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Impact of combined lifestyle factors on all-cause and cause-specific mortality and life expectancy in Chinese: the Singapore Chinese Health Study

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Abstract

Background: To examine the impact of combined lifestyle factors on premature mortality and life expectancy in Chinese adults.

Methods: A total of 44,052 Chinese adults aged 45 to 74 years free of cardiovascular disease (CVD), cancer, and diabetes were followed from recruitment (1993-1998) to the end of 2016 in the Singapore Chinese Health Study. A composite score (0-5 scale) was calculated based on five baseline healthy lifestyle factors including healthy diet, non-smoking status, light to moderate alcohol drinking, being physically active and optimal body mass index. Mortality cases were identified through linkage with the nationwide death registry.

Results: Adopting five healthy versus none was associated with a lower risk of all-cause and cause-specific mortality, and the hazard ratio (95% confidence interval) was 0.38 (0.29, 0.51) for all-cause mortality, 0.26 (0.13, 0.52) for CVD mortality, and 0.59 (0.37, 0.92) for cancer mortality. Non-adherence to 4-5 healthy lifestyle factors accounted for 34.9% (95% confidence interval: 29.2, 40.2) in population attributable fraction for all-cause mortality, 35.1% (23.7, 44.9) for CVD mortality, and 18.0% (6.5, 28.0) for cancer mortality. Conversely, adherence to 4-5 healthy lifestyle factors versus none could achieve a gain of 8.1 years in women and 6.6 years in men for the life expectancy at 50 years.

Conclusions: A healthier lifestyle is associated with a substantially reduced risk of mortality and a longer life expectancy in the Chinese population. Our findings highlight the necessity of coordinated actions targeting combined lifestyle factors in reducing the overall burden of diseases and premature deaths.

Key words: Cardiovascular disease; Cancer; Lifestyle; Mortality; Life expectancy

Introduction

Key modifiable lifestyle factors, including smoking, unhealthy diet, lack of physical activity, and excessive use of alcohol, are leading causes of global burden of disease and premature mortality (1). Since these factors often exert synergic and complementary effects in the development of non-communicable diseases (NCDs) (2), it is meaningful to evaluate the joint contribution of comprehensive lifestyle factors to the Sustainable Development Goal target 3.4 of reducing one third premature mortality from NCDs by 2030.

A meta-analysis of 15 cohort studies published in 2012 showed that a combination of at least four of five major healthy lifestyle factors (i.e., not smoking, normal weight, healthy diet, appropriate physical exercise, and moderate alcohol drinking) was associated with a 66% reduction of the all-cause mortality risk compared to zero healthy lifestyle factor (3). The population attributable fraction (PAF) of mortality associated with major adverse modifiable lifestyle factors was estimated to be 42%-60% in Western populations (4-7). Furthermore, previous studies showed that combined healthy lifestyles were likely to confer life expectancy gains ranging from 7.4 to 17.9 years in Western populations (2, 8-12). To date, there has been limited evidence on the impact of combined lifestyle factors on premature mortality in Asians, particularly the Chinese population. The PAF of mortality was estimated to be 33% in a Chinese study (13), which was much lower than reported in Western countries, and more importantly, the population life expectancy gains for a combined favorable lifestyle have not been estimated in Chinese yet.

In the Singapore Chinese Health Study (SCHS) among middle-aged and elderly Chinese, we aimed to 1) examine the association between combined healthy lifestyle factors and risk of all-cause and cause-specific mortality; 2) estimate the PAFs of all-cause and cause-specific premature mortality associated with non-adherence to healthy lifestyles; and 3) evaluate the potential impact of combined lifestyle factors on the life expectancy.

Methods

Study population

The study design of the SCHS has been previously described (14). In brief, the study aimed to examine the role of diet, lifestyle and environment on the development of common diseases such as cancer and cardiovascular disease (CVD) in a large prospective cohort of Singaporean Chinese. It recruited women and men aged 45 to 74 years from two major dialect groups (Hokkien or Cantonese) of Chinese residing in government-built housing estates, where 86% of Singaporeans lived at the period of recruitment. A total of 63,257 individuals (44.2% men and 55.8% women; about 85% of eligible participants who were invited) were enrolled between April 1993 and December 1998. Trained staff interviewed participants at their homes at recruitment using a structured questionnaire to collect information on demographic characteristics, lifestyle factors (usual diet, lifetime use of tobacco, and current physical activity), as well as medical history and menstrual/reproductive history (women only). The SCHS was approved by the Institutional Review Board at the National University of Singapore. Written informed consent was obtained from all study participants.

