

Relationship of the American Heart Association's Impact Goals (Life's Simple 7) With Risk of Chronic Kidney Disease: Results From the Atherosclerosis Risk in Communities (ARIC) Cohort Study

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Background—As part of its 2020 Impact Goals, the American Heart Association developed the Life's Simple 7 metric for cardiovascular health promotion. The relationship between the Life's Simple 7 metric and incident chronic kidney disease (CKD) is unknown.

Methods and Results—We estimated the association between Life's Simple 7 and incident CKD in 14 832 Atherosclerosis Risk in Communities study participants. Ideal levels of Life's Simple 7 health factors were the following: nonsmoker or quit >1 year ago; body mass index <25 kg/m²; ≥150 minutes/week of physical activity; healthy dietary pattern (high in fruits and vegetables, fish, and fiber-rich whole grains; low in sodium and sugar-sweetened beverages); total cholesterol <200 mg/dL; blood pressure <120/80 mm Hg; and fasting blood glucose <100 mg/dL. At baseline, mean age was 54 years, 55% were women, and 26% were African American. There were 2743 incident CKD cases over a median follow-up of 22 years. Smoking, body mass index, physical activity, blood pressure, and blood glucose were associated with CKD risk (all $P<0.01$), but diet and blood cholesterol were not. CKD risk was inversely related to the number of ideal health factors (P -trend<0.001). A model containing the Life's Simple 7 health factors was more predictive of CKD risk than the base model including only age, sex, race, and estimated glomerular filtration rate (Life's Simple 7 health factors area under the ROC curve: 0.73, 95% CI: 0.72, 0.74 versus base model area under the ROC curve: 0.68, 95% CI: 0.67, 0.69; $P<0.001$).

Conclusions—The AHA's Life's Simple 7 metric, developed to measure and promote cardiovascular health, predicts a lower risk of CKD. (*J Am Heart Assoc.* 2016;5:e003192 doi: 10.1161/JAHA.116.003192)

Key Words: epidemiology • kidney • lifestyle • prevention • risk factors

The 2020 Impact Goals of the American Heart Association (AHA) are to achieve a 20% improvement in cardiovascular health and 20% reduction in deaths due to cardiovascular disease and stroke in the United States by the year 2020.¹ To achieve these goals, the AHA recommended 7 healthy factors for cardiovascular disease prevention—Life's Simple 7—related to

total cholesterol, fasting blood glucose, blood pressure, smoking, body mass index, physical activity, and diet.² The diet recommendation addresses 5 components (fruits and vegetables, fish, fiber-rich whole grains, sodium, sugar-sweetened beverages) selected, in part, for consistency with the US Dietary Guidelines for Americans and AHA scientific statements.^{3–5}

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Aside from cardiovascular disease, several studies have reported on the relationship between AHA Life's Simple 7 and risk of other outcomes such as diabetes,⁶ depression,⁷ stroke,⁸ and cognitive impairment.⁹ The shared underlying pathophysiology leading to the development of cardiovascular and kidney disease suggests that cardioprotective recommendations might also be effective for kidney disease prevention.¹⁰ Two studies have investigated Life's Simple 7 and kidney disease progression among individuals with impaired kidney function.^{11,12} However, to the best of our knowledge, it is not known whether this combination of health factors as defined by AHA Life's Simple 7 is associated with incident chronic kidney disease in a general population. Determining the relationship between AHA's Life's Simple 7 and chronic kidney disease could not only illustrate the potential influence of the 2020 Impact Goals on kidney disease in the general population but also inform the design of public health interventions for kidney disease prevention.

Our objective was to assess the relationship of the overall Life's Simple 7 metric, the individual health factors, and each diet component with risk of incident chronic kidney disease in a large, community-based cohort free of chronic kidney disease at baseline.

Methods

Study Design and Population

The Atherosclerosis Risk in Communities (ARIC) study is a community-based cohort of 15 792 middle-aged (45–64 years of age), predominantly black and white men and women.¹³ Study participants were recruited and enrolled in 1987–1989 from 4 US communities: Forsyth County, North Carolina; Jackson, Mississippi; suburbs of Minneapolis, Minnesota; and Washington County, Maryland. Follow-up study visits occurred in 1990–1992 (visit 2), 1993–1995 (visit 3), 1996–1998 (visit 4), and 2011–2013 (visit 5). An ethics committee at each site approved the study protocol, and study participants provided informed consent at each study visit. After excluding participants with chronic kidney disease (defined using the same criteria as the chronic kidney disease outcome as described below) at baseline (n=356) and participants with missing data for any of the 7 health factors (n=604), the sample size was 14 832 (Figure 1). The current study is a prospective analysis of the ARIC study to characterize the relationship of Life's Simple 7 factors assessed at baseline (1987–1989) and the development of incident kidney disease during follow-up through the end of 2010. Aside from having the event (incident

