Circulation

ORIGINAL RESEARCH ARTICLE

Impact of Healthy Lifestyle Factors on Life Expectancies in the US Population

BACKGROUND: Americans have a shorter life expectancy compared with residents of almost all other high-income countries. We aim to estimate the impact of lifestyle factors on premature mortality and life expectancy in the US population.

METHODS: Using data from the Nurses' Health Study (1980–2014; n=78 865) and the Health Professionals Follow-up Study (1986–2014, n=44 354), we defined 5 low-risk lifestyle factors as never smoking, body mass index of 18.5 to 24.9 kg/m^2, ≥30 min/d of moderate to vigorous physical activity, moderate alcohol intake, and a high diet quality score (upper 40%), and estimated hazard ratios for the association of total lifestyle score (0–5 scale) with mortality. We used data from the NHANES (National Health and Nutrition Examination Surveys; 2013–2014) to estimate the distribution of the lifestyle score and the US Centers for Disease Control and Prevention WONDER database to derive the age-specific death rates of Americans. We applied the life table method to estimate life expectancy by levels of the lifestyle score.

RESULTS: During up to 34 years of follow-up, we documented 42 167 deaths. The multivariable-adjusted hazard ratios for mortality in adults with 5 compared with zero low-risk factors were 0.26 (95% confidence interval [CI], 0.22–0.31) for all-cause mortality, 0.35 (95% CI, 0.27–0.45) for cancer mortality, and 0.18 (95% CI, 0.12–0.26) for cardiovascular disease mortality. The population-attributable risk of nonadherence to 5 low-risk factors was 60.7% (95% CI, 53.6–66.7) for all-cause mortality, 51.7% (95% CI, 37.1–62.9) for cancer mortality, and 71.7% (95% CI, 58.1–81.0) for cardiovascular disease mortality. We estimated that the life expectancy at age 50 years was 29.0 years (95% CI, 28.3–29.8) for women and 25.5 years (95% CI, 24.7–26.2) for men who adopted zero low-risk lifestyle factors. In contrast, for those who adopted all 5 low-risk factors, we projected a life expectancy at age 50 years of 43.1 years (95% CI, 41.3–44.9) for women and 37.6 years (95% CI, 35.8–39.4) for men. The projected life expectancy at age 50 years was on average 14.0 years (95% CI, 11.8–16.2) longer among female Americans with 5 low-risk factors compared with those with zero low-risk factors; for men, the difference was 12.2 years (95% CI, 10.1–14.2).

CONCLUSIONS: Adopting a healthy lifestyle could substantially reduce premature mortality and prolong life expectancy in US adults.

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Clinical Perspective

What Is New?

- A comprehensive analysis of the impact of adopting low-risk lifestyle factors on life expectancy in the US population is lacking.
- Adherence to 5 low-risk lifestyle-related factors (never smoking, a healthy weight, regular physical activity, a healthy diet, and moderate alcohol consumption) could prolong life expectancy at age 50 years by 14.0 and 12.2 years for female and male US adults compared with individuals who adopted zero low-risk lifestyle factors.

What Are the Clinical Implications?

- Americans could narrow the life-expectancy gap between the United States and other industrialized countries by adopting a healthier lifestyle.
- Prevention should be a top priority for national health policy, and preventive care should be an indispensable part of the US healthcare system.

The United States is one of the wealthiest nations worldwide, but Americans have a shorter life expectancy compared with residents of almost all other high-income countries,[1,2] ranking 31st in the world for life expectancy at birth in 2015.[3] In 2014, with a total health expenditure per capita of $9402,[4] the United States was ranked first in the world for health expenditure as a percent of gross domestic product (17.1%).[4] However, the US healthcare system has focused primarily on drug discoveries and disease treatment rather than prevention. Chronic diseases such as cardiovascular disease (CVD) and cancer are the commonest and costliest of all health problems but are largely preventable.[5] It has been widely acknowledged that unhealthy lifestyles are major risk factors for various chronic diseases and premature death.[6]

More than 2 decades ago, McGinnis and Foege[7] and McGinnis and colleagues[8] suggested that the nation's major health policies should move to emphasize reducing unhealthy lifestyles. A meta-analysis[9] of 15 studies including 531 804 participants from 17 countries with a mean follow-up of 13.24 years suggested that ≈60% of premature deaths could be attributed to unhealthy lifestyle factors, including smoking, excessive alcohol consumption, physical inactivity, poor diet, and obesity. A healthy lifestyle was associated with an estimated increase of 7.4 to 17.9 years in life expectancy in Japan,[10] the United Kingdom,[11] Canada,[12] Denmark,[13] Norway,[13] and Germany.[13,14] However, a comprehensive analysis of the impact of adopting low-risk lifestyle factors on life expectancy in the US population is lacking. Therefore, our aim was to evaluate the potential impact of individual and combined lifestyle factors on premature death and life expectancy in the US population.

METHODS

The data, analytical methods, and study materials will be made available to other researchers from the corresponding authors on reasonable request for purposes of reproducing the results or replicating the procedure.

Overall Design

We first quantified the association between lifestyle-related low-risk factors and mortality on the basis of cohort data from the NHS (Nurses' Health Study)[15,16] and the HPFS (Health Professionals Follow-Up Study).[17] Then, we used data from the NHANES (National Health and Nutrition Examination Surveys; 2013–2014) to estimate the distribution of the lifestyle-related factors among the US population.[18] Furthermore, we derived the death rates of Americans from the CDC WONDER (Centers for Disease Control and Prevention Wide-Ranging Online Data for Epidemiologic Research) database.[19] Finally, we combined the results from those 3 sources to estimate the extended life expectancy associated with different categories of each individual lifestyle factor and a combination of low-risk lifestyle factors.

Study Population

The NHS began in 1976, when 121 700 female nurses 30 to 55 years of age responded to a questionnaire gathering medical, lifestyle, and other health-related information. In 1980, 92 468 nurses also responded to a validated food frequency questionnaire.[15,16] The HPFS[17] was established in 1986, when 51 529 male US health professionals (dentists, optometrists, osteopaths, podiatrists, pharmacists, and veterinarians) 40 to 75 years of age completed a mailed questionnaire about their medical history and lifestyle, including a food frequency questionnaire. We excluded participants with implausible energy intakes (women: <500 or >3500 kcal/d; men: <800 or >4200 kcal/d), with a body mass index (BMI) <18.5 kg/m^2 at baseline, or with a missing value for BMI, physical activity, alcohol, or smoking. After these exclusions, 78 865 female and 44 354 male participants remained in the analysis at baseline. The NHS and HPFS were approved by the institutional review board of Brigham and Women's Hospital in Boston; completion of the self-administered questionnaire was considered to imply informed consent.

We used the NHANES (2013–2014)[18] to estimate the population distribution of lifestyle-related factors among American adults. The analytical population consisted of 2128 adults 50 to 80 years of age with complete information on diet, BMI, physical activity, alcohol use, and smoking status. We also excluded participants with BMIs of <18.5 kg/m^2. The NHANES[18] included a nationally representative sample of the US population. It was approved by the National Center for Health Statistics research ethics review board. Signed consents were obtained from all participants.

Data Collection

Diet in the NHS and HPFS was assessed every 4 years with a validated food frequency questionnaire asking the frequency,

on average, a participant had consumed a particular amount of a specific type of food during the previous year.[15,16] Physical activity levels were investigated with a validated questionnaire and updated every 2 years.[20] Body weight and smoking habits were self-reported and updated every 2 years. Alcohol consumption was also collected by the food frequency questionnaire. Biennial questionnaires were used to collect information on potential confounders such as age, ethnicity, multivitamin use, regular aspirin use, postmenopausal hormone use (NHS only), and the presence or absence of a family history of diabetes mellitus, cancer, or myocardial infarction.

Dietary data in the NHANES[18] were collected by an interviewer-administered, computer-assisted, 24-hour dietary recall, which was an in-depth interview conducted by a trained interviewer who solicited detailed information about everything that the participant ate and drank in the prior 24 hours. Body weight and height were measured in a mobile examination center with standardized techniques and equipment. Smoking status was self-reported and included questions about numbers of cigarettes, pipes, or cigars smoked per day and whether the participant had smoked at least 100 cigarettes in his or her lifetime. Participants also reported duration of moderate and vigorous physical activity during leisure time and at work. Usual alcohol intakes were recorded by two 24-hour dietary recalls.[18]

Low-Risk Lifestyle Score

We included 5 lifestyle-related factors: diet, smoking, physical activity, alcohol consumption, and BMI. Because this study was focused on modifiable lifestyle factors, we did not include clinical risk factors such as hypertension, hypercholesterolemia, or medication use in the score.

Diet quality in the NHS, HPFS, and NHANES was assessed with the Alternate Healthy Eating Index score (Methods in the online-only Data Supplement), which is strongly associated with the onset of cardiometabolic disease in the general population.[21–23] We defined a healthy diet as a diet score in the top 40% of each cohort distribution. For smoking, we defined low risk as never smoking. For physical activity, we classified low risk as >30 min/d of moderate or vigorous activities (including brisk walking) that require the expenditure of at least 3 metabolic equivalents per hour. We defined low-risk alcohol consumption as moderate alcohol consumption, for example, 5 to 15 g/d for women and 5 to 30 g/d for men. BMI was calculated as self-reported weight (kilograms) divided by height (meters squared). Low-risk body weight was defined as BMI in the range of 18.5 to 24.9 kg/m^2.

For each low-risk factor, the participant received a score of 1 if he or she met the criterion for low risk. If the participant did not meet the criterion, he or she was classified as high risk for that factor and received a score of 0. The sum of these 5 scores provided a total number of low-risk factors of 0, 1, 2, 3, 4, or 5, with higher scores indicating a healthier lifestyle.

Ascertainment of Deaths

In the NHS and HPFS, deaths were identified from state vital statistics records, the National Death Index, reports by the families, and the postal system.[24] The follow-up for death in both cohorts was at least 98% complete. A physician reviewed death certificates or medical records to classify the cause of death according to *International Classification of Diseases, Eighth Revision* in the NHS (*International Classification of Diseases, Ninth Revision* in the HPFS).

We also derived the population all-cause, cardiovascular (I00–I99), and cancer mortality (C00–D48) rates for 2014 by sex and single-year ages ranging from 50 to 84 years from the CDC WONDER database of the US population.[19] Because the database provides mortality rates only up to age of 84, we estimated the all-cause and cause-specific mortality rates in single years of age from 85 to 105 years by extrapolation based on a Poisson regression model with both linear and quadratic terms for the midpoints of single-year age groups minus age of 49.5 years (Methods and Figure I in the online-only Data Supplement).

Statistical Analysis

Participants contributed person-time from the return of the baseline questionnaire (NHS, 1980; HPFS, 1986) until the date of death or the end of the follow-up period (June 30, 2014, for NHS and January 30, 2014, for HPFS), whichever came first. We used Cox proportional hazard models to calculate the adjusted hazard ratios (HRs) of all-cause, cancer, and cardiovascular mortality with their 95% confidence intervals (CIs) across categories of each individual factor and joint classification of number of low-risk factors (0, 1, 2, 3, 4, or 5).

