)									
<15	337	13·3	1 (ref)	123	4·9	1 (ref)	122	4·8	1 (ref)
15–29	1073	11·7	1·11 (0·98–1·25)	377	4·1	1·14 (0·93–1·40)	425	4·6	1·09 (0·89–1·33)
30–59	1791	11·4	1·18 (1·05–1·33)	558	3·6	1·17 (0·96–1·42)	740	4·7	1·14 (0·94–1·38)
≥60	2551	12·4	1·41 (1·26–1·58)	683	3·3	1·35 (1·11–1·64)	1156	5·6	1·48 (1·23–1·79)
Physical activity‡									
Quintile 1	10 906	10·4	1 (ref)	4556	4·3	1 (ref)	3188	3·0	1 (ref)
Quintile 2	8732	8·3	0·82 (0·80–0·84)	3506	3·3	0·79 (0·76–0·83)	2789	2·6	0·92 (0·87–0·97)
Quintile 3	8097	7·7	0·76 (0·74–0·78)	3008	2·8	0·70 (0·67–0·74)	2770	2·6	0·91 (0·86–0·96)
Quintile 4	7795	7·3	0·71 (0·69–0·73)	2803	2·6	0·67 (0·63–0·70)	2735	2·6	0·88 (0·83–0·92)
Quintile 5	6966	6·5	0·65 (0·63–0·67)	2384	2·2	0·61 (0·58–0·64)	2587	2·4	0·81 (0·77–0·86)
Diet score§									
0–1	11 994	10·6	1 (ref)	5352	4·7	1 (ref)	3332	2·9	1 (ref)
2	17 823	8·3	0·90 (0·88–0·92)	6499	3·0	0·88 (0·84–0·91)	5901	2·7	0·95 (0·91–0·99)
3	10 297	6·5	0·84 (0·81–0·87)	3628	2·3	0·81 (0·77–0·85)	3841	2·4	0·92 (0·87–0·98)
4	2163	5·6	0·80 (0·76–0·84)	711	1·8	0·73 (0·67–0·79)	907	2·3	0·92 (0·85–1·00)
5	219	5·4	0·74 (0·65–0·85)	67	1·6	0·62 (0·49–0·80)	88	2·2	0·80 (0·64–0·99)
Body shape									
BMI <18·5 kg/m²	4282	19·5	1·37 (1·32–1·42)	1439	6·6	1·13 (1·07–1·20)	1055	4·8	1·29 (1·20–1·38)
BMI 18·5–27·9 kg/m², waist circumference <90 cm (men) or <85 cm (women)	27 744	7·3	1 (ref)	10 155	2·7	1 (ref)	9708	2·6	1 (ref)
BMI 18·5–27·9 kg/m², waist circumference ≥90 cm (men) or ≥85 cm (women)	6523	8·8	1·20 (1·16–1·23)	2870	3·9	1·30 (1·24–1·37)	2042	2·8	0·99 (0·94–1·05)
BMI ≥28·0 kg/m², waist circumference <90 cm (men) or <85 cm (women)	310	5·2	1·21 (1·08–1·36)	129	2·2	1·47 (1·23–1·75)	110	1·8	1·00 (0·82–1·20)
BMI ≥28·0 kg/m², waist circumference ≥90 cm (men) or ≥85 cm (women)	3637	7·5	1·40 (1·34–1·47)	1664	3·4	1·66 (1·55–1·78)	1154	2·4	1·01 (0·94–1·09)

