"Life's Simple 7" and Long-Term Mortality After Stroke

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Background—The American Heart Association developed criteria dubbed "Life's Simple 7" defining ideal cardiovascular health: not smoking, regular physical activity, healthy diet, maintaining normal weight, and controlling cholesterol, blood pressure, and blood glucose levels. The impact of achieving these metrics on survival after stroke is unknown. We aimed to determine cardiovascular health scores among stroke survivors in the United States and to assess the link between cardiovascular health score and all-cause mortality after stroke.

Methods and Results—We assessed cardiovascular health metrics among a nationally representative sample of US adults with stroke (n=420) who participated in the National Health and Nutrition Examination Surveys in 1988–1994 (with mortality assessment through 2006). We determined cumulative all-cause mortality by cardiovascular health score under the Cox proportional hazards model after adjusting for sociodemographic characteristics and comorbidities. No stroke survivors met all 7 ideal health metrics. Over a median duration of 98 months (range, 53–159), there was an inverse dose-dependent relationship between number of ideal lifestyle metrics met and 10-year adjusted mortality: 0 to 1: 57%; 2: 48%; 3: 43%; 4: 36%; and ≥5: 30%. Those who met ≥4 health metrics had lower all-cause mortality than those who met 0 to 1 (hazard ratio, 0.51; 95% confidence interval, 0.28–0.92). After adjusting for sociodemographics, higher health score was associated with lower all-cause mortality (trend *P*-value, 0.022).

Conclusions—Achieving a greater number of ideal cardiovascular health metrics is associated with lower long-term risk of dying after stroke. Specifically targeting "Life's Simple 7" goals might have a profound impact, extending survival after stroke. (*J Am Heart Assoc*. 2015;4:e001470 doi: 10.1161/JAHA.114.001470)

Key Words: all-cause mortality • American Heart Association • ideal cardiovascular health metrics • Life's Simple 7 • Stroke

T he burden of stroke in life-years lost, diminished quality of life, and medical costs is enormous[1–3] and is expected to rise substantially over the next several decades.[4] Up to 90% of strokes can be prevented through optimization of modifiable risk factors and adoption of a healthy lifestyle.[5] Yet, nationally representative data suggest that the majority of the US population eat poorly and are sedentary.[6,7]

In 2010, the American Heart Association (AHA), emphasizing a new approach targeted at embracing the benefits of healthy living to increase the chance of living free of cardiovascular disease (CVD) and stroke, introduced a set of ideal cardiovascular health metrics that can be used to monitor health factors

and behaviors on individual and population levels.[8] Based on evidence from randomized, clinical trials and epidemiological studies, the AHA identified 7 ideal cardiovascular health metrics ("Life's Simple 7"), which encompass 3 medical metrics (blood pressure [BP], total serum cholesterol, and blood glucose) and 4 behavioral metrics (smoking, body mass index [BMI], physical activity, and diet).[8]

Less than 2% of the US population meets all 7 cardiovascular health metrics.[9–12] Published studies of populations generally free of a history of symptomatic cardiovascular events show that individuals who meet a higher number of Life's Simple 7 health metrics tend to have lower cardiovascular and all-cause mortality[13,14]; however, the impact of meeting these health metrics on long-term survival after a stroke is unknown. In this study, we assessed the prevalence of "ideal cardiovascular health" among stroke survivors in the United States, and the impact of meeting the Life's Simple 7 cardiovascular health metrics on outcome after stroke.

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Methods

Study Design and Participants

National Health and Nutrition Examination Surveys (NHANES) are a series of cross-sectional, national, stratified, multistage

probability surveys conducted by the National Center for Health Statistics (NCHS) in representative samples of the civilian, noninstitutionalized US population. Detailed descriptions of the plan and operation of each survey have been published, and NHANES received approval from the NCHS Research Ethics Review Board.[15] All participants were asked to sign an informed consent form.

We included adults aged ≥18 years with self-reported stroke from NHANES III (1988–1994). In order to determine mortality status, we used the NHANES III Linked Mortality File 2006 in which NHANES III–eligible participants were matched, using a probabilistic matching algorithm, to the National Death Index through December 31, 2006.[16]

Primary Outcome: All-Cause Mortality

The International Classification of Diseases Tenth Revision codes I00-I99 were used to identify deaths from all causes. Participants not matched with a death record were considered alive through the entire follow-up period.

