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Research Article

Association Between Combined Lifestyle Factors and Healthy Ageing in Chinese Adults: The Singapore Chinese Health Study

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Abstract

Background: The aim of the study was to examine the relations of individual lifestyle factors and its composite score with healthy ageing among Chinese adults.

Method: We included 14 159 participants aged 45–74 years at baseline from the Singapore Chinese Health Study, a population-based prospective cohort. A protective lifestyle score (0–5 scale) was calculated at baseline (1993–1998) and updated at the second follow-up visit (2006–2010) on the basis of optimal body mass index (18.5–22.9 kg/m^2), healthy diet (upper 40% of the Alternative Healthy Eating Index score), being physically active (≥2 h/wk of moderate activity or ≥0.5 h/wk of strenuous activity), nonsmoking (never smoking), and low-to-moderate alcohol drinking (>0 to ≤14 drinks/wk for men and >0 to ≤7 drinks/wk for women). Healthy ageing was assessed at the third follow-up visit (2014–2016) and was defined as absence of specific chronic diseases, absence of cognitive impairment and limitations in instrumental activities of daily living, good mental and overall self-perceived health, good physical functioning, and no function-limiting pain.

Results: About 20.0% (2834) of the participants met the criteria of healthy ageing after a median follow-up of 20 years. Each 1-point increase in the protective lifestyle score computed at baseline and second follow-up visits was associated with higher likelihood of healthy ageing by 25% (95% CI: 20%–30%) and 24% (18%–29%), respectively. The population-attributable risk percent of adherence to 4–5 protective lifestyle factors was 34.3% (95% CI: 25.3%–42.3%) at baseline and 31.3% (23.0%–38.7%) at second follow-up visits for healthy ageing. In addition, positive increase in lifestyle scores from baseline to second follow-up visits was also significantly associated with a higher likelihood of healthy ageing with an odds ratio of 1.18 (95% CI: 1.12%–1.24%) for each increment in protective lifestyle score.

Conclusions: Our findings confirmed that adopting healthy lifestyle factors, even after midlife, was associated with healthy ageing at old age.

Keywords: Diet, Healthy ageing, Obesity, Physical activity, Risk factor

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It is estimated that the number of people aged 60 years or older will be rising from 962 million in 2017 to 2.1 billion in 2050 globally (1). The accelerated process of ageing is accompanied by increases in age-related diseases and functional disabilities, causing tremendous individual and societal burdens. Hence, it is critical to identify modifiable factors affecting healthy ageing.

A number of studies have examined the relations of individual lifestyle factors, including diet (2), body weight (3), physical activity (4), smoking, and alcohol consumption (5), with the likelihood of healthy ageing in various populations. Their results suggested that greater adherence to the Alternative Healthy Eating Index-2010 (AHEI-2010) (2) and optimal midlife body mass index (BMI) (3) were significantly associated with greater likelihood of healthy ageing. In addition, meta-analyses of cohort studies revealed that higher levels of physical activity and never smoking were positively associated with healthy ageing, while the association between alcohol consumption and healthy ageing was equivocal (4,5).

However, lifestyle factors are not isolated. We hypothesized that people with multiple healthy lifestyle factors would have higher likelihood of healthy ageing than those with no or fewer healthy lifestyle factors, and the beneficial effect would be incremental. Thus, it would be more informative for studies that examine combined lifestyle factors in relation to likelihood of healthy ageing in population with different proportion of ageing phenotype. In addition, lifestyle factors may change over time, and it is unclear if improvement in lifestyle factors after midlife will improve the likelihood of healthy ageing.

To our knowledge, only 4 studies have evaluated the association between combined lifestyle factors and healthy ageing with 3 studies in European countries (6–8) and a study in Latin America and the Caribbean (9). All these studies reported that healthy lifestyles were associated with a high likelihood of healthy ageing. However, no similar study has been conducted in an Asian population.

Population ageing has become a concern in Asia and the world, and the number of older adult has continued to increase in Singapore (10). In this study, we aimed to examine the associations of individual and combined lifestyle factors (BMI, diet, physical activity, smoking, and alcohol drinking) at baseline and follow-up visits, as well as changes in lifestyle factors between baseline and follow-up visits, with the likelihood of healthy ageing. We also estimated the population-attributable risk percent (PAR%) of adherence to protective lifestyle factors for healthy ageing using data from the middle-aged and older participants of the Singapore Chinese Health Study.

Method

Study Population

The study design of the Singapore Chinese Health Study has been previously described (11). In brief, the study recruited men and women aged 45–74 years from 2 major dialect groups (Hokkien or Cantonese) of Chinese who lived in government-built housing estates in Singapore, where 86% of the total population resided at the time of recruitment. A total of 63 257 individuals were recruited between April 1993 and December 1998. After recruitment, the participants were re-contacted for follow-up interviews in 1999–2004 (the first follow-up by phone), 2006–2010 (the second follow-up by phone), and 2014–2016 (the third follow-up by face-to-face interview). The in-person interview at third follow-up visits also focused on the measurement of ageing outcomes. A total of 17 107 surviving participants participated in the third follow-up interview when they were aged 61–96 years. The study was approved by the Institutional Review Board at the National University of Singapore. Written informed consent forms were obtained from all study participants before enrollment.