Data from 487 209 participants. Multivariable models were adjusted for sex (men or women), education (no formal school, primary school, middle school, high school, college, or university or higher), marital status (married, widowed, divorced or separated, or never married), hip circumference (mm), family history of heart attack and stroke (presence, absence, or unknown; adjusted for analyses of all-cause and cardiovascular mortality), and family history of cancer (presence, absence, or unknown; adjusted for analyses of all-cause and cancer mortality). All five lifestyle factors were included simultaneously in the same model. HR=hazard ratio. BMI=body-mass index. *Participants who stopped smoking for reasons other than illness were classified as former smokers. Participants who had stopped smoking due to illness were classified as current smokers. †Less than daily group included never-regular drinkers and current weekly drinkers. Participants who used to drink at least once weekly but drank less than weekly at baseline were classified as former drinkers. ‡Physical activity level was categorised on the basis of age- (<50 years, 50–59 years, and ≥60 years) and sex-specific quintile of total physical activity level. §Diet score was created according to the following criteria: eating fresh vegetables daily, eating fresh fruits daily, eating red meat 1–6 days per week, eating legumes ≥4 days per week, eating fish ≥1 day per week. For each food group, the participant who met the criterion received a score of 1, and otherwise, 0.

***Table 1:* Multivariable-adjusted hazard ratios for all-cause and cause-specific mortality by individual lifestyle risk factors among 487 209 participants**

associated with a reduced risk of all-cause mortality (table 1). Compared with alcohol drinkers who drank pure alcohol <15 g per day, former drinkers (HR 1·42 [95% CI 1·27–1·59]) and heavy drinkers (>60 g/d; HR 1·41 [1·26–1·58]) experienced a similarly elevated death risk. Therefore, we combined these two groups for the subsequent analysis of life expectancy. Compared with participants with a BMI of 18·5–27·9 kg/m² and without abdominal obesity, those with underweight or obesity, either general or abdominal, had a higher death

	Deaths	Deaths per 1000 person-years	HR (95% CI)
Smoking*			
Never	664	0·2	1 (ref)
Former	59	0·4	1·29 (0·97–1·72)
Current (number of cigarettes or equivalents per day)			
1–9	247	0·9	1·78 (1·49–2·13)
10–19	209	0·6	1·53 (1·26–1·86)
≥20	270	0·4	1·59 (1·32–1·93)
Alcohol intake†			
Less than daily	1149	0·3	0·85 (0·50–1·45)
Former	123	0·8	1·10 (0·63–1·91)
Current daily (g of pure alcohol per day)			
<15	14	0·6	1 (ref)
15–29	34	0·4	0·82 (0·44–1·53)
30–59	52	0·4	0·83 (0·46–1·50)
≥60	77	0·4	0·96 (0·54–1·72)
Physical activity‡			
Quintile 1	322	0·3	1 (ref)
Quintile 2	309	0·3	0·88 (0·75–1·03)
Quintile 3	253	0·3	0·70 (0·59–0·83)
Quintile 4	291	0·3	0·64 (0·54–0·75)
Quintile 5	274	0·3	0·55 (0·46–0·66)
Diet score§			
0–1	531	0·5	1 (ref)
2	584	0·3	0·79 (0·69–0·91)
3	286	0·2	0·77 (0·64–0·91)
4	45	0·1	0·68 (0·49–0·94)
5	3	0·1	0·49 (0·16–1·54)
Body shape			
BMI <18·5 kg/m²	329	1·8	2·15 (1·86–2·50)
BMI 18·5–27·9 kg/m², waist circumference <90 cm (men) or <85 cm (women)	855	0·2	1 (ref)
BMI 18·5–27·9 kg/m², waist circumference ≥90 cm (men) or ≥85 cm (women)	184	0·3	1·45 (1·21–1·74)
BMI ≥28·0 kg/m², waist circumference <90 cm (men) or <85 cm (women)	7	0·1	1·90 (0·90–4·02)
BMI ≥28·0 kg/m², waist circumference ≥90 cm (men) or ≥85 cm (women)	74	0·2	1·86 (1·40–2·47)