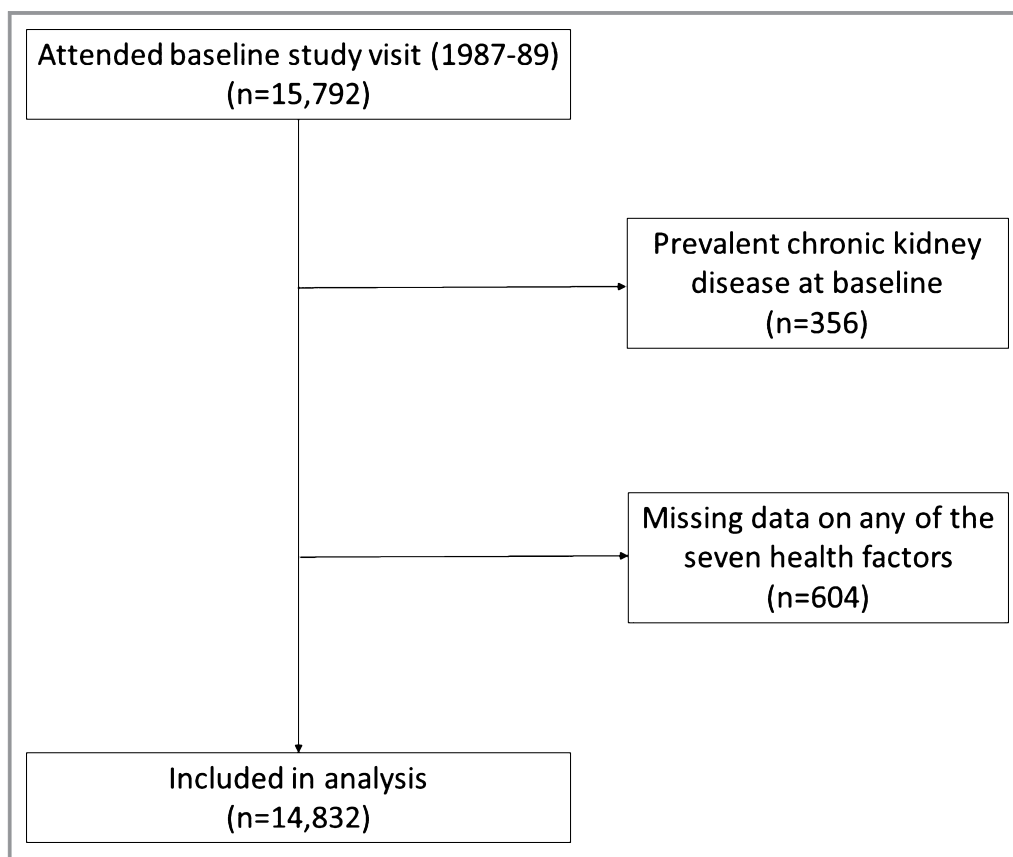


Figure 1. Flow chart of study participant selection.

Table 1. Definitions of Ideal, Intermediate, and Poor for Each Life's Simple 7 Health Factor

Health Factor	Ideal	Intermediate	Poor
Cigarette smoking	Never smoker or former smoker and quit >12 months ago	Former smoker and quit ≤12 months ago	Current smoker
Body mass index	<25 kg/m ²	25 to <30 kg/m ²	≥30 kg/m ²
Physical activity	≥150 minutes/week	1 to 149 minutes/week	None
Healthy diet score	4 to 5 components	2 to 3 components	0 to 1 components
Total cholesterol	<200 mg/dL (not treated)	200 to 239 mg/dL or treated to goal	≥240 mg/dL
Blood pressure	SBP <120 mm Hg and DBP <80 mm Hg (not treated)	SBP 120 to 139 mm Hg or DBP 80 to 89 mm Hg or treated to goal	SBP ≥140 mm Hg or DBP ≥90 mm Hg
Fasting blood glucose	<100 mg/dL (not treated)	100 to 125 mg/dL or treated to goal	≥126 mg/dL

DBP indicates diastolic blood pressure; SBP, systolic blood pressure.

chronic kidney disease), study participants were censored due to death from a cause other than kidney disease, loss to follow-up, or the end of the observation period.

Data Collection

At baseline, trained interviewers administered a questionnaire to collect information on demographic characteristics, health behaviors, medical history, and medication use. Body mass index was calculated as weight (in kilograms) divided by height (in meters squared) using measurements taken during

the baseline study visit. After 5 minutes of rest, 3 seated measurements of blood pressure were taken by a certified technician using a random-zero sphygmomanometer. The mean of the second and third blood pressure measurements was used for analysis.

