Trends in Cardiovascular Health Metrics and Associations With All-Cause and CVD Mortality Among US Adults

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CARDIOVASCULAR DISEASE (CVD) is the leading cause of deaths in the United States (>800,000, or about 1 in 3 overall deaths/y), with estimated annual direct and overall costs of $273 billion and $444 billion, respectively. Previous epidemiologic studies indicate that individuals who meet an increased number of cardiovascular health behaviors or factors (such as not smoking and achieving normal blood pressure, blood glucose level, and weight) have a significantly reduced risk of CVD incidence and mortality. Achieving and maintaining cardiovascular health behaviors and factors in individuals and communities could have significant effects on reducing CVD incidence and mortality at the population level.

Based on evidence from randomized clinical trials and epidemiologic studies, the American Heart Association (AHA) recently published recommendations aimed at improving cardiovascular health and reducing CVD mortality in the United States by encouraging the general population to meet 7 defined ideal cardiovascular health behaviors or factors, for the purpose of this study called cardiovascular health metrics (ie, not smoking; being physically active; having normal blood pressure, blood glucose and total cholesterol levels, and weight; and eating a healthy diet).

Objective To examine time trends in cardiovascular health metrics and to estimate joint associations and population-attributable fractions of these metrics in relation to all-cause and cardiovascular disease (CVD) mortality risk.


Main Outcome Measures All-cause, CVD, and ischemic heart disease (IHD) mortality.

Results Few participants met all 7 cardiovascular health metrics (2.0% [95% CI, 1.5%-2.5%] in 1988-1994, 1.2% [95% CI, 0.8%-1.9%] in 2005-2010). Among NHANES III participants, 2673 all-cause, 1085 CVD, and 576 IHD deaths occurred (median follow-up, 14.5 years). Among participants who met 1 or fewer cardiovascular health metrics, age- and sex-standardized absolute risks were 14.8 (95% CI, 13.2-16.5) deaths per 1000 person-years for all-cause mortality, 6.5 (95% CI, 5.5-7.6) for CVD mortality, and 3.7 (95% CI, 2.8-4.5) for IHD mortality. Among those who met 6 or more metrics, corresponding risks were 5.4 (95% CI, 3.6-7.3) for all-cause mortality, 1.5 (95% CI, 0.5-2.5) for CVD mortality, and 1.1 (95% CI, 0.7-2.0) for IHD mortality. Adjusted hazard ratios were 0.49 (95% CI, 0.33-0.74) for all-cause mortality, 0.24 (95% CI, 0.13-0.47) for CVD mortality, and 0.30 (95% CI, 0.13-0.68) for IHD mortality, comparing participants who met 6 or more vs 1 or fewer cardiovascular health metrics. Adjusted population-attributable fractions were 59% (95% CI, 33%-76%) for all-cause mortality, 64% (95% CI, 28%-84%) for CVD mortality, and 63% (95% CI, 5%-89%) for IHD mortality.

Conclusion Meeting a greater number of cardiovascular health metrics was associated with a lower risk of total and CVD mortality, but the prevalence of meeting all 7 cardiovascular health metrics was low in the study population.

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vascular health metrics,3,12,13 but none also reported the prevalence of cardio-
trends of CVD risk factors1,11 and some
ies have examined the prevalence and
all-cause and CVD mortality.
lar health metrics in relation to risk of
fractions (PAFs) of these cardiovascu-
trends of these 7 cardiovascular health
metrics among 44 959 persons 20 years
or older and estimated the joint asso-
ciations with CVD mortality.

In this study, we examined the time
trends of these 7 cardiovascular health
metrics among 44 959 persons 20 years
or older and estimated the joint associ-
ations and population-attributable
fractions (PAFs) of these cardiovascu-
lar health metrics in relation to risk of
all-cause and CVD mortality.

**METHODS**

**National Health and Nutrition Examination Survey**

The National Health and Nutrition Ex-
amination Survey (NHANES) com-
prises a series of cross-sectional, na-
tional, stratified, multistage probability
surveys of the civilian, noninstitution-
alized US population. Each survey par-
ticipant completed a household inter-
view and underwent a physical
examination. NHANES III was con-
ducted in 1988-1994; beginning in 1999, the survey became a continuous
program, with every 2 years represen-
ing 1 cycle.

For trends in cardiovascular health
metrics, we used data from NHANES III (1988-1994) (n=16 215), 1999-
2004 (n=13 097), and 2005-2010
(n=15 647). All nonpregnant partici-
pants 20 years or older with available
data on cardiovascular health metrics
were included in trends analyses for
each specific metric, whereas partici-
pants with complete information on all
7 cardiovascular health metrics were in-
cluded for distribution of health
metrics.

Detailed descriptions of the plan and
operation of each survey have been pub-
lished.14,15 NHANES III and NHANES
1999-2010 received institutional re-
view board approval and required pro-
vision of written informed consent.


**Linked Mortality File (2006)**

To examine the association and PAFs
of cardiovascular health metrics in re-
lation to risk of all-cause and CVD mor-
tality, we used data from the NHANES III Linked Mortality File, in
which NHANES III–eligible participants were
matched, using a probabilistic matching
algorithm, to the National Death In-
dex through December 31, 2006, to
determine their mortality status.

**International Classification of Di-
eses, Tenth Revision** codes were used
to identify participants for whom CVD
(codes 100-178) or ischemic heart dis-
ease (IHD) (codes 120-125) were listed
as the underlying cause of death. Follow-
up of participants continued until
dehat attributable to CVD, with cen-
soring at the time of death for those who
died from causes other than CVD. Par-
ticipants not matched with a death rec-
cord were considered alive through the
total follow-up period. A complete, de-
tailed description of the methodology
is available.16

**Definition of Cardiovascular Health Metrics**

The AHA definition of ideal, interme-
diate, and poor cardiovascular health
metrics for adults and the modified defi-
nitions used in our trends and associa-
tion analyses are presented in eTable 1,

Because duration of the physical activity
was not ascertained in NHANES III, each physical activity was assigned an
intensity value (metabolic equivalent
tasks [METs]) that represents the ra-
tio of the energy expenditure of the ac-
tivity to the basal metabolic rate.17,18 We
classified the participants as physi-
ically active (ideal category) if they en-
gaged in any physical activity with 3 to
5.9 METs and 5 or more times per week
or any physical activity with 6 or more
METs and 3.0 or more times per week.19,10 The questionnaires for physical
activity were consistent from
NHANES 1999 through 2006 with du-
ration (minutes) for each activity but
changed substantially in the 2007-
2008 cycle; thus, we restricted our trend
analysis for physical activity using
data from NHANES 1999-2004 and