Construction of a healthy lifestyle score

All lifestyle factors of research interest were assessed in the baseline survey. Details of five modifiable lifestyle factors are provided in the Supplemental Methods. We constructed a healthy lifestyle score using cigarette smoking, alcohol drinking, physical activity, diet and BMI. Participants scored one point for each of the following factors: Alternative Healthy Eating Index -2010 (AHEI-2010) score in the top 40%, lifetime non-smoking status, light to moderate drinking, physically active, and optimal BMI (Table 1). The healthy category of each lifestyle factor was determined based on our earlier analyses for associations between each factor and mortality and/or morbidity in this cohort (15-20). Since few participants scored 5 (0.6%), the overall healthy lifestyle score was re-categorized into five groups for

assessing associated PAFs and the impact on life expectancy: 0, 1, 2, 3 and 4-5, with a higher score representing a healthier lifestyle.

Death ascertainment

Information on date and primary cause of death was obtained through linkage with the nation-wide Singapore Birth and Death Registry through December 31, 2016. Causes of deaths were coded using the International Statistical Classification of Diseases and Related Health Problems 9th Revision (ICD-9, up to 31 December 2011) or 10th Revision (ICD-10 for years 2012-2016). Primary endpoints for current analyses included all-cause and cause-specific mortality from CVD (ICD-9 codes 390-459; ICD-10 codes I00-I99) and all cancers (ICD-9 codes 140–208; ICD-10 codes C00-C97).

Statistical analysis

We excluded 1,936 participants with a history of invasive cancer (except non-melanoma skin cancer), 2,505 with coronary heart disease (CHD), 772 with stroke, and 4,591 with diabetes at baseline. We also excluded 8,732 participants whose weight or height data were missing, 665 participants with extreme energy intakes (<600 or >3,000 kcal for women; <700 or >3,700 kcal for men), and 4 female participants without information of menopausal status at recruitment. A total of 44,052 participants (19,863 men, 45.1%) were included for main analyses. Person-years were counted from the date of baseline interview to the date of death, loss to follow-up, or December 31, 2016, whichever came first.

Cox proportional hazards regression models were applied to examine associations between individual lifestyle factors and risk of all-cause and cause-specific mortality, and to generate corresponding hazard ratios (HRs) and 95% confidence intervals (95% CIs). The proportional hazards assumption was tested by dividing the follow-up period into 3 intervals that held similar numbers of deaths and comparing effect sizes of lifestyle factors for risk of deaths; there was no evidence of departure from the assumption. We adjusted for sex, age (<50, 50–

54, 55–59, 60–64, 65-69, and >70), year of interview (1993-1995 and 1996-1998), dialect (Hokkien and Cantonese), level of education (no formal schooling, primary school, secondary school and above), marital status (married, separated/divorced, widowed, and never married), total energy intake (kcal/d), sleep duration (≤5, 6, 7, 8, and ≥9 hours/day), and menopausal status (women only). Family history of cancer was also adjusted for in analyses for cancer mortality. Similar approaches were adopted to estimate HRs and 95% CIs associated with the composite healthy lifestyle scores. We also estimated effect sizes in two separate scenarios: 1) including participants with baseline diabetes, CHD and stroke while excluding participants who died in the first two years of follow-up; and 2) excluding participants with baseline diabetes, CHD and stroke while including participants with missing values for BMI, total energy intake, and menopausal status (with multiple imputations). We additionally adjusted for prevalence of hypertension in a sensitivity analysis. To evaluate whether our findings differed by sex, we added in the model a product term between sex and the composite healthy lifestyle scores and assessed statistical significance using the likelihood ratio test. Assuming the observed associations between composite lifestyle scores and mortality were causal and our cohort was representative of Chinese in Singapore, we estimated the PAFs of all-cause and cause-specific mortality associated with healthy lifestyle factors. PAFs and corresponding 95% CIs were computed by combining the HR of each healthy lifestyle score category and the corresponding prevalence of each lifestyle score in the population using the PUNAFCC Stata module (21).

The life expectancy of participants following different levels of healthy lifestyles (represented by healthy lifestyle scores) was calculated using life tables starting at age 50 years and ending at age 105 years based on estimated HRs and prevalence of health lifestyle scores supplemented by population mortality rates from the Singapore Department of Statistics (22). The procedure was detailed in our previous analyses in the US population (Supplemental

Methods) (12). We also conducted six separate sensitivity analyses to test the robustness of our findings regarding life expectancy in different scenarios (Supplemental Methods).