Because lifestyle factors may affect mortality risk over an extended period of time, to best represent long-term effects, we calculated cumulative average levels of lifestyle factors using the latest 2 repeated measurements for our primary analysis of diet, physical activity, and alcohol consumption. For example, in the NHS, mortality cases that occurred between 1980 and 1982 were examined in relation to physical activity on the basis of data collected on the 1980 questionnaire, the average of the 1980 and 1982 physical activity measurements was used to assess risk of mortality in the 1982 to 1984 follow-up period, the average of the 1982 and 1984 physical activity measurements was used to assess risk of mortality in the 1984 to 1986 follow-up period, and so forth. For dietary Alternate Healthy Eating Index score and alcohol use, the average was calculated on the basis of 4-year repeated measurements. Smoking status was estimated from both smoking history and most recent status updated every other year and classified into 5 categories: never, past, and current smoking of 1 to 14, 15 to 24, and ≥25 cigarettes per day. To minimize the reverse causality bias resulting from weight loss caused by preexisting illness, we applied the lifelong maximum BMI.[25] For example, we applied the maximum value of BMI at age 18 years and BMI in 1980 to predict mortality between 1980 and 1982 and the maximum value of BMI at age 18 years, BMI in 1980, and BMI in 1982 to predict mortality between 1982 and 1984, and so forth. The same analytical strategy was applied to the HPFS. If data on low-risk factors were missing at a given time point, the last observation was carried forward. The following covariates were included in the multivariable model: age, ethnicity, current multivitamin use, current aspirin use, menopausal status and hormone use (women only), and family history of diabetes mellitus, myocardial infarction, or cancer. We applied a competing-risk regression model for cause-specific mortality by including

lifestyle factors as exposure and other risk factors as unconstrained covariates, allowing the effects of the covariates to vary across cause-specific mortality.[26]

We calculated the hypothetical population-attributable risk, an estimation of the percentage of premature mortality in the study population that theoretically would not have occurred if all people had been in the low-risk category, assuming that the observed associations represent causal effects. For these analyses, we used a single binary categorical variable (with all 5 low-risk factors) and compared participants in the low-risk category with the rest of the population (without all 5 low-risk factors or with any high-risk factor) to calculate the HRs. We combined these HRs with the prevalence of the low-risk category among American adults based on NHANES data to estimate the population-attributable risk.[27]

To calculate the life expectancy of participants following different levels of healthy lifestyles, we used life tables. We built the life table starting at age 50 years and ending at age 105 years with the following 3 estimates to calculate the cumulative survival from 50 years onward: (1) sex- and age-specific HRs of mortality associated with numbers of low-risk lifestyles derived from the NHS and HPFS; (2) sex- and age-specific population mortality rate of all causes, cardiovascular mortality (I00–I99), and cancer mortality (C00–D48) from the US CDC WONDER database[19]; and (3) age- and sex-specific population prevalence of the number of low-risk lifestyles derived from the NHANES.[18] We fitted multivariable-adjusted Cox regression models for each sex separately to calculate the age-specific HRs for mortality by the number of low-risk factors compared with zero low-risk factors. The model specification included linear and quadratic terms for the age variable (every 5 years up to 85 years) and the interactions between the number of low-risk factors and linear and quadratic terms of the age variable. The age-specific HRs for mortality were obtained as linear combinations of the relevant estimated coefficients, with age fixed at values corresponding to midpoints of 5-year age groups from age 50 to 85 years. The HR of age >85 years was assumed to be the same as that in the 85-year age group. Then we applied the age- and sex-specific HRs to estimate the life expectancy at different ages by the number of low-risk lifestyle factors (online-only Data Supplement).

In the sensitivity analysis, we applied the sex-specific HRs (adjusted for age only) for all-cause and cause-specific mortality to test the robustness of our findings. To address the potential aging effect on the association between lifestyle and mortality, we conducted a sensitivity analysis limited to NHS and HPFS participants <75 years of age. We conducted 3 stratified analyses: 1 analysis stratified by smoking status, another stratified by BMI status to estimate the joint effect of other 4 lifestyle factors, and the third stratified by baseline disease status (with or without elevated cholesterol, hypertension, or diabetes mellitus). To address the concern about the potential adverse effects of moderate alcohol intake, we created a healthy lifestyle score that was based on the other 4 low-risk factors without alcohol.

Because the binary variables could not account for the gradient in mortality risk with more extreme levels of these lifestyle factors, we conducted a third sensitivity analysis in which we calculated an expanded low-risk score on the basis of the associations between each lifestyle factor and mortality in the cohorts. We assigned scores of 1 (least healthy) to 5 (most healthy) to the categories of the lifestyle factors and summed the points across all 5 factors (score range, 5–25 points). For this analysis, the healthiest group was defined as never smoking, BMI between 18.5 and 22.9 kg/m^2, moderate alcohol intake (5–14.9 g/d), moderate or vigorous activity duration of ≥6 h/wk, and the highest quintile of the Alternate Healthy Eating Index diet score.

We used SAS version 9.3 (SAS Institute Inc, Cary, NC) to analyze the data. Statistical significance was set at a 2-tailed value of $P<0.05$. We used Monte Carlo simulation (parametric bootstrapping) with 10 000 runs to calculate the CIs of the life expectancy estimation with @RISK 7.5 (Palisade Corp, Ithaca, NY).

RESULTS

At baseline, participants with a higher number of low-risk lifestyle factors were slightly younger, more likely to use aspirin, and less likely to use multivitamin supplements (Table 1). During a median of 33.9 years of follow-up of women and 27.2 years of follow-up of men, 42 167 deaths were recorded (13 953 deaths resulting from cancer and 10 689 deaths caused by CVD).

Each individual component of a healthy lifestyle showed a significant association with risk of total mortality, cancer mortality, and CVD mortality (Table 2). A combination of 5 low-risk lifestyle factors was associated with an HR of 0.26 (95% CI, 0.22–0.31) for all-cause mortality, 0.35 (95% CI, 0.27–0.45) for cancer mortality, and 0.18 (95% CI, 0.12–0.26) for CVD mortality compared with participants with zero low-risk factors. The population-attributable risk of nonadherence to 5 low-risk lifestyle factors was 60.7% (95% CI, 53.6–66.7) for all-cause mortality, 51.7% (95% CI, 37.1–62.9%) for cancer mortality, and 71.7% (95% CI, 58.1–81.0) for cardiovascular mortality. We observed a similar association between the low-risk lifestyle factors and mortality before 75 years of age (Table I in the online-only Data Supplement). The low-risk lifestyle factors were associated with lower risk of cause-specific mortality in women and men similarly (Figure II in the online-only Data Supplement).

We observed a modest difference in HRs across age groups (Figure 1A). Using these age- and sex-specific HRs, we estimated that the life expectancy at age 50 years was 29.0 years (95% CI, 28.3–29.8) for women and 25.5 years (95% CI, 24.7–26.2) for men who adopted zero low-risk lifestyle factors. In contrast, for those who adopted all 5 low-risk factors, we projected a life expectancy at age 50 years of 43.1 years (95% CI, 41.3–44.9) for women and 37.6 years (95% CI, 35.8–39.4) for men (Figure 1B). Equivalently, women with 5 low-risk lifestyle factors could gain 14.0 years (95% CI, 11.8–16.8) of life expectancy on average, and men could gain 12.2 years (95% CI, 10.1–14.2) of life expectancy compared with those with zero low-risk

Table 1. Participant Characteristics* at Baseline According the Number of Low-Risk Lifestyle Factors

	Low-Risk Lifestyle Factors, n†					
	0	1	2	3	4	5
NHS (1980)						
n (%)	5216 (7.1)	19200 (26.3)	26790 (36.7)	19563 (26.8)	7179 (9.8)	917 (1.3)
Age, y	47.2 (6.9)	46.7 (7.1)	46.1 (7.2)	45.8 (7.3)	45.7 (7.3)	45.7 (7.3)
BMI, kg/m^2	29.8 (4.5)	26.6 (5.0)	24.5 (4.1)	23.1 (3.0)	22.3 (1.9)	22.1 (1.6)
Alternate Healthy Eating Index score	26.7 (3.4)	28.5 (5.0)	30.6 (6.0)	33.3 (6.2)	35.9 (5.5)	37.5 (4.3)
Physical activity, h/wk	1.7 (1.2)	2.4 (2.1)	3.6 (2.8)	5.1 (2.9)	6.5 (2.1)	7.1 (1.2)
Alcohol consumption, g/d	5.6 (12.6)	6.2 (12.4)	6.3 (10.8)	6.5 (9.1)	7.1 (6.8)	9.5 (2.8)
Past smoking, %	48.5	33.1	27.7	22.9	15.7	0.0
Current smoking, %	51.5	41.9	28.8	18.2	9.8	0.0
White, %	97.9	97.7	97.6	97.4	97.4	97.8
Multivitamin use, %	73.2	69.8	66.3	62.0	60.3	57.8
Regular aspirin use, %	49.4	51.9	53.2	53.5	55.6	52.5
Family history of diabetes mellitus, %	34.3	30.8	28.3	26.2	25.0	25.1
Family history of cancer, %	13.0	13.3	14.1	14.1	14.7	14.1
Family history of myocardial infarction, %	27.3	25.6	24.6	24.1	24.0	23.5
HPFS (1986)						
n (%)	4388 (11.4)	12133 (31.6)	14151 (36.9)	9337 (24.4)	3680 (9.6)	665 (1.7)
Age, y	55.0 (9.6)	54.1 (9.6)	53.6 (9.8)	53.7 (9.8)	53.2 (9.9)	53.0 (9.4)
BMI, kg/m^2	28.2 (3.2)	27.1 (3.4)	25.8 (3.3)	24.7 (2.8)	23.8 (2.0)	23.2 (1.2)
Alternate Healthy Eating Index score	39.5 (6.7)	42.9 (9.5)	47.2 (10.7)	51.6 (10.4)	55.8 (8.9)	58.6 (6.8)
Physical activity, h/wk	0.7 (0.9)	1.4 (2.5)	2.5 (3.6)	4.3 (5.4)	6.2 (5.4)	7.9 (5.5)
Alcohol consumption, g/d	16.3 (23.7)	11.6 (17.7)	10.3 (13.7)	10.5 (11.2)	10.7 (8.7)	12.6 (5.7)
Past smoking, %	76.6	54.2	41.9	30.2	18.1	0.0
Current smoking, %	23.4	14.9	7.8	3.3	1.5	0.0
White, %	94.5	94.2	93.8	94.0	94.5	97.0
Multivitamin use, %	43.0	41.3	38.8	35.9	31.6	33.1
Regular aspirin use, %	68.3	68.3	70.4	70.0	72.3	73.3
Family history of diabetes mellitus, %	22.1	22.9	20.9	19.9	19.9	21.8
Family history of cancer, %	32.5	33.1	34.4	35.1	35.2	37.1
Family history of myocardial infarction, %	34.4	33.7	33.3	34.0	32.6	33.6

BMI indicates body mass index; HPFS, Health Professionals' Follow-up Study; and NHS, Nurses' Health Study.

*Values are means (SD) or percentages and are standardized to age distribution of the study population except age itself.

†Low-risk lifestyle factors included cigarette smoking (never smoking), physically active (≥3.5 h/wk of moderate to vigorous intensity activity), high diet quality (upper 40% of Alternate Healthy Eating Index), moderate alcohol intake of 5 to 15 g/d (women) or 5 to 30 g/d (men), and normal weight (BMI, 18.5–24.9 kg/m^2).

lifestyle factors (Figure 1C). The preceding inferences were similar in sensitivity analyses using sex-specific HRs adjusted for age (Figure IIIA and IIIB in the online-only Data Supplement). Among women, on average, ≈30.8% of the gained life expectancy at age 50 years from adopting 5 versus zero low-risk lifestyle factors was attributable to reduced CVD death and the remainder to lower cancer (21.2%) or other causes (48.0%) of mortality. For men, the corresponding percentage was 34.1%, 22.8%, and 43.1%, respectively (Figure IIIC in the online-only Data Supplement). We observed a consistent dose-response relationship between the increasing number of low-risk factors and gained life expectancy among both smokers and nonsmokers (Figure IV in the online-only Data Supplement), among both normal-weight and overweight adults (Figure V in the online-only Data Supplement), and among individuals with and without chronic conditions at baseline (Figure VI in the online-only Data Supplement).