Assessment of Lifestyle Factors

The measurement contents of each survey and detailed assessment of lifestyle factors are shown in the Supplementary Figure 1 and Supplementary Methods. Briefly, dietary intake over the past year was assessed only at baseline using a validated, 165-item, semi-quantitative food frequency questionnaire for the study participant. The other factors were assessed at baseline interview and updated at the second follow-up interview: weight and height were used to calculate BMI as weight (kg) divided by height squared (m^2); cigarette smoking was determined by asking questions about whether the participant had smoked at least 1 cigarette a day for 1 year or longer; for alcohol drinking in the past year, participants were asked in separate questions about their consumption of beer, wine, western hard liquor, and Chinese hard liquor, and to choose from 8 categories of frequency (ranging from "never or hardly ever" to "2 or more times a day"), as well as 4 defined portion sizes; physical activity was determined by asking the number of hours per week spent on moderate activities and strenuous sports using a questionnaire modified from the European Prospective Investigation in Cancer (EPIC) study (12).

Construction of a Protective Lifestyle Score

We constructed a protective lifestyle score using BMI, diet, physical activity, cigarette smoking, and alcohol drinking. The 5 lifestyle factors for the composite score were selected based on knowledge from our previous investigations on their individual impacts on health (including morbidity, mortality, and cognitive impairment) in the same cohort (13–16), as well as the WHO recommendations for weight categories in Asians (17). Participants scored 1 point for each of the following protective lifestyle factors: optimal BMI (18.5–22.9 kg/m^2), healthy diet (AHEI-2010 score in the top 40% of this cohort), being physically active (≥2 h/wk of moderate activity or ≥0.5 h/wk of strenuous activity), nonsmoking (never smoking), and low-to-moderate alcohol drinking (>0 to ≤14 drinks/wk for men and >0 to ≤7 drinks/wk for women). The combined lifestyle score was the sum of the 5 lifestyle factors with a range from 0 to 5. Participants with a score of 0 had no protective lifestyle factors and those with 5 had maximum protective lifestyle factors. Since few participants scored 0 (n = 750) or 5 (n = 141) at baseline, the overall protective score was re-categorized into 4 groups: 0–1, 2, 3, and 4–5, with a higher score representing a healthier lifestyle. We did not consider sleep duration in the main analysis but included it in a sensitivity analysis, because it was not included in most other previous publications on this topic (6–9).

For the combined lifestyle score at the second follow-up visit, while we were able to use updated information for the other factors, we had to use baseline diet information to complete the computation.

Assessment of Healthy Ageing

The definition of healthy ageing has been described in previous studies (6,18,19). The definition of healthy ageing in this study addressed 7 domains, namely no history of major chronic diseases, no impairment of cognitive function, no limitations in instrumental activities of daily living (IADL), good mental health, good overall self-perceived health, good physical functioning, and no function-limiting pain. The major chronic diseases included in our definition

of healthy ageing were compiled from previous studies (18,19), and which were inquired in the baseline or third follow-up questionnaires, including cancer, acute myocardial infarction, angina, heart failure, coronary artery bypass graft or angioplasty, stroke, diabetes, kidney failure, Parkinson's disease, and chronic lung diseases. The other components of healthy ageing were only assessed at the third follow-up visit: cognitive function was evaluated using the Singapore Modified Mini-Mental State Examination (SM-MMSE), which had been validated in the Singapore population (20,21); IADL was assessed on the basis of the Lawton IADL scale (22), which had been validated in the Asian population (23); mental status was assessed by using the 15-item Geriatric Depression Scale (GDS-15) (24), which had been validated in older Asians (25); overall self-perceived health was assessed by asking a question "In general, would you say your health is: excellent, very good, good, fair, poor?"; and physical function and function-limiting pain were assessed by using the EQ-5D questionnaire (26); studies have shown high test–retest reliability and validity of EQ-5D in the Asian population (27). Among participants who survived to at least age 65 years at the third follow-up visit, those who met these 7 criteria were considered to have healthy ageing (Table 1).

Statistical Analysis

A total of 17 107 surviving participants aged 61–96 years completed the third follow-up investigation. We excluded the following participants from the analysis: those who had self-reported a diagnosis of cancer, cardiovascular disease, or diabetes at baseline (n = 1329), with certain extreme energy intakes at baseline (<600 or >3000 kcal for women; <700 or >3700 kcal for men; n = 212), missing values on the outcome measures in the healthy ageing definition (n = 319), and younger than 65 years at the third follow-up visit (n = 1088). Finally, 14 159 participants were included in the analysis of baseline lifestyle factors and healthy ageing. In the analysis of lifestyle factors at the second follow-up visit and changes in lifestyle factors from baseline to the second follow-up visit, we further excluded 2363 participants who had reported a diagnosis of Parkinson's disease, cardiovascular disease, or diabetes at the second follow-up interview, leaving 11 796 participants in the analysis (Figure 1).