We used Stata 14 (StataCorp LLC, College Station, TX) for statistical analyses. All *P* values were two-sided. Life expectancies were projected through life tables in Microsoft Office Excel 2016, and the 95% CIs were estimated by Monte Carlo simulation (parametric bootstrapping) with 10,000 runs with @RISK 7.5 (Palisade Corp, Ithaca, NY) (12).

Results

Population characteristics

Of 44,052 participants, 19,863 (45.1%) were men and mean (standard deviation) age was 55.3 (7.7) years old (Table 2). At baseline, compared to their counterparts, participants with a higher composite healthy lifestyle score were more likely to be better educated and physically active, and to have low BMI, high AHEI-2010 scores, and optimal sleep duration, but less likely to be former or current smokers.

Associations between healthy lifestyle scores and all-cause mortality and mortality from CVD and cancer

During a median follow-up of 20.6 years, we documented 11,628 deaths in this cohort, of which 3,408 were due to CVD and 4,352 due to cancer (Supplemental Table 1). All five lifestyle factors were individually associated with risk of all-cause mortality, CVD and cancer mortality. The healthy categories of the five lifestyle factors generally showed protective associations with all-cause mortality and mortality from CVD, while such protective associations were not evident with cancer mortality related to optimal BMI (HR, 1.00; 95% CI: 0.93, 1.06) and low-to-moderate alcohol drinking (HR, 1.04; 0.96, 1.13) (Table 3). There were decreasing trends in the all-cause mortality and mortality from CVD and cancer as the number of healthy lifestyle factors increased (*P* for trend <0.001 for all). A healthy lifestyle score of 5 was associated with an HR of 0.38 (95% CI: 0.29, 0.51) for all-cause mortality, 0.26 (95% CI: 0.13, 0.52) for CVD mortality, and 0.59 (95% CI: 0.37, 0.92) for cancer mortality compared with a score of zero (Table 3). Similar findings were noted when we included participants with baseline diabetes and CVD but excluded those who died in the first two years of follow up (Supplemental Table 2), or when we excluded participants with baseline diabetes and CVD but imputed missing values for participants with missing values for major covariates (Supplemental Table 3). There was statistical evidence of heterogeneity

regarding associations between healthy lifestyle scores and all-cause mortality (*P* for interaction =0.014) among women versus men; however, no heterogeneity was observed for CVD (*P* for interaction =0.77) and cancer mortality (*P* for interaction =0.09; Supplemental Table 4). When participants with baseline diabetes and CVD were not excluded, the protective effect of healthy lifestyle factors on all-cause mortality was significant among participants without baseline diabetes, but was insignificant among their counterparts; similar findings were noted for participants without baseline stroke versus their counterparts (*P* for interaction =0.04 for both; Supplemental Figure 1).

Population-level contributions of unhealthy lifestyles to all-cause mortality and mortality from CVD and cancer

Overall, non-adherence to 4-5 healthy lifestyle factors accounted for 34.9% (95% CI: 29.2, 40.2) in PAF for all-cause mortality, 35.1% (23.7, 44.9) for CVD mortality, and 18.0% (6.5, 28.0) for cancer mortality (Table 3). The PAFs for all-cause mortality (36.7% versus 30.7%) and mortality from CVD (35.2% versus 34.2%) and cancer (22.4% versus 9.2%) were higher in men than women (Supplemental Table 4). When we additionally adjusted for prevalent hypertension, risk estimates for healthy lifestyle scores and associated PAFs did not change materially for either total or cause-specific mortality (Supplemental Table 5). When alcohol drinking was excluded from the healthy lifestyle score, the PAFs were 34.2% (95% CI: 25.9, 41.5), 39.0% (22.4, 52.1), and 22.3% (5.4, 36.1) for total, CVD and cancer mortality, respectively (Supplemental Table 6). When sleep duration was incorporated in the healthy lifestyle score, the PAFs were 37.4% (31.4, 42.9), 37.6% (25.4, 47.9), and 21.3% (9.2, 31.7) for total, CVD and cancer mortality, respectively (Supplemental Table 7).