Definition of Life's Simple 7 Cardiovascular Health Metrics

The AHA definitions for ideal, intermediate, and poor health were used for BP, cholesterol, BMI, and physical activity[8]; however, modified definitions were used for fasting plasma glucose (FPG), smoking, and healthy diet score (Table 1). For BP, ideal health was defined as untreated BP <120/80 mm Hg; intermediate health was defined as BP 120 to

139/80 to 89 mm Hg or <120/80 mm Hg on antihypertensive medications; and poor health was defined as BP >140/90 mm Hg. Mean BP was the average of up to 3 standardized BP measurements taken during a single encounter based on a standardized protocol.[17] For cholesterol, ideal health was defined as untreated total serum cholesterol <200 mg/dL; intermediate health was defined as untreated total serum cholesterol 200 to 239 mg/dL or treated to <200 mg/dL; and poor health was defined as total serum cholesterol >240 mg/dL. Hemoglobin A1c (HbA1c), rather than FPG, was used to describe diabetic health, because a sizeable percentage of participants in NHANES were not fasting. Ideal health was defined as HbA1c concentration <5.7% not on glucose-lowering meds; intermediate health was defined as HbA1c 5.7% to 6.4% or <5.7% on glucose-lowering medications; and poor health was defined as HbA1c ≥6.5%, consistent with previous analyses using NHANES data.[13,14] For smoking, ideal health was defined as never smoker; intermediate health was defined as former smoker; and poor health was defined as current smoker. NHANES III lacks information on when participants quit smoking. We used the categories of "never," "former," and "current" smoking across surveys for comparability. BMI was calculated from measured weight and height. For BMI, ideal health was defined as BMI <25 kg/m^2; intermediate health was defined as BMI 25 to 29.9 kg/m^2; and poor health was defined as BMI ≥30 kg/m^2. For physical activity, participants were asked about the frequency and duration of participation in moderate and vigorous physical activity during the past 30 days. The weekly number of minutes of moderate or vigorous activity, and the weekly

Table 1. Definition of Life's Simple 7 Cardiovascular Health Metrics*

| Metric | Level of Cardiovascular Health | | |
	Poor	Intermediate	Ideal
Blood pressure	Treated BP ≥140/90 mm Hg, and BP ≥140/90 mm Hg	SBP 120 to 139 mm Hg or DBP 80 to 89 mm Hg or treated to <120/80 mm Hg	<120/80 mm Hg, without BP-lowering meds
Total cholesterol	≥240 mg/dL	200 to 239 mg/dL or treated to <200 mg/dL	<200 mg/dL, without lipid-lowering medication
Glucose/diabetes†	HbA1c >6.4%	HbA1c 5.7% to 6.4% or treated with insulin or oral meds to HbA1C <5.7%	HbA1c <5.7%, without meds
Smoking‡	Current smoker	Former smoker	Never smoker
Body weight	BMI ≥30 kg/m^2	25 to 29.9 kg/m^2	<25 kg/m^2
Physical activity	No activity	1 to 149 minutes moderate/vigorous per week	>=150 minutes moderate/vigorous per week
Diet§	HEI <50	HEI 50 to 80	HEI >80

AHA indicates American Heart Association; BMI, body mass index; BP, blood pressure; DBP, diastolic blood pressure; FPG, fasting plasma glucose; HbA1C, hemoglobin A1c; HEI, Healthy Eating Index; SBP, systolic blood pressure.
*The AHA definitions for poor, intermediate, and ideal health were used for blood pressure, cholesterol, BMI, and physical activity[8]; however, modified definitions were used for FPG, smoking, and health diet score.
†Glucose/diabetes: AHA defined poor health as FPG ≥126 mg/dL or HgbA1C ≥7%, intermediate health as FPG 100 to 125 mg/dL or HgbA1C <7%, and ideal health as FPG <100 mg/dL.
‡Smoking: AHA defined poor health as current smoker, intermediate health as quit smoking <12 months, and ideal health as never smoker or quit smoking ≥12 months.
§HEI score includes 3 of 5 primary criteria included in the AHA healthy dietary score: fruits and vegetables, whole grains, and sodium. Not included are sugar-sweetened beverages and fish consumption.

number of minutes of vigorous activity were summed. Ideal health was defined as ≥150 minutes/week of moderate or vigorous activity; intermediate health was defined as 1 to 149 minutes/week of moderate or vigorous activity; and poor health was defined as 0 minute/week of moderate or vigorous activity. The Healthy Eating Index (HEI) score was used to evaluate diet. We used the original HEI created by the US Department of Agriculture in 1995.[18] The index was determined from dietary information collected by a single 24-hour recall administered in person to participants attending the medical examination. The HEI includes 3 of the 5 primary criteria included in the AHA healthy dietary score: intake of fruits and vegetables, whole grains, and sodium. Not included are sugar-sweetened beverages and fish consumption. Ideal health was defined as HEI >80; intermediate health was defined as HEI 50 to 80; and poor health was defined as HEI <50.