Multivariable-adjusted logistic regression models were used to estimate the odds ratios (ORs) and the corresponding 95% confidence intervals (CIs) for the associations between individual and combined lifestyle factors at baseline and second follow-up interviews, as well as changes of lifestyle scores from baseline to the second follow-up visit, and the likelihood of healthy ageing. In multivariable models, we adjusted for sex, age at healthy ageing measurement, year of baseline interview, dialect group, marital status, education level, total energy intake, and sleep duration. For the association between individual lifestyle factors and healthy ageing, individual lifestyle factors were further mutually adjusted in the multivariable model. In the analysis of changes in lifestyle factors from baseline to the second follow-up visit, the healthy lifestyle score at baseline was further adjusted in the multivariable model.

Assuming that the observed associations between composite lifestyle scores and healthy ageing were causal, we estimated the PAR% of protective lifestyle factor for usual ageing in this cohort. For usual ageing, PAR% represented the percentage of usual ageing in the study population that could have been prevented if all individuals had been in the protective lifestyle factor category. In other words, this represented the percentage of healthy ageing in the study population that would have been achieved if all individuals had been in the protective lifestyle factor category. We estimated the PAR% based on the following formula (28):

$$PAR\% = 100 \times P_e\,(\mathrm{OR} - 1) \div [P_e\,(\mathrm{OR} - 1) + 1]$$

Where P_e was the proportion of participants with 0–3 protective lifestyle factors in the study population and the OR was derived from the logistic regression model for usual ageing.

We conducted stratified analysis according to age groups at the third follow-up visit: <70, 70–75, and >75, and examined the association in each age group. We also conducted a series of sensitivity analyses to test the robustness of our findings. First, given

Table 1. Definition of Healthy Ageing for Participants Who Survived to Age ≥65 Years at the Third Follow-up Interview

Criteria	Definition	Additional Information on the Instrument Used
No history of major chronic diseases	No history of cancer, acute myocardial infarction, angina, heart failure, coronary artery bypass graft or angioplasty, stroke, diabetes, kidney failure, Parkinson's disease, and chronic lung diseases.	The list of major chronic diseases were derived from previous studies (18,19).
No impairment of cognitive function	Score ≥18 for participants with no formal education; ≥21 for primary school education; ≥25 for secondary school or higher.	We used education-specific cutoff points suggested by the Shanghai Dementia Study (21).
No limitations in IADL	Each activity is rated a dichotomized score ("0" for less able and "1" for more able). No limitations in IADL were defined as a total score of 8.	The Lawton IADL scale consists of 8 questions about ability or limitations in telephone, shopping, preparing food, housekeeping, doing laundry, traveling away from home, taking medications properly, and handling personal finances (22).
Good mental health	Defined as a GDS-15 score <5.	Each item requires a dichotomous response (yes or no) that is scored as 1 or 0, respectively (24).
Good overall self-perceived health	Participants rated their health as good or excellent.	A question was asked: In general, would you say your health is: excellent, very good, good, fair, poor?
Good physical functioning	Identified as having no problem with mobility, self-care, and usual activities.	The EQ-5D consists of 5 dimensions of health on mobility, self-care, usual activities, pain/discomfort, and anxiety/depression (26).
No function-limiting pain	Identified as having no pain or discomfort.	EQ-5D: see above explanations

Note: EQ-5D = EuroQol Group's 5-domain questionnaire; GDS-15 = 15-item Geriatric Depression Scale; IADL = instrumental activities of daily living.

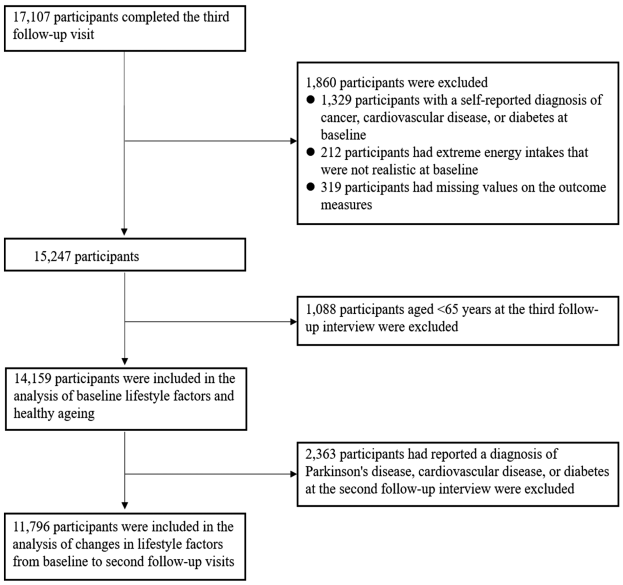

Figure 1. Flow chart of sample selection.