Healthy lifestyle scores and life expectancy

We noted increased trends in HRs associated with healthy lifestyle scores across age groups (Figure 1A). Using sex- and age-specific HRs, we estimated that the life expectancy at age 50

was 32.0 years (95% CI: 30.1, 33.8) for women and 30.1 years (28.5, 31.5) for men if they adopted none of the five healthy lifestyle factors (Figure 1B). However, the life expectancy at age 50 could reach 40.1 years (37.4, 42.8) and 36.7 years (34.5, 38.9), respectively in women and men who had a healthy lifestyle score of 4-5. Thus, women with 4-5 healthy lifestyle factors could gain an average of 8.1 years (5.8, 10.5) for the life expectancy at age 50 compared with those without any healthy lifestyle factors, while the difference of life expectancy among men could be up to 6.6 years (4.9, 8.4; Figure 1C). In addition, adopting 2 healthy lifestyle factors could lead to a life expectancy gain of 5.7 years in women and 3.2 years in men. Life expectancy gains were consistent in sensitivity analyses using sex-specific HRs adjusted for age and other covariates (9.0 years for women and 7.6 years for men; Supplemental Figure 2), or using sex- and age-specific HRs estimated in strata defined by different combinations of each sex and 5-year intervals (8.2 years for women and 6.3 years for men; Supplemental Figure 3), or when the protective level of BMI was assumed to be 18.5-22.9 kg/m^2 for both women and men (7.1 years for women and 5.7 years for men; Supplemental Figure 4), or when BMI and smoking were weighted more than other factors in the composite healthy score (8.1 years for women and 7.6 years for men; Supplemental Figure 5). In the sensitivity analysis using a healthy score that excluded light to moderate alcohol drinking, 6.8 years (5.7, 7.9) for women and 6.0 years (5.5, 6.5) for men could be gained by adopting 4 healthy lifestyle factors (Supplemental Figure 6). When sleep duration (6-8 hours/day as protective versus other durations) was incorporated into the composite score, an increment of 10.2 years (6.5, 13.8) for women and 9.4 years (6.7, 12.2) for men could be achieved for adopting 5-6 healthy lifestyle factors (Supplemental Figure 7).

Discussion

Although the importance of combined lifestyle factors on prevention of mortality is widely recognized (3), studies on this topic are still lacking in Asian populations. We found that healthier lifestyles as defined by adopting more healthy lifestyle factors could lead to substantially reduced risk of all-cause and cause-specific mortality and increased life expectancy in Chinese. Our findings consolidate the evidence that supports systematically addressing major conventional lifestyle risk factors as actionable targets in the context of alarming burden of NCDs in the general population (1, 23).

In our study, participants who adopted 5 healthy lifestyle factors had 62%, 74%, and 41% reductions in risk of all-cause mortality and mortality from CVD and cancer, compared with those with none of the healthy factors. Three recent studies have examined the joint impact of lifestyle factors on mortality among Chinese (13, 15, 24). Although lifestyle factors of interest were selected and defined slightly differently in these studies, they consistently corroborated our finding that a healthy lifestyle substantially reduced risks of all-cause and cause-specific mortality. We further quantified the PAFs of all cause-mortality and mortality from CVD and cancer for a composite lifestyle pattern. We found that about 1/3 total deaths and CVD deaths and about 1/6 cancer deaths can be averted if 4-5 healthy lifestyle factors could be adopted by all. The PAF estimates in women and men were lower than those reported for total (33.4% versus 41.0%), CVD (40.0% versus 58.7%), and cancer mortality (18.9% versus 38.0%) in Shanghai (13, 24). In addition, all these estimates for all-cause and cause-specific mortality for women and men combined were lower than our recent projections (60.7% for all-cause mortality, 71.7% for CVD mortality, and 51.7% for cancer mortality) in the US population (12). Such discrepancies may be because the risk estimate (e.g. HR of 0.39 in the US population versus 0.66 in the SCHS for all-cause mortality) and prevalence of those in the highest category of healthy lifestyle score (~2.0% versus 6.0%) differed largely in our two

studies. The Singapore Chinese generally had a lower BMI and lower prevalence of smoking compared to Western population. Despite a smaller effect of the protective association with a higher healthy lifestyle score, our findings still demonstrate that large reductions in mortality are possible if public health interventions can comprehensively improve the uptake of healthy lifestyle factors at the population level.