The healthy diet score from the AHA ranges from 0 to 5 and is calcu-
lated by summing the following com-
ponents, assigning 1 point each for the
consumption of fruits and vegetables
(≥4.5 cups/d), fish (≥two 3.5-oz
servings/ wk), fiber-rich whole grains
(≥three 1-oz-equivalent servings/d),
sodium (<1500 mg/d), and sugars-
sweetened beverages (≤36 oz/wk).10

We estimated the healthy diet score
based on the food frequency ques-
tionnaire (FFQ) for all the dietary ele-
ments, with the exception of sodium,
for which we used the National Can-
cer Institute methods to estimate the
usual intakes of sodium.20 The FFQ
was administered in NHANES III,
NHANES 2003-2004, and NHANES
2005-2006 cycles only. For trend and
association analyses, we dichotomized
the score as fewer than 2 vs 2 or more
components, owing to the paucity of
participants with a score of 4 or
greater (<1.0%).

Fasting plasma glucose values were
available for a subsample of NHANES
participants (NHANES III, n=6939;
NHANES 1999-2004, n=5635; and
NHANES 2005-2010, n=6679). For
analysis for physical activity using
data from NHANES 1999-2004 and

The healthy diet score from the
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(≥4.5 cups/d), fish (≥two 3.5-oz
servings/ wk), fiber-rich whole grains
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participants with a score of 4 or
greater (<1.0%).

Fasting plasma glucose values were
available for a subsample of NHANES
participants (NHANES III, n=6939;
NHANES 1999-2004, n=5635; and
NHANES 2005-2010, n=6679). For
trend analysis, we presented the preva-
ience of fasting plasma glucose levels
but used glycated hemoglobin (HbA1c)
values less than 5.7% as a proxy for fast-
ing glucose levels less than 100 mg/dL
(to convert to mmol/L, multiply by
0.0555) for the distribution of 7 car-
diovascular health metrics and the asso-
ciation study, as suggested by Ameri-
can Diabetes Association.21

The AHA definition of ideal cat-
alogy of smoking status included for-
ter smokers who had not smoked for
12 months or longer. Time since smok-
ning cessation was not assessed in
NHANES III. We used the categories of
“never,” “former,” and “current” smok-
ing across surveys for comparability.
However, because the results from
NHANES 1999-2004 and 2005-2010
indicated that only about 3% of for-
ter smokers had quit for less than 12
CARDIOVASCULAR HEALTH METRICS AND MORTALITY


<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Age, mean (95% CI), y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Men</td>
<td>16 215</td>
<td>45.0 (44.0-45.9)</td>
<td>13 097</td>
</tr>
<tr>
<td>Women</td>
<td>8465</td>
<td>51.8 (51.0-52.6)</td>
<td>6499</td>
</tr>
<tr>
<td>Race/ethnicity</td>
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<tr>
<td>Non-Hispanic white</td>
<td>6697</td>
<td>76.9 (74.9-79.7)</td>
<td>6567</td>
</tr>
<tr>
<td>Non-Hispanic black</td>
<td>4517</td>
<td>10.7 (9.6-11.9)</td>
<td>2530</td>
</tr>
<tr>
<td>Mexican American</td>
<td>4348</td>
<td>4.8 (4.1-5.6)</td>
<td>2954</td>
</tr>
<tr>
<td>Other</td>
<td>653</td>
<td>7.7 (6.2-9.4)</td>
<td>1046</td>
</tr>
<tr>
<td>Prevalence, % (95% CI)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

NHANES 1988-1994
- Men: 16 215, 45.0 (44.0-45.9)
- Women: 8465, 51.8 (51.0-52.6)
- Non-Hispanic white: 6697, 76.9 (74.9-79.7)
- Non-Hispanic black: 4517, 10.7 (9.6-11.9)
- Mexican American: 4348, 4.8 (4.1-5.6)
- Other: 653, 7.7 (6.2-9.4)

NHANES 1999-2004
- Men: 13 097, 45.6 (45.1-46.2)
- Women: 6499, 51.2 (50.4-51.9)
- Non-Hispanic white: 6567, 72.0 (69.7-75.1)
- Non-Hispanic black: 2530, 10.6 (9.8-12.7)
- Mexican American: 2954, 6.9 (5.5-8.7)
- Other: 1046, 10.5 (8.2-13.3)

NHANES 2005-2010
- Men: 15 647, 46.8 (46.1-47.4)
- Women: 7831, 51.1 (50.4-51.7)
- Non-Hispanic white: 7631, 69.9 (66.2-73.4)
- Non-Hispanic black: 3117, 11.1 (9.4-13.0)
- Mexican American: 2844, 8.4 (6.7-10.4)
- Other: 2055, 10.7 (9.0-12.6)

Abbreviation: NHANES, National Health and Nutrition Examination Survey.

¹Age-standardized for the entire population by the direct method to the US 2000 Census population using the age groups 20-29, 30-39, 40-49, 50-59, 60-69, 70-79, and 80 years or older.

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Sex
Age, mean (95% CI), y
16 215 45.0 (44.0-45.9)
13 097 45.6 (45.1-46.2)
15 647 46.8 (46.1-47.4)

Components vs
exceptions of the healthy diet score (2 points for the other categories, with the
7 metrics as dichotomous variables using
vascular health metrics) by recoding the
health metrics score (number of cardio-
months, we combined “never” and
“former” smoking as a single group in
the association study.