The Life's Simple 7 cardiovascular health score was constructed by summing the number of ideal health metrics achieved, ranging from 0 to 7 (0 was the worst score and 7 was the optimal score). A point was given only when the participant met the criteria for ideal health. Participants with missing data on any of the 7 cardiovascular health metrics (BP, total serum cholesterol, HbA1C, smoking, BMI, physical activity, and HEI) were excluded from the analysis of the prevalence of "ideal cardiovascular health".

Covariates in our association analyses included age, sex, race/ethnicity, poverty income ratio (PIR), education level, myocardial infarction (MI), and alcohol intake. Race/ethnicity was classified as non-Hispanic white, non-Hispanic black, Mexican American, and other. Socioeconomic status was assessed using PIR (≤2.00 classified as poor). Educational level was classified as ≤12 years or >12 years of formal education. Alcohol consumption was defined as having at least 12 drinks of any type of alcoholic beverage in the past year.

Statistical Analysis

We estimated the survey-weighted prevalence of the baseline sociodemographic and medical characteristics of the cohort and by health metrics score subgroups (0–1, 2–3, and 4+). The distributions of each categorical variable were compared across subgroups using the Rao–Scott chi-square test. We determined the proportion of stroke survivors who met each health metric and assessed the survey weighted prevalence of each score. To assess disparities in health metric scores by sociodemographic, we compared the distribution of sex, race/ethnicity, PIR, and education level between persons with low health metrics score (defined as 0–1 metrics in the ideal category) versus high health metrics score (≥4 metrics in the ideal category) using the Rao–Scott chi-squared test. A cutoff of ≥4 was chosen based upon the sample size and effect size (data not shown). We used survey adjusted logistic regression

Table 2. Patient Sociodemographic and Comorbid Characteristics, NHANES 1988–1994

	Overall Cohort	0 to 1	2 to 3	4+	
	N=420	N=87	N=263	N=70	P Value
Age, %					
18 to 64 y	38.7	25.3	58.2	16.5	0.14
≥65 years	61.3	13.2	68.8	18.0	
Sex, %					
Women	51.4	20.3	66.2	13.5	0.10
Men	48.6	15.4	63.1	21.4	
Race/ethnicity, %					
Non-Hispanic white	79.6	16.5	65.1	18.4	0.09
Non-Hispanic black	10.8	34.3	53.4	12.3	
Mexican American	2.2	25.2	57.3	17.5	
Other	7.4	7.6	79.1	13.3	
Poverty income ratio, %					
≤2.00	50.7	18.6	69.6	11.8	0.025
>2.00	40.5	19.8	58.5	21.7	
Education level, %					
≤12th grade	76.6	20.5	63.6	16.0	0.058
>12th grade	23.4	9.6	68.5	22.0	
Comorbidities, %					
Hypertension*					<0.01
No	31.7	2.2	69.7	28.1	
Yes	68.3	25.2	62.4	12.4	
Diabetes[†]					<0.01
No	72.1	10.9	67.6	21.5	
Yes	27.9	36.0	57.0	6.9	
Hypercholesterolemia[‡]					<0.01
No	45.4	15.5	46.0	38.5	
Yes	54.6	22.3	69.1	8.7	
Low HDL[§]					0.06
No	50.2	16.2	61.0	22.8	
Yes	49.8	19.6	68.4	11.9	
Myocardial infarction					0.44
No	75.9	16.6	64.7	18.8	
Yes	24.1	22.2	64.8	13.0	
Alcohol[¶]					0.90
No	75.3	18.5	64.8	16.7	
Yes	24.7	16.1	64.4	19.4	

BP indicates blood pressure; HDL, high-density lipoprotein; NHANES, National Health and Nutrition Examination Survey.