To our knowledge, our study is the first one in Chinese populations and one of the only two in Asians to examine the combined impact of lifestyle factors on life expectancy. We estimated that the adherence to 4-5 healthy lifestyle factors could prolong life expectancy at 50 years by 8.1 (from 32.0 to 40.1) years in women and 6.6 years (from 30.1 to 36.7) in men. Our estimates of life expectancy gains for a healthy lifestyle pattern were slightly lower than reported among other populations. A healthy lifestyle was associated with estimated life expectancy increase by 10.3 years (men) and 8.3 years (women) in Japan (2), 12.2 years (men) and 14.0 years (women) in the US (12), 17.0 years (men) and 13.9 years (women) in Germany (11), and 17.9 years in Canada (9). Similar to speculations for PAFs, causes of such variability might include different definitions and components of a healthy lifestyle pattern, and its different distributions in various populations (12). For example, we used age-specific BMI and sex-specific alcohol drinking indicators to calculate the composite lifestyle score, which were based on our previous findings in the same cohort (15, 17, 19). In addition, we have excluded those with CVD, cancer and diabetes at baseline in the main analyses. In our sensitivity analyses, we found that excluding alcohol drinking from the score reduced life expectancy gains among both women and men, while adding sleep duration increased the gains, which demonstrates that maintaining a healthy lifestyle including additional factors carry more benefits for life expectancy and mortality reduction.

Our findings have strong practical implications for population health in Singapore. The life expectancies at 50 years of age were 36.1 years in women and 32.0 years in men in Singapore

in 2016 according to estimates from the Singapore Department of Statistics (25), which were about four years lower than those achievable through adopting the most favorable lifestyle as projected in our study. Although the life expectancy at 50 years has been extended by about 4 years in Singapore from 2003 to 2016 owing to economic development and medical advances (25), adherence to a healthier lifestyle may potentially accelerate the progress in the future. Of note, our estimates suggested that even adopting two of the five healthy lifestyle factors could achieve half of the overall achievable life expectancy gains. In our study, only 6.0% of the participants adhered to the healthy lifestyle (4-5 healthy factors), while 39.3% adopted 0-1 healthy lifestyle factor, which is suggestive of a large gap between current and ideal population lifestyle.

This study has major strengths including a prospective nature, large sample size, almost complete follow-up, and stringent mortality ascertainment. However, there are certain limitations to be acknowledged. First, the lifestyle data were self-reported and may potentially suffer from misclassification and residual confounding (15), leading to imprecise estimates. Given the consistency of our results for each individual lifestyle factor with those from other major studies, we believe that our findings are valid and reliable. Second, we used a simple dichotomization algorithm to combine the lifestyle factors into a composite, which might be problematic since different lifestyle factors may carry differential weights for such combination. However, our tentative approach to assign more weights to BMI and smoking did not identify substantial changes in the life expectancy gains. Third, all analyzed lifestyle factors were reported at baseline and not updated due to unavailability of repeated measures, so they may not capture long-term exposures. Fourth, we used the prevalence of different levels of risk factors from the SCHS to calculate life expectancy. Such proxies might not reflect the distribution of lifestyle characteristics in the whole Chinese population in Singapore. Fifth, our estimates may not be readily generalizable to other populations, or

Chinese populations living in other areas because of different distributions of lifestyle factors and population structure and characteristics.

In conclusion, we estimated that adhering to a healthier lifestyle could potentially reduce about one third of total and CVD deaths and about one sixth of cancer deaths and achieve a gain of 8.1 years in women and 6.6 years in men for the life expectancy at 50 years. Our findings highlight the necessity of multi-sectorial coordinated actions targeting multiple modifiable lifestyle factors in order to reduce the overall burden of diseases and premature deaths.

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Conflict of Interests

Dr. Yanping Li reported receiving research support from the California Walnut Commission. Dr. An Pan reported receiving research support from By-Health Inc. outside of the submitted work. All other authors declare that there is no conflict of interests.

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Tables

Table 1. Definition of healthy lifestyle factors

Table 2. Baseline characteristics of study participants according to the healthy lifestyle score

Table 3. Associations of healthy lifestyle factors with all-cause and cause-specific mortality

Table 1. Definition of healthy lifestyle factors

	Healthy group	Others
BMI		
Age<65 years	18.5-21.4 kg/m^2	<18.5 and ≥21.5 kg/m^2
Age≥65 years	18.5-24.4 kg/m^2	<18.5 and ≥24.5 kg/m^2
Cigarette smoking	Never smoking	Ever smoking
Alcohol drinking		
Men	>0 to ≤14 drinks/week	None or >14 drinks/week
Women	>0 to ≤7 drinks/week	None or >7 drinks/week
Physical activity	Moderate activity ≥2 hours/week, or strenuous activity for ≥0.5 hours/week	Moderate activity <2 hour/week, and strenuous activity for <0.5 hour/week
Diet quality	Highest 40% AHEI-2010 score	Lower 60% AHEI-2010 score

Abbreviations: AHEI-2010, Alternative Healthy Eating Index -2010; BMI, body mass index.