We constructed a cardiovascular health metrics score (number of cardio-
vascular health metrics) by recoding the
7 metrics as dichotomous variables using
receding a point for the AHA ideal category vs 0 points for the other categories, with
the exceptions of the healthy diet score (<2 components [0 points] vs ≥2 [1 point])
and smoking (never and former [1 point] vs current smoking [0 points])
and calculating scores as (never and former smoking [1 point] vs current smoking [0 points])
and calculating scores as (never and former smoking [1 point] vs current smoking [0 points])
+ (ideal physical activity [1 point] vs others [0 points])
+ (body mass index [BMI, calculated as
weight in kilograms divided by height in meters squared] <25 [1 point] vs others [0 points])
+ (healthy diet score ≥2 [1 point] vs <2 components [0 points])
+ (total cholesterol <200 mg/dL [to convert to mmol/L, multiply by 0.0259]
untreated [1 point] vs others [0 points])
+ (blood pressure <120/80 mm Hg untreated [1 point] vs others [0 points])
+ (HbA1c <5.7% [1 point] vs others [0 points]).
All participants were classified
as meeting 0, 1, 2, 3, 4, 5, 6, or 7 cardiovascular health metrics. For this
score, we excluded participants missing
data on 1 or more of the cardiovascular
health metrics. These dichoto-
mized variables were used in the
association study and calculation of
PAFs.

Other covariates in our association
analyses were race/ethnicity, educa-
tion, alcohol consumption, and fam-
ily history of CVD (yes/no). Race/
ethnicity was classified as non-
Hispanic white, non-Hispanic black,
Mexican American, or other. Educa-
tional attainment was classified as less
than 12 years, 12 to 15 years, or more
than 15 years of formal education.
Alcohol consumption was classified as 0,
fewer than 3, or 3 or more drinks per
week.

Statistical Analysis
We estimated the weighted means and percentages of the selected covariates
for NHANES 1988-1994, 1999-2004,
and 2005-2010. We calculated the
age-standardized and weighted prevale-
ence and 95% CIs of the cardiovascu-
lar health metrics and the cardio-
vascular health metrics score. We used
logistic regression to test for linear
trends in changes in cardiovascular
health metrics by including a time vari-
able corresponding to the approxi-
mate midpoint of the surveys and ad-
justed for age, sex, and race/ethnicity.

For the association analysis, we used
Cox proportional hazards regression to
estimate the hazard ratios (HRs) and
95% CIs for all-cause, CVD, and IHD
mortality associated with each cardio-
vascular health metrics as well as health
metrics score as a single categorical vari-
able. For the joint HRs, we combined
the participants with 0 or 1 cardiovas-
cular health metric as the reference
group, because of the paucity of par-
ticipants who met none of the defined
health metrics. We also combined par-
ticipants with 6 or 7 cardiovascular
health metrics into a single group for
a stable estimate. We presented age-, sex-, and race/ethnicity–adjusted HRs
as well as fully adjusted HRs. The mul-
tivariable-adjusted HRs included age,
sex, race/ethnicity, educational attain-
ment, alcohol consumption, family his-
tory of CVD, and 7 cardiovascular
health metrics. A P value for trends
across the HRs for the categories of the
health metrics score was calculated
using a Satterthwaite adjusted F test.

We calculated adjusted PAFs to pro-
vide an estimate of the proportion of all-
cause and CVD mortality in this co-
hort that hypothetically would have
been avoided or postponed, assuming
a causal relationship, during the fol-
low-up if all participants met all 7 car-
diovascular health metrics. All-
case and CVD mortality rates (per
1000 person-years), adjusted for age
and sex, were calculated by the num-er of cardiovascular health metrics
using the direct method of standard-
ization, with age and sex distribution
of the whole cohort as the standard.
The number of person-years of follow-up
was calculated from the time of entry
into the study until date of death or the
termination date of the study. We also
calculated Kaplan-Meier survival curves
for cumulative all-cause, CVD, and IHD
mortality by the cardiovascular health
metrics score categories and log-rank
tests for difference in cumulative mor-
tality across cardiovascular health metrics
score categories.

We conducted several sensitivity
analyses. First, we conducted strati-
ification, alcohol consumption per
week.

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fied analyses of cardiovascular health metrics and all-cause and CVD mortality by age (<60 vs ≥60 years), sex, race/ethnicity, and educational attainment (<12 vs ≥12 years). We tested for interactions of cardiovascular health metrics with these covariates by including respective interaction terms in the Cox models based on Satterthwaite-

### Table 2. Age-Standardized and Weighted Prevalence of Meeting Cardiovascular Health Metrics in Adults—NHANES 1988-1994, 1999-2004, and 2005-2010

