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CADIOVASCULAR HEALTH AND INCIDENT HYPERTENSION IN AFRICAN AMERICANS: THE JACKSON HEART STUDY

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Abstract

Several modifiable health behaviors and health factors that comprise the Life's Simple 7, a cardiovascular health metric, have been associated with hypertension risk. We determined the association between cardiovascular health and incident hypertension in the Jackson Heart Study, a cohort of African-Americans. We analyzed participants without hypertension or cardiovascular disease at baseline (2000–2004) who attended 1 follow-up visit in 2005–2008 or 2009–2012 (n=1878). Body mass index, physical activity, diet, cigarette smoking, blood pressure, total cholesterol and fasting glucose were assessed at baseline and categorized as ideal, intermediate or poor using the American Heart Association's Life's Simple 7 definitions. Incident hypertension was defined at the first visit wherein a participant had systolic blood pressure ≥ 140 mmHg, diastolic blood pressure ≥ 90 mmHg or self-reported taking antihypertensive medication. The percentage of participants with 1, 2, 3, 4, 5 and 6 ideal Life's Simple 7 components was 6.5%, 22.4%, 34.4%, 25.2%, 10.0% and 1.4%, respectively. No participants had 7 ideal components. During follow-up (median: 8.0 years), 944 (50.3%) participants developed hypertension, including 81.3% with 1 and 11.1% with 6 ideal components. The multivariable-adjusted hazard ratios (95% confidence interval) for incident hypertension comparing participants with 2, 3, 4, 5 and 6 versus 1 ideal component were 0.80 (0.61–1.03), 0.58 (0.45–0.74), 0.30 (0.23–0.40), 0.26 (0.18–0.37) and 0.10 (0.03–0.31), respectively (p-trend<0.001). This association was present among participants with baseline systolic blood pressure<120 mmHg and diastolic blood pressure<80 mmHg and, separately systolic blood pressure 120–139 or diastolic blood pressure 80–89 mmHg. African-Americans with better cardiovascular health have lower hypertension risk.

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Keywords

African American; incident hypertension; Life's Simple 7; cardiovascular health

Compared with whites, African Americans have higher blood pressure (BP) levels beginning in childhood and a higher incidence and prevalence of hypertension across the lifespan.¹⁻⁴ Although antihypertensive medication is effective in lowering BP and cardiovascular disease (CVD) risk, it does not lower risk to the same level as someone without hypertension.^{5, 6} Preventing hypertension is a central component for reducing CVD among African Americans.^{7, 8}

In 2010, the American Heart Association (AHA) announced a strategic impact goal for the year 2020 “to improve cardiovascular health in all Americans by 20%, while reducing deaths from CVD and stroke by 20%”.^{1, 9} The concept of cardiovascular health was described to help promote health behaviors and highlight the importance of preventing CVD risk factors from developing and sustaining the absence of CVD throughout the life-course.⁹ The AHA identified 4 health behaviors (i.e., body mass index [BMI], physical activity, diet, cigarette smoking) and 3 health factors (i.e., BP, total cholesterol and fasting glucose levels) that can be modified to reduce the number of CVD and stroke events occurring in the United States.⁹ Termed Life's Simple 7, these components are being used by the AHA to monitor the cardiovascular health of the US population.⁹ Each Life's Simple 7 component has been defined using poor, intermediate and ideal levels in order to monitor the full spectrum of cardiovascular health.⁹

Studies have shown that having ideal levels of more Life's Simple 7 components is associated with a lower incidence of CVD.^{1, 10-13} Data on interventions that prevent hypertension in African Americans are limited.^{7, 8} Determining the benefits of ideal cardiovascular health on the risk for hypertension may provide evidence to develop multifaceted prevention approaches tailored for African Americans.¹ Therefore, we evaluated the association of cardiovascular health defined by the Life's Simple 7 with incident hypertension among African Americans. We hypothesized that better cardiovascular health would be associated with a lower risk for developing hypertension. Results from the current study may provide evidence that the AHA's Life's Simple 7 cardiovascular health metric designed to monitor CVD risk is a practical, population-level approach for surveillance of hypertension risk in African Americans.