In a sensitivity analysis using a low-risk score without moderate alcohol intake, the projected life expectancy at age 50 years was on average 11.4 years (95% CI, 9.5–13.3) longer among female Americans with 4 low-risk factors compared with those with zero low-

Table 2. HRs (95% CIs) of Total and Cause-Specific Mortality According to Individual Lifestyle Risk Factors*

	Person-Years	Deaths Resulting From Any Cause		Cancer Deaths		CVD Deaths	
		Cases	HR (95% CI)	Cases	HR (95% CI)	Cases	HR (95% CI)
Body mass index, kg/m^2							
18.5–22.9	624 140	5337	1.06 (1.02–1.09)	1868	0.96 (0.91–1.02)	1077	1.02 (0.94–1.10)
23–24.9	677 848	7289	1.0 (Referent)	2588	1.0 (Referent)	1716	1.0 (Referent)
25–29.9	1 381 081	17 903	1.05 (1.02–1.08)	5935	1.01 (0.96–1.06)	4738	1.16 (1.10–1.23)
30–34.9	518 621	7427	1.25 (1.21–1.29)	2371	1.12 (1.05–1.18)	2006	1.66 (1.56–1.78)
≥35	250 013	4211	1.67 (1.61–1.74)	1191	1.24 (1.16–1.33)	1152	2.58 (2.39–2.79)
Cigarette smoking							
Never	1 508 401	13 694	1.0 (Referent)	4324	1.0 (Referent)	3390	1.0 (Referent)
Past	1505 488	23 155	1.41 (1.38–1.44)	7526	1.50 (1.44–1.56)	6045	1.38 (1.32–1.44)
Current 1–14/d	174 422	2458	2.02 (1.93–2.10)	873	2.00 (1.86–2.15)	596	2.08 (1.91–2.27)
Current 15–24/d	163 678	1756	2.33 (2.21–2.45)	729	2.28 (2.11–2.48)	428	2.62 (2.37–2.91)
Current ≥25/d	99 716	1104	2.87 (2.70–3.06)	501	2.97 (2.70–3.27)	230	2.78 (2.43–3.19)
Alcohol consumption, g/d							
0	1 037 840	16 611	1.27 (1.24–1.30)	4671	1.03 (0.98–1.08)	4263	1.49 (1.41–1.57)
1–4.9	1 087 210	10 454	1.03 (1.00–1.06)	3841	0.98 (0.93–1.03)	2632	1.13 (1.07–1.20)
5–14.9	773 186	8041	1.0 (Referent)	2953	1.0 (Referent)	2007	1.0 (Referent)
15–29.9	345 034	4009	0.99 (0.96–1.03)	1417	0.99 (0.93–1.06)	1017	0.97 (0.90–1.05)
≥30	208 434	3052	1.25 (1.19–1.30)	1071	1.21 (1.13–1.30)	770	1.17 (1.08–1.27)
Physical activity, h/wk							
0	1 089 120	24 254	1.0 (Referent)	6997	1.0 (Referent)	6177	1.0 (Referent)
0.1–0.9	921 192	8239	0.65 (0.63–0.66)	3044	0.71 (0.68–0.75)	2159	0.69 (0.66–0.73)
1.0–3.4	515 731	3751	0.56 (0.54–0.58)	1491	0.66 (0.62–0.70)	930	0.54 (0.50–0.57)
3.5–5.9	369 688	2524	0.50 (0.48–0.52)	1023	0.60 (0.56–0.64)	590	0.44 (0.40–0.48)
≥6	555 972	3399	0.44 (0.43–0.46)	1398	0.55 (0.52–0.58)	833	0.39 (0.37–0.43)
Alternate Healthy Eating Index score							
Fifth 1	736 051	11 125	1.0 (Referent)	3438	1.0 (Referent)	2588	1.0 (Referent)
Fifth 2	701 947	9228	0.86 (0.83–0.88)	2983	0.89 (0.85–0.93)	2306	0.89 (0.84–0.94)
Fifth 3	689 795	8082	0.77 (0.75–0.79)	2677	0.81 (0.77–0.85)	2073	0.81 (0.76–0.86)
Fifth 4	672 973	7250	0.70 (0.68–0.72)	2511	0.76 (0.72–0.80)	1954	0.75 (0.71–0.80)
Fifth 5	650 937	6482	0.63 (0.61–0.65)	2344	0.70 (0.67–0.74)	1768	0.67 (0.63–0.71)
No. of 5 low-risk factors†							
0	458 169	9286	1.0 (Referent)	2785	1.0 (Referent)	2430	1.0 (Referent)
1	1 101 853	16 329	0.79 (0.77–0.81)	5227	0.83 (0.79–0.87)	4143	0.75 (0.71–0.79)
2	1 053 250	10 908	0.61 (0.59–0.62)	3821	0.68 (0.65–0.71)	2719	0.54 (0.51–0.57)
3	596 784	4408	0.47 (0.45–0.49)	1607	0.53 (0.50–0.57)	1101	0.40 (0.38–0.43)
4	208 683	1113	0.35 (0.33–0.37)	458	0.44 (0.40–0.49)	270	0.28 (0.25–0.32)
5	32 964	123	0.26 (0.22–0.31)	55	0.35 (0.27–0.45)	26	0.18 (0.12–0.26)
For not having all 5 low-risk factors vs all others							
HR of 5 vs. <5 low-risk factors			0.39 (0.33–0.46)		0.48 (0.37–0.63)		0.28 (0.19–0.42)
PAR, %‡			60.7 (53.6–66.7)		51.7 (37.1–62.9)		71.7 (58.1–81.0)

CI indicates confidence interval; CVD, cardiovascular disease; HR, hazard ratio; and PAR, population-attributable risk.

*Multivariable-adjusted HR adjusted for age; sex; ethnicity; current multivitamin use; current aspirin use; family history of diabetes mellitus, myocardial infarction, or cancer; and menopausal status and hormone use (women only).

†Low-risk lifestyle factors included cigarette smoking (never smoking), physically active (≥3.5 h/wk of moderate to vigorous intensity activity), high diet quality (upper 40% of Alternate Healthy Eating Index), moderate alcohol intake of 5 to 15 g/d (women) or 5 to 30 g/d (men), and normal weight (body mass index, 18.5–24.9 kg/m^2).

‡Estimation of PAR of having any high-risk factors was based on the prevalence of not having all 5 low-risk factors among American adults from NHANES (National Health and Nutrition Examination Surveys) data.

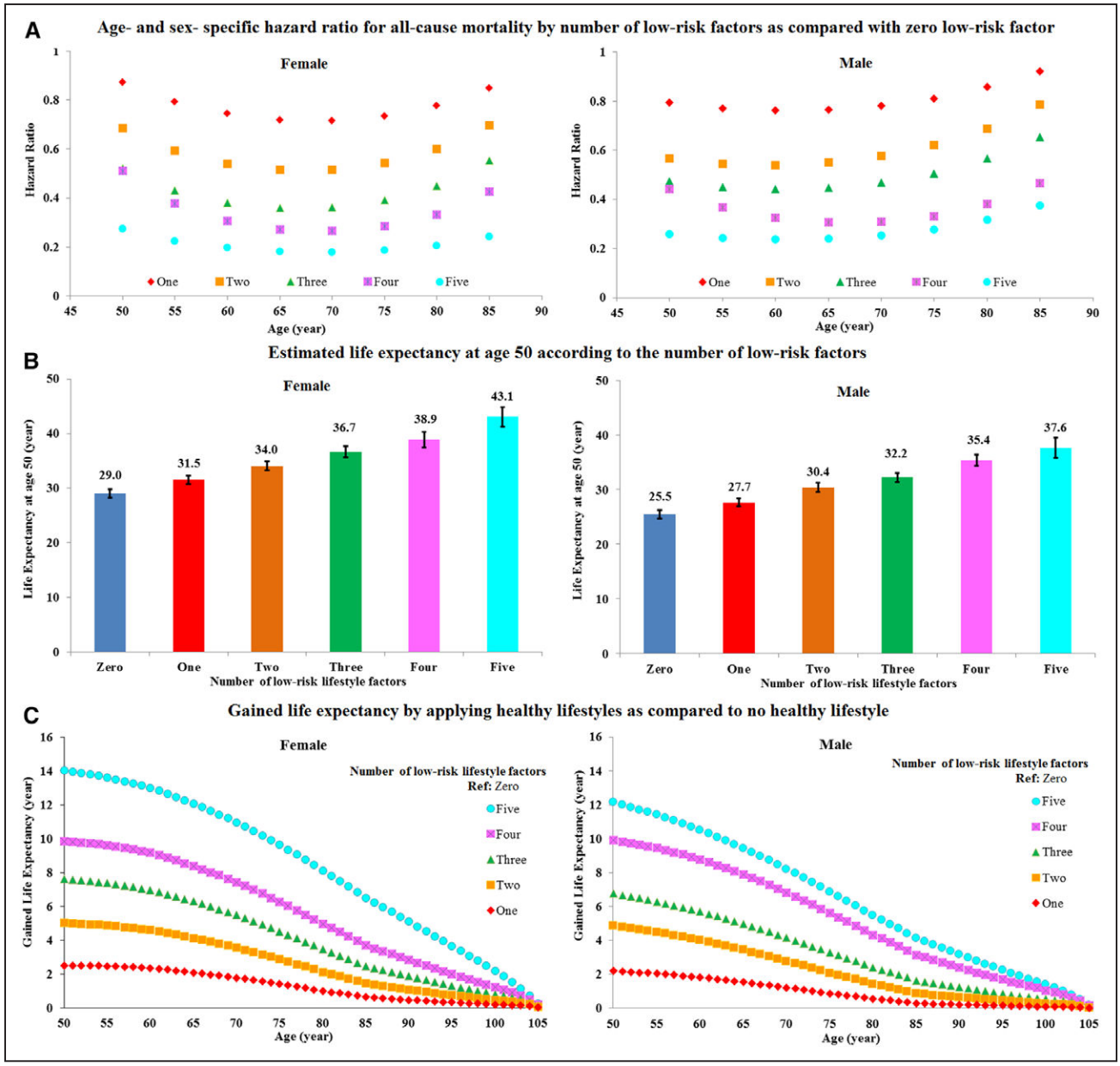

Figure 1. Life expectancy estimated from the overall mortality rate of Americans (Centers for Disease Control and Prevention [CDC] report), the prevalence of lifestyle factors using NHANES (National Health and Nutrition Examination Surveys) data 2013 to 2014, and age- and sex-specific hazard ratios.

A, Hazard ratio; **B**, life expectancy at age 50 years; **C**, life expectancy by age. Low-risk lifestyle factors included cigarette smoking (never smoking), physically active (≥3.5 h/wk of moderate to vigorous intensity activity), high diet quality (upper 40% of Alternate Healthy Eating Index), moderate alcohol intake of 5 to 15 g/d (female) or 5 to 30 g/d (male), and normal weight (body mass index <25 kg/m^2). Estimates of cumulative survival from 50 years of age onward among the 5 lifestyle risk factor groups were calculated by applying the following: (1) all-cause and cause-specific mortality rates were obtained from the US CDC WONDER database; (2) distribution of different numbers of low-risk lifestyles was based on the US NHANES 2013 to 2014; and (3) multivariate-adjusted hazard ratios (sex- and age-specific) for all-cause mortality associated with the 5 low-risk lifestyles compared with those without any low-risk lifestyle factors, adjusted for ethnicity, current multivitamin use, current aspirin use, family history of diabetes mellitus, myocardial infarction, or cancer, and menopausal status and hormone use (women only), were based on data from the NHS (Nurses' Health Study) and HPFS (Health Professionals Follow-up Study). CDC WONDER indicates Centers for Disease Control and Prevention Wide-Ranging Online Data for Epidemiologic Research; and Ref, reference.

risk factors; for men, the difference was 10.0 years (95% CI, 9.2–10.9; Figure VII in the online-only Data Supplement).