<table>
<thead>
<tr>
<th>Cardiovascular Health Metric</th>
<th>NHANES 1988-1994&lt;sup&gt;a&lt;/sup&gt;</th>
<th>NHANES 1999-2004&lt;sup&gt;a&lt;/sup&gt;</th>
<th>NHANES 2005-2010&lt;sup&gt;a&lt;/sup&gt;</th>
<th>P Value for Trends&lt;sup&gt;b&lt;/sup&gt;</th>
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<tr>
<td>Smoking status</td>
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<tr>
<td>Never</td>
<td>7932</td>
<td>6604</td>
<td>8232</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Former</td>
<td>4041</td>
<td>3486</td>
<td>3891</td>
<td>.008</td>
</tr>
<tr>
<td>Current</td>
<td>4241</td>
<td>2986</td>
<td>3515</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Physical activity&lt;sup&gt;d&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ideal</td>
<td>5932</td>
<td>4679</td>
<td>4541</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Intermediate</td>
<td>6624</td>
<td>2436</td>
<td>911</td>
<td>.51</td>
</tr>
<tr>
<td>None</td>
<td>3625</td>
<td>5389</td>
<td>1565</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>BMI&lt;sup&gt;e&lt;/sup&gt;</td>
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<tr>
<td>&lt;25.0</td>
<td>6413</td>
<td>4122</td>
<td>4541</td>
<td>&lt;.001</td>
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<tr>
<td>25.0-29.9</td>
<td>5653</td>
<td>4563</td>
<td>5283</td>
<td>.17</td>
</tr>
<tr>
<td>30.0</td>
<td>4117</td>
<td>3896</td>
<td>5610</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Healthy diet score&lt;sup&gt;f&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>&lt;2 components</td>
<td>4932</td>
<td>709</td>
<td>637</td>
<td>&lt;.001</td>
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<tr>
<td>≥2 components</td>
<td>1128</td>
<td>2413</td>
<td>2148</td>
<td>.02</td>
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<tr>
<td>Total serum cholesterol, mg/dL&lt;sup&gt;g&lt;/sup&gt;</td>
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<td></td>
<td></td>
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<tr>
<td>&lt;200 (untreated)</td>
<td>7281</td>
<td>5428</td>
<td>6571</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>200-239 or treated to goal</td>
<td>5000</td>
<td>4894</td>
<td>6229</td>
<td>.001</td>
</tr>
<tr>
<td>≥240</td>
<td>3167</td>
<td>2101</td>
<td>2155</td>
<td>&lt;.001</td>
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<tr>
<td>Blood pressure, mm Hg&lt;sup&gt;h&lt;/sup&gt;</td>
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<tr>
<td>&lt;120/80 (untreated)</td>
<td>6170</td>
<td>4322</td>
<td>5675</td>
<td>.09</td>
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<tr>
<td>120-139/80-89 mm Hg or treated to goal</td>
<td>6015</td>
<td>4030</td>
<td>6454</td>
<td>&lt;.001</td>
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<td>≥140/≥90 mm Hg</td>
<td>4000</td>
<td>3204</td>
<td>2956</td>
<td>.04</td>
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<tr>
<td>Fasting blood glucose, mg/dL&lt;sup&gt;i&lt;/sup&gt;</td>
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<tr>
<td>&lt;100</td>
<td>4352</td>
<td>3408</td>
<td>3572</td>
<td>&lt;.001</td>
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<tr>
<td>100-126</td>
<td>2038</td>
<td>1729</td>
<td>2380</td>
<td>.001</td>
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<tr>
<td>≥126</td>
<td>549</td>
<td>498</td>
<td>727</td>
<td>.92</td>
</tr>
<tr>
<td>No. of cardiovascular health metrics&lt;sup&gt;j&lt;/sup&gt;</td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>0</td>
<td>166</td>
<td>46</td>
<td>54</td>
<td>1.4 (1.0-2.0)</td>
</tr>
<tr>
<td>1</td>
<td>1188</td>
<td>269</td>
<td>280</td>
<td>7.3 (6.6-8.2)</td>
</tr>
<tr>
<td>2</td>
<td>2063</td>
<td>616</td>
<td>595</td>
<td>18.0 (16.1-20.0)</td>
</tr>
<tr>
<td>3</td>
<td>3943</td>
<td>715</td>
<td>771</td>
<td>25.5 (22.9-28.4)</td>
</tr>
<tr>
<td>4</td>
<td>3584</td>
<td>618</td>
<td>642</td>
<td>22.4 (21.5-23.3)</td>
</tr>
<tr>
<td>5</td>
<td>2371</td>
<td>342</td>
<td>419</td>
<td>16.6 (14.6-18.7)</td>
</tr>
<tr>
<td>6</td>
<td>934</td>
<td>128</td>
<td>168</td>
<td>7.5 (6.2-9.1)</td>
</tr>
<tr>
<td>7</td>
<td>166</td>
<td>31</td>
<td>26</td>
<td>1.2 (0.8-1.9)</td>
</tr>
<tr>
<td>0-1</td>
<td>1354</td>
<td>315</td>
<td>334</td>
<td>8.8 (8.0-9.6)</td>
</tr>
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<td>≥6</td>
<td>1100</td>
<td>159</td>
<td>194</td>
<td>8.8 (7.3-10.6)</td>
</tr>
</tbody>
</table>

Abbreviations: BMI, body mass index; NHANES, National Health and Nutrition Examination Survey. SI conversion factors: To convert total cholesterol values to mmol/L, multiply by 0.0259; to convert glucose values to mmol/L, multiply by 0.0595.

<sup>a</sup>For trends across the surveys using logistic regression model adjusted for age, sex, and race/ethnicity, all tests 2-tailed.

<sup>b</sup>For nonpregnant participants 20 years or older with available cardiovascular health metrics were included in trends analyses for each specific metric; therefore, sample sizes might vary by the cardiovascular health metrics.

<sup>c</sup>Ideal: 150 minutes per week or more at moderate intensity or 75 minutes per week or more at vigorous intensity or 150 minutes per week or more at moderate-vigorous intensity. Intermediate: 1 to 149 minutes per week at moderate intensity or 1 to 74 minutes per week at vigorous intensity or 150 minutes per week or more at moderate-vigorous intensity. Duration of the physical activity was not ascertained in NHANES III; see “Methods” for details of classification of physical activity.

<sup>d</sup>See “Methods” for details of calculation of cardiovascular health metrics scores.

<sup>e</sup>Calculated as weight in kilograms divided by height in meters squared.

<sup>f</sup>See “Methods” for details of calculation of healthy diet score. Trends may be attributed to change in questionnaires from NHANES III to NHANES 1999-2004 and NHANES 2005-2010.

<sup>g</sup>Interved value.

<sup>h</sup>Fasting glucose level was available for the subsample of participants in NHANES III, NHANES 1999-2004, and NHANES 2005-2010.

<sup>i</sup>See “Methods” for details of calculation of cardiovascular health metrics scores.

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adjusted tests. Second, because BMI and total cholesterol levels showed a U-shaped relationship with all-cause and CVD mortality in this cohort, we used BMI less than 30 vs 30 or greater and total cholesterol levels less than 240 mg/dL vs 240 mg/dL or greater in the sensitivity analyses. Third, we estimated the associations of cardiovascular health metrics in relation to the risk of cancer mortality (eTables 2-8).

The proportional hazards assumption of the Cox models was evaluated with Schoenfeld residuals, which revealed no significant departures from proportionality in hazards over time (P > .05). Data were analyzed using SAS release 9.2 and SUDAAN release 10, taking into account the complex sampling design. All tests were 2-sided, and P < .05 was considered statistically significant.

RESULTS

Demographic characteristics of the study participants are reported in Table 1. As shown in Table 2, the prevalence of current smoking declined from 27.9% (95% CI, 26.4%-29.3%) in NHANES III (1988-1994) to 22.6% (95% CI, 21.3%-24.1%) in 2005-2010 (P < .001 for trend). The prevalence of adults with desirable total cholesterol levels (<200 mg/dL) and blood pressure (<120 mm Hg/<80 mm Hg) remained largely unchanged. However, the prevalence of consuming a healthy diet (≥2 healthy diet score components), having a BMI less than 25, and having a fasting glucose level less than 100 mg/dL declined significantly from 1988-1994 to 2005-2010 (P < .05).

Few participants (<2%) met all 7 cardiovascular health metrics. The prevalence of meeting 6 or more cardiovascular health metrics was 10.3% (95% CI, 9.4%-11.3%) in 1988-1994 and 8.8% (95% CI, 7.3%-10.6%) in 2005-2010, and the prevalence of meeting 1 or fewer cardiovascular health metrics increased from 7.2% (95% CI, 6.5%-8.0%) to 8.8% (95% CI, 8.0%-9.6%) (P < .05 for trend).