*BP >140/90 mm Hg or on antihypertensive medications, or self-report.

[†]Hemoglobin A1C ≥6.5% or on diabetes medications, or self-report.

[‡]Total serum cholesterol ≥240 mg/dL or on cholesterol medications.

[§]HDL <50 mg/dL for women or <40 mg/dL for men.

[¶]Alcohol consumption in past year.

Table 3. Weighted Prevalence of Meeting Life's Simple 7 Ideal Cardiovascular Health Metrics in Stroke Survivors, National Health and Nutrition Examination Survey (NHANES) 1988–1994

	Overall Cohort
Blood pressure, mm Hg (%)	
<120/80 (untreated)	13.1
120 to 139/80 to 89 or treated to goal	41.7
≥140/90	45.2
Total serum cholesterol, mg/dL (%)	
<200 mg/dL (untreated)	28.7
200 to 239 mg/dL or treated to <200 mg/dL	34.1
≥240 mg/dL	37.2
Hemoglobin A1C, %	
<5.7%, without meds	51.0
5.7 to 6.4 or treated <5.7%	30.6
>6.4%	18.3
Smoking, %	
Never	37.4
Former	40.5
Current	22.1
Body mass index, kg/m^2 (%)	
<25	35.7
25 to 29.9	37.3
≥30	26.9
Physical activity, %	
≥150 minutes per week	18.0
1 to 149 minutes per week	37.8
No activity	44.2
Healthy diet, %	
Healthy eating Index >80	22.3
Healthy eating index 50 to 80	63.5
Healthy eating index <50	14.2
Number of ideal health metrics, pooled, %	
0 to 1	17.9
2 to 3	64.7
4+	17.4
Number of ideal health metrics, %	
0	3.1
1	14.8
2	35.7
3	29.0
4	13.3
5	2.8
6	1.3
7	—

to examine the odds of having low versus high score according to age, sex, race/ethnicity, PIR, and education level before and after simultaneously adjusting for each of the above demographic characteristics, as well as hypertension, diabetes, hypercholesterolemia, MI, and alcohol intake.

To evaluate the association between health metrics category and the risk of all-cause mortality, we used the Cox regression model, before and after adjusting for covariates. To evaluate whether the relationship between health metrics category and the risk of all-cause mortality differed by sex, race/ethnicity, income, and education, we included interaction terms in the above models. Trend *P* values were computed by including the health metrics score as a continuous variable in the models. We calculated the 10-year adjusted incidence of mortality for each category of the health metric score by level of each sociodemographic factor and overall under the above Cox model. We computed the rate of all-cause mortality per 1000 person-years for each health metric category empirically with adjustment for age. First, we computed the age-specific mortality rates by dividing the total number of deaths by the total number of person-years follow-up (multiplying by 1000 to obtain rate per 1000 person-years) for age categories <65, 65 to 74, and ≥75 years. We computed the age-adjusted mortality rate as the weighted average of the above age-specific mortality rates, with the weights equal to the observed proportions of persons in each age category in the overall stroke cohort. In addition, we calculated the covariate-adjusted rate of all-cause mortality per 1000 person-years for each health category under the Poisson regression model after simultaneously adjusting for age, sex, race/ethnicity, education level, and PIR, taking into account the NHANES survey design.

We excluded 65 (13%) of the 485 participants from the analyses because of incomplete health metric data. In order to assess the potential influence of missing data on the results, we compared covariates and each of 7 health metric items between persons with and without missing data to determine whether the distributions were comparable in the 2 groups. In addition, missing values were imputed using the Markov chain Monte Carlo imputation and additional sensitivity analyses were performed after adjusting for covariates. Data were analyzed using STATA software (version 11.2; StataCorp LP, College Station, TX) and R (version 3.0.2; R Foundation for Statistical Computing, Vienna, Austria).