Fasting blood samples were collected during study visits. Blood levels of glucose were measured by the modified hexokinase/glucose-6-phosphate dehydrogenase method. Blood levels of creatinine were measured by the modified kinetic Jaffe method, calibrated to account for differences in laboratory tests, and standardized to the National Institute of

Table 2. Criteria for Scoring the Life's Simple 7 Healthy Diet*

Individual Component of the Healthy Diet Score	Meets Criteria (1 Point)	Does Not Meet Criteria (0 Points)	Food Items
Dietary supplementation			
Fruits and vegetables	≥4.5 cups/day	<4.5 cups/day	Fresh apples or pears; oranges; peaches, apricots or plums; bananas; other fruits; string beans or green beans; broccoli; cabbage, cauliflower, brussels sprouts; carrots; corn; spinach, collards, or other greens; peas or lima beans; dark yellow, winter, squash such as acorn, butternut; sweet potatoes; beans or lentils such as pinto, blackeye, baked beans; tomatoes; potatoes
Fish	≥two 3.5-oz servings/week	<two 3.5-oz servings/week	Dark meat fish such as salmon, mackerel, swordfish, sardines, bluefish; canned tuna fish; other fish such as cod, perch, catfish
Fiber-rich whole grains	≥three 1 oz-equivalent servings/day (≥1.1 g fiber/10 g carbohydrate)	<three 1 oz-equivalent servings/day (<1.1 g fiber/10 g carbohydrate)	Fiber and carbohydrate as calculated using USDA sources for nutritional content of food items
Dietary restriction			
Sodium	<1500 mg/day	≥1500 mg/day	Sodium as calculated using USDA sources for nutritional content of food items
Sugar-sweetened beverages	≤450 kcal (36 oz)/week	>450 kcal (36 oz)/week	Regular soft drinks such as Coke, Pepsi, 7-Up, ginger ale; fruit-flavored punch or noncarbonated beverages such as lemonade, Kool-Aid, or Hawaiian Punch

USDA indicates United States Department of Agriculture.

*Intake recommendations are expressed for a daily caloric intake of 2000 kcal, and are scaled to calories consumed for each participant. Total score is calculated as the sum of scores for each of the 5 individual components (range: 0–5).

Standards and Technology standard.^{14,15} Total blood cholesterol concentration was assessed by enzymatic procedures.¹⁶

Usual dietary intake was assessed at baseline using a semiquantitative 66-item food-frequency questionnaire administered by trained interviewers to improve accuracy and completeness.^{17,18} Frequency and portion size of each food item was multiplied by nutritional content from US Department of Agriculture sources to estimate intake of micro- and macronutrients.

Categorization of Life's Simple 7 Health Factors

Individual health factors were categorized as poor, intermediate, or ideal according to the AHA Life's Simple 7 criteria (Table 1). Ideal levels of health factors were: nonsmoker or quit >1 year ago; body mass index <25 kg/m²; ≥150 minutes/week of physical activity; healthy diet score (see below); total cholesterol <200 mg/dL; blood pressure <120/80 mm Hg; and fasting blood glucose <100 mg/dL. Study participants who were treated to target levels for hypercholesterolemia, hypertension, or diabetes were classified as intermediate for the respective health factor.

The healthy diet score was calculated as the sum of the scores for each of 5 individual components for which the recommended intake levels were: (1) ≥4.5 servings of fruits and vegetables per day; (2) ≥7 ounces of fish per week; (3) ≥3 ounces of fiber-rich whole grains per day (≥1.1 g of dietary fiber/10 g of carbohydrate per day); (4) <1500 mg of sodium per day; and (5) ≤36 ounces of sugar-sweetened beverages per week (Table 2). The range is from 0 to 5, with a lower score being unhealthy.

Measurement of Other Covariates

Diabetes was defined at baseline as fasting blood glucose ≥126 mg/dL, non-fasting glucose ≥200 mg/dL, reported history of diabetes, or use of diabetes medication in the preceding 2 weeks. Hypertension was defined as systolic blood pressure ≥140 mm Hg, diastolic blood pressure ≥90 mm Hg, or use of antihypertensive medication in the preceding 2 weeks. Estimated glomerular filtration rate (eGFR) was calculated with standardized serum creatinine according to the Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) estimating equation.¹⁹

Ascertainment of Chronic Kidney Disease Cases

Incident chronic kidney disease was assessed from baseline through December 31, 2010 and defined as (1) development of eGFR <60 mL/min per 1.73 m² accompanied by ≥25% eGFR decline, (2) International Classification of Diseases 9/10 code for a hospitalization due to chronic kidney disease identified by

surveillance of hospitalizations and annual follow-up phone calls with study participants, (3) International Classification of Diseases 9/10 code for a death due to chronic kidney disease identified by linkage to the National Death Index, or (4) end-stage renal disease identified by linkage to the US Renal Data System registry.²⁰ As a sensitivity analysis, incident chronic kidney disease was defined using visit-based measures (ie, eGFR <60 mL/min per 1.73 m² at a subsequent study visit accompanied by ≥25% eGFR decline relative to baseline).