Of the nonpregnant adults 20 years or older with complete data on all 7 cardiovascular health metrics and complete mortality follow-up information (n = 15,305), we sequentially excluded 1262 participants who reported a history of myocardial infarction, stroke, or congestive heart failure, 465 with diagnosed cancer, and 266 with BMI less than 18.5 at baseline. After these exclusions, 13,312 NHANES III participants were available for the association study. There were 2673 total, 1085 CVD, and 576 IHD deaths among 182,352 person-years of follow-up (median follow-up, 14.5 years). Younger participants, women, non-Hispanic whites, and those with higher education levels tended to meet a greater number of cardiovascular health metrics (eTable 9).

After multivariable adjustment, not smoking, being physically active, having normal blood pressure, and having an HbA1c level less than 5.7% were independently associated with a significantly lower risk of all-cause mortality (Table 3). A similar pattern was observed for CVD mortality (Table 4).
Not smoking, eating a healthy diet (≥2 healthy diet score components), and having an HbA1c level less than 5.7% were independently associated with a significantly reduced rate of IHD mortality (Table 5).

Adjusted PAFs for all-cause mortality ranged from 10.5% (95% CI, 6.2%-14.7%) for HbA1c level of 5.7% or greater to 30.4% (95% CI, 19.4%-40.6%) for elevated blood pressure (Table 3); PAFs for CVD mortality ranged from 8.8% (95% CI, 2.1%-15.4%) for HbA1c level of 5.7% or greater to 40.6% (95% CI, 24.5%-54.6%) for elevated blood pressure (Table 4); PAFs for IHD mortality ranged from 7.5% (95% CI, 3.0%-14.7%) for HbA1c level of 5.7% or greater to 34.7% (95% CI, 6.6%-57.7%) for elevated blood pressure (Table 5).

Among participants who met 1 or fewer cardiovascular health metrics, age- and sex-standardized absolute risks were 14.8 (95% CI, 13.2-16.5) deaths per 1000 person-years for all-cause mortality, 6.5 (95% CI, 5.5-7.6) for CVD mortality, and 3.7 (95% CI, 2.8-4.5) for IHD mortality. Among participants who met 6 or more cardiovascular health metrics, corresponding risks were 5.4 (95% CI, 3.6-7.3) deaths per 1000 person-years for all-cause mortality, 1.5 (95% CI, 0.5-2.5) for CVD mortality, and 1.1 (95% CI, 0.7-2.0) for IHD mortality (P < .001 for linear trends) (Figure 1).

Comparing participants with 6 or more vs 1 or fewer cardiovascular health metrics, the adjusted HR was 0.49 (95% CI, 0.33-0.74) for all-cause mortality, 0.24 (95% CI, 0.13-0.47) for CVD mortality, and 0.30 (95% CI, 0.13-0.68) for IHD mortality. Meeting a greater number of cardiovascular health metrics was associated with a significantly lower risk of all-cause, CVD, and IHD mortality (P < .001 for linear trends) (Table 6). Adjusted PAFs were 58.6% (95% CI, 33.2%-76.1%) for all-cause mortality, 63.9% (95% CI, 28.0%-84.1%) for CVD mortality, and 62.9% (95% CI, 53.3%-89.1%) for IHD mortality.

Figure 2 shows the Kaplan-Meier survival curves for cumulative all-cause, CVD, and IHD mortality among participants meeting 0-1, 2, 3, 4, 5, and 6 or more cardiovascular health metrics (P < .001 for all log-rank tests). The patterns of the reduced risk for all-cause, CVD, or IHD mortality, in association with meeting greater numbers of cardiovascular health metrics, remained largely consistent across subgroups defined by age, sex, race/ethnicity, and educational attainment (eTables 2-5). The significant interaction between cardiovascular health metrics and age group (<60 vs ≥60 years, P < .02) on CVD mortality suggested that meeting cardiovascular health metrics might offer greater protection against premature CVD deaths among younger participants (eTable 2). However, the absolute numbers of CVD deaths that would be avoided or postponed by meeting a greater number of cardiovascular health metrics would be substantially larger among older participants because of much higher baseline risk in the older population.

**COMMENT**

Using a series of nationally representative samples of the adult population, our results indicated that prevalence of current smoking continued to decline since 1988. However, the desirable level of untreated blood pressure (<120/80 mm Hg) and total cholesterol level (<200 mg/dL) remained unchanged, and the prevalence of desirable levels of BMI (<25) and fasting glucose (<100 mg/dL) continued to decline for

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Table 4. Adjusted Hazard Ratio and Population-Attributable Fraction of Cardiovascular Health Metrics and Risk of CVD Mortality—NHANES III Linked Mortality File

<table>
<thead>
<tr>
<th>Cardiovascular Health Metrica</th>
<th>Cases/ Participants</th>
<th>Age-, Sex-, and Race/Ethnicity-Adjusted</th>
<th>Fully Adjustedb</th>
<th>Adjusted PAF (95% CI)c</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current smoking</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>229/3542</td>
<td>1 [Reference]</td>
<td>1 [Reference]</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>856/9770</td>
<td>0.46 (0.38-0.57)</td>
<td>0.50 (0.39-0.64)</td>
<td>13.7 (4.8-22.3)</td>
</tr>
<tr>
<td>Physical activity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>718/8316</td>
<td>1 [Reference]</td>
<td>1 [Reference]</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>367/4996</td>
<td>0.74 (0.63-0.87)</td>
<td>0.77 (0.65-0.92)</td>
<td>11.9 (1.3-22.3)</td>
</tr>
<tr>
<td>BMIa</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≥25</td>
<td>694/8160</td>
<td>1 [Reference]</td>
<td>1 [Reference]</td>
<td></td>
</tr>
<tr>
<td>&lt;25</td>
<td>391/5152</td>
<td>1.00 (0.85-1.18)</td>
<td>1.05 (0.88-1.25)</td>
<td>NA</td>
</tr>
<tr>
<td>Healthy diet score</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;2 components</td>
<td>763/10 245</td>
<td>1 [Reference]</td>
<td>1 [Reference]</td>
<td></td>
</tr>
<tr>
<td>≥2 components</td>
<td>322/3067</td>
<td>0.74 (0.60-0.90)</td>
<td>0.82 (0.67-1.02)</td>
<td>13.2 (3.5-29.2)</td>
</tr>
<tr>
<td>Total serum cholesterol, mg/dL</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≥200</td>
<td>357/6481</td>
<td>1 [Reference]</td>
<td>1 [Reference]</td>
<td></td>
</tr>
<tr>
<td>&lt;200 (untreated)</td>
<td>728/6831</td>
<td>0.98 (0.84-1.15)</td>
<td>1.02 (0.87-1.21)</td>
<td>NA</td>
</tr>
<tr>
<td>Blood pressure, mm Hg</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≥120/≥80</td>
<td>981/7947</td>
<td>1 [Reference]</td>
<td>1 [Reference]</td>
<td></td>
</tr>
<tr>
<td>&lt;120/&lt;80 (untreated)</td>
<td>104/3565</td>
<td>0.61 (0.45-0.83)</td>
<td>0.64 (0.47-0.86)</td>
<td>40.6 (24.5-54.6)</td>
</tr>
<tr>
<td>HbA1ca, %</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≥5.7</td>
<td>497/3233</td>
<td>1 [Reference]</td>
<td>1 [Reference]</td>
<td></td>
</tr>
<tr>
<td>&lt;5.7</td>
<td>588/10 079</td>
<td>0.66 (0.54-0.80)</td>
<td>0.71 (0.58-0.86)</td>
<td>8.8 (2.1-15.4)</td>
</tr>
</tbody>
</table>