Results

Participant Characteristics

A total of 485 participants of NHANES III (1988–1994) reported history of stroke. Of those, 65 (13%) had missing data for at least 1 health metric and therefore were excluded, leaving 420 with complete data on the 7 health metrics for

Table 4. Weighted Prevalence and OR of Having Low Health Score (0–1) vs High Health Score (4+) Stratified by Sex, Race, Poverty Index Ratio, and Education

	Score 0 to 1 (%)	Score 4+ (%)	Crude		Adjusted*	
			OR (0–1 vs 4+)	*P* Value	OR (0–1 vs 4+)	*P* Value
Age						
18 to 64 y	25.3	16.5	Reference		Reference	
≥65 years	13.2	18.0	0.48 (0.20–1.12)	0.09	0.69 (0.28–1.71)	0.42
Sex						
Men	15.4	21.4	Reference	—	Reference	—
Women	20.3	13.5	2.08 (1.21–3.55)	0.008	3.18 (1.01–10.05)	0.048
Race/ethnicity						
Non-Hispanic white	16.5	18.4	Reference	—	Reference	—
Non-Hispanic black	34.3	12.3	3.11 (1.37–7.09)	0.007	3.63 (1.00–13.10)	0.049
Mexican American	25.2	17.5	1.61 (0.69–3.78)	0.27	5.24 (0.94–29.08)	0.058
Other	7.6	13.3	0.64 (0.22–1.87)	0.42	1.18 (0.17–8.43)	0.87
Poverty index ratio						
>2.00	19.8	21.7	Reference	—	Reference	—
≤2.00	18.6	11.8	1.73 (0.90–3.35)	0.103	1.23 (0.40–3.81)	0.72
Education						
>12th grade	9.6	22.0	Reference	—	Reference	—
≤12th grade	20.5	16.0	2.95 (0.81–10.77)	0.102	8.76 (2.08–36.82)	0.003

*Adjusted for sex, race, poverty index ratio, education, hypertension, diabetes, hypercholesterolemia, myocardial infarction, and alcohol intake. OR indicates odds ratio.

analysis. Median follow-up length was 98 months (range, 53–159). Table 2 shows the baseline sociodemographic and comorbid characteristics by health metric category (score 0–1, 2–3, and 4+) and overall. In the overall cohort, most participants were non-Hispanic white (79.6%), 65 years of age or older (61.3%), and had ≤grade 12 education (76.6%).

Performance on Life's Simple 7 Cardiovascular Health Metric

No participant met all 7 ideal health metrics; 17.9% scored 0 to 1; the majority (64.7%) scored 2 to 3; and 17.4% scored ≥4 (Table 3). Of the ideal health metric categories, 13.1% had untreated BP <120/80 mm Hg, 28.7% had untreated total cholesterol <200 mg/dL, 51.0% had HbA1c <5.7%, 37.4% had never smoked, 35.7% had BMI <25 kg/m^2, 18.0% endorsed moderate-to-vigorous exercise for 150 minutes per week or more, and 22.3% consumed a healthy diet (HEI >80).

Risk of Having Low Health Metric Score by Sociodemographic Characteristic

Women were more likely to have poor cardiovascular health scores (0–1) compared to men (odds ratio [OR], 2.08; 95% confidence interval [CI], 1.21–3.55), an association that

persisted even after adjustment for race/ethnicity, PIR, education, and comorbidities (adjusted OR, 3.18; 95% CI, 1.01–10.05; Table 4). Blacks had over 3 times greater odds of having poor cardiovascular health than Whites (OR, 3.11; 95% CI, 1.37–7.09; adjusted OR, 3.63; 95% CI, 1.00–13.10), and after adjustment for covariates, those with less than or equal to a 12th-grade education were more likely to have poor cardiovascular health than those with more than a 12th-grade education (adjusted OR, 8.76; 95% CI, 2.08–36.82; Table 4). Mexican Americans trended toward poorer cardiovascular health compared to non-Hispanic whites (adjusted OR, 5.24; 95% CI, 0.94–29.08; Table 4).

Association Between Life's Simple 7 and Mortality

Over a median of 98 months (53–159 months) of follow-up, there were 320 deaths from all causes. The absolute rates of all-cause mortality among participants who had cardiovascular health metric scores of 0 to 1, 2, 3, and 4+ were 80.3±9.7, 70.2±5.1, 62.7±5.3, and 53.0±7.5 deaths per 1000 person-years, respectively (trend, *P*<0.0001), after adjusting for age, sex, race/ethnicity, PIR, and education (Table 5). Meeting a greater number of cardiovascular health metrics was associated with a lower risk of cumulative 10-

Table 5. Mortality Rate and HRs According to Number of Health Metrics in NHANES Participants With Self-Reported History of Stroke