Statistical Analysis

Descriptive statistics (mean, SD, proportion) were used to describe baseline characteristics according to the number of ideal Life's Simple 7 factors. Differences in baseline characteristics by number of ideal health factors were evaluated using tests for trend.²¹

We used Cox proportional hazards regression to estimate chronic kidney disease risk according to categories of the 7 individual health factors (ideal, intermediate, poor) in the same model, the overall metric (number of ideal health factors), and categories of the 5 individual diet characteristics. The categories for 6 and 7 ideal health factors were collapsed together due to the small number of participants and absence of chronic kidney disease events among these participants with all 7 ideal health factors. Multivariable regression models were adjusted for demographic characteristics (age, sex, and race) and baseline kidney function (eGFR modeled as 2 linear spline terms with a knot at 90 mL/min per 1.73 m²). For the individual components of the healthy diet, we additionally adjusted for body mass index, physical activity, diabetes, and hypertension. We tested for trend in risk estimates according to ordered categories (ideal, intermediate, poor) for the 7 individual health factors, number of ideal health factors, and levels of dietary intake of the 5 diet factors as continuous variables. Harrell's C statistic was used to calculate area under the receiver operating characteristic curve (AUC). Linear combinations were used to test for differences between AUC values for the base model including age, sex, race, and eGFR versus the expanded model including all of the Life's Simple 7 factors plus the base model. Sensitivity analyses were conducted to assess different definitions of the healthy diet score. Effect modification by race and sex was assessed by stratified analysis and tests of interaction. Analyses were conducted using Stata statistical software version 13 (StataCorp LC, College Station, TX).

Results

Baseline Characteristics

In the overall study population, mean age at baseline was 54 years, 55% were women, and 26% were African American.

Younger age, female sex, and white ethnicity were associated with a higher number of ideal levels of Life's Simple 7 health factors ($P < 0.001$ for all; Table 3). Body mass index, systolic blood pressure, and proportion of people with diabetes and hypertension—all health characteristics incorporated into the Life's Simple 7 metric—were lower with higher Life's Simple 7 scores (all $P < 0.001$). Kidney function also varied according to number of ideal Life's Simple 7 health factors, but the absolute differences in eGFR values were small. There was no significant trend in total caloric intake according to number of ideal health factors.

Distribution of Ideal Health Factors

The largest proportion of the study population meeting ideal criteria was for cigarette smoking (72.4%; Table 4). Having an ideal healthy dietary pattern was the rarest (6.2%). Over half of the study population had 2 or 3 ideal health factors (Table 5). A small proportion of the population met none of the ideal criteria (2.6%) and a similar number of study participants met the ideal criteria for 6 or 7 health factors (2.8%).

Individual Health Factors and Risk of Incident Chronic Kidney Disease

Over a median follow-up of 22 years (271 285 total person-years), there were 2743 incident chronic kidney disease cases. Compared to poor levels of health factors, the risk of chronic kidney disease was lower with intermediate and ideal levels of health factors for smoking, body mass index, physical activity, blood pressure, and fasting blood glucose (all P for trend < 0.01 ; Table 4). The strongest association with

chronic kidney disease risk was observed with ideal levels of fasting blood glucose (hazard ratio [HR] for ideal: 0.37, 95% CI: 0.33, 0.41; HR for intermediate: 0.40, 95% CI: 0.36, 0.45) followed by blood pressure (HR for ideal: 0.50, 95% CI: 0.44, 0.56; HR for intermediate: 0.73, 95% CI: 0.67, 0.81). Ideal levels of the healthy diet score (P -value for trend=0.55) and total cholesterol level (P -value for trend=0.62) were not associated with incident chronic kidney disease.

A model containing the Life's Simple 7 health factors was more predictive of chronic kidney disease risk than the base model including only age, sex, race, and eGFR (ideal Life's Simple 7 health factors AUC: 0.73, 95% CI: 0.72, 0.74 versus base model AUC: 0.68, 95% CI: 0.67, 0.69; $P < 0.001$).

Number of Ideal Health Factors and Risk of Incident Chronic Kidney Disease

Approximately a third of study participants with 0 ideal health factors at baseline developed chronic kidney disease during follow-up, whereas only 6.5% of those with 6 or 7 ideal health factors developed chronic kidney disease (Table 5). There was a graded relationship between number of ideal Life's Simple 7 health factors and risk of incident chronic kidney disease after adjusting for age, sex, race, and eGFR (Figure 2; P -value for trend < 0.001). Compared to 0 ideal health factors, having 6 or 7 health factors was associated with 81% reduced risk of chronic kidney disease (HR: 0.19, 95% CI: 0.12, 0.29).

Components of the Healthy Diet Score and Risk of Incident Chronic Kidney Disease

Of the 5 individual healthy diet score components, the largest proportions of the study population met the ideal criteria for

Table 3. Baseline Characteristics* for Study Participants According to Number of Ideal Life's Simple 7 Factors