Methods

Study population

The Jackson Heart Study (JHS), a community-based prospective cohort study, was designed to evaluate CVD risk among African Americans.¹⁴ Between 2000 and 2004, the JHS enrolled 5,306 non-institutionalized African Americans aged 20 years from the Atherosclerosis Risk in the Community (ARIC) study site in Jackson, Mississippi (n=1,626), and a representative sample of urban and rural Jackson, Mississippi metropolitan tri-county (Hinds, Madison and Rankin counties) residents, volunteers, randomly contacted individuals

and secondary family members of participants (n=3,680).¹⁵ Participants from the ARIC study were eligible for the JHS if they lived in the Jackson, Mississippi metropolitan tri-county area, completed the fourth ARIC study exam in 1996–1998 and trained recruiters determined they were physically and mentally competent in order to increase the probability of retention.¹⁶ The current analysis was restricted to JHS participants with complete information on SBP, DBP and antihypertensive medication use at the baseline exam. Participants with hypertension, defined below, at baseline were excluded from the current analyses. As the concept of cardiovascular health emphasizes preventing CVD, participants who self-reported a physician diagnosis of myocardial infarction (MI) or stroke at baseline were excluded. Among participants who were enrolled in the ARIC study, history of MI and stroke also included adjudicated events that occurred following the ARIC baseline study visit and prior to their enrollment in the JHS. Participants who did not attend Exam 2 (2005–2008) or Exam 3 (2009–2012) and did not have complete data on SBP, DBP and use of antihypertensive medication from at least one of these exams were excluded because we were not able to determine if they developed incident hypertension. After applying these criteria, we analyzed data from 1,878 JHS participants. Institutional Review Boards at the University of Mississippi Medical Center, Jackson State University and Tougaloo College approved the JHS protocol. The Institutional Review Board at the University of Alabama at Birmingham approved the current analysis of de-identified data. All participants provided written informed consent.

Data Collection

Baseline data were collected during an in-home interview and clinic examination. Trained research staff administered questionnaires to collect self-reported information on age, sex, education, annual household income, marital status, history of MI and stroke, parental history of hypertension, antihypertensive, lipid-lowering and anti-diabetes medication use, cigarette smoking, diet and physical activity. Also, the pill bottles for prescription and over the counter medications taken in the two weeks prior to the study exam were reviewed. The names of medications were recorded and categorized by class. Trained research staff also measured height, weight and BP and collected blood and urine samples.

Albumin and creatinine were quantified from a 24-hour urine collection or from a spot urine sample using the nephelometric immunoassay and enzymatic methods, respectively.¹⁷ Serum creatinine was measured using enzymatic methods and calibrated to Isotope Dilution Mass Spectroscopy (IDMS) traceable creatinine.¹⁸ Estimated glomerular filtration rate (eGFR) was calculated using the Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) equation.¹⁹ CKD was defined as urinary-albumin-to-urinary-creatinine ratio ≥ 30 mg/g and/or eGFR <60 ml/min/1.73 m².

Life's Simple 7—The AHA's Life's Simple 7 components are comprised of 4 health behaviors (BMI, physical activity, diet and cigarette smoking) and 3 health factors (BP, total cholesterol and fasting glucose). Definitions have been published for categorizing each Life's Simple 7 component as being ideal, intermediate and poor (Table S1).⁵

Health behaviors (BMI, physical activity, diet, cigarette smoking)—Height and weight were measured during the baseline study visit. Body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared. Using a modified Baecke questionnaire that was validated in the JHS using pedometers and accelerometers, the weekly duration and annual frequency of participation in sports/exercises over the previous year were recorded and summed to calculate a total number of minutes per week spent in moderate or vigorous physical activity.^{20, 21} Dietary intake of fruits, vegetables, fish, whole grains, sodium and sugary beverages were assessed using a 158-item food frequency questionnaire (FFQ) that was validated in a subset of the JHS participants using 24-hour dietary recall repeated over four consecutive months.²² Cigarette smoking status was defined using the same questions as the ARIC study including “Have you smoked more than 400 cigarettes in your lifetime?” and “Do you now smoke cigarettes?”²³

Health factors (BP, total cholesterol, fasting glucose)—Clinic BP was measured at each exam following a standardized protocol.¹² After participants had sat for at least 5 minutes in an upright position with their back and arms supported, feet flat on the floor, legs uncrossed and an appropriate cuff size was fitted, trained staff conducted two BP measurements in their right arm.^{14, 24} Cuff size was determined from an arm circumference measurement. One minute elapsed between the two measurements. A random-zero sphygmomanometer (Hawksley and Sons Ltd) was used at baseline and Exam 2. A semi-automatic oscillometric device (Omron HEM-907XL, Omron Healthcare Inc., Lake Forest, IL) was used for all participants at Exam 3. A BP comparability sub-study was performed in 2,115 participants who had their BP measured simultaneously with a random-zero sphygmomanometer and the oscillometric device using a Y-connector at Exam 2.²⁵ Since semi-automated devices are commonly used in clinical practice, the random-zero BP measurements were calibrated to the semi-automated device by modeling the differences in BP measurements between devices as a function of the random-zero sphygmomanometer. Detailed information related to the calibration is provided in the Supplemental Materials. Figure S1 shows Bland-Altman plots comparing systolic and, separately diastolic BP measurements using the random-zero sphygmomanometer and oscillatory device.