Abbreviations: BMI, body mass index; CVD, cardiovascular disease; HbA1c, glycated hemoglobin; HR, hazard ratio; IHD, ischemic heart disease; NA, not available; NHANES, National Health and Nutrition Examination Survey; PAF, population-attributable fraction.

*SI conversion factors: To convert total cholesterol values to mmol/L, multiply by 0.0259.

aSee Table 3, footnote “a.”

bSee Table 3, footnote “b.”

cSee Table 3, footnote “c.”

dCalculated as weight in kilograms divided by height in meters squared.

eAn HbA1c value less than 5.7% was used as a proxy for a fasting glucose level less than 100 mg/dL.
the study period. The prevalence of meeting all 7 cardiovascular health metrics was low.

During a median of 14.5 years of follow-up in the NHANES III Linked Mortality File cohort, participants who met 6 or more vs 1 or fewer cardiovascular health metrics had a 51% lower risk of all-cause mortality, a 76% lower risk of CVD mortality, and a 70% lower risk of IHD mortality. In addition, meeting a greater number of cardiovascular health metrics also appeared to be associated with lower risk for all-cancer mortality (eTable 6).

Elevated blood pressure, including prehypertension and hypertension, was associated with the largest adjusted PAFs for all-cause and CVD deaths in this cohort (30.4% and 40.6%, respectively). Hypertension affected approximately 68 million individuals in the United States in 2009.27 Studies suggest that for every 10% increase in hypertension treatment, an estimated 14 000 deaths would be prevented annually.28 Although the awareness, treatment, and management of hypertension are extremely important in prevention of CVD incidence and mortality, our results indicated that the desirable level of blood pressure ($<120/80$ mm Hg) among the adult population remained unchanged since Table 5.

### Table 5. Adjusted Hazard Ratio and Population-Attributable Fraction of Cardiovascular Health Metrics and Risk of IHD Mortality—NHANES III Linked Mortality File

<table>
<thead>
<tr>
<th>Cardiovascular Health Metric</th>
<th>Cases/Participants</th>
<th>Age-, Sex-, and Race/Ethnicity–Adjusted</th>
<th>Fully Adjusted</th>
<th>Adjusted PAF (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current smoking</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>120/3542</td>
<td>1 [Reference]</td>
<td>1 [Reference]</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>456/9770</td>
<td>0.42 (0.32-0.56)</td>
<td>0.48 (0.35-0.66)</td>
<td>16.7 (6.4-26.6)</td>
</tr>
<tr>
<td>Physical activity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>377/8316</td>
<td>1 [Reference]</td>
<td>1 [Reference]</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>199/4996</td>
<td>0.76 (0.61-0.94)</td>
<td>0.83 (0.65-1.06)</td>
<td>7.8 (0.0-22.2)</td>
</tr>
<tr>
<td>BMI</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$&lt;25$</td>
<td>353/8160</td>
<td>1 [Reference]</td>
<td>1 [Reference]</td>
<td></td>
</tr>
<tr>
<td>$25$</td>
<td>223/5152</td>
<td>1.11 (0.87-1.42)</td>
<td>1.16 (0.90-1.49)</td>
<td>NA</td>
</tr>
<tr>
<td>Healthy diet score</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$&lt;2$ components</td>
<td>412/10 245</td>
<td>1 [Reference]</td>
<td>1 [Reference]</td>
<td></td>
</tr>
<tr>
<td>$\geq2$ components</td>
<td>164/3067</td>
<td>0.65 (0.48-0.87)</td>
<td>0.74 (0.55-0.98)</td>
<td>20.6 (1.2-38.6)</td>
</tr>
<tr>
<td>Total serum cholesterol, mg/dL</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$&lt;200$</td>
<td>391/6481</td>
<td>1 [Reference]</td>
<td>1 [Reference]</td>
<td></td>
</tr>
<tr>
<td>$\geq200$ (untreated)</td>
<td>185/6831</td>
<td>0.98 (0.78-1.22)</td>
<td>1.00 (0.79-1.30)</td>
<td>NA</td>
</tr>
<tr>
<td>Blood pressure, mm Hg</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$&lt;120/80$ (untreated)</td>
<td>58/5365</td>
<td>0.66 (0.38-1.12)</td>
<td>0.67 (0.39-1.13)</td>
<td>34.7 (6.6-57.7)</td>
</tr>
<tr>
<td>$HbA_1c,$ %</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$&lt;5.7$</td>
<td>262/3233</td>
<td>1 [Reference]</td>
<td>1 [Reference]</td>
<td></td>
</tr>
<tr>
<td>$\geq5.7$ (untreated)</td>
<td>314/10 079</td>
<td>0.66 (0.51-0.85)</td>
<td>0.71 (0.55-0.90)</td>
<td>7.5 (3.0-14.7)</td>
</tr>
</tbody>
</table>

Abbreviations: BMI, body mass index; CVD, cardiovascular disease; $HbA_1c,$ glycated hemoglobin; HR, hazard ratio; IHD, ischemic heart disease; NA, not available; NHANES, National Health and Nutrition Examination Survey; PAF, population-attributable fraction. SI conversion factors: To convert total cholesterol values to mmol/L, multiply by 0.0259.