	Number of Ideal Life's Simple 7 Factors							<i>P</i> Value for Trend
	0	1	2	3	4	5	6 to 7	
N (%)	380 (2.6)	2217 (15.0)	3821 (25.8)	3935 (26.5)	2750 (18.5)	1316 (8.9)	413 (2.8)	—
Age, y	54.7 (5.5)	54.9 (5.5)	54.8 (5.7)	54.2 (5.8)	53.4 (5.8)	52.6 (5.6)	51.9 (5.5)	< 0.001
Female sex	54.5% (207)	54.1% (1200)	51.3% (1961)	51.9% (2044)	59.3% (1631)	64.0% (842)	67.6% (279)	< 0.001
Black race	42.4% (161)	39.6% (878)	32.9% (1256)	23.0% (904)	15.9% (437)	9.5% (125)	6.3% (26)	< 0.001
BMI, kg/m ²	30.9 (4.5)	30.7 (5.5)	29.2 (5.2)	27.4 (5.0)	25.5 (4.3)	23.9 (3.3)	22.7 (2.4)	< 0.001
Diabetes mellitus	26.5% (100)	26.0% (575)	15.5% (593)	7.6% (299)	3.4% (93)	1.1% (15)	1.0% (4)	< 0.001
Hypertension	68.2% (259)	60.6% (1343)	46.6% (1782)	29.4% (1157)	15.1% (414)	5.7% (75)	2.2% (9)	< 0.001
SBP, mm Hg	132.6 (20.9)	130.4 (18.4)	126.9 (18.2)	120.0 (17.2)	113.6 (15.6)	107.9 (12.3)	104.9 (10.5)	< 0.001
eGFR, mL/min per 1.73 m ²	106.1 (16.2)	103.6 (15.7)	103.1 (15.2)	102.7 (14.2)	102.9 (12.8)	103.0 (12.2)	103.2 (11.1)	0.01
Caloric intake, kcal/day	1607 (607)	1606 (608)	1634 (630)	1645 (611)	1611 (585)	1632 (601)	1634 (559)	0.11

BMI indicates body mass index; eGFR, estimated glomerular filtration rate; SBP, systolic blood pressure.

*Mean (SD) for continuous variables and % (n) for categorical variables unless otherwise stated.

Table 4. Risk of Incident Chronic Kidney Disease Associated With Life's Simple 7 Health Factors

Health Factor (%)	N	CKD Cases, n (%)	IR (95% CI)*	HR (95% CI) [†]	P Value
Cigarette smoking					
Ideal (72.4)	10 740	1955 (18.2)	9.6 (9.2, 10.0)	0.67 (0.62, 0.73)	<0.001
Intermediate (1.5)	215	44 (20.5)	12.0 (9.0, 16.1)	1.03 (0.76, 1.40)	0.83
Poor (26.1)	3877	744 (19.2)	11.6 (10.8, 12.5)	1 [Reference]	—
P-value for trend				<0.001	
Body mass index					
Ideal (33.4)	4955	684 (13.8)	7.3 (6.8, 7.8)	0.74 (0.66, 0.82)	<0.001
Intermediate (39.4)	5849	1069 (18.3)	9.9 (9.3, 10.5)	0.80 (0.73, 0.88)	<0.001
Poor (27.2)	4028	990 (24.6)	14.3 (13.4, 15.2)	1 [Reference]	—
P-value for trend				<0.001	
Physical activity					
Ideal (39.2)	5808	1020 (17.6)	9.4 (8.8, 9.9)	0.89 (0.81, 0.97)	0.009
Intermediate (24.0)	3554	589 (16.6)	8.8 (8.1, 9.6)	0.88 (0.79, 0.97)	0.01
Poor (36.9)	5470	1134 (20.7)	11.9 (11.2, 12.6)	1 [Reference]	—
P-value for trend				0.007	
Healthy diet score					
Ideal (6.2)	923	176 (19.1)	10.3 (8.9, 12.0)	0.99 (0.83, 1.18)	0.92
Intermediate (72.6)	10 765	1994 (18.5)	10.1 (9.7, 10.6)	1.02 (0.93, 1.13)	0.63
Poor (21.2)	3144	573 (18.2)	10.0 (9.2, 10.9)	1 [Reference]	—
P-value for trend				0.55	
Total cholesterol					
Ideal (36.9)	5478	923 (16.9)	9.1 (8.5, 9.7)	0.96 (0.87, 1.06)	0.44
Intermediate (38.2)	5660	1032 (18.2)	9.9 (9.3, 10.5)	0.96 (0.88, 1.05)	0.40
Poor (24.9)	3694	788 (21.3)	12.0 (11.2, 12.9)	1 [Reference]	—
P-value for trend				0.62	
Blood pressure					
Ideal (41.8)	6203	730 (11.8)	5.9 (5.5, 6.3)	0.50 (0.44, 0.56)	<0.001
Intermediate (41.1)	6095	1298 (21.3)	12.0 (11.4, 12.7)	0.73 (0.67, 0.81)	<0.001
Poor (17.1)	2534	715 (28.2)	18.1 (16.8, 19.5)	1 [Reference]	—
P-value for trend				<0.001	
Fasting blood glucose					
Ideal (51.5)	7639	1118 (14.6)	7.5 (7.1, 8.0)	0.37 (0.33, 0.41)	<0.001
Intermediate (38.8)	5752	1059 (18.4)	10.2 (9.6, 10.8)	0.40 (0.36, 0.45)	<0.001
Poor (9.7)	1441	566 (39.3)	29.5 (27.1, 32.0)	1 [Reference]	—
P-value for trend				<0.001	

CKD indicates chronic kidney disease; HR, hazard ratio; IR, incidence ratio.