Table 2. Baseline characteristics of study participants according to the healthy lifestyle score

	Total	Healthy lifestyle score					
		0	1	2	3	4	5
No. of participants [a], %	44,052	3,525 (8.0)	13,767 (31.3)	15,553 (35.3)	8,567 (19.5)	2,371 (5.4)	269 (0.6)
Men, %	19,863 (45.1)	2,921 (82.9)	6,120 (44.5)	5,913 (38.0)	3,576 (41.7)	1,177 (49.6)	156 (58.0)
Age, mean (SD), years	55.3 (7.7)	56.1 (7.2)	55.3 (7.6)	55.2 (7.8)	55.3 (8.0)	55.5 (8.2)	54.8 (8.2)
Dialect group, %							
Cantonese	20,951 (47.6)	1,343 (38.1)	6,098 (44.3)	7,539 (48.5)	4,496 (52.5)	1,315 (55.5)	160 (59.5)
Hokkien	23,101 (52.4)	2,182 (61.9)	7,669 (55.7)	8,014 (51.5)	4,071 (47.5)	1,056 (44.5)	109 (40.5)
Education [a], %							
No formal education	10,113 (23.0)	748 (21.2)	3,751 (27.3)	3,714 (23.9)	1,585 (18.5)	295 (12.4)	20 (7.4)
Primary school	19,545 (44.4)	1,973 (56.0)	6,395 (46.5)	6,774 (43.6)	3,425 (40.0)	877 (37.0)	101 (37.6)
≥Secondary school	14,394 (32.7)	804 (22.8)	3,621 (26.3)	5,065 (32.6)	3,557 (41.5)	1,199 (50.6)	148 (55.01)
BMI, mean (SD), kg/m^2	23.0 (3.5)	23.5 (4.1)	23.7 (3.7)	22.9 (3.4)	22.2 (3.0)	21.6 (2.4)	20.6 (1.2)
Smoking status, %							

Never smoking	31,114 (70.6)	0	8,829 (64.1)	12,421 (79.9)	7,411 (86.5)	2,184 (92.1)	269 (100)
Former smoking	4,442 (10.1)	1,062 (30.1)	1,679 (12.2)	1,126 (7.2)	486 (5.7)	89 (3.8)	0
Current smoking	8,496 (19.3)	2,463 (69.9)	3,259 (23.7)	2,006 (12.9)	670 (7.8)	98 (4.1)	0
Alcohol drinking, mean (SD), drinks/week	1.0 (4.0)	2.4 (7.8)	0.9 (4.6)	0.7 (2.9)	0.9 (2.3)	1.5 (2.4)	2.0 (2.2)
Physically active [b], %	10,417 (23.6)	0	833 (6.1)	3,246 (20.9)	4,159 (48.6)	1,910 (80.6)	269 (100)
AHEI-2010, mean (SD)	50.1 (7.4)	43.9 (5.2)	46.2 (5.6)	51.0 (6.9)	54.9 (6.4)	57.5 (5.6)	59.1 (5.6)
Sleep, 6-8 hours/day, %	37,461 (85.0)	2,940 (83.4)	11,616 (84.4)	13,232 (85.1)	7,369 (86.0)	2,055 (86.7)	249 (92.6)
Menopause [c], %	16,221 (67.1)	523 (86.6)	5,150 (67.4)	6,418 (66.6)	3,289 (65.9)	779 (65.2)	62 (54.9)

Abbreviations: AHEI-2010, Alternative Healthy Eating Index -2010; BMI, body mass index; SD, standard deviation.

[a] Percentages may not add up to 100% due to rounding.

[b] Physically active was defined as moderate activity ≥2 hours/week, or strenuous activity for ≥0.5 hours/week.

[c] Only for women.