BP was measured by technicians who were trained and certified to follow the research protocol. A study coordinator or BP supervisor conducted training. Instruction on BP measurement using the random-zero sphygmomanometer included listening to recordings of Korotkoff sounds and observing BP measurements. Certification to measure BP required staff to pass a test in which the technician and instructor simultaneously measured BP using a Y-tube stethoscope. The JHS Coordinating Center conducted quality control by monitoring digit preference, comparing mean BP measurements within and between technicians, providing feedback during regular meetings and through re-certification testing every six months. SBP and DBP were defined as the mean of the two measurements at each exam. Normal BP was defined as SBP <120 mm Hg and DBP < 80 mm Hg.⁶ Prehypertension was defined as SBP between 120 and 139 mm Hg with DBP < 90 mm Hg or DBP between 80 and 89 mmHg with SBP < 140 mm Hg.⁶

Blood samples collected after an overnight fast (8 hours) were used to quantify total cholesterol, hemoglobin A1c (HbA1c) and blood glucose.⁹

Incident hypertension—At each exam, participants were categorized as taking antihypertensive medication if they self-reported use of BP lowering medication for high BP in the two weeks prior to their clinic examination. Incident hypertension was defined as the first follow-up exam at which a participant had SBP ≥ 140 mm Hg, DBP ≥ 90 mm Hg or self-reported antihypertensive medication use.

Statistical analysis

The distribution of ideal Life's Simple 7 components was calculated for participants included in the current analysis. Baseline characteristics and the cumulative incidence of hypertension during follow-up were calculated overall and by number of ideal Life's Simple 7 components. Since there were few participants with 0 ideal Life's Simple 7 components, those with 0 or 1 component were grouped together. Also, no participants had all 7 ideal Life's Simple 7 components. The cumulative incidence of hypertension and 95% confidence intervals (CI) was calculated among participants with 1, 2, 3, 4, 5 and 6 ideal components. Hazard ratios (HR) and 95% CI for incident hypertension associated with 2, 3, 4, 5 and 6 versus 1 ideal component were calculated using interval-censored regression. Interval-censored regression was used because the exact date when participants developed hypertension during follow-up was unknown, only that it occurred between two study visits.²⁶ Participants who attended the baseline exam and at least one follow-up exam but did not develop hypertension were censored at the last exam they attended. The interval-censored regression model accounted for the time since baseline at which each event occurred and the censoring of participants who did not have complete follow-up. We selected variables for adjustment *a priori* based on their known associations with the Life's Simple 7 components (exposure) and incident hypertension (outcome). An initial model included adjustment for age, sex, education, income and marital status. A second model included further adjustment for CKD and parental history of hypertension. Analyses were repeated for participants with normal BP and prehypertension, separately, and after excluding BP as a Life's Simple 7 component. Also, the association between number of ideal health behaviors (i.e., BMI, physical activity, diet, smoking status) and factors (i.e., BP, cholesterol, glucose), separately, was calculated. The association for the levels (i.e., intermediate and ideal versus poor) of individual Life's Simple 7 components with incident hypertension was calculated. Next, a Life's Simple 7 score was determined for each participant by assigning individual components 2 points for an ideal level, 1 point for an intermediate level and 0 points for a poor level. The composite score was calculated as the sum of assigned values (possible range: 0 to 14 points) with higher scores indicating better cardiovascular health. Participants were categorized by Life's Simple 7 composite scores into similarly sized groups (i.e., Life's Simple 7 scores 6, 7, 8, 9, 10, 11). The cumulative incidence of hypertension and adjusted HRs for incident hypertension associated with the Life's Simple 7 score were calculated, overall, and for participants with normal BP and prehypertension. In a sensitivity analysis, we required self-reported antihypertensive medication use to be confirmed by the presence of one or more classes of antihypertensive medication on the pill bottle review. In this analysis, incident hypertension was defined as the first follow-up visit where a participant had SBP ≥ 140 mm Hg, DBP ≥ 90 mm Hg or self-reported antihypertensive medication use with one or more classes of antihypertensive medication present on the pill bottle review. For the above analyses, missing data were imputed with 10 data sets using

chained equations.²⁷ The number and percentage of participants with missing data for each variable included in this analysis is reported in Table S2. In a sensitivity analysis, we also repeated the main analyses after excluding participants missing relevant data (i.e., a complete case analysis). P-values <0.05 were considered statistically significant. Analyses were conducted using SAS version 9.4 (SAS Institute, Inc., Cary, NC) or Stata/IC version 12.1 (Stata Inc., College Station, TX).