We also estimated the gained life expectancy related to each of the lifestyle factors. As expected, increased exercise, not smoking or a reduced amount of smoking

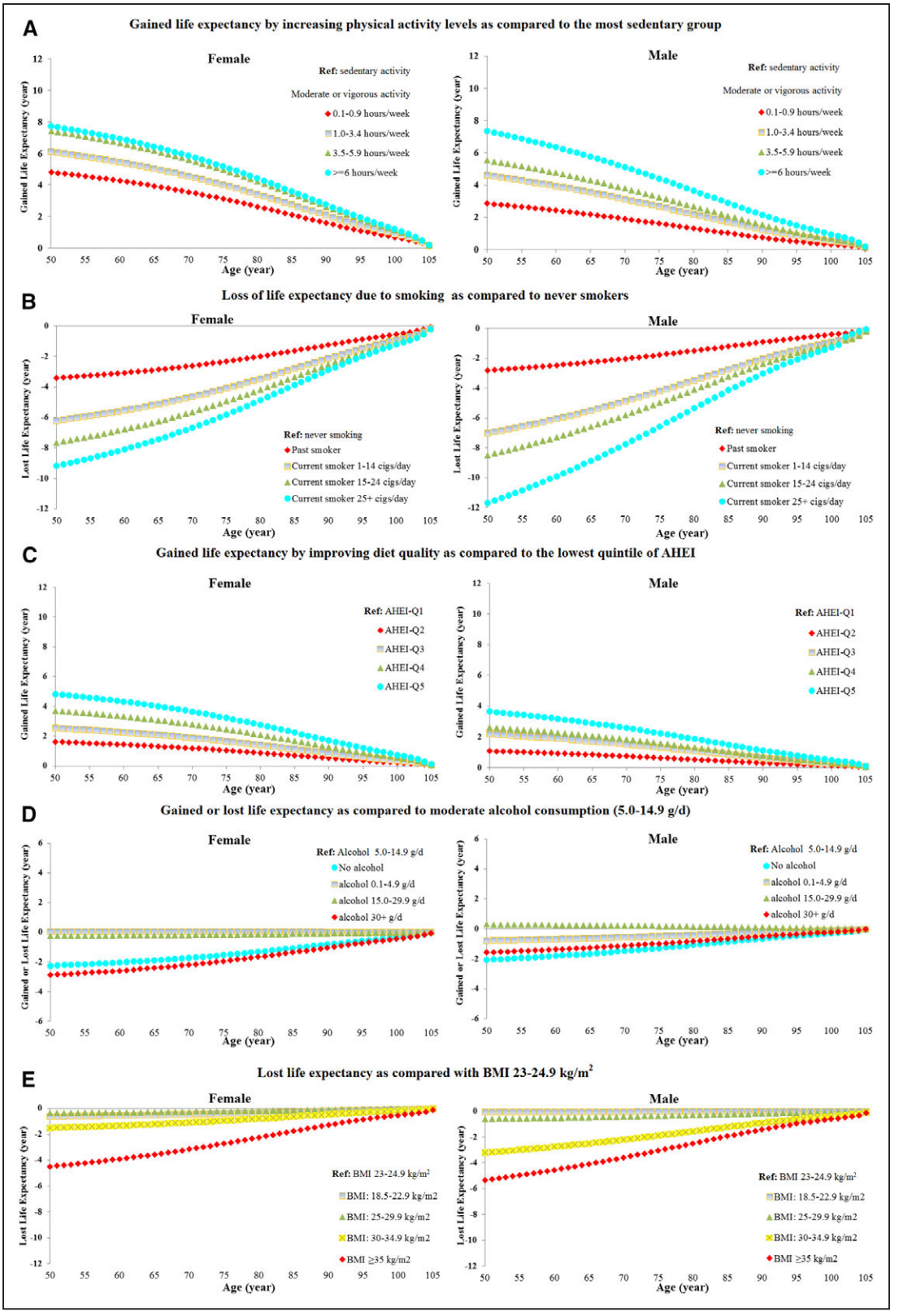

Figure 2. Projected gained or lost life expectancy according to individual low-risk lifestyle factors.
A, Physical activity; **B**, smoking; **C**, diet; **D**, alcohol; **E**, body mass index. Estimates of cumulative survival from 50 years of age onward among different levels of each lifestyle factor were calculated by applying the following: (1) all-cause and cause-specific mortality rates were obtained from the US CDC WONDER database; (2) distributions of different groups of each lifestyle factor were based on the US NHANES (National Health and Nutrition Examination (*Continued*)

if a smoker, a healthy dietary pattern, moderate alcohol intake, and optimal body weight were all associated with longer life expectancy (Figure 2). The estimate based on the expanded low-risk score indicated a 20.5-year difference in life expectancy at age 50 years in women (19.6 years among men) who adhered to the highest expanded lifestyle score compared with the lowest expanded score (Figure VIII in the online-only Data Supplement).

DISCUSSION

We estimated that adherence to 5 low-risk lifestyle-related factors could prolong life expectancy at age 50 years by 14.0 and 12.2 years for female and male US adults, respectively, compared with individuals who adopted zero low-risk lifestyle factors. These estimates suggest that Americans could narrow the life-expectancy gap between the United States and other industrialized countries by adopting a healthier lifestyle. In 2014, the life expectancy for American adults at age 50 years was 33.3 years for women and 29.8 years for men.[28] We estimated that the life expectancies were 29.0 years for women and 25.5 years for men if they had zero low-risk factors but could be extended to 43.1 years for women and 37.6 years for men if they adopted all 5 low-risk factors. However, in US adults, adherence to a low-risk lifestyle pattern has decreased during the last 3 decades, from 15% in 1988 to 1992 to 8% in 2001 to 2006,[29] driven primarily by the increasing prevalence of obesity.

The life expectancy of Americans increased from 62.9 years in 1940 to 76.8 years in 2000 and 78.8 years in 2014.[28] This increase could be the result of a number of factors such as improvements in living standards, improved medical treatment, substantial reduction in smoking,[30] and a modest improvement in diet quality.[23] However, some unhealthy lifestyle factors may have counterbalanced the gain in life expectancy, particularly the increasing obesity epidemic[30,31] and decreasing physical activity levels.[32] In our study, three fourths of premature CVD deaths and half of premature cancer deaths in the United States could be attributed to lack of adherence to a low-risk lifestyle. There is still much potential for improvement in health and life expectancy, which depends not only on an individual's efforts but also on the food, physical, and policy environments.[33,34] A recent study found that low-income residents in relatively wealthy areas such as New York and San Francisco had significantly longer life expectancies than those in poorer regions such as Gary, IN, and Detroit.[35] This phenomenon suggests that the living environment contributes to life expectancy beyond socioeconomic status. For instance, residents in affluent cities have more access to public health services and less exposure to smoking because of the more restricted policies on smoking in public.[35] Studies[36] have linked healthy eating and exercise habits with built, social, and socioeconomic environment assets (access to parks, social ties, affluence) and unhealthy behaviors with built environment inhibitors (access to fast food outlets), suggesting that supporting environments for health lifestyle should be 1 part of the promotion of longevity for the US population. Prevention should be a top priority for national health policy, and preventive care should be an indispensable part of the healthcare system.

Our estimation of gained life expectancy by adopting a low-risk lifestyle was broadly consistent with previous studies. A healthy lifestyle was associated with an estimated greater life expectancy of 8.3 years (women) and 10.3 years (men) in Japan,[10] 17.9 years in Canada,[12] and 13.9 years (women) and 17.0 years (men) in Germany,[14] as well as 14 years' difference in chronological age in the United Kingdom.[11] Data from 3 European cohorts from Denmark, Germany, and Norway[13] suggested that men and women 50 years of age who had a favorable lifestyle would live 7.4 to 15.7 years longer than those with an unfavorable lifestyle. These estimates were somewhat different because of different definitions of a low-risk lifestyle and study population characteristics.[10,12–14]

We observed that a healthy diet pattern, moderate alcohol consumption, nonsmoking status, a normal weight, and regular physical activity were each associated with a low risk of premature mortality. Smoking is a strong independent risk factor of cancer, diabetes mellitus, CVDs, and mortality potentially through inducing oxidative stress and chronic inflammation, and smoking cessation has been associated with a reduction of these excess risks.[37–39] A healthy dietary pattern and its major food components have been associated with lower risk of morbidities and mortality of diabetes mellitus, CVD, cancer, and neurodegenerative disease,[40] and its potential health benefits have been replicated in clinical trials.[41] Physical activity and weight control significantly reduced the risk of diabetes mellitus, cardiovascular risk factors, and breast cancer.[42–44] Although no long-term trial of alcohol consumption on chronic disease risk has been conducted, cardiovascular benefits of moderate alcohol consumption have been consistently observed in large cohort

Figure 2 Continued. Surveys) 2013 to 2014; (3) multivariate-adjusted hazard ratios (sex-specific) for all-cause and cause-specific mortality associated with each lifestyle factor adjusted for ethnicity; current multivitamin use; current aspirin use; family history of diabetes mellitus, myocardial infarction, or cancer; and menopausal status and hormone use (women only) were based on data from the NHS (Nurses' Health Study) and HPFS (Health Professionals Follow-up Study). AHEI indicates Alternate Healthy Eating Index; BMI, body mass index; CDC WONDER, Centers for Disease Control and Prevention Wide-Ranging Online Data for Epidemiologic Research; cigs, cigarettes; Q, quartile; and Ref, referent.

studies.[45] Results of our sensitivity analysis further indicated that combinations of the healthy lifestyle factors were particularly powerful: the larger the number of low-risk lifestyle factors, the longer the potential prolonged life expectancy, regardless of the combined factors.[5]

A major strength of this study is the long follow-up of 2 large cohorts with detailed and repeated measurements of diet and lifestyle and low rates of loss to follow-up. Another important strength is the combination of the cohort estimates with a nationally representative study, the NHANES, which improved the generalizability of our findings. Although the HRs between lifestyle factors and mortality were estimated from only our cohort data, they were similar to those published in other populations.[9–14] Because our cohorts included mostly white health professionals, we could not specifically examine the overall impact of lifestyle adherence among different ethnic subgroups; further studies are warranted to examine the impact of lifestyle factors in other ethnic and racial groups.

The current study has several limitations. First, diet and lifestyle factors were self-reported; thus, measurement errors are inevitable. However, the use of repeated measures of these variables could reduce measurement errors and represent long-term diet and lifestyle. Second, we counted the number of lifestyle factors on the basis of the dichotomized value of each lifestyle factor, although the lifestyle factors were differentially associated with mortality. However, our analysis based on an expanded score considered different levels of each risk factor and yielded similar results. Third, we did not fully consider the baseline comorbid conditions and background medical therapies. Although our stratification analysis by baseline chronic conditions of diabetes mellitus, hypertension, and elevated cholesterol provided some support for the hypothesis that adopting a healthy lifestyle is important for both healthy individuals and those with existing chronic conditions, further studies among individuals with diagnosed cancer and CVDs are warranted.

CONCLUSIONS

We estimate that adherence to a low-risk lifestyle could prolong life expectancy at age 50 years by 14.0 and 12.2 years in female and male US adults compared with individuals without any of the low-risk lifestyle factors. Our findings suggest that the gap in life expectancy between the United States and other developed countries could be narrowed by improving lifestyle factors.

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Disclosures

None.

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Impact of Healthy Lifestyle Factors on Life Expectancies in the US Population

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Supplemental Methods

Alternate Healthy Eating Index (AHEI) score

Diet quality in NHS, HPFS and NHANES was assessed using the AHEI score, which is based on foods and nutrients predictive of chronic disease risk. Briefly, points were assigned for intake of each component on a scale from 0 to 10, with 10 indicating adherence to the recommended levels of servings per day. We included 10 components of the index in our diet score: high intakes of vegetables, fruit, nuts, whole grains, polyunsaturated fatty acids, and long-chain omega-3 fatty acids and low intakes of red and processed meats, sugar sweetened beverages, *trans* fat, and sodium. In this analysis, AHEI was divided in quintiles.

Statistical Method Used for Estimating Years of Life Gained

We applied three pieces of information to estimate the gained life expectancy associated with adherence to a healthy lifestyle (henceforth "exposure groups").[1]

(1) Sex- and age-specific hazard ratios for all-cause in each exposure group versus the reference derived from the Nurses' Health Study (NHS) and the Health Professionals Follow-up Study (HPFS);

(2) Population all-cause and cause-specific mortality rates derived from the CDC WONDER database of the US Centers for Disease Control and Prevention;

(3) Prevalence of exposure groups in the US population derived from the NHANES (2013-2014).

The lifetables for each of the 6 exposure groups in male and female, separately, were built on the estimated population mortality rates in each exposure group, and the later was estimated using sex specific hazard ratios for mortality by exposure groups in the NHS and HPFS,

prevalence of exposure groups from NHANES 2013-2014 and the overall population mortality rates by single-year age intervals and sex. We estimated gained life-expectancy as differences in expectation of life at any given age between any two lifetables compared.

Population all-cause (and cause-specific) mortality rates per 100,000 per sex and per single-year age group were obtained for the US population of 2014 from the Center for Disease Control (CDC) WONDER online database (https://wonder.cdc.gov/ucd-icd10.html). Because the mortality rates were provided only up to age 84 years old, but we desired to estimate the overall population survival curves until 105 years, we used a Poisson regression model with both linear and quadratic terms for the midpoints of single-year age groups minus age 50.5 years to extrapolate the mortality rates for each single year of age after 84 years (eFigure 1).