Figure 1. Age- and Sex-Standardized Mortality Rates per 1000 Person-Years of All-Cause, CVD, and IHD Mortality, by Number of Cardiovascular Health Metrics—NHANES III Linked Mortality File

Error bars indicate 95% CIs. Y-axis segments shown in blue indicate range from 0 to 8. CVD indicates cardiovascular disease; IHD, ischemic heart disease; NHANES, National Health and Nutrition Examination Survey.
1988. In addition to high sodium intake,29 overweight or obesity, lack of physical activity, high alcohol intake, and poor diet are other important modifiable risk factors for elevated blood pressure and hypertension, supporting the importance of primordial prevention of elevated blood pressure through behavioral and policy changes.30

Smoking was associated with the second-largest adjusted PAF for all-cause mortality and significantly contributed to the CVD mortality in our study. Although the prevalence of smoking among US adult populations declined over the last 40 years,31,32 about 1 in 5 US adults (23%) were current cigarette smokers in 2005-2010. Every 5% increase in smoking cessation would prevent 7000 deaths annually.28 Continuing to implement population-based prevention strategies, operationalize tobacco control policies, and promote clinical cessation interventions would further reduce the prevalence of smoking and improve cardiovascular health in the population at large.

Many observational studies provide strong evidence to support the benefits of healthy diets and physical activity on CVD incidence and mortality.25,35 Both diet and physical activity affect the presence and severity of CVD risk factors.44-46 Despite the recommendations and well-known benefits of eating fruits and vegetables daily and engaging in regular physical activity, only about 1 in 5 adults met the AHA intermediate level of healthy diet (≥2 healthy diet score components), less than 1% met the ideal level (≥4 components), and there was no evidence of increased prevalence of healthy diet over time. Although the prevalence of physical activity has increased slightly since the late 1980s,44,46 the majority of US adults are not physically active at levels that can promote health. Additionally, significant racial/ethnic disparities in physical activity levels have been observed.44-47 Federal, state, and local public health agencies should continue to implement evidence-based, culturally appropriate public education and policy initiatives to further increase physical activity levels and promote healthy diets among all adults in the United States.

The prevalence of BMI less than 25 and fasting glucose levels less than 100 mg/dL continues to decline signifi-

### Table 6. Adjusted Hazard Ratios of All-Cause and CVD Mortality by Cardiovascular Health Metrics—NHANES III Linked Mortality File

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>No. of Cardiovascular Health Metrics&lt;sup&gt;b&lt;/sup&gt;</th>
<th>P Value for Trends&lt;sup&gt;c&lt;/sup&gt;</th>
<th>Adjusted PAF (95% CI)&lt;sup&gt;d&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>All-cause mortality</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All deaths</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. of participants</td>
<td>1236</td>
<td>2608</td>
<td>3370</td>
</tr>
<tr>
<td>Total person-years</td>
<td>15,894</td>
<td>34,666</td>
<td>45,515</td>
</tr>
<tr>
<td>Age-, sex-, and race/ethnicity−adjusted HR</td>
<td>1 [Reference]</td>
<td>0.79 (0.67-0.94)</td>
<td>0.69 (0.58-0.81)</td>
</tr>
<tr>
<td>Fully adjusted HR&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1 [Reference]</td>
<td>0.81 (0.68-0.97)</td>
<td>0.71 (0.60-0.84)</td>
</tr>
<tr>
<td><strong>CVD mortality</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CVD deaths</td>
<td>183</td>
<td>303</td>
<td>300</td>
</tr>
<tr>
<td>No. of participants</td>
<td>1236</td>
<td>2608</td>
<td>3370</td>
</tr>
<tr>
<td>Total person-years</td>
<td>15,894</td>
<td>34,666</td>
<td>45,515</td>
</tr>
<tr>
<td>Age-, sex-, and race/ethnicity−adjusted HR</td>
<td>1 [Reference]</td>
<td>0.72 (0.58-0.89)</td>
<td>0.55 (0.43-0.69)</td>
</tr>
<tr>
<td>Fully adjusted HR&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1 [Reference]</td>
<td>0.73 (0.59-0.91)</td>
<td>0.56 (0.44-0.71)</td>
</tr>
<tr>
<td><strong>IHD mortality</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IHD deaths</td>
<td>94</td>
<td>163</td>
<td>158</td>
</tr>
<tr>
<td>No. of participants</td>
<td>1236</td>
<td>2608</td>
<td>3370</td>
</tr>
<tr>
<td>Total person-years</td>
<td>15,894</td>
<td>34,666</td>
<td>45,515</td>
</tr>
<tr>
<td>Age-, sex-, and race/ethnicity−adjusted HR</td>
<td>1 [Reference]</td>
<td>0.72 (0.54-0.98)</td>
<td>0.52 (0.39-0.70)</td>
</tr>
<tr>
<td>Fully adjusted HR&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1 [Reference]</td>
<td>0.74 (0.55-1.00)</td>
<td>0.54 (0.40-0.72)</td>
</tr>
</tbody>
</table>

Abbreviations: CVD, cardiovascular disease; HR, hazard ratio; IHD, ischemic heart disease; NHANES, National Health and Nutrition Examination Survey; PAF, population-attributable fraction.

<sup>a</sup>Adjusted for age, sex, race/ethnicity, educational attainment, alcohol intake, family history of CVD, smoking status, physical activity, body mass index, health diet score, total cholesterol level, blood pressure, and glycated hemoglobin level.

<sup>b</sup>See “Methods” for details of calculation of cardiovascular health metrics scores.

<sup>c</sup>For trends across the categories of cardiovascular health metrics scores based on Satterthwaite adjusted F test; all tests 2-tailed.