Data from 451 233 participants. Multivariable models were adjusted for sex (men or women), education (no formal school, primary school, middle school, high school, college, or university or higher), marital status (married, widowed, divorced or separated, or never married), hip circumference (mm), family history of heart attack and stroke (presence, absence, or unknown; adjusted for analyses of all-cause and cardiovascular mortality), and family history of cancer (presence, absence, or unknown; adjusted for analyses of all-cause and cancer mortality). All five lifestyle factors were included simultaneously in the same model. HR=hazard ratio. BMI=body-mass index. *Participants who stopped smoking for reasons other than illness were classified as former smokers. Participants who had stopped smoking due to illness were classified as current smokers. †Less than daily group included never-regular drinkers and current weekly drinkers. Participants who used to drink at least once weekly but drank less than weekly at baseline were classified as former drinkers. ‡Physical activity level was categorised on the basis of age-specific (<50 years, 50–59 years, and ≥60 years) and sex-specific quintile of total physical activity level. §Diet score was created according to the following criteria: eating fresh vegetables daily, eating fresh fruits daily, eating red meat 1–6 days per week, eating legumes ≥4 days per week, eating fish ≥1 day per week. For each food group, the participant who met the criterion received a score of 1, and otherwise, 0.

Table 2: **Multivariable-adjusted hazard ratios for mortality from chronic respiratory diseases by individual lifestyle risk factors among 451 233 participants**

risk. Most of the associations between individual lifestyle factors and mortality risks for cardiovascular disease, cancer, and chronic respiratory disease were similar to those of all-cause mortality (tables 1 and 2). Results by sex are presented in the appendix (appendix pp 16–19).

When low-risk lifestyle factors were considered jointly, compared with participants with 0–1 low-risk lifestyle factors, the adjusted HR of participants who had five low-risk lifestyle factors was 0·38 (95% CI 0·34–0·43) for all-cause mortality, 0·37 (0·30–0·46) for cardiovascular disease mortality, 0·47 (0·39–0·56) for cancer mortality, and 0·30 (0·14–0·64) for chronic respiratory diseases mortality. The PAR% of not adopting all five low-risk lifestyle factors was 37·8% (30·7 to 44·5) for all-cause mortality, 42·8% (30·5 to 53·6) for cardiovascular disease mortality, 29·9% (17·8 to 41·2) for cancer mortality, and 36·3% (–16·3 to 72·9) for chronic respiratory disease mortality (figure 1). The exclusion of deaths that occurred during the first 2 years of the follow-up did not substantially alter the results (appendix pp 20–23). Fine-Gray regression models yielded slightly attenuated risk estimates for cause-specific mortality (appendix pp 24–25). All five low-risk lifestyle factors, including non-smoking, moderate alcohol intake, physical activity, healthy dietary habits, and absence of underweight or obesity, were associated with longer life expectancy (figure 2).

Using sex-specific HRs, the estimated life expectancy at age 30 years for individuals with 0–1 low-risk lifestyle factors was 41·7 years (95% CI 41·5–42·0) for men and 47·3 years (46·6–48·0) for women. For those who adopted all five low-risk lifestyle factors, the estimated life expectancy at age 30 years was 50·5 years (95% CI 48·5–52·4) for men and 55·4 years (53·5–57·4) for women (figure 3A). By comparing individuals adopting all five low-risk lifestyle factors with those who adopted 0–1, the gain in life expectancy at age 30 years, on average, was 8·8 years (95% CI 6·8–10·7) for men and 8·1 years (6·5–9·9) for women (figure 3B; appendix p 26).

Compared with participants with 0–1 low-risk lifestyle factors, the gained years of life at age 30 years from adopting five low-risk factors were attributable to reduced death from cardiovascular disease (2·4 years [27% of the total extended life expectancy] for men and 3·7 years [46%] for women), cancer (2·6 years [30%] for men and 0·9 years [11%] for women), chronic respiratory disease (0·6 years [7%] for men and 1·2 years [15%] for women), and other causes (3·2 years [36%] for men and 2·3 years [28%] for women; figure 3C). The life expectancy estimates remained robust in sensitivity analyses using sex-specific and age-at-risk specific HRs (appendix p 29) and using mortality data from 2019 (appendix p 30).