	Number of Cardiovascular Health Metrics				
	0 to 1	2	3	4+	Trend *P* Value
No. of deaths/at risk	66/87	126/161	79/102	49/70	—
No. of person years	738.5	1406.3	868.4	627.7	—
Crude mortality rate per 1000 person-years	75.9±20.5	77.1±13.7	67.5±14.5	54.4±14.5	—
Complete case analysis					
Age-adjusted mortality rate per 1000 person-years	97.9±12.9	90.5±8.1	76.6±8.6	63.1±9.2	<0.01
Age, sex, race, PIR, education-adjusted mortality rate per 1000 person-years	80.3±9.7	70.1±5.1	62±5.2	53.0±7.5	<0.01
10-years adjusted mortality, %*	56.6%±7.5%	47.6%±5.2%	42.9%±6.5%	34.6%±6.7%	0.025
Adjusted HR (95% CI)*	Reference	0.77 (0.50–1.20)	0.67 (0.40–1.13)	0.51 (0.28–0.92)	0.022
Imputed analysis					
Age, sex, race, PIR, education-adjusted mortality rate per 1000 person-years[†]	83.0±8.6	72.4±4.9	59.8±4.8	57.6±7.7	<0.01
10-years adjusted mortality, %*[†]	59.8%±6.6%	50.2%±4.1%	41.8%±4.5%	38.4%±6.2%	0.016
Adjusted HR (95% CI)*[†]	Reference	0.74 (0.51–1.07)	0.57 (0.37–0.90)	0.52 (0.30–0.93)	0.016

CI indicates confidence interval; PIR, poverty income ratio; HR, hazard ratio; NHANES, National Health and Nutrition Examination Survey.
*Adjusting for age, sex, race, PIR, and education.
[†]Missing values were imputed using Markov chain Monte Carlo imputation method.

year all-cause mortality (56.6%±7.5%, 47.6%±5.2%, 43.0%±6.5%, and 34.6%±6.7%; *P*=0.025) after adjusting for covariates. Compared to the low cardiovascular health metric group (0–1), participants who achieved at least 4 ideal cardiovascular health metrics had 49% reduction in the rate of all-cause mortality after a stroke (hazard ratio [HR], 0.51; 95% CI, 0.28–0.92). The age-standardized mortality rate according to number of health metrics revealed a strong inverse linear, dose-dependent relationship between meeting greater numbers of health metrics and mortality (FigureA). There was an inverse dose-dependent relationship between cardiovascular health score and all-cause mortality (FigureB). The association between higher cardiovascular health scores and reduced risk of all-cause mortality persisted regardless of sex, race/ethnicity, income, or education; however, because sample sizes in each of the subgroups were smaller, there was limited ability to detect significant results in most of the subgroups (data not shown).

Missing Data Analysis

To reduce the possibility that missing data could influence the directionality of the cardiovascular health score and mortality relationship, we imputed the missing values using the Markov chain Monte Carlo imputation method and adjusted for covariates. The imputed analysis again demonstrated an inverse dose-dependent relationship between cardiovascular health score and mortality (*P*<0.001). The results were in close agreement with the previous results using the complete cases (Table 5).

The variables with >5% missing values were HEI (5.4% missing), cholesterol (7.2% missing), and HbA1C (6.8% missing). Comparing covariates in persons who had complete data for all 7 health metrics versus those who did not, incomplete cases were more likely to be women (70% vs 51%), non-Hispanic black (37% vs 11%), and older (mean age 73 vs 66 years). In addition, they were more likely to have elevated BP (57% vs 44%) and to be physically inactive (80% vs 41%; Table 6).