Results

Participant characteristics

The percentage of participants with 0 or 1, 2, 3, 4, 5 and 6 ideal Life's Simple 7 components is shown in Figure 1. Participants with more ideal Life's Simple 7 components were younger, less likely to be men, have less than a high school education, household income < \$25,000 annually and CKD (Table 1). Also, participants with more ideal Life's Simple 7 components had lower mean SBP and DBP at baseline.

Number of ideal Life's Simple 7 components and incident hypertension

Over a median follow-up of 8.0 years (maximum: 11.8 years), 944 (50.3%) participants developed hypertension (618 incident cases at Exam 2 and 326 incident cases at Exam 3). The cumulative incidence of hypertension was lower among participants with more ideal Life's Simple 7 components (p-trend<0.001; Figure 2). After multivariable adjustment, the HR (95% CI) for incident hypertension comparing 2, 3, 4, 5 and 6 versus 1 ideal component were 0.79 (0.62–1.02), 0.57 (0.45–0.73), 0.30 (0.23–0.40), 0.26 (0.18–0.37) and 0.10 (0.03–0.32), respectively (p-trend<0.001; Table 2, top panel). The cumulative incidence of hypertension was lower with increasing numbers of ideal Life's Simple 7 components among participants who had normal BP and prehypertension, separately (Table 2, middle and bottom panel). Also, the cumulative incidence of hypertension was lower with more ideal Life's Simple 7 components when the ideal number of Life's Simple 7 was calculated without BP as a component (Table S3).

Number of ideal Life's Simple 7 health behaviors and factors and incident hypertension

Overall, 8.1%, 59.1%, 29.3%, 3.5% of participants had 0, 1, 2 and 3 ideal behavioral components, respectively. No participants had ideal levels of all 4 health behaviors. Also, 6.0%, 28.1%, 41.7%, and 24.2% of participants had 0, 1, 2 and 3 ideal health factors, respectively. Participants with more ideal Life's Simple 7 health behaviors and health factors had a lower incidence of hypertension before and after multivariable adjustment (Table 3).

Life's Simple 7 individual components and incident hypertension

The percentage of participants with ideal Life's Simple 7 components was 18.6% for BMI; 23.1% for physical activity, 0.6% for diet, 85.9% for smoking status, 45.2% for BP, 51.6% for total cholesterol and 87.3% for fasting blood glucose. The incidence of hypertension was lower for intermediate and ideal versus poor levels of BMI, physical activity, diet and fasting blood glucose, ideal compared with poor smoking status and ideal compared with intermediate BP before and after multivariable adjustment (Table 4). Cholesterol was not associated with incident hypertension after adjustment.

Life's Simple 7 score and incident hypertension

The cumulative incidence of hypertension was lower among participants with higher Life's Simple 7 scores (Table S4, top panel). After multivariable adjustment, the HR (95% CI) for developing hypertension associated with Life's Simple 7 scores of 7, 8, 9, 10 and 11 versus 6 were 0.96 (0.78–1.18), 0.72 (0.59–0.89), 0.60 (0.49–0.74), 0.35 (0.27–0.46) and 0.29 (0.21–0.40), respectively. Higher Life's Simple 7 scores were associated with a lower risk for hypertension among participants with normal BP and prehypertension, analyzed separately (Table S4, middle and bottom panel).

Sensitivity analyses

The results were consistent with the main analyses when incident hypertension was defined as SBP \geq 140 mm Hg, DBP \geq 90 mm Hg or self-reported antihypertensive medication use with one or more classes of antihypertensive medication identified during the pill bottle review. During follow-up, 50.4% of participants met the definition for hypertension used in the sensitivity analysis. Better cardiovascular health and, separately, better health behaviors and health factors were associated with lower risk for hypertension (Tables S5 and S6). Also, better levels of BMI, physical activity, diet and fasting blood glucose were associated with lower risk for hypertension (Table S7). Ideal compared with poor smoking status and ideal compared with intermediate BP were also associated with lower risk for hypertension. Cholesterol was not associated with incident hypertension. Results of the complete cases analyses were consistent with the main results (Tables S8, S9 and S10).

Discussion

In this community-based study of African Americans, two-thirds of participants had three or fewer ideal Life's Simple 7 components and no participants had all seven. There was a strong graded association between having more ideal Life's Simple 7 components and a lower incidence of hypertension. This association was consistent among participants with normal BP and prehypertension. Also, having more ideal health behaviors and health factors were each associated with a progressively lower incidence of hypertension.