In subgroup analysis stratified by residence, education level, smoking status, obesity status, or disease status at baseline, we observed a consistent relationship between the increasing number of low-risk lifestyle factors and the gained life expectancy at age 30 years across

	Deaths	Deaths per 1000 person-years	HR (95% CI)	PAR% (95% CI)
Number of low-risk lifestyle factors				
All causes				
0–1	6308	15·7	1 (ref)	
2	13 862	11·0	0·75 (0·72–0·77)	
3	15 471	7·2	0·59 (0·57–0·60)	
4	6539	4·7	0·48 (0·46–0·49)	
5	316	2·9	0·38 (0·34–0·43)	
HR of 5 *vs* <5 low-risk factors			0·63 (0·56–0·70)	37·8 (30·7 to 44·5)
Cardiovascular diseases				
0–1	2241	5·6	1 (ref)	
2	5579	4·4	0·79 (0·75–0·83)	
3	5995	2·8	0·60 (0·57–0·63)	
4	2347	1·7	0·49 (0·46–0·52)	
5	95	0·9	0·37 (0·30–0·46)	
HR of 5 *vs* <5 low-risk factors			0·59 (0·48–0·72)	42·8 (30·5 to 53·6)
Cancer				
0–1	2114	5·3	1 (ref)	
2	4349	3·5	0·75 (0·71–0·79)	
3	5061	2·4	0·64 (0·60–0·67)	
4	2407	1·7	0·57 (0·53–0·60)	
5	138	1·3	0·47 (0·39–0·56)	
HR of 5 *vs* <5 low-risk factors			0·71 (0·60–0·84)	29·9 (17·8 to 41·2)
Chronic respiratory diseases				
0–1	242	0·7	1 (ref)	
2	497	0·4	0·64 (0·54–0·75)	
3	543	0·3	0·43 (0·37–0·51)	
4	160	0·1	0·25 (0·20–0·31)	
5	7	0·1	0·30 (0·14–0·64)	
HR of 5 *vs* <5 low-risk factors			0·66 (0·31–1·40)	36·3 (–16·3 to 72·9)

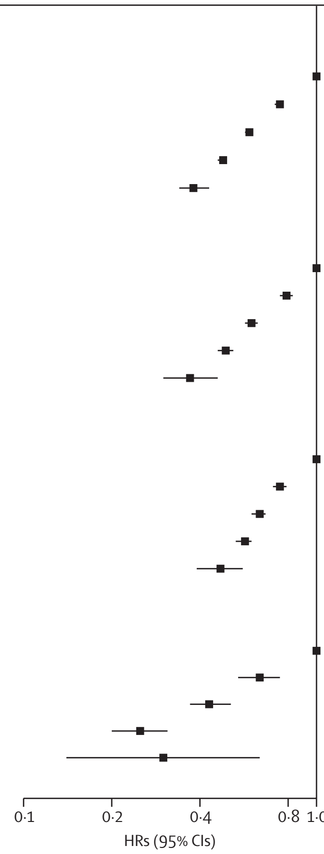

Figure 1: **Multivariable-adjusted HRs and PARs% for all-cause and cause-specific mortality, by the number of low-risk lifestyle factors**
Multivariable models were adjusted for sex (men or women), education (no formal school, primary school, middle school, high school, college, or university or higher), marital status (married, widowed, divorced or separated, or never married), hip circumference (mm), family histories of heart attack and stroke (presence, absence, or unknown; adjusted for analyses of all-cause and cardiovascular mortality), and family history of cancer (presence, absence, or unknown; adjusted for analyses of all-cause and cancer mortality). Low-risk lifestyle factors were defined as: never smoking or having stopped for reasons other than illness; less than daily drinking or drinking <30 g (men) and <15 g (women) of pure alcohol per day (former drinkers excluded); engaging in an age-specific (<50 years, 50–59 years, and ≥60 years) and sex-specific median or higher level of physical activity; scoring 4–5 for all food groups; having a BMI between 18·5 and 27·9 kg/m² and a waist circumference <90 cm (men) and <85 cm (women). HR=hazard ratio. PAR%=population attributable risk percent.

subpopulations (appendix pp 31–35). In the analysis using an expanded low-risk score, the average life expectancy at age 30 years for individuals with a score of at least 23 was 13·5 years longer for men and 12·1 years longer for women than those with a score of 8 or less (appendix 36–37).