Discussion

In this national sample of US adults from NHANES III (1988–1994) with follow-up mortality assessment through 2006, no stroke survivors met all 7 criteria for ideal cardiovascular health. There was a strong dose-dependent inverse relationship between the number of ideal cardiovascular health metrics achieved and all-cause mortality after a stroke regardless of sex, race/ethnicity, income, or education. Stroke survivors who met 4 or more health metrics had a significant 49% reduction in all-cause mortality. This is the first study to delineate the distribution of cardiovascular health metrics among stroke survivors and to show the graded inverse correlation between number of ideal cardiovascular health and mortality after stroke.
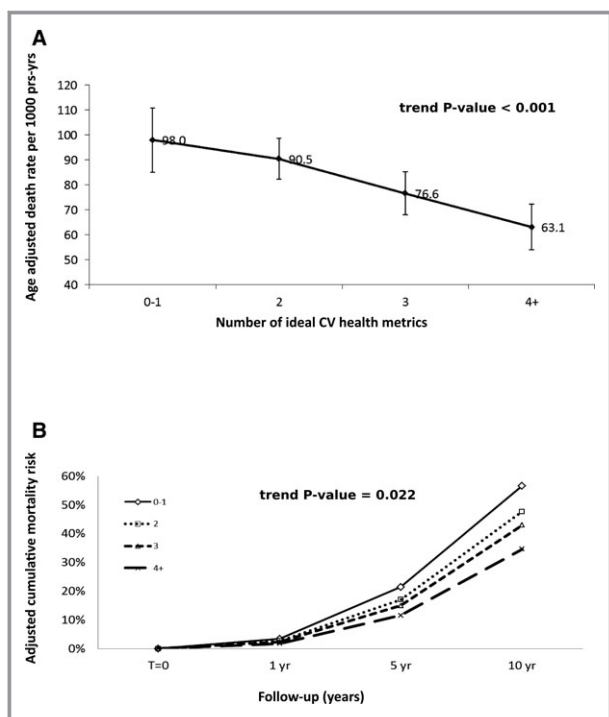
Figure. A, Age-standardized mortality rate per 1000 person-years according to ideal cardiovascular health score. B, Adjusted cumulative all-cause mortality risk across time by ideal cardiovascular health score. Adj indicates adjusted; py, person-years; yr, year(s).

Our findings of poor performance on cardiovascular health metrics are similar to several studies in different populations, including Northern Manhattan; Forsyth County, North Carolina; Jackson, Mississippi; Washington County, Maryland; Minneapolis, Minnesota; and Allegheny County, Pennsylvania.[9–12] Recent analyses have similarly demonstrated marked reductions in mortality[5,13,14,19] and 20-year fatal and nonfatal CVD event rates[10] with higher cardiovascular health scores.

Of the 7 ideal cardiovascular health metrics, stroke survivors performed worst on behavioral health metric items, namely, physical activity and diet. Only 1 of 5 individuals endorsed engaging in moderate or vigorous physical activity at least 150 minutes per week, and similar proportions had an ideal diet score. These findings highlight the difficulty stroke survivors have in achieving behavioral health benchmarks and the need for concurrent targeted interventions.

This study has several limitations. First, in NHANES, stroke is determined by self-report; the survey does not collect data regarding stroke type, duration poststroke, stroke severity, or poststroke functional status, all factors that could play roles in stroke mortality and were not controlled for. Self-reported stroke has a positive predictive value of 79%, a sensitivity of 80%, and specificity of 99%, suggesting that self-report can reliably be used in epidemiological analysis.[20] Second, NHANES is a cross-sectional sample of the US population;

therefore, the study assessed the health metrics at the time of the interview and examination, not at the time of the stroke. In addition, because of the study's cross-sectional nature, we were unable to capture temporal changes in each of the participant's cardiovascular health metrics. Third, NHANES only captures noninstitutionalized individuals and those who can comprehend and respond to surveys, resulting in a possible bias toward a healthier population. Fourth, only participants with complete data for all 7 components of cardiovascular health were included in prevalence estimates for ideal cardiovascular health, which could introduce unaccounted selection bias. The results of the missing data using Markov chain Monte Carlo imputation, however, demonstrated close agreement with the analysis using the complete cases, further strengthening the validity of our findings. Fifth, there remains uncertainty about ideal goals for BP, cholesterol level, and physical activity after stroke. Sixth, the sample size was relatively small in sub-subgroup analyses, which may have limited our ability to detect significant trends attributable to lack of power. Because of the sample size, a cutoff of ≥ 4 ideal health metrics was chosen to compare to participants with ≤ 1 ideal health metric in order to have significant effect size. It is likely that if another threshold were chosen, a gradation of effect may be observed with more individuals falling into the higher categories of ideal health behaviors. Nevertheless, our findings are consistent with literature using cut-off points at ≥ 5[13] or ≥ 6,[14] showing that the number of LS7 ideal health metrics was significantly and inversely related to all-cause mortality among stroke survivors. Finally, whereas the National Death Index has long been validated to calculate population mortality estimates,[21] the matching algorithm inevitably introduced selection bias in not matching special populations, such as immigrants, undocumented residents, and nonwhite minorities.

Our study has several strengths, including a nationally representative sample of US adults with a long follow-up for mortality, rigorous and validated survey and examination procedures, adjustment for numerous possible confounders, and robust estimations of absolute mortality and cumulative 10-year mortality rates, with multiple models adjusting for various potential confounders.