We fitted multivariable-adjusted Cox regression models for each gender separately to calculate the age specific hazard ratios for mortality by the number of low-risk factors as compared with zero low-risk factors. The model specification included linear and quadratic terms for the age variable (every 5-years, up to 85 years), and the interactions between the number of low-risk factors with linear and quadratic terms of age variable. The age specific hazard ratios for mortality were obtained as linear combinations of the relevant estimated coefficients, with age fixed at values corresponding to midpoints of 5-year age-groups from age 50 onwards to age 85. The HR of age above 85 was assumed to be the same as that in the 85 years age group. Then we applied the age- and sex- specific HRs to estimate the life expectancy at different age of female and male separately.

We built the life table starting at age 50 years and ending at 105 years by single-year age intervals. Survival probability was set of 1 at age 50 years and probability of survival between ages x and x + 1 was calculated based on probability of dying (mortality rate) between ages x

and x+1 assuming that survivor function declines linearly between ages x and x + 1.[2,3] The life expectancy at any given age was derived by dividing the total person-years that would be lived beyond age x by the number of persons who survived to that age interval.[2]

Sex-specific prevalence of exposure groups in the US population was derived from the NHANES (2013-2014). We inferred the age-specific mortality rates appropriate for our reference group IR_{a0} as:[4]

$$IR_{a0} = \frac{IR_a}{\left(p_{a0} + \sum_{j=1}^{5} p_{aj} \times RR_{aj}\right)}$$

Where IR_a is the population mortality rate for age group a, p_{aj} is the age-specific prevalence of exposure group j, and RR_{aj} is the age-specific hazard ratio in comparison of exposure group j versus reference group ($j = 0$). The age-specific mortality rates in each of the non-reference exposure groups were then inferred in turn by multiplying the age-specific mortality rate for the reference group IR_{a0} by the age-specific hazard ratios RR_{aj}.

Finally, life table for each exposure group was built based on each sex- and age-specific IRaj and the gain in life expectancy according to different exposure groups (number of low-risk lifestyle factor) was estimated as difference in the life expectancy at any given age between the reference group and each of the low-risk group (Figure 1B in the manuscript).

Supplemental References

1. Emerging Risk Factors Collaboration, Di Angelantonio E, Kaptoge S, et al. Association of Cardiometabolic Multimorbidity With Mortality. JAMA. 2015;314(1):52-60.

2. Arias E. United States life tables, 2008. Natl Vital Stat Rep. 2012 Sep 24;61(3):1-63.

3. Chiang CL, World Health Organization. Life table and mortality analysis. 1979. Publisher: Geneva : World Health Organization.

4 Woloshin S, Schwartz LM, Welch HG. The risk of death by age, sex, and smoking status in the United States: putting health risks in context. J Natl Cancer Inst 2008;100(12):845-53.

Supplemental Table 1 Hazard ratios (95% CIs) of total and cause-specific mortality among participants prior to 75 years according to individual lifestyle risk factors[*]

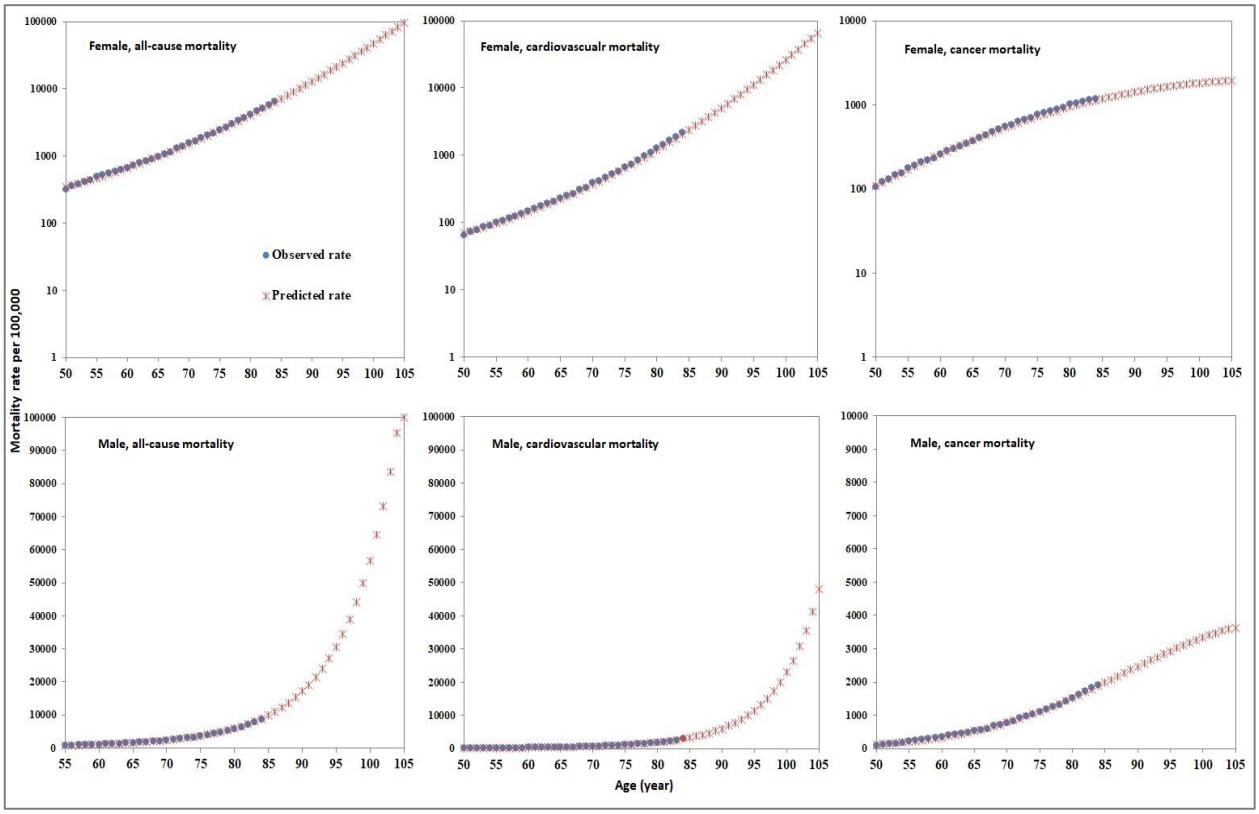
	Person Years	Deaths from any cause		Cancer deaths		Cardiovascular deaths	
		Cases	RR (95% CI)	Cases	RR (95% CI)	Cases	RR (95% CI)
Body mass index (kg/m^2)							
18.5-22.9	562354	2664	1.15 (1.09-1.21)	1290	1.02 (0.94-1.09)	476	1.22 (1.08-1.38)
23-24.9	583042	2949	1.0(ref.)	1522	1.0(ref.)	555	1.0(ref.)
25-29.9	1150992	7156	1.09 (1.04-1.13)	3360	1.02 (0.96-1.08)	1722	1.35 (1.23-1.49)
30-34.9	434413	3385	1.35 (1.29-1.42)	1433	1.12 (1.04-1.20)	915	2.12 (1.90-2.36)
≥35	215683	2244	1.87 (1.77-1.98)	831	1.32 (1.21-1.44)	613	3.40 (3.02-3.83)
Cigarette smoking							
Never	1290489	5521	1.0(ref.)	2587	1.0(ref.)	1186	1.0(ref.)
Past	1240208	9254	1.51 (1.46-1.56)	4235	1.52 (1.45-1.60)	2206	1.60 (1.49-1.72)
Current 1-14/day	160682	1418	2.14 (2.02-2.27)	602	1.86 (1.71-2.04)	355	2.62 (2.33-2.95)
Current 15-24/day	157531	1286	2.46 (2.31-2.61)	584	2.13 (1.95-2.34)	335	3.32 (2.94-3.76)
Current ≥25/day	97576	919	3.22 (3.00-3.46)	428	2.82 (2.54-3.13)	199	3.60 (3.09-4.19)
Alcohol consumption (g/day)							
0	848882	6633	1.34 (1.29-1.40)	2656	1.04 (0.98-1.10)	1711	1.81 (1.66-1.97)
1-4.9	960473	5038	1.03 (0.98-1.07)	2522	0.98 (0.92-1.04)	1118	1.17 (1.07-1.29)
5-14.9	669556	3577	1.0(ref.)	1800	1.0(ref.)	754	1.0(ref.)
15-29.9	289685	1642	0.99 (0.93-1.05)	793	0.98 (0.90-1.06)	354	0.96 (0.84-1.09)
≥30	177888	1508	1.38 (1.30-1.46)	665	1.26 (1.15-1.38)	344	1.33 (1.17-1.52)
Physical activity (hours/week)							
0	845324	9126	1.0(ref.)	3805	1.0(ref.)	2232	1.0(ref.)
0.1-0.9	811380	4165	0.62 (0.60-0.65)	2037	0.70 (0.66-0.74)	964	0.62 (0.58-0.68)
1.0-3.4	462343	1928	0.53 (0.50-0.55)	994	0.63 (0.59-0.68)	403	0.46 (0.41-0.51)
3.5-5.9	330135	1331	0.47 (0.45-0.50)	672	0.57 (0.52-0.62)	281	0.40 (0.35-0.45)
≥6	497302	1848	0.44 (0.42-0.46)	928	0.54 (0.50-0.58)	401	0.37 (0.33-0.41)
Alternative healthy eating index							
Fifth 1	636924	4988	1.0(ref.)	2165	1.0(ref.)	1116	1.0(ref.)
Fifth 2	599813	3910	0.81 (0.78-0.85)	1797	0.87 (0.82-0.92)	889	0.80 (0.73-0.88)
Fifth 3	588706	3560	0.74 (0.71-0.77)	1647	0.79 (0.74-0.85)	836	0.74 (0.68-0.81)
Fifth 4	572043	3150	0.66 (0.63-0.69)	1469	0.71 (0.67-0.76)	769	0.68 (0.62-0.74)
Fifth 5	548998	2790	0.58 (0.55-0.60)	1358	0.66 (0.61-0.70)	671	0.58 (0.52-0.64)
Number of 5 low-risk factors[**]							
Zero	379007	4141	1.0(ref.)	1681	1.0(ref.)	1103	1.0(ref.)
One	926243	7046	0.74 (0.71-0.77)	3171	0.82 (0.77-0.87)	1662	0.65 (0.60-0.70)
Two	906085	4678	0.54 (0.52-0.56)	2294	0.65 (0.61-0.69)	1002	0.41 (0.38-0.45)
Three	521881	1927	0.40 (0.38-0.42)	961	0.49 (0.46-0.53)	406	0.29 (0.26-0.33)
Four	183975	544	0.32 (0.30-0.35)	294	0.44 (0.39-0.50)	98	0.20 (0.16-0.24)
Five	29294	62	0.23 (0.18-0.29)	35	0.33 (0.24-0.47)	10	0.12 (0.06-0.22)
For not having five low-risk factors vs. all others (95% CI)		**HRs**	0.37 (0.29-0.48)		0.48 (0.34-0.67)		0.23 (0.12-0.42)
		PAR[§] (%)	62.7 (52.1-71.0)		51.7 (32.3-65.5)		76.8 (56.7-87.6)