*Incidence rate per 1000 person-years.

[†]Adjusted for age, sex, race, and baseline estimated glomerular filtration rate (linear spline terms with a knot at 90 mL/min per 1.73 m²).

self-reported consumption of sugar-sweetened beverages (75.1%) defined as ≤ 36 ounces per week (Table 6). Similar to the finding for the overall diet score, none of the individual

components was significantly associated with risk of incident chronic kidney disease either in categorical or continuous analysis (all *P*-values ≥ 0.09).

Table 5. Risk of Incident Chronic Kidney Disease Associated With Number of Ideal Life's Simple 7 Health Factors

Number of Ideal Health Factors (%)	N	CKD Cases, n (%)	IR (95% CI)*	HR (95% CI) [†]	P Value
Zero (2.6)	380	114 (30.0)	21.4 (17.8, 25.7)	1 [Reference]	—
One (15.0)	2217	591 (26.7)	16.6 (15.4, 18.0)	0.74 (0.60, 0.90)	0.003
Two (25.8)	3821	806 (21.1)	12.1 (11.3, 13.0)	0.54 (0.44, 0.66)	<0.001
Three (26.5)	3935	707 (18.0)	9.6 (9.0, 10.4)	0.46 (0.38, 0.56)	<0.001
Four (18.5)	2750	370 (13.5)	6.8 (6.1, 7.5)	0.36 (0.29, 0.45)	<0.001
Five (8.9)	1316	128 (9.7)	4.6 (3.9, 5.5)	0.27 (0.21, 0.34)	<0.001
Six or seven (2.8)	413	27 (6.5)	3.1 (2.1, 4.5)	0.19 (0.12, 0.29)	<0.001
<i>P</i> -value for trend				<0.001	

CKD indicates chronic kidney disease; HR, hazard ratio; IR, incidence ratio.

*Incidence rate per 1000 person-years.

[†]Adjusted for age, sex, race, and baseline estimated glomerular filtration rate (linear spline terms with a knot at 90 mL/min per 1.73 m²).

Sensitivity Analyses

There was no evidence of effect modification by sex (*P*-value for interaction >0.20) or racial group (*P*-value for interaction >0.30).

Effects estimates were similar to the main results using several definitions for healthy diet score components: sugar-sweetened beverages were restricted to regular soft drinks only; orange juice and grapefruit juice were included in the fruits and vegetables category; and white potatoes and sweet potatoes were removed from the fruits and vegetables category.

Using eGFR exclusively for the definition of chronic kidney disease, there were fewer cases and lower incidence rates, but relative risk estimates for chronic kidney disease by number of ideal Life's Simple 7 health factors were similar to those for the composite definition of chronic kidney disease (Table 7).

Discussion

In this population-based cohort study of individuals without kidney disease at baseline, the AHA's Life's Simple 7 healthy lifestyle metric was associated with reduced risk of incident chronic kidney disease even after accounting for demographic characteristics and baseline kidney function. In particular, not smoking, low body mass index, regular physical activity, normal blood pressure, and normal blood glucose levels were associated with a lower risk of chronic kidney disease; whereas a healthy dietary pattern and normal total cholesterol were not. None of the 5 components of the healthy diet score was significantly associated with chronic kidney disease. There was a strong inverse relationship between number of ideal health factors and the development of chronic kidney disease.

To the best of our knowledge, this is the first investigation of a combination of health factors as defined by AHA Life's Simple 7 and incident chronic kidney disease in a general population. Two studies have been published on Life's Simple 7 and kidney disease progression among individuals with impaired kidney function.^{11,12} In a subset of participants in the Reasons for Geographic and Racial Differences in Stroke (REGARDS) study with eGFR <60 mL/min per 1.73 m² (n=3093), 160 end-stage renal disease cases were observed over a median follow-up of 4 years.¹¹ Consistent with our findings, there was a graded relationship between number of ideal health factors and end-stage renal disease risk (HR for 4 versus 0 or 1 ideal factors: 0.52, 95% CI: 0.27, 0.98). However, this relationship was no longer significant after adjusting for eGFR, whereas our results persisted. The attenuation of the association suggests that maintaining optimal levels of health factors and following a healthy lifestyle may be particularly effective for preventing disease before the onset of kidney impairment.

With respect to the individual health factors, as in the present analysis, the REGARDS study found significant protective effects associated with ideal categories of physical activity, blood pressure, and blood glucose, but not with blood cholesterol or diet. Our results and the REGARDS study are consistent with the considerable body of literature reporting no association between total blood cholesterol and chronic kidney disease risk, with the possible exception of triglycerides and high-density lipoprotein cholesterol.^{22–24} Unlike our study, the risk of end-stage renal disease was not significantly associated with body mass index or smoking.