Discussion

Our results suggest that adherence to each of the five low-risk lifestyle factors, namely never smoking or quitting for reasons other than illness, no excessive alcohol use, being physically active, healthy eating habits, and a BMI between 18·5 and 27·9 kg/m² without abdominal obesity, was associated with longer life expectancy for Chinese adults. The estimated life expectancy at age 30 years for individuals with all five low-risk factors was on average 8·8 years longer in men and 8·1 years longer in women than those with 0–1 low-risk factors. The estimated improved life expectancy for men and women was mostly attributable to reduced death from cardiovascular disease, cancer, and chronic respiratory disease.

To the best of our knowledge, this is the first study to quantify the association between combined lifestyle factors and life expectancy in China. In 2015, the average life expectancy at age 30 years for Chinese adults was 45·5 years for men and 51·3 years for women.[23] In the present study, the estimated life expectancy at age 30 for individuals with 0–1 low-risk lifestyle factors was 41·7 years for men and 47·3 years for women. However, adopting all five low-risk lifestyle factors was associated with an improved life expectancy at age 30, reaching 50·5 years for men and 55·4 years for women. The Singapore Chinese Health Study—which had a median of 20·6 years of follow-up data—showed that the differences in life expectancy when comparing individuals with 4–5 low-risk lifestyle factors with those with zero