Prior studies have demonstrated an association between having more ideal Life's Simple 7 components and a lower incidence of CVD in African Americans.^{9, 11, 28–33} Among 3,107 African American participants of the ARIC study who were followed for a median 18.7 years, the age-sex adjusted CVD incidence rates per 1,000 person years (95% CI) for participants with 0, 1, 2, 3, 4 and 5 ideal Life's Simple 7 components were 40.4 (32.0–51.5), 25.3 (22.4–28.6), 16.9 (15.0–19.1), 14.2 (12.2–16.5), 8.7 (6.6–11.5) and 3.3 (1.5–7.4), respectively.²⁹ Having more Life's Simple 7 components in the ideal range has also been associated with a lower risk for incident cognitive impairment^{34, 35}, venous thromboembolism³⁶, vascular and non-vascular death,²⁸ end-stage renal disease³⁷ and CKD³⁸ in African Americans.

Several individual Life's Simple 7 components have been associated with an increased risk for hypertension, including higher BMI, physical inactivity, diet, cigarette smoking and higher BP, cholesterol and fasting glucose levels.³⁹ The presence of multiple Life's Simple 7

components may accelerate the development of hypertension. Systematic reviews report that ideal cardiovascular health behaviors (i.e., ideal BMI, physical activity, diet, cigarette smoking status) are associated with lower levels of health factors (i.e., BP, cholesterol and glucose).^{1, 9, 29, 40} The results from the current study indicate that having more ideal Life's Simple 7 components overall and, separately, a higher number of health behaviors and health factors are associated with lower hypertension risk.

The percentage of US adults 20 years old who have ideal levels of all Life's Simple 7 components was <1% in the 2011–2012 National Health and Nutrition Examination Survey (NHANES).¹ Prior studies indicate that African Americans are less likely to have ideal cardiovascular health compared with whites.^{1, 9, 11, 28–31} Only one-third of JHS participants without hypertension at baseline had four or more ideal Life's Simple 7 components highlighting a need for interventions that improve cardiovascular health in African Americans to lower the incidence of hypertension and, ultimately, CVD risk.

Antihypertensive medication use lowers CVD risk in adults with hypertension.⁴¹ However, CVD risk remains higher among people with controlled BP on antihypertensive medication compared with adults with similar BP but without hypertension.⁴² This highlights the benefits of maintaining low BP levels across the lifespan.^{5, 6, 42} The Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure (JNC7) recommends lifestyle modification to lower BP and reduce CVD risk, but evidence for their use to prevent hypertension in African Americans is limited.^{6–8} In a systematic review of intervention studies (e.g., increasing physical activity, improving diet/nutrition and weight and stress reduction) for lowering BP or achieving BP targets, 27 studies were identified that included at least 50% enrollment of African-American participants or at least 50% of African-American participants in subgroup analyses. Health behavior modification including increasing physical activity, improving diet/nutrition and weight and stress reduction was associated with lower BP levels, improved BP control and lower incident hypertension.^{7, 8} More evidence was available for limiting sodium intake compared with using physical activity, weight loss and stress reduction approaches to lower BP levels.⁷ The current study of 1,878 African Americans suggests that improving poor and intermediate cardiovascular health to an ideal level may lower the risk for developing hypertension. Furthermore, it provides evidence that the Life's Simple 7, an established cardiovascular health metric, may be a practical, population-level approach for surveillance of hypertension risk in African Americans.

The current study has several strengths. The JHS represents one of the largest cohort studies of African Americans with standardized and longitudinal data collection for evaluating CVD risk. BP was measured following a standardized protocol at each exam. Despite these strengths, there are also limitations. The JHS may be considered small relative to some other cohort studies or studies using administrative claims data.^{43, 44} However, administrative data rarely include all of the Life's Simple 7 components. Also, the high rate of hypertension in the JHS provided enough power to detect small differences in the outcome across categories of the number of ideal Life's Simple 7 components. Physical activity, diet and cigarette smoking were self-reported and objective measures of these factors were not available. BP was measured only two times at each study visit. Also, BP was measured using different

devices at baseline and during follow-up. However, we were able to calibrate the BP measurements across study exams. While the median follow-up of 8 years may be considered short, the high incidence of hypertension in African Americans provided a large number of outcomes for this analysis.

Perspectives

There was a strong graded association between having more ideal Life's Simple 7 components and a lower risk for hypertension. This association was present among participants with normal BP and prehypertension. Having more ideal health behaviors and, separately, ideal health factors, were each associated with a lower risk for hypertension. The current study suggests that even modest improvements in cardiovascular health behaviors and risk factors may lower the risk for hypertension in African Americans. Additionally, the Life's Simple 7 is an established metric that can be used to monitor hypertension risk in African Americans.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Novelty and Significance

What's new?

- Few data are available on global cardiovascular health and hypertension risk in African Americans.
- Determining the benefits of ideal cardiovascular health on incident hypertension among African Americans may provide evidence for using the Life's Simple 7 to monitor this high-risk population for hypertension.

What is relevant?

- The majority of African Americans had less than 3 ideal Life's Simple 7 components and no participants had all 7.
- Hypertension developed in 81.3% of participants with 1 ideal component compared to 11.1% of participants with 6 ideal components.
- There was a strong graded association between higher numbers of ideal Life's Simple 7 components and lower hypertension risk after multivariable adjustment.