the controversy about alcohol consumption on health outcomes (29,30), 2 separate sensitivity analyses were conducted which excluded alcohol consumption from the composition of lifestyle score or changed the cut point for low-to-moderate alcohol drinking as monthly to weekly drinking. Second, we included past smoking together with never smoking as nonsmoking variable. Third, we incorporated sleep duration (protective 6–8 h/d vs <6/>8 h/d) into the lifestyle score. Forth, we assigned polytomous weights to each lifestyle factor in the composite lifestyle score. Fifth, we included those who died before age 65 years into the usual ageing group. Sixth, given that weight loss might be secondary to preclinical diseases or due to chronic illnesses not captured in our study (31), we excluded participants with a BMI below 18.5 kg/m^2. Seventh, given that healthy ageing was defined at age 70 years in some studies (2,30), we conducted 2 separate analyses on those who survived to at least 70 (n = 9315) or 75 years old (n = 5363). Finally, we assigned all participants with missing data at the third follow-up visit to the usual ageing group, or assigned those who survived at the third follow-up visit but did not attend the visit to the healthy ageing group. All analyses were performed using SAS 9.4 (SAS Institute Inc.).

Results

The baseline characteristics of study participants according to the number of protective lifestyle factors are shown in the Table 2. The mean ages at baseline, second follow-up, and third follow-up visits were 53.3 (*SD*: 6.1), 66.4 (*SD*: 6.1), and 73.7 (*SD*: 6.0) years, respectively. The proportions of participants with 0/1, 2, 3, and 4/5 protective lifestyle factors were 32.9%, 35.6%, 23.0%, and 8.5% at baseline, respectively. These proportions were 22.4%, 35.3%, 29.9%, and 12.4% at the second follow-up visit, respectively. At baseline, participants with a higher protective lifestyle score were more likely to be Cantonese and better educated, and as expected, to be more physically active, to have a lower BMI while higher AHEI-2010 scores, and less likely to be ever smokers.

Of 14 159 participants who survived to age 65 years or older, 2834 (20.0%) met the criteria of healthy ageing. From the multivariable-adjusted analyses using data collected at baseline, each protective lifestyle factor was associated with a higher likelihood of healthy ageing with varying effect size (Table 3 and Supplementary Table 1). Compared with the referent group with the lowest combined lifestyle scores (0–1), the multivariable-adjusted ORs (95% CIs) of healthy ageing for 2, 3, and 4–5 protective lifestyle scores were 1.35 (1.21–1.51), 1.67 (1.48–1.87), and 2.06 (1.77–2.41), respectively (p for trend < .001); each 1-point increase in protective lifestyle score was related to a 25% higher likelihood of healthy ageing (95% CI: 20%–30%); the PAR% of adherence to 4–5 protective lifestyle factors was 34.3% (95% CI: 25.3%–42.3%) for healthy ageing (Table 3 and Supplementary Table 2). These associations were consistent in the second follow-up visit (Table 3). In addition, the associations were consistent in different age groups (<70, 70–75, and >75 years old; p for interaction = .16, Supplementary Table 3).

For changes in lifestyle scores between baseline and the second follow-up visit, positive increase in score that represented improvement in lifestyle factors was significantly associated with a higher likelihood of healthy ageing (Table 4). Compared with participants without changes in lifestyle, the participants who improved their lifestyle scores in a positive manner had an OR (95% CI) of 1.22 (1.10%–1.35%) for likelihood of healthy ageing. For each number increment in protective lifestyle factors, there was an 18% (95% CI: 12%–24%) higher likelihood of healthy ageing (Table 4). Similar results were observed when a different reference group was used: compared with participants who maintained a lifestyle score ≤2 at both baseline and second follow-up interviews, those who changed the lifestyle score from ≤2 at baseline to >2 at second follow-up interviews had a significant 21% (95% CI: 7%–37%) higher likelihood of healthy ageing.

In analyses of each component of healthy ageing, a higher score of the protective lifestyle factors was significantly associated with better outcomes in different domains that defined healthy ageing in this study (Supplementary Table 4).

The results remained materially unchanged in the sensitivity analyses that excluded alcohol consumption from the composition of lifestyle score or changed the cutoff point for low-to-moderate alcohol drinking (Supplementary Table 5); included past smoking together with never smoking as nonsmoking variable (Supplementary Table 6); included sleep duration in the composition of lifestyle score (Supplementary Table 7); assigned polytomous weight to each lifestyle factor in the composite lifestyle score (Supplementary Table 8); included those who died before age 65 years into the usual ageing group (Supplementary Table 9); excluded participants with a BMI below 18.5 kg/m^2 (Supplementary Table 10); included only those who were either at least 70 or 75 years old at the third follow-up visit (Supplementary Table 11); or assigned all participants with missing data at the third follow-up visit to the usual ageing group (Supplementary Table 12). But the results were attenuated while remained significant in the sensitivity analysis that assigned all survival participants who did not attend the third follow-up visit to the healthy ageing group (Supplementary Table 12).