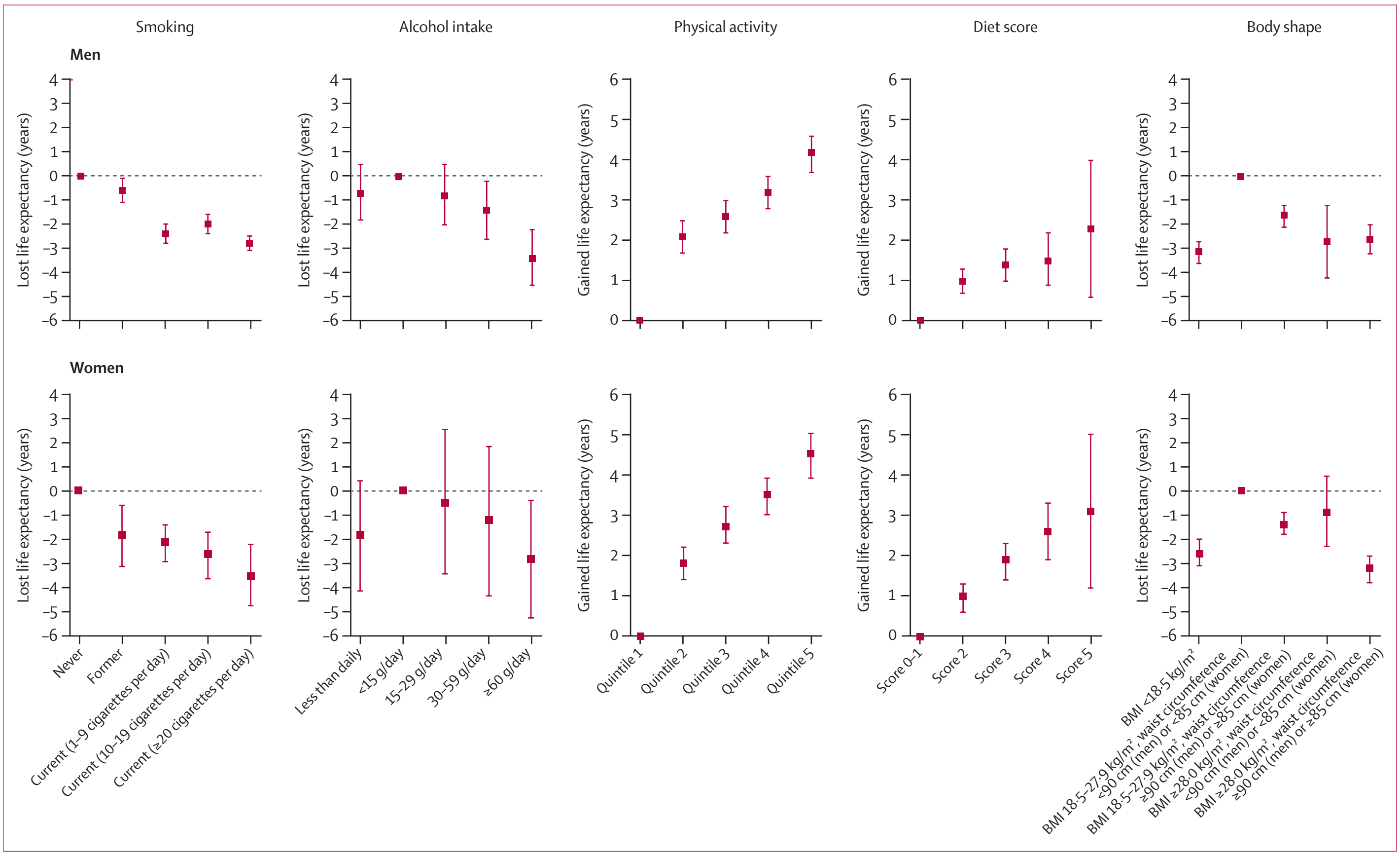

Figure 2: **Projected gained or lost life expectancy at age 30 years, by individual lifestyle factors**
Former alcohol drinkers were included in the heavy drinking category (≥60 g of pure alcohol per day). Data points shown without confidence intervals represent the reference group. BMI=body-mass index.

low-risk lifestyle factors at age 50 years were 6·6 years for men and 8·1 years for women.[24] In the present study, the corresponding estimates of gained life-years at 50 years were 7·7 years for men and 7·6 years for women, similar to the estimates from the aforementioned study, but with a smaller sex difference.

Our findings were consistent with previous studies in high-income countries; life expectancy increased with increasing numbers of low-risk lifestyle factors. Adherence to a healthy lifestyle has been associated with a 17·9-year increase in life expectancy at age 20 for Canadians,[6] and 12·2 years (for men) and 14 years (for women) at age 50 years for Americans,[5] and 18·5 years (for men) and 15·7 years (for women) at age 40 years for the EPIC-Heidelberg cohort population from Germany.[7] By contrast, the estimates of gained life-years in our study were lower than that of the three aforementioned studies. This inconsistency might be explained by the differences between populations in the definitions and components of a healthy lifestyle and their prevalence.[5] Additionally, in developing countries, potential environmental hazards in the home, work, and broader outdoor environment, such as ambient and household air pollution, and chemical contamination of food and water, could increase the burden of diseases.[25] Therefore, the relative impact of a healthy lifestyle alone on life expectancy might be slightly diminished in developing countries.

In the cause-specific decomposition analysis of the life expectancy differences, we observed that compared with individuals with 0–1 low-risk lifestyle factors, about two thirds of the increased life expectancy from adopting all five low-risk factors could be explained by the reduced death from cardiovascular disease, cancer, and chronic respiratory disease, all representing the leading causes of death in the Chinese population. A larger proportion (72%) of the gained life expectancy between individuals with all five low-risk lifestyle factors and those with 0–1 low-risk lifestyle factors in women was attributable to the reduced death from cardiovascular disease, cancer, and chronic respiratory disease than that in men (64%). Additionally, the major contributors to the life expectancy difference were from cardiovascular disease and other causes among women and from cancer and other causes among men. This difference might be related to the sex differences in the relative risks of lifestyle risk factors for various outcomes, disease burden patterns, and prevalence of lifestyle risk factors.