Summary

- African Americans with better cardiovascular health had a lower incidence of hypertension.
- The Life's Simple 7 metric may be a useful framework for monitoring hypertension risk in African Americans.

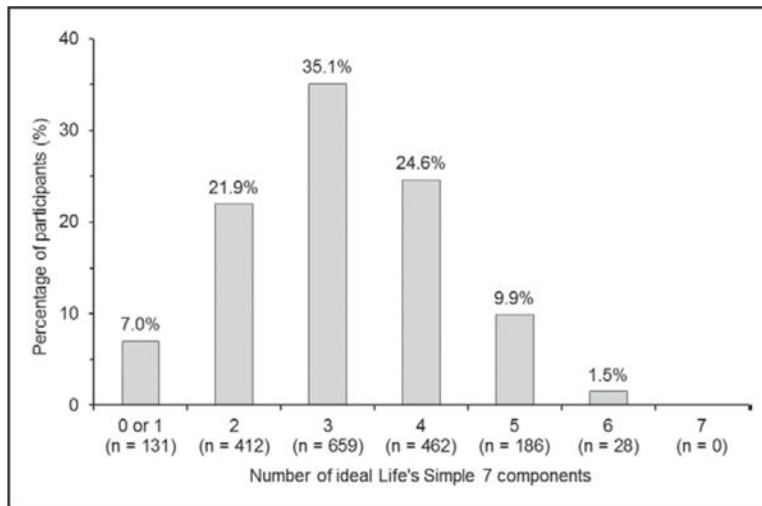


Figure 1. Distribution of the number of ideal Life's Simple 7 components among Jackson Heart Study participants without hypertension at baseline (n=1878).

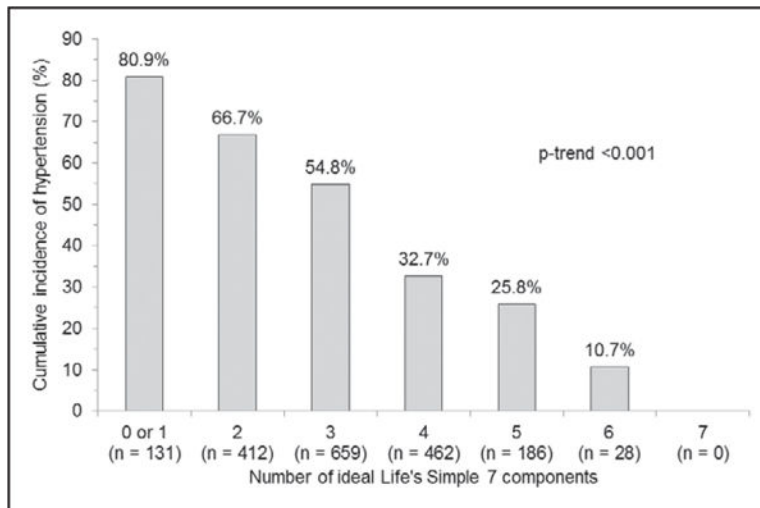


Figure 2. Cumulative incidence of hypertension by number of ideal Life's Simple 7 components (n=1878).

Table 1

Baseline characteristics of Jackson Heart Study participants without hypertension by number of ideal Life's Simple 7 components.

Characteristic	Overall (n=1878)	Number of Ideal Life's Simple 7 Components*						p-trend
		0 or 1 (n=131)	2 (n=412)	3 (n=659)	4 (n=462)	5 (n=186)	6 (n=28)	
Age, years	49.0 ± 11.9	54.2 ± 10.9	53.2 ± 11.2	49.5 ± 11.6	46.1 ± 11.3	43.0 ± 11.7	37.4 ± 9.8	<0.001
Men	39.0%	44.3%	42.2%	38.2%	35.3%	41.4%	28.6%	0.058
Less than a high school education	11.7%	22.1%	17.2%	10.3%	7.4%	9.1%	0.0%	<0.001
Household income < \$25,000 annually	29.1%	38.2%	29.9%	30.2%	25.5%	26.9%	21.4%	0.005
Married	58.6%	61.1%	60.2%	57.5%	61.7%	50.0%	57.1%	0.195
Chronic kidney disease	7.3%	19.8%	11.2%	6.4%	4.1%	1.6%	7.1%	<0.001
Parental history of high blood pressure	68.3%	66.4%	65.3%	68.3%	70.3%	71.5%	67.9%	0.112
Systolic blood pressure, mmHg	118.6 ± 10.6	125.8 ± 8.0	124.3 ± 8.7	119.8 ± 10.3	113.6 ± 9.6	110.7 ± 8.1	108.5 ± 6.1	<0.001
Diastolic blood pressure, mmHg	74.1 ± 7.3	75.3 ± 7.2	76.4 ± 7.3	74.6 ± 7.3	72.2 ± 6.7	71.1 ± 6.4	70.6 ± 6.7	<0.001
Life's Simple 7 individual components								
Ideal body mass index	18.6%	3.8%	3.4%	13.2%	25.5%	53.2%	96.4%	<0.001
Ideal physical activity	23.1%	1.5%	5.3%	17.9%	32.5%	61.3%	100.0%	<0.001
Ideal diet	0.6%	0.0%	0.0%	0.5%	0.9%	2.2%	3.6%	0.001
Ideal smoking status	85.9%	56.5%	79.9%	86.5%	93.3%	97.3%	100.0%	<0.001
Ideal blood pressure level	45.2%	2.3%	11.9%	38.2%	74.5%	93.0%	100.0%	<0.001
Ideal total cholesterol level	51.6%	3.8%	20.1%	50.7%	74.5%	94.1%	100.0%	<0.001
Ideal fasting blood glucose level	87.3%	23.7%	79.4%	93.0%	98.9%	98.9%	100.0%	<0.001