Discussion

In this large prospective cohort of Chinese adults who survived to at least age 65 years, about 20.0% of participants achieved healthy ageing. After adjustment for potential confounders, higher scores of the protective lifestyle factors were associated with a higher

Table 2. Baseline Participant Characteristics According to Protective Lifestyle Score (*N* = 14 159)

Protective lifestyle score	Total	0/1	2	3	4/5
No. of participants, %	14 159 (100.0)	4660 (32.9)	5041 (35.6)	3259 (23.0)	1199 (8.5)
No. of healthy ageing, %	2834 (20.0)	701 (15.0)	1000 (19.8)	786 (24.1)	347 (28.9)
Men, %	5808 (41.0)	2193 (47.1)	1775 (35.2)	1255 (38.5)	585 (48.8)
Age at baseline, mean (*SD*), y	53.3 (6.1)	53.8 (6.2)	53.2 (6.0)	53.0 (5.9)	53.1 (6.1)
Age at second follow-up, mean (*SD*), y	66.4 (6.1)	66.9 (6.1)	66.4 (6.1)	66.0 (5.9)	66.0 (6.2)
Age at third follow-up, mean (*SD*), y	73.7 (6.0)	74.1 (6.1)	73.6 (6.0)	73.4 (5.9)	73.4 (6.1)
BMI, mean (*SD*), kg/m^2	23.1 (3.2)	24.0 (3.5)	23.1 (3.1)	22.3 (2.7)	21.7 (2.0)
AHEI-2010, mean (*SD*)	50.8 (7.3)	46.2 (5.4)	50.8 (6.8)	54.8 (6.5)	57.7 (5.4)
Dialect group, %					
Cantonese	6826 (48.2)	2068 (44.4)	2382 (47.3)	1691 (51.9)	685 (57.1)
Hokkien	7333 (51.8)	2592 (55.6)	2659 (52.7)	1568 (48.1)	514 (42.9)
Education, %					
No formal education	2781 (19.6)	1181 (25.3)	1026 (20.3)	475 (14.6)	99 (8.3)
Primary school	6466 (45.7)	2335 (50.1)	2298 (45.6)	1382 (42.4)	451 (37.6)
≥Secondary school	4912 (34.7)	1144 (24.6)	1717 (34.1)	1402 (43.0)	649 (54.1)
Nonsmoking	10 984 (77.6)	2669 (57.3)	4249 (84.3)	2930 (89.9)	1136 (94.8)
Alcohol drinking, mean (*SD*), drinks/wk	0.8 (3.3)	1.0 (4.7)	0.5 (2.4)	0.8 (2.4)	1.2 (1.9)
Physical activity, mean (*SD*), h/wk	1.8 (4.5)	1.1 (4.1)	1.5 (4.3)	2.4 (4.7)	4.0 (5.1)
Sleep, 6–8 h/d, %	12 268 (86.6)	4016 (86.2)	4334 (86.0)	2853 (87.5)	1065 (88.8)
No chronic diseases	9247 (65.3)	2814 (60.4)	3322 (65.9)	2251 (69.1)	860 (71.7)
No impairment of cognitive function	12 108 (85.5)	3907 (83.8)	4313 (85.6)	2825 (86.7)	1063 (88.7)
No limitations in IADL	10 403 (73.5)	3202 (68.7)	3763 (74.7)	2498 (76.7)	940 (78.4)
Good mental health	10 451 (73.8)	3178 (68.2)	3730 (74.0)	2551 (78.3)	992 (82.7)
Good overall self-perceived health	7012 (49.5)	2116 (45.4)	2427 (48.2)	1760 (54.0)	709 (59.1)
Good physical functioning	12 454 (88.0)	3969 (85.2)	4447 (88.2)	2946 (90.4)	1092 (91.1)
No function-limiting pain	11 427 (80.7)	3762 (80.7)	4035 (80.0)	2638 (81.0)	992 (82.7)

Note: AHEI-2010 = Alternative Healthy Eating Index-2010; BMI = body mass index; IADL = instrumental activities of daily living.

Table 3. Associations of Individual and Combined Protective Lifestyle Factors With Healthy Ageing[a]