In the Chronic Renal Insufficiency Cohort study, some of the Life's Simple 7 factors—smoking, physical activity, diet, and body mass index—were related to kidney disease progression.¹² Among 3006 Chronic Renal Insufficiency Cohort study participants, there were 726 chronic kidney disease events

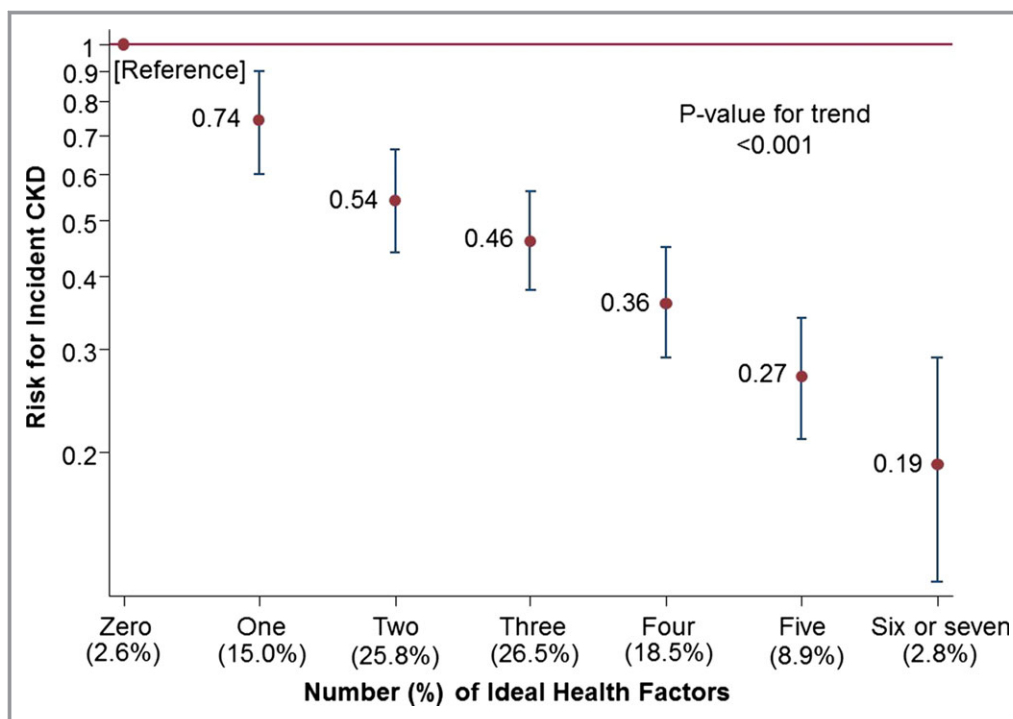


Figure 2. Dose–response relationship between number of Ideal Life’s Simple 7 Health Factors and adjusted hazard ratios for incident chronic kidney disease. Adjusted for age, sex, race, and baseline estimated glomerular filtration rate (linear spline terms with a knot at 90 mL/min per 1.73 m²). Dots represent hazard ratios. Bars on either side of dots represent 95% CI. CKD indicates chronic kidney disease.

over a median follow-up period of 4 years. Similar to the present study and REGARDS, there was a significant association between physical activity and kidney disease risk (except after adjustment for eGFR), but not diet. Also consistent with our findings but in contrast to REGARDS, abstaining from cigarette smoking offered a significant protective effect against kidney disease. The number of ideal lifestyle factors was not related to chronic kidney disease progression in the Chronic Renal Insufficiency Cohort study. Paradoxically, the authors reported lower kidney disease risk with higher body mass index. There is substantial evidence supporting our result that lower body mass index is associated with reduced risk of chronic kidney disease, but there is some heterogeneity in the literature.^{25–28} Some of the inconsistencies between studies may be due to differences in defining ideal levels of the Life’s Simple 7 factors or differences in study populations (chronic kidney disease versus general population cohorts) with the potential for reverse causality in persons with prevalent chronic kidney disease.

There are some limitations to consider when interpreting our results. The observed lack of association between dietary factors and chronic kidney disease is likely due to imprecision and inaccuracies in estimating dietary intake. The food frequency questionnaire is not the ideal instrument for assessing dietary intake, especially sodium. Biomarkers of dietary intake, such as 24-hour urinary sodium levels, were

not available in this study. The specific diet factors and thresholds used to define a heart healthy diet may not have captured the diet characteristics that are relevant for kidney health. Another study limitation, as with any observational study, is the potential influence of residual confounding on the study results due to unmeasured and imprecisely measured confounders. However, the ARIC study cohort is well characterized and data have been collected by standardized procedures with rigorous quality control. There were substantial differences in baseline characteristics according to number of ideal Life’s Simple 7 factors. These baseline characteristics and the strongest risk factors for chronic kidney disease were either incorporated in the Life’s Simple 7 metric or included as covariates in the multivariable regression models. Another limitation is the assessment of Life’s Simple 7 factors at a single time point, which reflects how this health promotion strategy would likely be implemented (ie, during a clinical encounter with a health professional).