Table 3. Associations of healthy lifestyle factors with all-cause and cause-specific mortality

	Person years	All deaths		CVD deaths		Cancer deaths	
		Cases	HR (95% CI) [a]	Cases	HR (95% CI) [a]	Cases	HR (95% CI) [a]
Individual healthy lifestyle factors (%)							
Optimal BMI [b]	266,984	4,538	0.90 (0.87, 0.94)	1,271	0.80 (0.75, 0.87)	1,640	1.00 (0.93, 1.06)
Never smoking	613,728	6,143	0.61 (0.58, 0.63)	1,864	0.80 (0.74, 0.87)	2,216	0.55 (0.52, 0.60)
Light to moderate alcohol drinking [c]	148,453	1,988	0.90 (0.86, 0.95)	549	0.89 (0.80, 0.97)	845	1.04 (0.96, 1.13)
Physically active [d]	200,425	2,573	0.87 (0.83, 0.91)	762	0.89 (0.82, 0.96)	953	0.89 (0.83, 0.96)
Highest 40% AHEI-2010 score	342,788	4,063	0.87 (0.84, 0.91)	1,114	0.81 (0.75, 0.87)	1,634	0.99 (0.93, 1.06)
Healthy lifestyle score [e]							
0	61,722	1,497	Reference	458	Reference	549	Reference
1	257,908	3,942	0.78 (0.73, 0.82)	1,158	0.78 (0.69, 0.87)	1,489	0.85 (0.77, 0.94)
2	300,049	3,775	0.64 (0.60, 0.68)	1,123	0.68 (0.61, 0.76)	1,381	0.72 (0.65, 0.80)
3	167,394	1,890	0.54 (0.51, 0.58)	528	0.55 (0.49, 0.63)	715	0.67 (0.60, 0.75)
4	46,387	477	0.45 (0.41, 0.50)	133	0.48 (0.39, 0.58)	198	0.64 (0.54, 0.76)
5	5,329	47	0.38 (0.29, 0.51)	8	0.26 (0.13, 0.52)	20	0.59 (0.37, 0.92)

Per 1 point increase			0.82 (0.81, 0.84)		0.83 (0.80, 0.86)		0.88 (0.86, 0.91)
P for trend [f]			<0.001		<0.001		<0.001
For having 4/5 healthy lifestyle factors	HR	524	0.66 (0.60, 0.72)	141	0.65 (0.55, 0.77)	218	0.82 (0.72, 0.95)
vs all others	PAF [g], %		34.9 (29.2, 40.2)		35.1 (23.7, 44.9)		18.0 (6.5, 28.0)

Abbreviations: AHEI-2010, Alternative Healthy Eating Index -2010; BMI, body mass index; CI, confidence interval; CVD, cardiovascular disease; HR, hazard ratio; PAF, population attributable fraction.

[a] HRs adjusted for sex, age (<50, 50–54, 55–59, 60–64, 65-69, and >70 years), year of interview (1993-1995 and 1996-1998), dialect (Hokkien and Cantonese), level of education (no formal schooling, primary school, secondary school and above), marital status (married, separated/divorced, widowed, and never married), total energy intake (kcal/d), sleep duration (≤5, 6, 7, 8, and ≥9 hours/day), menopausal status (women only), and lifestyle factors in the table. Family history of cancer was also adjusted for in analyses for cancer deaths.

[b] Optimal BMI was defined as 18.5-21.4 kg/m^2 for participants aged<65 years or 18.5-24.4 kg/m^2 for participants aged≥65 years.

[c] Light to moderate alcohol drinking was defined as >0 to ≤14 drinks/week for men, and >0 to ≤7 drinks/week for women.

[d] Physically active was defined as moderate activity ≥2 hours/week, or strenuous activity for ≥0.5 hours/week.

[e] HRs adjusted for sex, age (<50, 50–54, 55–59, 60–64, 65-69, and >70), year of interview (1993-1995 and 1996-1998), dialect (Hokkien and Cantonese), level of education (no formal schooling, primary school, secondary school and above), marital status (married, separated/divorced,

widowed, and never married), total energy intake (kcal/d), sleep duration (≤5, 6, 7, 8, and ≥9 hours/day), and menopausal status (women only). Family history of cancer was also adjusted for in analyses for cancer deaths.