	Baseline (*N* = 14 159)		**Second Follow-up (11 796)**	
Variables	Cases/*N*	OR (95% CI)	Cases/*N*	OR (95% CI)
Individual healthy lifestyle factors[b]				
Optimal BMI	1448/6138	1.41 (1.30–1.54)	1313/4865	1.29 (1.18–1.40)
Never smoking	2295/10 984	1.27 (1.12–1.43)	2216/8910	1.27 (1.12–1.44)
Being physically active	790/3422	1.18 (1.07–1.31)	1746/6895	1.21 (1.10–1.33)
Low-to-moderate alcohol drinking	582/2498	1.13 (1.01–1.27)	479/1652	1.20 (1.06–1.36)
Highest 40% AHEI-2010 score	1277/5664	1.23 (1.12–1.34)	1262/4718	1.22 (1.12–1.33)
No. of protective lifestyle factors (scores)				
0–1	701/4660	1.00	501/2638	1.00
2	1000/5041	1.35 (1.21, 1.51)	930/4164	1.26 (1.11, 1.43)
3	786/3259	1.67 (1.48, 1.87)	931/3532	1.53 (1.34, 1.75)
≥4	347/1199	2.06 (1.77, 2.41)	472/1462	1.99 (1.70, 2.33)
Per 1-point increase		1.25 (1.20, 1.30)		1.24 (1.18, 1.29)
p for trend[c]		<.001		<.001
For having 4/5 protective lifestyle factors vs all others	347/1199 vs 2487/12 960 PAR[d], %	1.57 (1.37, 1.80) 34.3 (25.3, 42.3)	472/1462 vs 2362/10 334 PAR,[d] %	1.52 (1.34, 1.72) 31.3 (23.0, 38.7)

Notes: AHEI-2010 = Alternative Healthy Eating Index-2010; BMI = body mass index; CI = confidence interval; OR = odds ratio; PAR = population-attributable risk.

[a]The covariates in the models included sex, age at healthy ageing measurement, year of baseline interview (1993–1995 and 1996–1998), dialect group (Hokkiens, Cantonese), marital status (married, widowed, separated/divorced, never married), education level (no formal education, primary school, secondary school and above), total energy intake (kcal/d), and sleep duration (6–8 and <6 or >8 h/d). In the analysis of individual lifestyle factors, they were mutually adjusted in the model. [b]Optimal BMI was defined as 18.5–22.9 kg/m^2; being physically active was defined as moderate activity ≥2 h/wk, or strenuous activity for ≥0.5 h/wk; low-to-moderate alcohol drinking was defined as >0 to ≤14 drinks/wk for men and >0 to ≤7 drinks/wk for women. Dietary intake was only assessed at baseline, and dietary intake during the second follow-up visit was replaced by baseline diet information. [c]*p* values for trend were from a likelihood ratio test comparing the model with protective lifestyle factor index score as an ordered categorical variable to the model without it. [d]PAR% and 95% CIs were estimated based on the OR of the logistic regression model and the proportion of participants with non-adherence to 4/5 protective lifestyle category among Chinese adults from the Singapore Chinese Health study.

Table 4. Associations of Changes in Lifestyle Scores From Baseline to the Second Follow-up Visit With Likelihood of Healthy Ageing (*N* = 11 796)

Outcomes	Cases/*N*	OR (95% CI)[a]
Changes in lifestyle scores (range)		
Decreased (−5 to −1)	631/2561	0.85 (0.75, 0.96)
Unchanged	1046/4440	1.00
Increased (1–5)	1157/4795	1.22 (1.10, 1.35)
Per 1-point increase		1.18 (1.12, 1.24)
p for trend[b]		<.001
Changes in lifestyle scores (category)		
Maintain a score ≤2 from baseline to second follow-up	1153/5671	1.00
Change the score from ≤2 at baseline to >2 at second follow-up	555/2251	1.21 (1.07, 1.37)
Maintain a score >2 from baseline to second follow-up	848/2743	1.23 (1.02, 1.48)
Change the score from >2 at baseline to ≤2 at second follow-up	278/1131	0.93 (0.75, 1.14)

Notes: CI = confidence interval; OR = odds ratio.

[a]ORs adjusted for sex, age at healthy ageing measurement, year of baseline interview (1993–1995 and 1996–1998), dialect group (Hokkiens, Cantonese), marital status (married, widowed, separated/divorced, never married), education level (no formal education, primary school, secondary school and above), total energy intake (kcal/d), sleep duration (6–8 and <6 or >8 h/d), and baseline protective lifestyle score. [b]*p* values for trend were from a likelihood ratio test comparing the model with protective lifestyle factor index score as an ordered categorical variable to the model without it.

likelihood of healthy ageing. In addition, positive increase in score from baseline to the second follow-up visit was also significantly associated with a highly likelihood of healthy ageing.

It is worth mentioning that there are many definitions of healthy ageing. Atallah et al. (6) defined healthy ageing based on components of physical functioning, cognitive functioning, IADL limitations, depressive symptoms, overall self-perceived health, function-limiting pain, and absence of major chronic diseases, which was similar to the definition of healthy ageing in our study. Sowa et al. (7) used a definition based on 3 components: health status, functional capacity, and the perceived meaning of life. Sabia et al. (8) created a definition of cognitive, physical, respiratory, and cardiovascular functioning, the absence of disability and chronic disease, and good mental health. Daskalopoulou et al. (9) created a healthy ageing index of daily disabilities and difficulties, pain and sleep problems, and cognition abilities. In addition, the definition of protective lifestyle factor also varied in different studies. For example, Atallah et al. (6) generated a 5-component healthy lifestyle index and being

physically active was defined as >30 min/d brisk walking or equivalent. However, Daskalopoulou et al. (9) generated a 4-component healthy lifestyle index and physical activity was categorized as "very physically active," "fairly," "not very," and "not at all." Regardless of the definitions, all studies have consistently shown that high diet quality, being physically active, never smoking, and drinking alcohol at low-to-moderate level were factors positively associated with healthy ageing.