HR: Hazard ratio; PAR: Population-Attributable-Risk

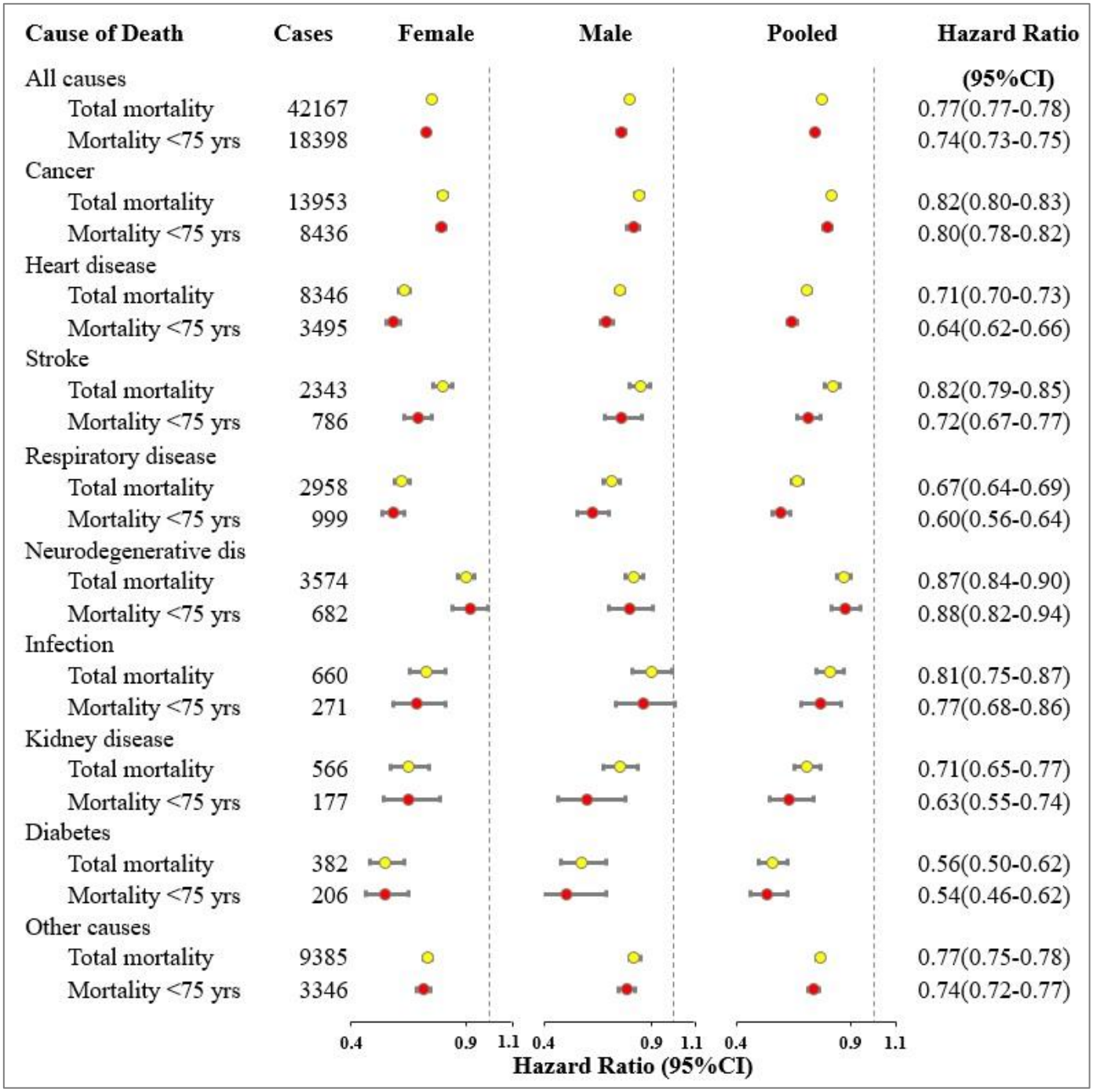
[*] Multivariable adjusted hazard ratio adjusted for age, sex, ethnicity, current multivitamin use, current aspirin use, family history of diabetes mellitus, myocardial infarction, or cancer, and menopausal status and hormone use (for female).

[**]Low-risk lifestyle factors included: cigarette smoking (never smoking), physical active (≥3.5 hours/week moderate to vigorous intensity activity), high diet quality (upper 40% of alternative healthy eating index (AHEI), moderate alcohol intake of 5-15 g/day (female) or 5-30 g/day (male), and normal weight (body mass index 18.5-24.9 kg/m^2).

[§] Estimation of PAR was based on the prevalence of not having five low-risk factors among American adults from NHANES data.

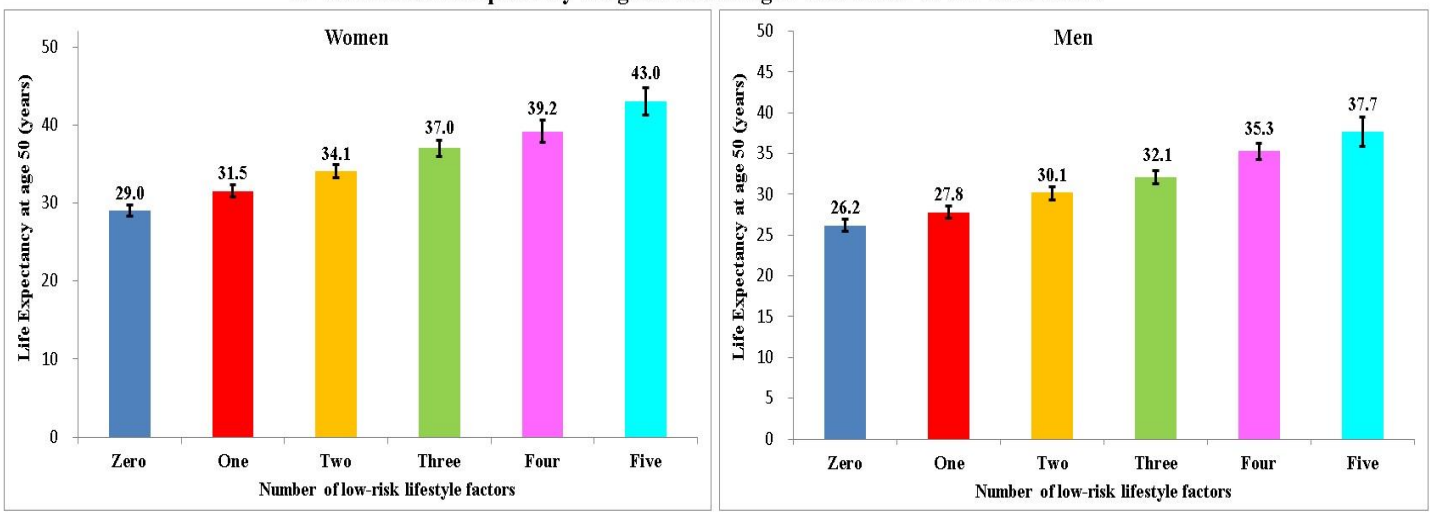


Supplemental Figure 1 Observed and predicted rate of US population mortality rates of 2014.

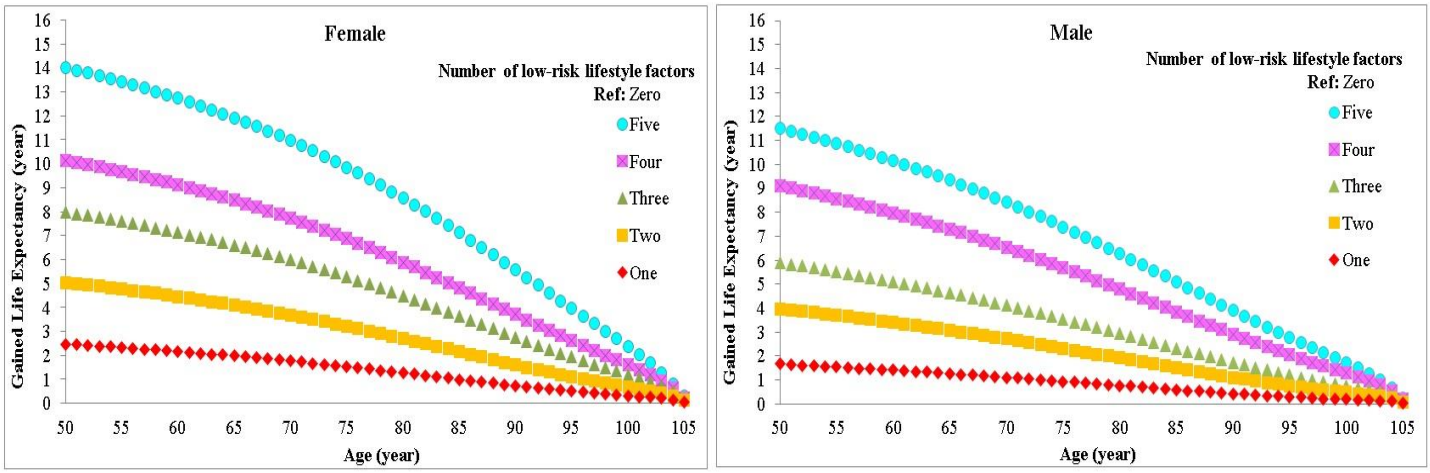


Supplemental Figure 2 Hazard ratios for total and cause-specific death associated with an increment of each low-risk lifestyle factor. Hazard ratios adjusted for age, sex, ethnicity, current multivitamin use, current aspirin use, family history of diabetes mellitus, myocardial infarction, or cancer, and menopausal status and hormone (for female only). Low-risk lifestyle factors included: cigarette smoking (never smoking), physical active (≥3.5 hours/week moderate to vigorous intensity activity), high diet quality (upper 40% of alternative healthy eating index (AHEI), moderate alcohol intake of 5-15 g/day (female) or 5-30 g/day (male), and normal weight (body mass index 18.5-24.9 kg/m^2).

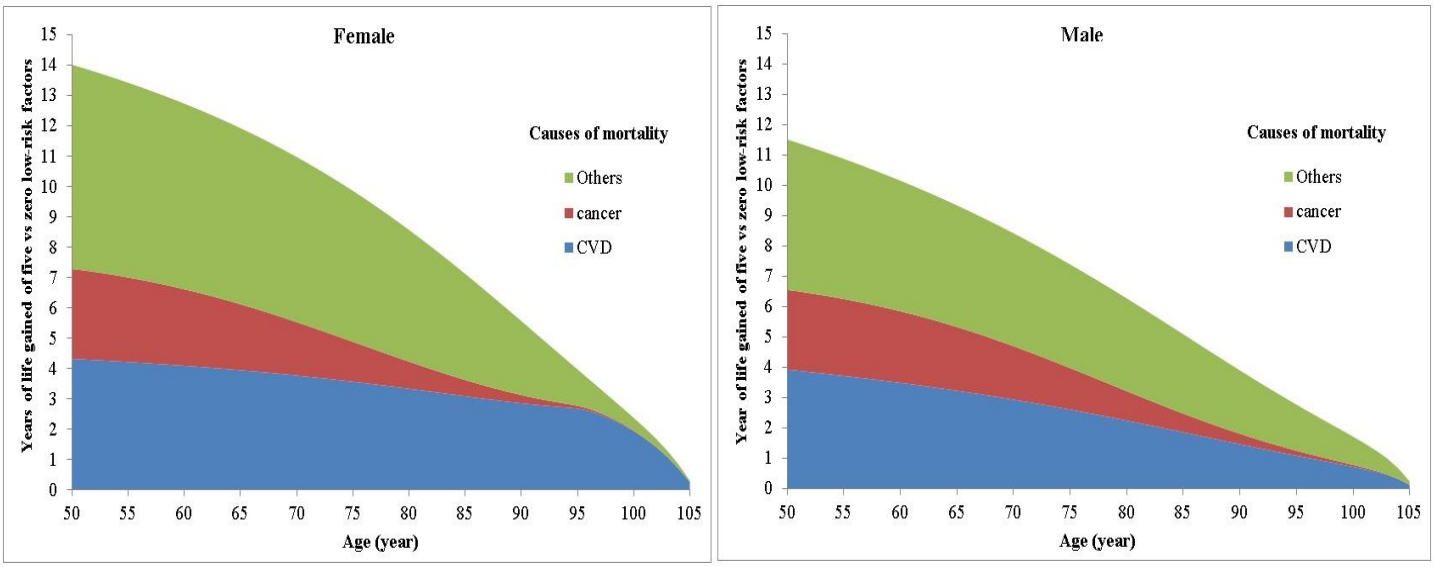
A: Estimated life expectancy at age 50 according to the number of low-risk factors



B: Estimated gained life expectancy at different age by applying healthy lifestyle as compared to zero low-risk factor