Numbers reported in table are mean ± standard deviation or percentages.

The definition for each ideal Life's Simple 7 component is shown in Table 1.

* No participants had 7 Ideal Life's Simple 7 components.

Table 2

Hazard ratios for incident hypertension associated with the number of ideal Life's Simple 7 components in the overall population and for participants with normal blood pressure and prehypertension, separately, at baseline.

Number of Ideal Life's Simple 7 components*	N cases of incident hypertension/N at risk (% with incident hypertension)	Hazard ratio (95% confidence interval)	
		Model 1	Model 2
Overall* (n=1878)			
0 or 1	106 / 131 (80.9%)	1 (reference)	1 (reference)
2	275 / 412 (66.7%)	0.78 (0.61–1.00)	0.79 (0.62–1.02)
3	361 / 659 (54.8%)	0.56 (0.44–0.72)	0.57 (0.45–0.73)
4	151 / 462 (32.7%)	0.30 (0.23–0.39)	0.30 (0.23–0.40)
5	48 / 186 (25.8%)	0.25 (0.17–0.35)	0.26 (0.18–0.37)
6	3 / 28 (10.7%)	0.10 (0.03–0.31)	0.10 (0.03–0.32)
p-trend	<0.001	<0.001	<0.001
Normal blood pressure**† (n=911)			
0 or 1	6 / 12 (50.0%)	1 (reference)	1 (reference)
2	42 / 76 (55.3%)	1.34 (0.50–3.57)	1.34 (0.50–3.62)
3	112 / 275 (40.7%)	0.82 (0.32–2.07)	0.82 (0.32–2.13)
4	89 / 347 (25.6%)	0.52 (0.21–1.31)	0.53 (0.21–1.36)
5	39 / 173 (22.5%)	0.50 (0.19–1.30)	0.51 (0.19–1.35)
6	3 / 28 (10.7%)	0.23 (0.05–1.00)	0.24 (0.05–1.03)
p-trend	<0.001	<0.001	<0.001
Prehypertension**‡ (n=967)			
0 or 1	100 / 119 (84.0%)	1 (reference)	1 (reference)
2	233 / 336 (69.3%)	0.75 (0.58–0.96)	0.76 (0.59–0.98)
3	249 / 384 (64.8%)	0.69 (0.54–0.90)	0.70 (0.55–0.91)
4	62 / 115 (53.9%)	0.52 (0.37–0.73)	0.53 (0.38–0.75)
5	9 / 13 (69.2%)	0.87 (0.44–1.74)	0.93 (0.47–1.87)
6	*	*	*
p-trend	<0.001	<0.001	0.001

* For the overall population and among participants with normal blood pressure, the maximum number of ideal components was 6. In participants with prehypertension, the maximum number of ideal components was 5 since these participants cannot have ideal or intermediate blood pressure by definition.

† Normal blood pressure was defined as systolic blood pressure <120 mmHg and diastolic blood pressure <80 mmHg.

‡ Prehypertension was defined as systolic blood pressure between 120 and 139 mmHg and/or diastolic blood pressure between 80 and 89 mmHg. For participants with prehypertension, the maximum number of ideal components was 5.

Model 1 is adjusted for age, sex, education, income and marital status.

Model 2 is adjusted for the variables in Model 1 and parental history of hypertension and chronic kidney disease.

Table 3

Hazard ratios for incident hypertension associated with the number of ideal Life's Simple 7 health behaviors and factors, separately (n=1878).