Future directions may include prospectively assessing the relationship between cardiovascular health metric and mortality after stroke, or extending the analysis to NHANES cycles beyond 1988–1994 (with linked mortality data beyond 2006) to increase sample size to provide the power needed for subgroup analyses. Whereas the present study demonstrated a graded mortality benefit from meeting a higher number of ideal cardiovascular health metrics after stroke, the extent to which each of the health metrics contributed to the mortality benefit is unclear. Future studies may focus on quantifying the population-attributable risk of each of the respective 7 cardiovascular

Table 6. Comparison of Covariates and Health Metrics Between Participants With and Without Complete Data for the 7 Health Metrics

| | Incomplete Case | | | Complete Cases | | | |
| | N=65 | | | N=420 | | | |
	N	Percent*	Percent†	N	Percent*	Percent†	P Value
Age							0.06
18 to 64 y	12	20.2	4.9	119	38.7	95.1	
≥65 years	53	79.8	11.3	301	61.3	88.7	
Sex							0.03
Men	28	29.9	5.7	215	48.6	94.3	
Women	37	70.1	11.8	205	51.4	88.2	
Race/ethnicity							
Non-Hispanic white	7	3.2	12.7	67	2.2	87.3	<0.01
Non-Hispanic black	26	59.9	6.9	237	79.6	93.1	
Mexican American	32	36.9	25.0	100	10.8	75.0	
Other	0	0.0	—	16	7.4	100.0	
Poverty income ratio							0.24
≤200%	40	61.0	10.5	244	50.7	89.5	
>200%	15	26.9	6.1	129	40.5	93.9	
Education level							0.18
≤12 grade	61	89.0	10.2	350	76.6	89.8	
>12 grade	4	11.0	4.4	70	23.4	93.9	
Blood pressure, mm Hg							0.04
<120/80 (untreated)	6	5.9	3.9	34	13.8	96.1	
120 to 139/80 to 89	21	37.0	7.7	176	42.1	92.3	
≥140/90	35	57.1	10.9	210	44.0	89.1	
Total serum cholesterol, mg/dL							0.30
<200 mg/dL (untreated)	7	22.9	4.0	136	29.0	96.0	
200 to 239 mg/dL	9	23.2	3.4	144	34.7	96.6	
≥240 mg/dL	14	53.9	7.2	140	36.3	92.8	
Hemoglobin A1C							0.36
<5.7%, without medications	9	32.0	3.1	194	52.05	96.9	
5.7 to 6.4 or treated <5.7%	14	37.7	6.2	133	30.26	93.8	
>6.4%	9	30.3	8.3	93	17.69	95.2	
Smoking							0.18
Never	25	37.8	9.0	171	37.40	92.3	
Former	31	50.2	11.0	171	39.56	89.1	
Current	9	12.0	4.8	78	23.04	94.1	
Body mass index, kg/m^2							0.34
<25	22	32.6	7.7	148	36.01	92.3	
25 to 29.9	24	48.4	10.9	165	36.32	89.1	
≥30	13	19.0	5.9	107	27.66	94.1	

Table 6. Continued

	Incomplete Case			Complete Cases			
	N=65			N=420			
	N	Percent*	Percent†	N	Percent*	Percent†	P Value
Physical activity							<0.01
≥150 minutes per week	9	12.6	6.4	72	18.10	93.6	
1 to 149 minutes per week	6	7.6	1.8	127	40.75	98.2	
No activity	50	79.8	15.9	221	41.15	84.1	
Healthy diet							0.81
Healthy Eating Index >80	6	24.2	5.2	76	22.17	94.8	
Healthy Eating Index 50 to 80	24	57.7	4.3	281	63.79	95.7	
Healthy Eating Index <50	9	18.1	6.0	63	14.04	94.0	

*Survey-weighted percentage over subgroups.
†Survey-weight percentage over complete vs noncomplete cases.

health metrics in stroke survivors. Furthermore, future studies comparing the gain in health benefits associated with a change from poor to intermediate health with the gain associated with a change from intermediate to ideal health for each metric may yield helpful insights that will be of value to clinicians in optimizing the cardiovascular health of their patients. In the meantime, these results suggest the need for targeted interventions aimed at improving cardiovascular health metrics in this vulnerable population.

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