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The lifestyle-related factors included in this study and the definition of their low-risk group were generally consistent with previous studies, except for physical activity and obesity indicators. Many studies in high-income countries specifically focused on leisure-time physical activity. However, most of the physical activity in the current population was occupational and household.[26] We defined the low-risk group according to total physical activity, and being physically active was associated with an increase in life expectancy at age 30 by more than 4 years. We suggest that this alternative definition of physical activity is valid in the Chinese population. Regarding adiposity measures, by contrast to previous studies that only included BMI,[5,7,24] this study used both BMI and waist circumference. A recent meta-analysis of 72 prospective studies suggests that the measures of central adiposity could be used with BMI as an auxiliary indicator to determine the risk of premature death.[27]

This study has several strengths. First, the nature of the CKB study in terms of its large sample size, long-term follow-up, and the high number of documented deaths enables us to obtain more precise sex-specific effect estimates for all-cause and cause-specific mortality than do smaller studies. The inclusion of a geographically spread population living in urban and rural areas, with different socio-demographic characteristics, and the loss to follow-up rate of less than 1%, make the effect estimates broadly applicable. Second, we used a nationally representative survey to estimate the prevalence of lifestyle factors, improving the representativeness of the findings for the Chinese population. Third, existing studies mainly investigated the impact of lifestyle factors on life expectancy at middle age and old age, such as life expectancy at 50 years.[5,24] The present study expands on previous findings and supports the benefits of starting a healthy lifestyle early at a young age.

Several limitations also merit discussion when interpreting the results. First, the lifestyle behaviours were self-reported in CKB and CNHS, most likely leading to biased results towards the null in the estimated associations and might have provided overestimates in the prevalence of low-risk lifestyle factors. Second, we only used information on lifestyle factors at one timepoint at baseline in the CKB without considering their potential changes during the follow-up. However, one of our previous studies using resurvey data from a subset of the CKB population showed that the lifestyle of most participants remained relatively stable over long periods.[28] Third, we dichotomised each lifestyle factor and counted the number of low-risk lifestyle factors, ignoring the difference in the magnitude of association between various lifestyle factors and death. However, two previous studies compared the analyses using weighted lifestyle scores with non-weighted scores, and no significant differences were observed.[24,29] Fourth, the definitions of low-risk lifestyle factors might not be entirely consistent between the CKB and CNHS due to subtle differences in the questionnaires. Nevertheless, slight changes in the prevalence of lifestyle factors would not substantially affect the results of our study under different simulation scenarios. Other limitations include the observational nature of the study precluding causal inference, the CKB cohort not being fully representative of the Chinese