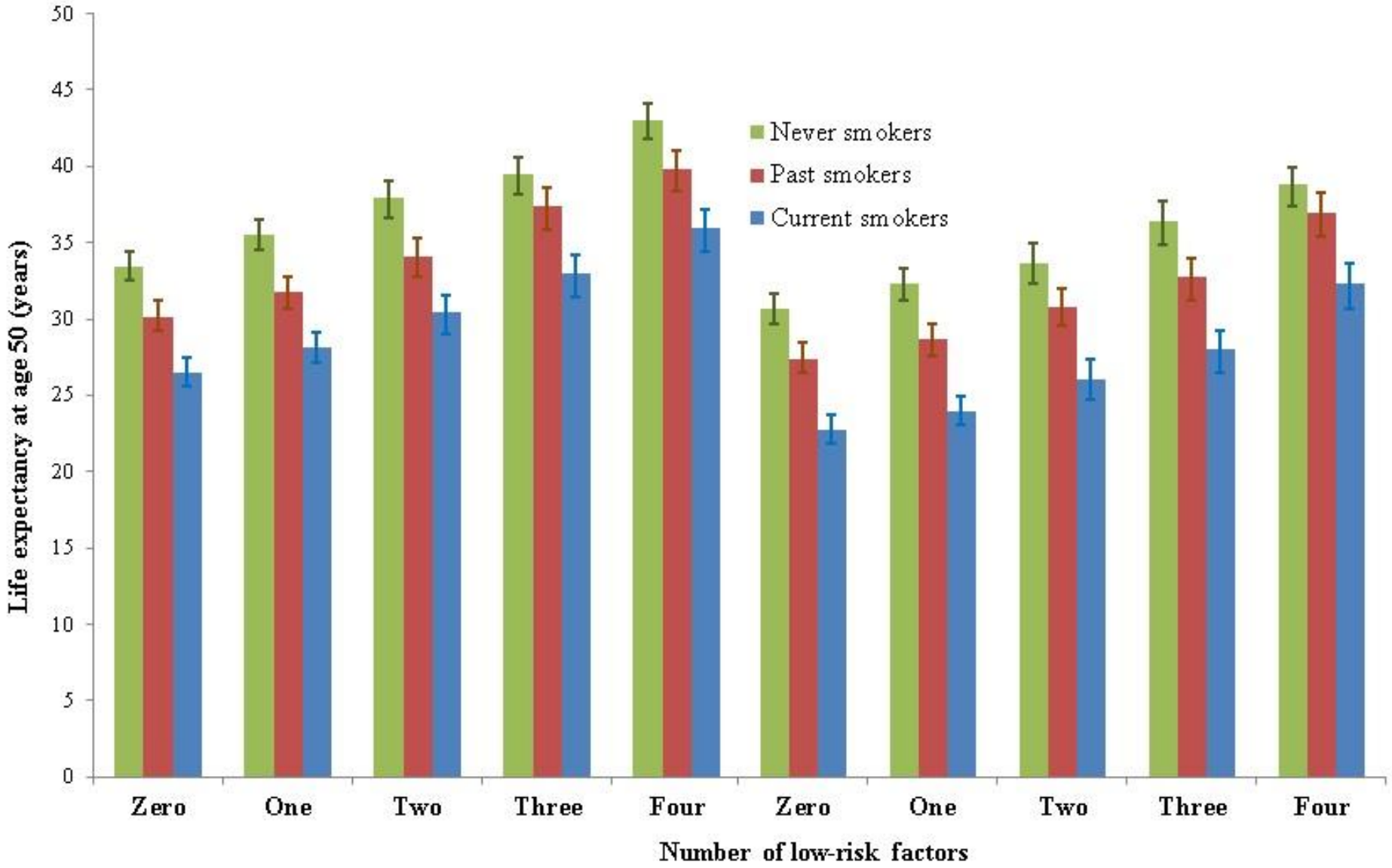
C: Estimated future years of life gained from adopting five versus zero low-risk factors attributable to less CVD, cancer and other mortality causes



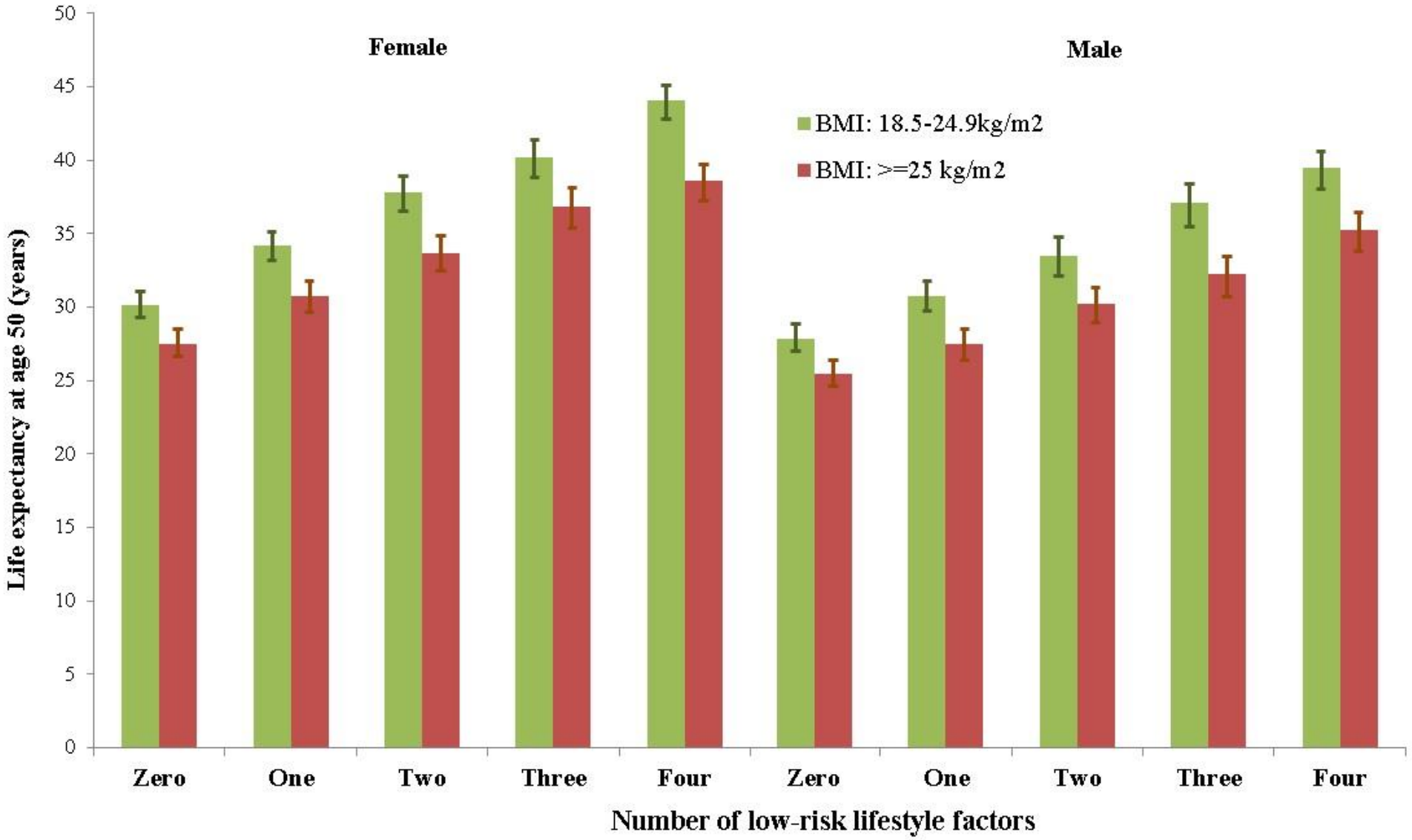
Supplemental Figure 3: Life expectancy estimated based on overall mortality rate of Americans (CDC report) and the prevalence of lifestyle factors using NHANES data 2013-2014 and sex-specific Harvard Ratios (A: life expectancy at age 50; B: life expectancy by age; C: attributable life expectancy) [*, †]

* Low-risk lifestyle factors included: cigarette smoking (never smoking), physically active (≥3.5 hours/week moderate to vigorous intensity activity), high diet quality (upper 40% of alternative healthy eating index (AHEI), moderate alcohol intake of 5-15 g/day (female) or 5-30 g/day (male), and normal weight (body mass index <25 kg/m^2).

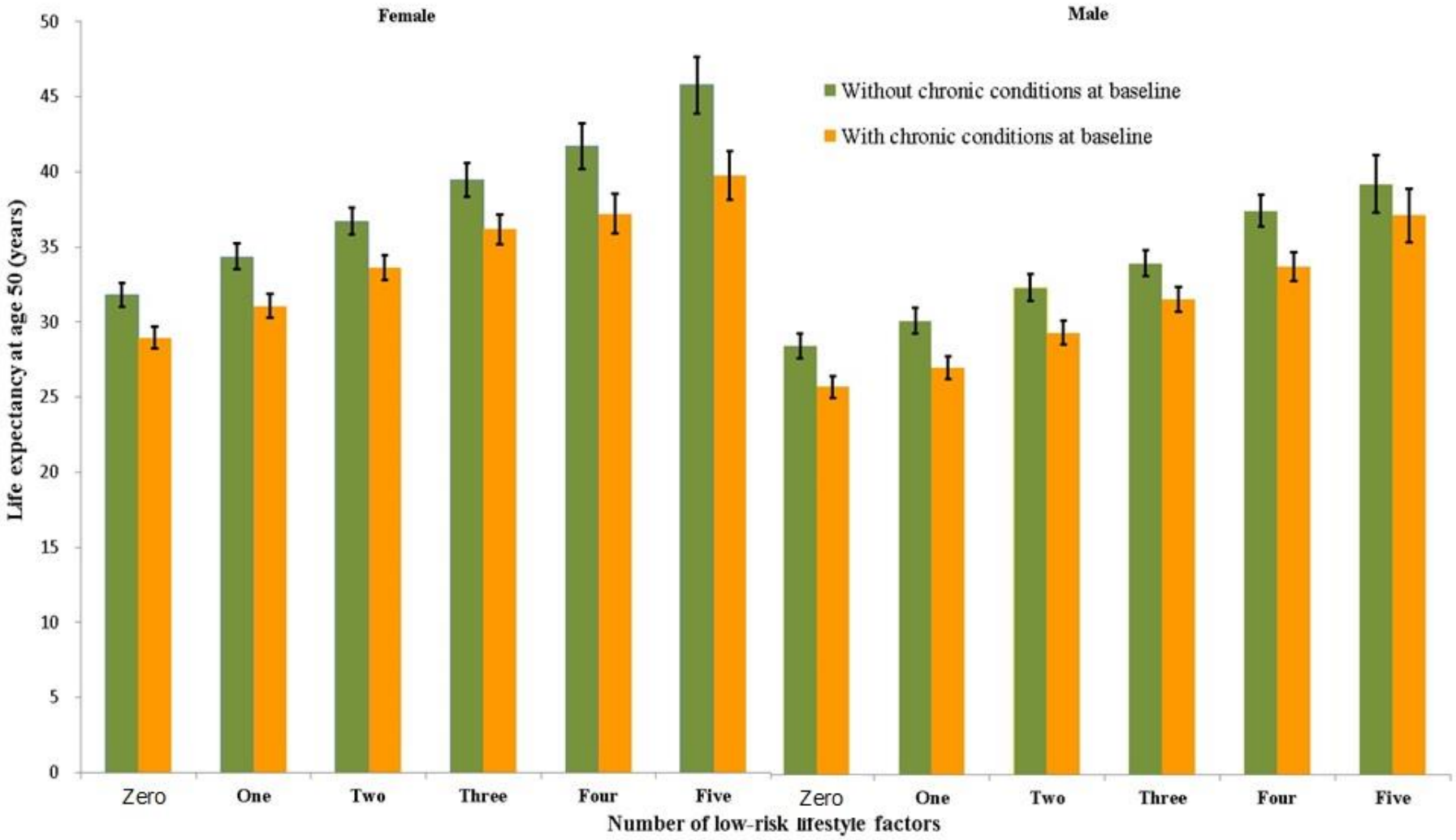
†The estimates of cumulative survival from 50 years of age onward among the 5 lifestyle risk factor groups were calculated by applying: (1) all-cause and cause-specific mortality rates were obtained from the US CDC WONDER database; (2) distribution of different numbers of low-risk lifestyles was based on the US NHANES 2013-2014; (3) multivariate-adjusted hazard ratios (gender-specific but same across age) for all-cause and cause-specific mortality associated with the 5 low-risk lifestyles as compared to those without any low-risk lifestyle factors, adjusted for age, ethnicity, current multivitamin use, current aspirin use, family history of diabetes mellitus, myocardial infarction, or cancer, and menopausal status and hormone use (females only), were based on data from the NHS and HPFS.