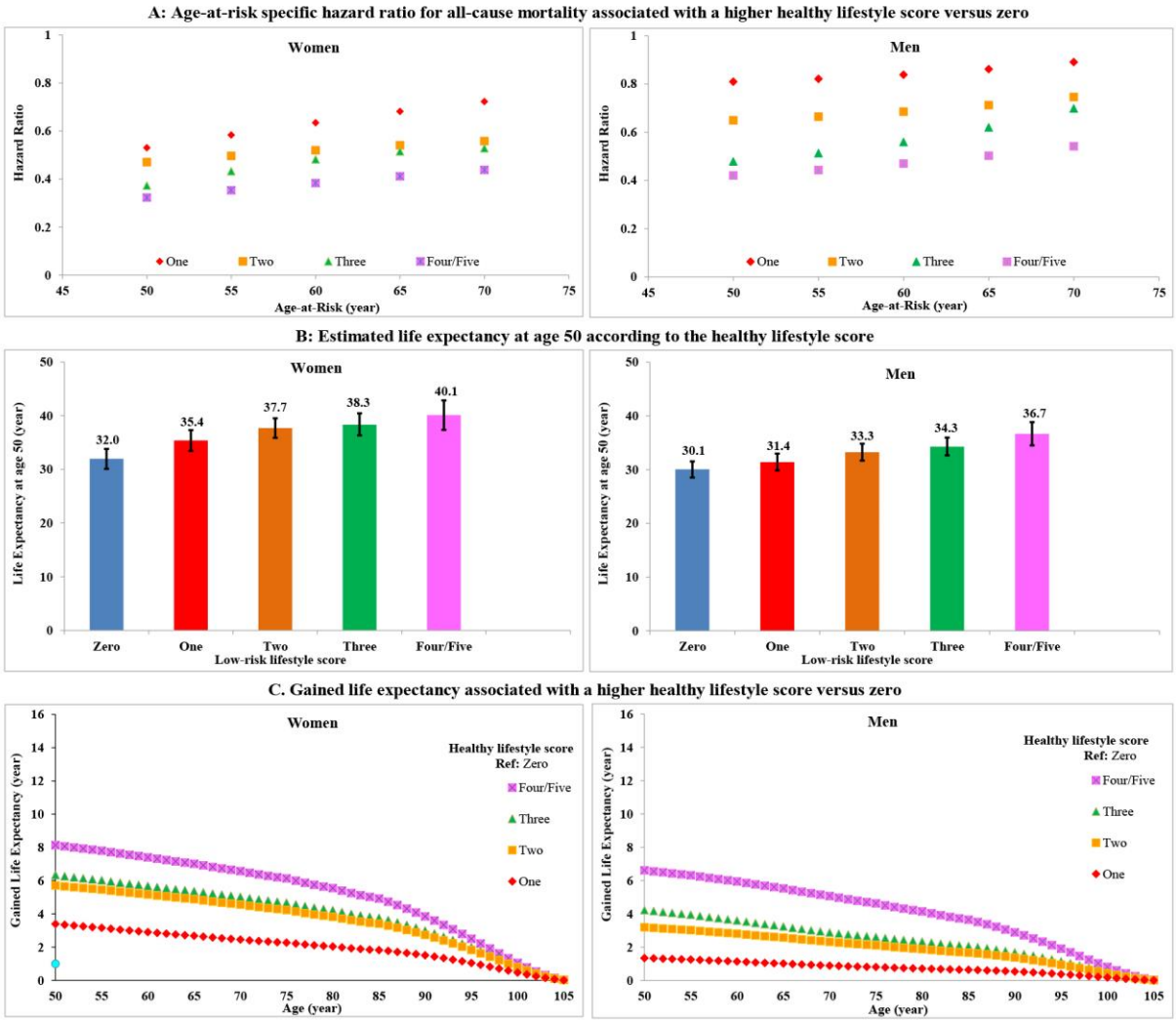
[f] *P* values for trend were from a likelihood ratio test comparing the model with healthy lifestyle score as an ordered categorical variable to the model without it.

[g] PAFs were estimated for nonadherence to 4/5 healthy factors using the distribution of different healthy score categories among Chinese adults from the Singapore Chinese Health Study.

Figure legends

Figure 1. Impact of five healthy lifestyle factors on life expectancy. Estimated from the overall mortality rate in Singapore, the prevalence of lifestyle factors, and sex- and age-specific HRs

Figure 1


A: Age-at-risk specific hazard ratio for all-cause mortality associated with a higher healthy lifestyle score versus zero
Women
Men
Hazard Ratio
Age-at-Risk (year)
One
Two
Three
Four/Five
B: Estimated life expectancy at age 50 according to the healthy lifestyle score
Life Expectancy at age 50 (year)
32.0
35.4
37.7
38.3
40.1
30.1
31.4
33.3
34.3
36.7
Zero
One
Two
Three
Four/Five
Low-risk lifestyle score
C. Gained life expectancy associated with a higher healthy lifestyle score versus zero
Gained Life Expectancy (year)
Healthy lifestyle score
Ref: Zero
Age (year)