Our study also has several strengths. The results were robust to different definitions and forms of the health factors (ie, categorical and continuous), and were consistent across sex and racial groups. The ARIC study population is large and diverse; thus, the results are broadly generalizable to adults in the United States. Given the extended follow-up period, we were able to enumerate several thousand incident chronic kidney disease events in individuals free of kidney disease at

Table 6. Risk of Incident Chronic Kidney Disease Associated With Individual Components of the Healthy Diet Score*

Individual Components of Healthy Diet Score (%)	N	CKD Cases, n (%)	IR (95% CI) [†]	HR (95% CI) [‡]	P Value
Fruits and vegetables					
Meets criteria (19.8)	2942	558 (19.0)	10.5 (9.6, 11.4)	0.94 (0.83, 1.07)	0.35
Does not meet criteria (80.2)	11 889	2185 (18.4)	10.0 (9.6, 10.5)	1 [Reference]	—
P-value for trend				0.99	
Fish					
Meets criteria (29.3)	4345	822 (18.9)	10.3 (9.6, 11.1)	0.97 (0.89, 1.07)	0.56
Does not meet criteria (70.7)	10 487	1921 (18.3)	10.0 (9.6, 10.5)	1 [Reference]	—
P-value for trend				0.30	
Fiber-rich whole grains					
Meets criteria (11.1)	1643	324 (19.7)	10.9 (9.8, 12.2)	1.03 (0.89, 1.19)	0.72
Does not meet criteria (88.9)	13 189	2419 (18.3)	10.0 (9.6, 10.4)	1 [Reference]	—
P-value for trend				0.82	
Sodium					
Meets criteria (68.1)	10 101	1858 (18.4)	10.0 (9.6, 10.5)	1.00 (0.89, 1.14)	0.95
Does not meet criteria (31.9)	4731	885 (18.7)	10.4 (9.7, 11.1)	1 [Reference]	—
P-value for trend				0.09	
Sugar-sweetened beverages					
Meets criteria (75.1)	11 133	2043 (18.4)	10.0 (9.6, 10.4)	0.97 (0.88, 1.08)	0.60
Does not meet criteria (24.9)	3699	700 (18.9)	10.4 (9.7, 11.2)	1 [Reference]	—
P-value for trend				0.22	

CKD indicates chronic kidney disease; HR, hazard ratio; IR, incidence rate.

*Intake recommendations are expressed for a daily caloric intake of 2000 kcal, and are scaled to calories consumed for each participant. Further details about the AHA Healthy Diet Score and criteria for the individual components are provided in Table 2.

[†]Incidence rate per 1000 person-years.

[‡]Adjusted for total caloric intake, age, sex, race, baseline estimated glomerular filtration rate (linear spline terms with a knot at 90 mL/min per 1.73 m²), body mass index, physical activity, diabetes, and hypertension.

baseline, whereas previous studies were limited to chronic kidney disease cohorts with fewer kidney disease events. We have provided a comprehensive assessment of all 7 health

factors for the overall Life's Simple 7 metric and for each factor individually including the 5 components of the healthy diet score as they relate to chronic kidney disease risk.

Table 7. Risk of Incident Chronic Kidney Disease (Defined Using eGFR*) Associated With Number of Ideal Life's Simple 7 Health Factors

Number of Ideal Health Factors (%)	N	CKD Cases, n (%)	IR (95% CI) [†]	HR (95% CI) [‡]	P Value
Zero (2.3)	331	30 (9.1)	11.8 (8.2, 16.8)	1 [Reference]	—
One (14.4)	2055	188 (9.2)	10.9 (9.4, 12.6)	0.74 (0.50, 1.09)	0.13
Two (25.6)	3662	300 (8.2)	9.1 (8.1, 10.2)	0.51 (0.35, 0.74)	<0.001
Three (26.8)	3828	307 (8.0)	8.3 (7.4, 9.3)	0.48 (0.33, 0.70)	<0.001
Four (18.9)	2699	177 (6.6)	6.5 (5.6, 7.5)	0.40 (0.27, 0.59)	<0.001
Five (9.2)	1308	83 (6.4)	5.8 (4.7, 7.2)	0.34 (0.22, 0.51)	<0.001
Six or seven (2.9)	411	15 (3.7)	3.3 (2.0, 5.5)	0.19 (0.10, 0.35)	<0.001
P-value for trend				<0.001	

CKD indicates chronic kidney disease; eGFR, estimated glomerular filtration rate; HR, hazard ratio; IR, incidence ratio.

*Incident chronic kidney disease defined as eGFR <60 mL/min per 1.73 m² accompanied by ≥25% eGFR decline.

[†]Incidence rate per 1000 person-years.

[‡]Adjusted for age, sex, race, and baseline eGFR (linear spline terms with a knot at 90 mL/min per 1.73 m²).

In conclusion, the AHA Life's Simple 7 metric, developed to measure and promote cardiovascular health, predicts reduced risk of incident chronic kidney disease. Five of 7 Life's Simple 7 factors (not smoking, normal body mass index, regular physical activity, normal blood pressure, and normal blood glucose) were protective against kidney disease in a general population. Attainment of ideal cardiovascular health may also have substantial benefit for prevention of chronic kidney disease. Recommending these ideal health factors may be effective as a population-wide chronic kidney disease preventive strategy.

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Disclosures

None.

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