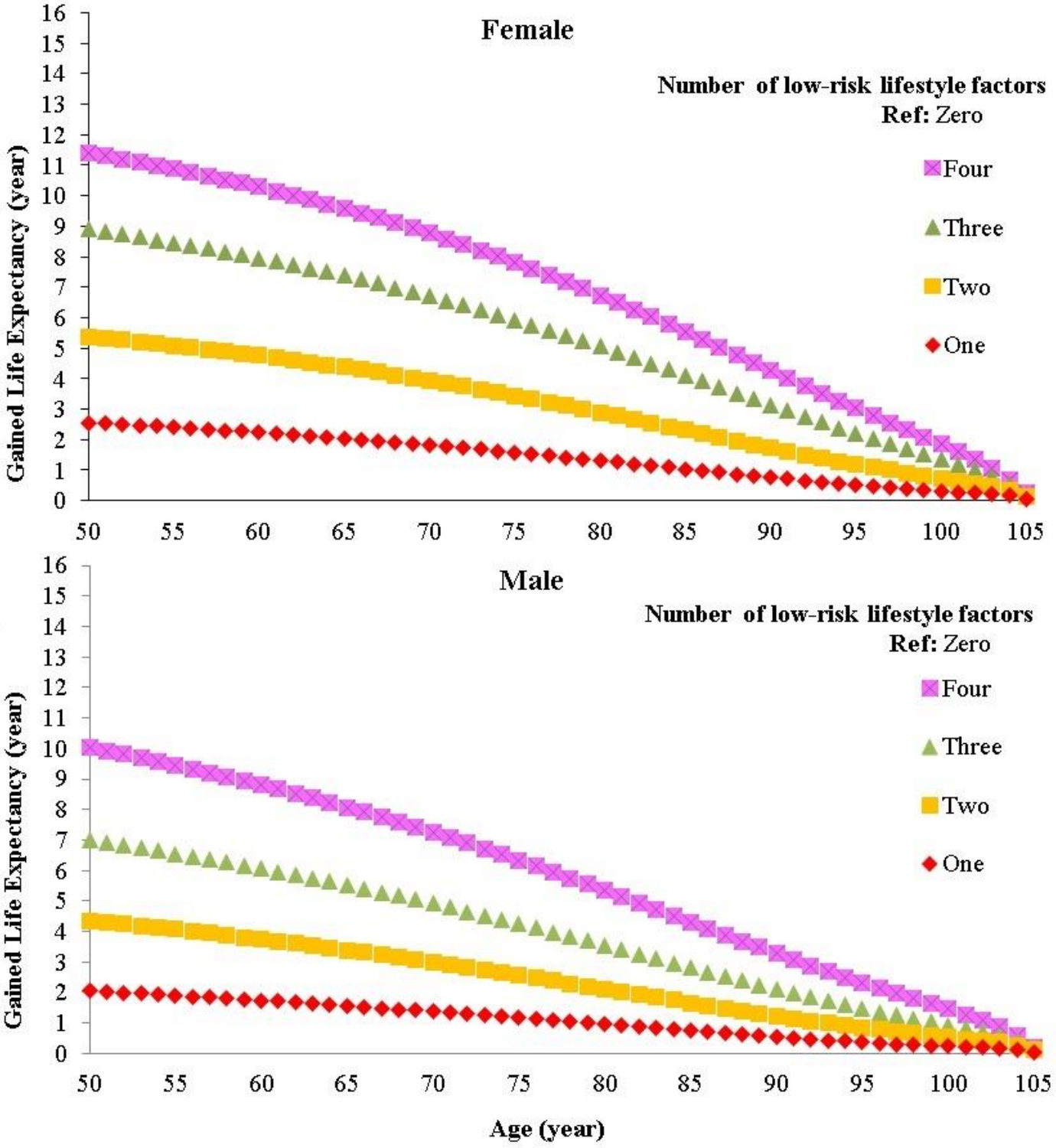
Supplemental Figure 4 Estimated life expectancy at age 50 according to the number of low-risk factors stratified by smoking status (Low-risk lifestyle factors included: physical active (≥3.5 hours/week moderate to vigorous intensity activity), high diet quality (upper 40%of alternative healthy eating index (AHEI), moderate alcohol intake of 5-15 g/day (female) or 5-30 g/day (male), and normal weight (body mass index 18.5-24.9 kg/m^2).



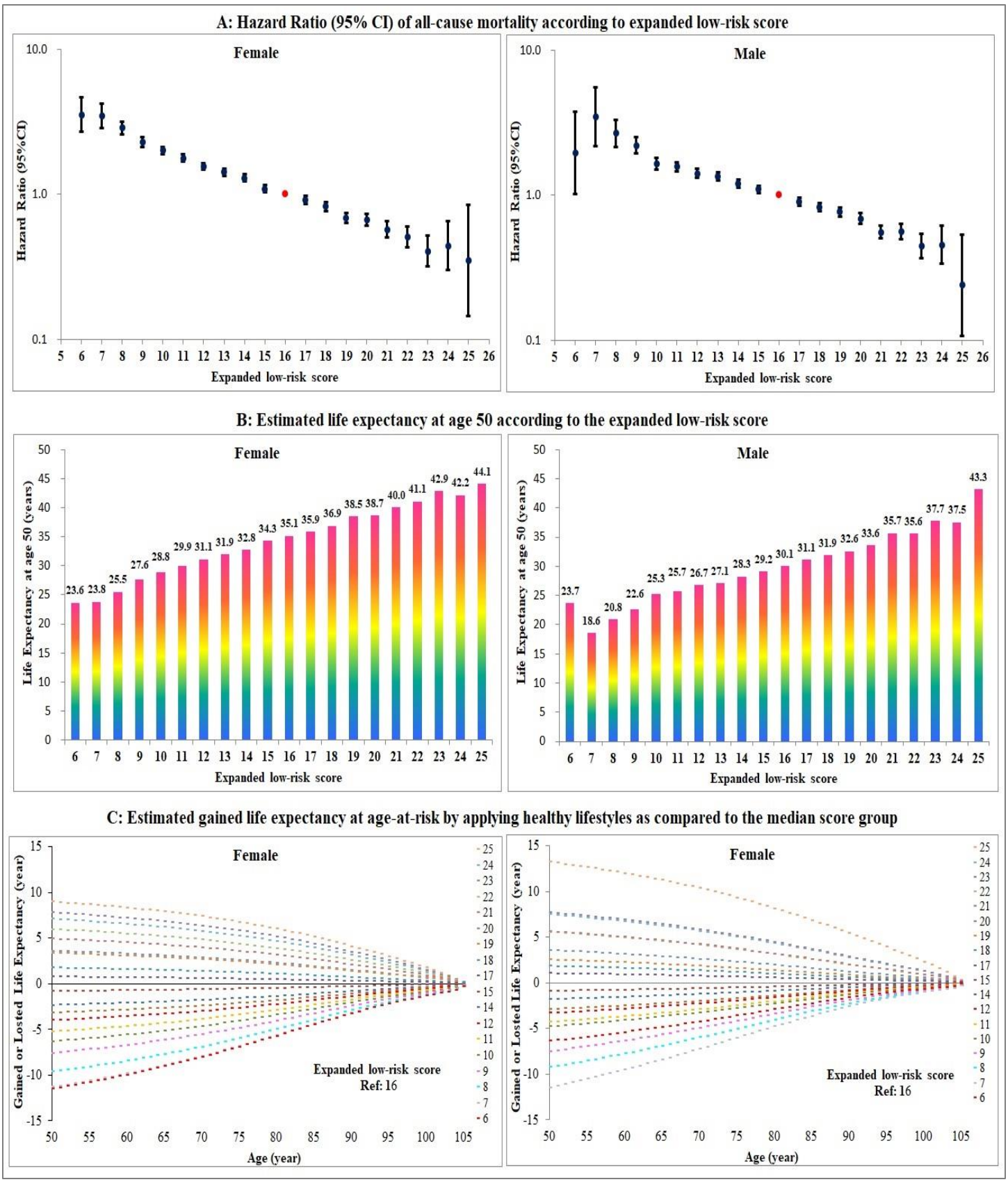
Supplemental Figure 5 Estimated life expectancy at age 50 according to the number of low low-risk factors stratified by BMI status (Low-risk lifestyle factors included: physical active (≥3.5 hours/week moderate to vigorous intensity activity), high diet quality (upper 40%of alternative healthy eating index (AHEI), and never smoking)



Supplemental Figure 6 Estimated life expectancy at age 50 according to the number of low-risk factors stratified by the disease status at baseline



Supplemental Figure 7 Sensitivity analysis of excluding moderate alcohol intake from the low-risk score (Estimated gained life expectancy at different age by applying one to four low-risk factors as compared to zero low-risk factor; low-risk lifestyle factors included: physical active (≥3.5 hours/week moderate to vigorous intensity activity), high diet quality (upper 40%of alternative healthy eating index (AHEI), normal weight (body mass index 18.5-24.9 kg/m^2), and cigarette smoking (never smoking)).



Supplemental Figure 8: Hazard Ratio of all-cause mortality and estimated life expectancy according to expanded low-risk score (A: hazard ratio; B: life expectancy at age 50; C: life expectancy by age)*,**

[*] For expanded low-risk score, we assigned scores of 1 (least healthy) to 5 (most healthy) to the categories of the lifestyle factors and summed the points across all 5 factors as below (score for each category is listed in the bracket following:

- Body mass index (kg/m^2): 18.5-22.9 (5), 23-24.9 (4), 25-29.9 (3), 30-34.9 (2), ≥35 (1)
- Cigarette smoking: never (5), past (4), current 1-14/day (3), Current 15-24/day (2), Current ≥25/day (1)
- Alcohol consumption (g/day): 0 (1), 1-4.9 (3), 5-14.9 (5), 15-29.9 (4), ≥30 (2)
- Physical activity (hours/week): 0 (1), 0.1-0.9 (2), 1.0-3.4 (3), 3.5-5.9 (4), ≥6 (5)
- Alternative healthy eating index: Fifth 1 (1), Fifth 2 (2), Fifth 3 (3), Fifth 4 (4), Fifth 5 (5)

Because too few participants classified in score=5, so the score 5 and 6 are combined as score 5-6, and the overall range of expanded low-risk score was 6-25; The cases of all-cause mortality according to the expanded low-risk score was score 5-6: 64 deaths; 7: 125; 8: 552; 9: 1393; 10: 2501; 11: 3652; 12: 4329; 13: 4982; 14: 5134; 15: 4628; 16: 4084; 17: 3393; 18: 2664; 19: 1883; 20: 1318; 21: 756; 22: 449; 23: 179; 70: 66, 25: 11.

[**]The estimates of cumulative survival from 50 years of age onward among the 5 lifestyle risk factor groups were calculated by applying

- All-cause and cause-specific mortality rates were obtained from the US CDC WONDER database;
- Distribution of different numbers of low-risk lifestyles was based on the US NHANES 2013-2014; The proportion of the expanded low-risk score was: score 5-6: 0.14%; 7: 0.47%; 8: 1.30%; 9: 2.21%; 10: 2.30%; 11: 5.67%; 12: 6.51%; 13: 6.61%; 14: 9.56%; 15: 8.96%; 16: 12.29%; 17: 10.84%; 18: 8.41%; 19: 7.84%; 20: 6.06%; 21: 4.23%; 22: 2.65%; 23: 1.58%; 24: 1.42%; 25: 0.29%.
- Multivariate-adjusted hazard ratios (gender-specific) for all-cause and cause-specific mortality associated with the expanded low-risk score as compared to whose score equal 16 (median score), adjusted for age, ethnicity, current multivitamin use, current aspirin use, family history of diabetes mellitus, myocardial infarction, or cancer, and menopausal status and hormone use (females only), were based on data of NHS and HPFS.