Number of Ideal Life's Simple 7 components	N cases of incident hypertension/N at risk (% with incident hypertension)	Hazard ratio (95% confidence interval)	
		Model 1	Model 2
Health behaviors[*]			
0	98 / 152 (64.5%)	1 (reference)	1 (reference)
1	601 / 1109 (54.2%)	0.73 (0.59–0.91)	0.74 (0.59–0.92)
2	224 / 551 (40.7%)	0.53 (0.42–0.68)	0.54 (0.43–0.69)
3	21 / 66 (31.8%)	0.39 (0.24–0.63)	0.40 (0.25–0.64)
p-trend	<0.001	<0.001	<0.001
Health factors[†]			
0	91 / 113 (80.5%)	1 (reference)	1 (reference)
1	351 / 527 (66.6%)	0.73 (0.57–0.94)	0.74 (0.57–0.96)
2	378 / 783 (48.3%)	0.48 (0.37–0.62)	0.49 (0.38–0.63)
3	124 / 455 (27.3%)	0.24 (0.18–0.32)	0.25 (0.18–0.33)
p-trend	<0.001	<0.001	<0.001

* Health behaviors: body mass index, physical activity, diet and smoking status. There were no participants with all 4 ideal health behaviors.

† Health factors: blood pressure, total cholesterol and fasting blood glucose.

Model 1 is adjusted for age, sex, education, income and marital status.

Model 2 is adjusted for the variables in Model 1 and parental history of hypertension and chronic kidney disease.

Table 4

Hazard ratios for incident hypertension associated with the levels of cardiovascular health for individual Life's Simple 7 components (n=1878).

Level of cardiovascular health	N cases of incident hypertension/N at risk (% with incident hypertension)	Hazard ratio (95% confidence interval)	
		Model 1	Model 2
Body mass index			
Poor	496 / 869 (57.1%)	1 (reference)	1 (reference)
Intermediate	310 / 659 (47.0%)	0.74 (0.64–0.86)	0.75 (0.65–0.87)
Ideal	138 / 350 (39.4%)	0.60 (0.49–0.72)	0.61 (0.50–0.74)
P-trend	<0.001	<0.001	<0.001
Physical activity			
Poor	437 / 776 (56.3%)	1 (reference)	1 (reference)
Intermediate	324 / 668 (48.5%)	0.87 (0.75–1.00)	0.86 (0.74–0.99)
Ideal	183 / 434 (42.2%)	0.76 (0.64–0.91)	0.76 (0.63–0.90)
P-trend	<0.001	0.002	0.001
Diet			
Poor	646 / 1268 (50.9%)	1 (reference)	1 (reference)
Intermediate	295 / 598 (49.3%)	0.89 (0.77–1.03)	0.89 (0.77–1.03)
Ideal	3 / 12 (25.0%)	0.30 (0.10–0.95)	0.32 (0.10–0.99)
P-trend	0.267	0.031	0.032
Cigarette smoking			
Poor	147 / 246 (59.8%)	1 (reference)	1 (reference)
Intermediate	9 / 19 (47.4%)	0.91 (0.46–1.82)	0.92 (0.46–1.82)
Ideal	788 / 1613 (48.9%)	0.74 (0.61–0.89)	0.74 (0.62–0.90)
P-trend	0.018	0.001	0.002
Blood pressure *			
Poor *	*	*	*
Intermediate	693 / 1029 (67.3%)	1 (reference)	1 (reference)
Ideal	251 / 849 (29.6%)	0.32 (0.28–0.37)	0.33 (0.28–0.38)
P-trend	<0.001	<0.001	<0.001
Total cholesterol			
Poor	154 / 267 (57.7%)	1 (reference)	1 (reference)
Intermediate	337 / 642 (52.5%)	0.97 (0.79–1.20)	1.00 (0.81–1.23)
Ideal	453 / 969 (46.7%)	0.95 (0.77–1.18)	0.98 (0.80–1.22)
P-trend	0.001	0.655	0.855
Fasting blood glucose			
Poor	68 / 85 (80.0%)	1 (reference)	1 (reference)
Intermediate	101 / 153 (66.0%)	0.70 (0.51–0.97)	0.71 (0.51–0.98)
Ideal	775 / 1640 (47.3%)	0.48 (0.37–0.63)	0.49 (0.37–0.65)
P-trend	<0.001	<0.001	<0.001

* Participants with poor blood pressure (systolic blood pressure ≥ 140 mmHg or diastolic blood pressure ≥ 90 mmHg or self-reported antihypertensive medication) were excluded from the analysis based on the primary outcome being incident hypertension. The intermediate category is the reference for the blood pressure component of the Life's Simple 7.

Model 1 is adjusted for age, sex, education, income and marital status.

Model 2 is adjusted for the variables in Model 1 and parental history of hypertension and chronic kidney disease.

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