Overweight and obesity have now become an important global public health problem. The Global Burden of Disease (GBD) study has shown that high BMI is one of the largest contributors to disability-adjusted life-years (DALYs) (32). Our analyses indicated that participants with a BMI >23 kg/m^2 had lower likelihood of healthy ageing compared with those with BMIs between 18.5 and 22.9 kg/m^2, which are consistent with findings from previous studies (3,6). In addition, the mean baseline BMI was 23.1 kg/m^2 in our study, which is lower than the mean BMI in the British Whitehall II study (25.5 kg/m^2) (3). Other studies have also reported that nutrition and diet are the major determinants of healthy ageing (33). Higher AHEI-2010 scores have been consistently found to be associated with decreased risk of major chronic disease (34,35) and all-cause mortality (34), as well as with lower risk of depression (36), physical function impairment (37), and cognitive function impairment (15). Consistent with our findings, the Nurses' Health Study (NHS) also showed that greater adherence to the AHEI-2010 was related to higher odds of healthy ageing (2).

We observed that being physically active, never smoking, and low-to-moderate alcohol consumption were each associated with higher likelihood of healthy ageing. This is in line with results from published meta-analyses (4,5). Higher levels of physical activity have been shown to reduce the incidence of obesity and noncommunicable diseases (38), improve quality of life (39), and increase mean and maximum life span (40). In addition, previous studies have demonstrated that smoking is a strong independent risk factor of cardiovascular disease, diabetes mellitus, cancer, and many other diseases (41,42). Nevertheless, the associations between alcohol consumption and health outcomes remain equivocal. Although some evidence suggested that low-to-moderate alcohol consumption was associated with a reduced risk of incidence and mortality of cardiovascular disease (43), the GBD 2016 results showed that the level of alcohol consumption that minimized health loss was zero (29). However, in our sensitivity analyses that excluded alcohol consumption from the composition of lifestyle score or that changed the cut point for low-to-moderate alcohol drinking, the results were not materially changed. Hence, although the controversy about alcohol consumption on health outcomes persists (29,43), low-to-moderate alcohol drinking, defined as >0 to ≤14 drinks/wk for men and >0 to ≤7 drinks/wk for women, was found to have significant protective effect in our study. In addition, adding optimal sleep duration into the score increased the protective effects, which demonstrates that maintaining a healthy lifestyle including additional factors may carry further benefits for healthy ageing.

We observed the cumulative impact of protective lifestyle factors on healthy ageing—the greater the number of the protective lifestyle factors, the greater the benefit. This is in line with results from published studies (6,8). Atallah et al (6) found that participants with 4 and 5 healthy lifestyle index had 34% and 46% higher probability of healthy ageing compared with participants with 0 or 1 healthy lifestyle index, respectively. Sabia et al (8) found that participants engaging in 2, 3, and 4 healthy behaviors had 1.72, 2.19, and 3.25 times greater odds of successful ageing compared with participants who engaged in no healthy behaviors, respectively. In addition, we reported that the PAR% of adherence to 4–5 protective lifestyle factors was 34.3% for healthy ageing during the 20-year follow-up in our cohort. However, the corresponding PAR% of at least 3 healthy behaviors was 14.6% in a French population during a 13-year follow-up (6) and the PAR% of 1–4 healthy behaviors was 47% in a British population during a 16-year follow-up (8). The discrepancies among these studies may be due to heterogeneity in effect sizes and prevalence of defined protective lifestyle factors.

We further illustrated that improvements in lifestyle behaviors after midlife were also associated with a higher likelihood of healthy ageing. Our findings were in line with some other studies about changes in lifestyle factors and risks of diabetes, cardiovascular disease, and mortality (44–46). Data from the NHS and the Health Professionals Study showed that improvements in lifestyle behaviors from pre- to postdiabetes diagnosis were associated with a significantly lower risk of subsequent cardiovascular disease events (44). Data from the Västerbotten Intervention Programme showed that improvements of lifestyle behaviors between baseline and 10-year follow-up were associated with reduced diabetes risk (45). Data from the Atherosclerosis Risk in Communities Study showed that a midlife switched to healthy lifestyle was associated with reduced cardiovascular disease and mortality risk (46). Therefore, the current evidence emphasizes the importance of improvements in lifestyle behaviors to reduce disease and mortality risk and increase possibility of healthy ageing.