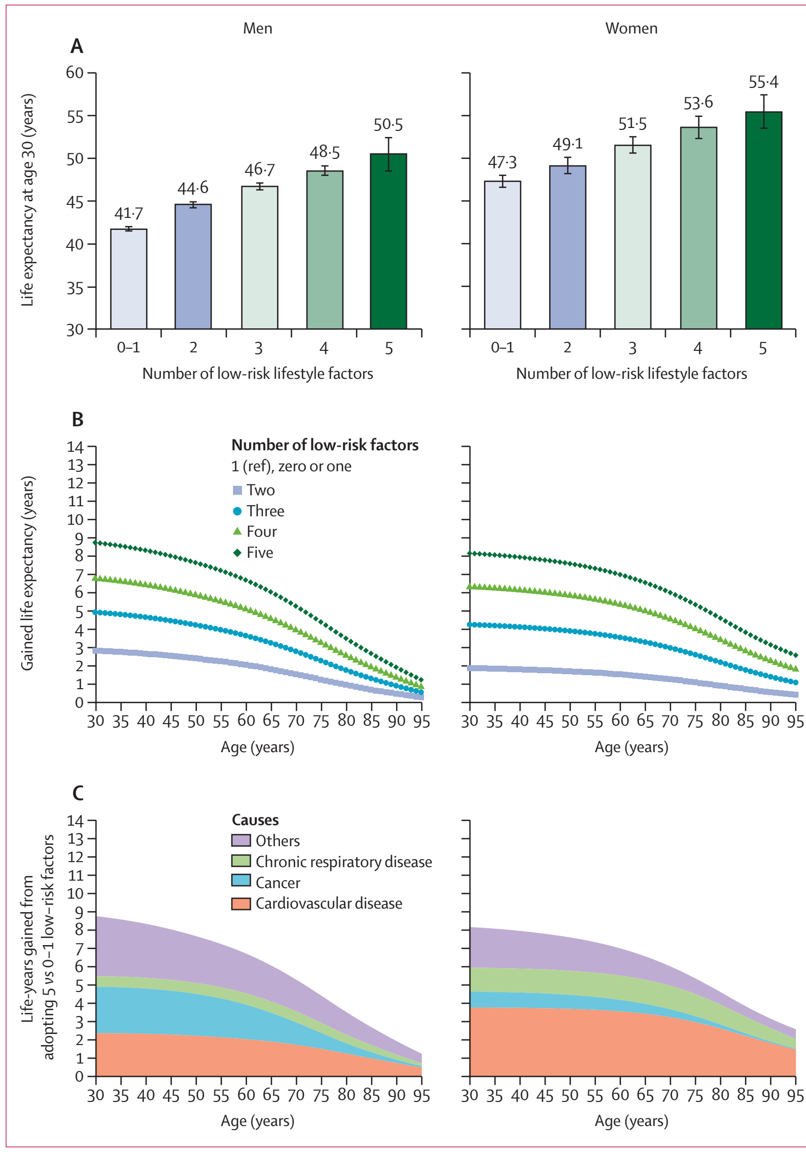

Figure 3: **Life expectancy and years of life gained by the number of low-risk lifestyle factors and attribution of the causes of death**

(A) Estimated life expectancy at age 30 years by the number of low-risk lifestyle factors. (B) Gained age-specfic life expectancy from adopting low-risk lifestyle habits. (C) Estimated years of life gained from adopting five versus 0–1 low-risk lifestyle factors attributable to reduced death from cardiovascular disease, cancer, chronic respiratory disease, and other causes. Low-risk lifestyle factors were defined as: never smoking or having stopped for reasons other than illness; less than daily drinking or drinking <30 g (men) and <15 g (women) of pure alcohol per day (former drinkers excluded); engaging in an age-specific (<50 years, 50–59 years, and ≥60 years) and sex-specific median or higher level of physical activity; scoring 4–5 for all food groups; having a BMI between 18·5 and 27·9 kg/m² and a waist circumference <90 cm (men) and <85 cm (women). BMI=body-mass index.

population, and the neglect of potential secular changes in health risk factors or clinical advances in the future.

This study of the Chinese population shows that adopting a low-risk lifestyle was associated with a higher life expectancy, than not adopting a low-risk lifestyle, at age 30 years by 8·8 years in men and 8·1 years in women; mostly accounted for by reduced deaths from cardiovascular disease, cancer, and chronic respiratory disease. Assuming that the observed associations are causal, there is still much room for improvement in the life expectancy of the Chinese population through population-wide healthy lifestyle interventions. For example, a recent study from Hong Kong has shown the possibility of realising this vision, emphasising the crucial role of tobacco control in improving life expectancy.[30] Public health interventions that improve adoption of healthy lifestyles should be one of the priorities for implementing the Healthy China 2030 agenda.

Contributors

QS and DY are joint first authors. JL and LL conceived and designed the study, and contributed to the interpretation of the results and critical revision of the manuscript for valuable intellectual content. LL, ZC, and JC, as members of the CKB steering committee, designed and supervised the conduct of the study, obtained funding, and together with CY, YG, PP, LY, YC, HD, XY, SS, and YW, acquired the CKB data. DY, LZ, and WZ designed and supervised the conduct of the CNHS. QS, DY, and JF accessed, verified, and analysed the data. QS drafted the manuscript. The corresponding authors attest that all listed authors meet authorship criteria and that no others meeting the criteria have been omitted. JL, LL, and LZ are the guarantors. All authors had access to the data, have read and approved the final manuscript, and accept responsibility for the decision to submit for publication.

Declaration of interests

We declare no competing interests.

Data sharing

Details of how to access China Kadoorie Biobank data and details of the data release schedule are available from: https://www.ckbiobank.org/site/Data+Access. The CNHS data will be available from the corresponding authors on request.

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