<sup>d</sup>Adjusted for age, sex, race/ethnicity, educational attainment, alcohol intake, and family history of CVD and cardiovascular health metrics.
sically, whereas the prevalence of obesity and diabetes continues to increase among US adults, although the increase in obesity rates has slowed since mid-2000.48-52 It is estimated that 36% of US adults are obese, 8.3% have diabetes, and more than 50% of persons with diagnosed diabetes are also obese.51-53 The high prevalence of obesity and the increasing prevalence of diabetes could offset the positive effects of the decline in other CVD risk factors56,57 and continue to slow improvements in cardiovascular health. To address these competing influences, public health intervention programs aimed at improving lifestyle choices, eg, increasing physical activity and promoting healthy eating, should be made more widely available. For example, translating the Diabetes Prevention Program to community-based settings has shown promising results in improving diet and physical activity, reducing body weight, and improving cardiovascular health in general.58,59

Body mass index and total cholesterol level showed a U-shaped association with CVD mortality in this cohort.24,26 In our sensitivity analyses using BMI less than 30 vs 30 or greater and total cholesterol level less than 240 mg/dL vs 240 mg/dL or greater, these categories of BMI and total cholesterol level were associated with lower risk of CVD mortality (eTable 7), and adjusted HRs were 0.35 (95% CI, 0.26-0.46) for all-cause mortality, 0.21 (95% CI, 0.13-0.33) for CVD mortality, and 0.19 (95% CI, 0.10-0.34) for IHD mortality, comparing participants with 6 or more vs 1 or fewer cardiovascular health metrics (eTable 8). However, the prevalence of desirable total cholesterol level (<200 mg/dL) remained unchanged since 1988. Apart from actively managing cholesterol levels with medications, comprehensive primary prevention strategies promoting a healthy diet and lifestyle to increase the prevalence of desirable total cholesterol levels will improve the cardiovascular health status of the general population.

The major strengths of our study include the use of data from a series of nationally representative samples of US adults for trend analyses of cardiovascular health metrics and from a nationally representative cohort of US adults with a long duration of follow-up (median, 14.5 years) for mortality study; the availability of 7 cardiovascular health metrics measurements or appropriate proxy measurements; detailed data on potential confounders for CVD; and the estimation of adjusted PAFs for 7 cardiovascular risk factors.

Our study has several limitations. First, the NHANES III Linked Mortality File included only the baseline measurements of cardiovascular health metrics. We were not able to quantify the effects of changes in these factors over the life course on all-cause and CVD mortality. Second, the survey questionnaire about physical activity was consistent from NHANES 1999-2004 and 2005-2006 regarding duration (minutes) for each activity. However, NHANES III included no information on duration, and we thus used METs and number of times per week to approximate the AHA definition.

Figure 2. Kaplan-Meier Curves for Cumulative All-Cause, CVD, and IHD Mortality, by Number of Cardiovascular Health Metrics—NHANES III Linked Mortality File

<table>
<thead>
<tr>
<th>Cardiovascular health metrics</th>
<th>Follow-up, y</th>
<th>Log-rank P&lt;.001</th>
<th>Cumulative Mortality</th>
<th>No. at risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-1</td>
<td>1236</td>
<td>1188</td>
<td>1115</td>
<td>1025</td>
</tr>
<tr>
<td>2</td>
<td>2608</td>
<td>2511</td>
<td>2400</td>
<td>2240</td>
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<tr>
<td>3</td>
<td>3081</td>
<td>2931</td>
<td>2815</td>
<td>2700</td>
</tr>
<tr>
<td>4</td>
<td>3081</td>
<td>2931</td>
<td>2815</td>
<td>2700</td>
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<tr>
<td>5</td>
<td>2060</td>
<td>2026</td>
<td>1982</td>
<td>1936</td>
</tr>
<tr>
<td>6</td>
<td>957</td>
<td>947</td>
<td>936</td>
<td>924</td>
</tr>
</tbody>
</table>

Y-axis segments shown in blue indicate range from 0 to 0.2. CVD indicates cardiovascular disease; IHD, ischemic heart disease; NHANES, National Health and Nutrition Examination Survey.
Third, the FFQ in NHANES III used “past month” as the reference period, but the FFQ in NHANES 2003-2004 and 2005-2006 used “previous 12 months.” The interpretation of trends should take into account this difference. Fourth, the analyses of the effects of some modifiable risk factors, especially obesity and mortality, are subject to confounding by smoking and reverse causality because of preexisting conditions, which might have led to an underestimate of these effects on mortality. In the multivariate analyses, the association for the healthy diet score was also underestimated because the effects of a healthy diet are partly mediated through intermediate cardiovascular risk factors such as blood pressure and levels of cholesterol and glucose.

Fifth, we used an HbA1c level less than 5.7% to approximate a fasting glucose level less than 100 mg/dL, as suggested by the American Diabetes Association. This might have resulted in an underestimate of the prevalence of prediabetes. Sixth, PAFs derived from an observational study could lead to biased estimates of the effects of changing CVD risk factors on deaths avoided or postponed; a well-designed randomized clinical trial would have been ideal but not feasible. In addition, it is unlikely that in reality all participants would change to meet the ideal or desirable cardiovascular health metrics; the generalized impact fraction might be a more practical evaluation of the effects of changes in risk factors.

Seventh, the NHANES III Linked Mortality File identified causes of death through the National Death Index; the index is based on death certificates, which are subject to errors in classification of the cause of death. Eighth, our study examined the association of cardiovascular health metrics with CVD mortality but not incidence. However, the pattern of associations observed in our study was consistent with that for CVD incidence.

Healthy People 2020 and the AHA’s national strategy to reduce CVD morbidity and mortality by 20% by 2020 through promoting ideal cardiovascular health metrics represents a great challenge but also an achievable goal. Coordinated efforts, such as the recently announced Million Hearts initiative, align CVD prevention and control activities across the public and private sectors, creating opportunities to reduce the burden of CVD across a large segment of the population.

In summary, our findings indicate that the presence of a greater number of cardiovascular health metrics was associated with a graded and significantly lower risk of total and CVD mortality. However, the prevalence of meeting all 7 cardiovascular health metrics was low in the adult population.


Author Contributions: Drs Yang and Zhang had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

Study concept and design: Yang, Hu.

Analysis and interpretation of the data: Yang, Cogswell, Flanders, Hong, Zhang, Loustalot, Gillespie, Merritt, Hu.

Drafting of the manuscript: Yang, Hu.

Critical revision of the manuscript for important intellectual content: Yang, Cogswell, Flanders, Hong, Zhang, Loustalot, Gillespie, Merritt, Hu.

Statistical expertise: Yang, Flanders.

Study supervision: Yang, Hu.

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