Our findings have strong practical implications for public health in Singapore and Asia. The rapidly ageing population is one of the most challenging public health and policy issues in Singapore and worldwide (10). Adherence to a healthier lifestyle may potentially increase the number of people with healthy ageing, which in turn reduces the burden of diseases and increases life expectancy. However, the proportion of people who manage to achieve healthy lifestyle seems to be low worldwide. Data from the NHS and the Health Professionals Study showed that only 10.3% of participants had 4–5 protective lifestyle factors (47). Data from the China Kadoorie Biobank cohort showed that only 14.7% of participants had 4–6 protective lifestyle factors (48). In our study, only 8.5% of the participants adhered to 4–5 protective lifestyle factors, whereas 32.9% adopted none or only one protective lifestyle factor at baseline. We observed an increased proportion of participants with 4–5 protective lifestyle factors at second follow-up interviews (12.4%). It is possible that a higher prevalence of those with more protective lifestyle factors at second follow-up interviews than at baseline could be explained by survival bias. In addition, the prevalence of the protective level of each factor differed, and the prevalence of those who were physically active or consumed low-to-moderate alcohol drinking was generally low in the whole population. We believe that the low prevalence of alcohol consumption among older Chinese in this population could be due to social and/or cultural reasons, and not directly related to health. Hence, to close the gap between current and ideal lifestyle patterns, public health educational efforts that focus on smoking cessation, promoting a physical activity-friendly environment, accessibility and affordability of healthy foods, and weight management will need to be strengthened.

The study has several strengths including prospective design, large sample size, long-term follow-up, and repeated assessments of lifestyle factors. Several limitations need to be acknowledged. First, there could be selection bias since participants in the third follow-up visit did not include those who died or those who were

alive but did not attend the third follow-up visit. As shown in our previous publication (15), those who participated in the third follow-up visit were younger and generally had healthier lifestyle and less comorbidities at baseline compared with those who did not participate in the third follow-up visit. Thus, the proportion of participants who met the criteria of healthy ageing was likely to be lower among those who did not participate in the third follow-up visit compared with those who attended the visit, and possible selection bias might have led to an underestimation of the associations observed in our study. We deemed that the "true" association between protective lifestyle factors and healthy ageing might be between our main analysis and the sensitivity analysis of assigning all participants with missing data at the third follow-up visit to the usual ageing group.

Second, most domains involved in the definition of healthy ageing were only assessed at the third follow-up visit. We excluded participants who had self-reported a diagnosis of cancer, cardiovascular disease, or diabetes at baseline for the association between baseline lifestyle factors and healthy ageing. When examining the association at the second follow-up visit as well as the changes of lifestyle scores from baseline to the second follow-up visit, we further excluded participants who had reported a diagnosis of Parkinson disease, cardiovascular disease, or diabetes at the second follow-up interview. However, we did not have information on other diseases, mental health status, cognition, and physical problems at baseline and the second follow-up visit. In addition, the duration between the second and third follow-up visits was short (mean 7.3 years), thus reverse causation is still possible.

Third, our main analysis included those who survived to at least 65 years for the definition of healthy ageing. However, the results were not materially different from the sensitivity analyses of including individuals who lived up to 70 or 75 years. In addition, since the mean age was 73.7 years at the third follow-up visit, we were unable to assess the health status when they were 65 years old during the follow-up. For example, it is possible that some people who were considered to have usual ageing at the third follow-up visit could have met the criteria of healthy ageing at 65 years old before the third follow-up visit. Thus, the proportion of healthy ageing observed in our study might be underestimated. Fourth, as economic status was not measured in the cohort, its potential impact on our results could not be investigated. Fifth, dietary intake was not updated during follow-up, which might confound the results. Nevertheless, other prospective cohorts, namely, the NHS, NHS II, and the Health Professionals Follow-up Study, which had their participants undergo repeated assessment of the diet every 4 years, had shown that diet after midlife was generally stable as only 19.5% of these participants experienced moderate-to-large changes in diet quality scores after more than 20 years (49). In addition, we used a simple dichotomization algorithm for each factor to compute the lifestyle score as a composite, which might introduce misclassification since different lifestyle factors may carry differential weights for their individual effects on healthy ageing. However, our tentative approach of assigning polytomous, instead of dichotomous, weights to each lifestyle factor did not identify substantial changes in the likelihood of healthy ageing. Sixth, our estimates may not be readily generalizable to other populations, or Chinese people living in other parts of the world because of the differences in distributions of these selected lifestyle factors, and population structure and characteristics. However, the overall conclusion that healthy lifestyles promote healthy ageing should be generalizable to other populations.

Conclusions

Our findings confirm that adherence to a healthy lifestyle is associated with a substantially higher likelihood of healthy ageing among Chinese adults. In addition, positive improvement in adopting protective lifestyle factors, even after midlife, is associated with a higher likelihood of healthy ageing. These findings further highlight the importance of coordinated actions targeting multiple modifiable lifestyle factors in order to achieve healthy ageing in the older population.

Supplementary Material

Supplementary data are available at *The Journals of Gerontology, Series A: Biological Sciences and Medical Sciences* online.

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Conflict of Interest

None declared.

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