The American Heart Association Ideal Cardiovascular Health and Incident Type 2 Diabetes Mellitus Among Blacks: The Jackson Heart Study

ORIGINAL RESEARCH

The American Heart Association Ideal Cardiovascular Health and Incident Type 2 Diabetes Mellitus Among Blacks: The Jackson Heart Study

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***Background*—**The concept of ideal cardiovascular health (CVH), defined by the American Heart Association primarily for coronary heart disease and stroke prevention, may apply to diabetes mellitus prevention among blacks.

***Methods and Results*—**Our sample included 2668 adults in the Jackson Heart Study with complete baseline data on 6 of 7 American Heart Association CVH metrics (body mass index, healthy diet, smoking, total cholesterol, blood pressure, and physical activity). Incident diabetes mellitus was defined as fasting glucose ≥126 mg/dL, physician diagnosis, use of diabetes mellitus drugs, or glycosylated hemoglobin ≥6.5%. A summary CVH score from 0 to 6, based on presence/absence of ideal CVH metrics, was derived for each participant. Cox regression was used to estimate adjusted hazard ratios. Mean age was 55 years (65% women) with 492 incident diabetes mellitus events over 7.6 years (24.6 cases/1000 person-years). Three quarters of participants had only 1 or 2 ideal CVH metrics; no participant had all 6. After adjustment for demographic factors (age, sex, education, and income) and high-sensitivity C-reactive protein, each additional ideal CVH metric was associated with a 17% diabetes mellitus risk reduction (hazard ratio, 0.83; 95% CI, 0.74–0.93). The association was attenuated with further adjustment for homeostasis model assessment for insulin resistance (hazard ratio, 0.89; 95% CI, 0.79–1.00). Compared with participants with 1 or no ideal CVH metric, diabetes mellitus risk was 15% and 37% lower in those with 2 and ≥3 ideal CVH metrics, respectively.

***Conclusions*—**The AHA concept of ideal CVH is applicable to diabetes mellitus prevention among blacks. These associations were largely explained by insulin resistance. **(*J Am Heart Assoc*. 2017;6:e005008. DOI: 10.1161/JAHA.116.005008.)**

Key Words: American Heart Association • black • cardiovascular disease risk factors • diabetes mellitus • primary prevention

Blacks have a disproportionately higher risk of type 2 diabetes mellitus and higher rates of diabetes mellitus–related complications and death than non-Hispanic whites.[1] Overweight and obesity, fasting hyperglycemia, physical inactivity, and poor dietary habits are important modifiable risk factors for the development of diabetes mellitus, and interventions targeting these factors have been shown to delay or prevent the development of diabetes mellitus.[2–5] Based on evidence on the role of 7 modifiable cardiovascular health (CVH) factors and behaviors (smoking, total cholesterol, fasting glucose, body mass index [BMI], healthy diet, blood pressure, and physical activity), the American Heart Association (AHA) defined the concept of ideal CVH as part of efforts to decrease cardiovascular disease (CVD) and stroke incidence and mortality.[6] Given the commonality in risk factors between CVD and diabetes mellitus, the concept of ideal CVH may be applicable to the primordial and primary prevention of diabetes mellitus.

Fewer Americans, particularly blacks, achieve ideal CVH, especially for BMI, physical activity, and healthy diet, which have been strongly associated with incident diabetes

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An accompanying Table S1 is available at http://jaha.ahajournals.org/content/6/6/e005008/DC1/embed/inline-supplementary-material-1.pdf

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Clinical Perspective

What is New?

- Our findings show a robust association between the American Heart Association–defined ideal cardiovascular health (CVH; healthy body mass index, healthy diet, nonsmoking status, normal total cholesterol, normal blood pressure, and physical activity) and diabetes mellitus risk reduction among middle-aged blacks.
- This association is driven, in large part, by insulin resistance.
- The effects of the ideal CVH metrics on reducing diabetes mellitus risk may be cumulative and synergistic.

What are the Clinical Implications?

- To prevent 1 case of diabetes mellitus in the population, it would require 55 people to meet 3 American Heart Association ideal CVH targets and 49 people to meet 4 or more targets.
- Primary care interventions with a focus on improving health behaviors so that more blacks achieve the American Heart Association targets for ideal CVH may have a significant impact in reducing diabetes mellitus risk.
- For clinicians, encouraging their patients to meet these American Heart Association ideal CVH targets could represent a great step forward in preventing diabetes mellitus.

mellitus.[7–9] The association between AHA-defined ideal CVH and the development of diabetes mellitus is less clear among blacks than among other race-ethnic groups. Fretts et al, using data on American Indians from the SHFS (Strong Heart Family Study), showed that having at least 2 AHA-defined ideal CVH metrics, compared with 1 or none, significantly reduced the odds of developing diabetes mellitus.[10] In MESA (Multi-Ethnic Study of Atherosclerosis),[11] participants with 2 to 3 and 4 or more ideal CVH metrics had a 34% and 75% lower risk of incident diabetes mellitus, respectively. In MESA, the association between ideal CVH and diabetes mellitus was less robust among blacks and Hispanics compared with whites and Chinese.[11] Among blacks, though there was a significant trend in diabetes mellitus risk reduction with increasing number of ideal CVH metrics, there was no apparent association between each level of ideal CVH metric and the referent group (no ideal CVH metric). This lack of association could be attributed, in large part, to insufficient power in the stratified analysis. The MESA study and JHS (Jackson Heart Study) recruited blacks from different geographical regions in the United States. The JHS is a single-site study and recruited all blacks from Jackson, Mississippi, a state with the highest rates of diabetes mellitus in the nation.[12] In contrast, blacks in the MESA study were recruited primarily from Maryland and North Carolina, and to a lesser extent New York, California, and Illinois. The JHS enrolled more blacks, and there are more incident cases of diabetes mellitus among blacks in the JHS than in MESA, and, as such, the JHS is well powered to address this question.

If ideal CVH, as defined by the AHA, is applicable to diabetes mellitus prevention among blacks, future joint efforts for CVD and diabetes mellitus prevention in this population may provide 1 effective and cost-efficient strategy for public health experts and policy makers to tackle the growing challenge of diabetes mellitus and CVD. To investigate this further, we examined the association between AHA-defined ideal CVH and incident diabetes mellitus in the JHS, a large cohort of blacks. Specifically, we sought to determine whether there was a graded relationship between increasing number of ideal CVH metrics and diabetes mellitus risk reduction, and the role insulin resistance plays in this association. We hypothesized that increasing number of ideal CVH metrics will be significantly associated with a lower incidence of diabetes mellitus.

Methods

Study Sample

The JHS enrolled 5301 participants aged 21 to 94 years at the time of the baseline assessment (2000–2004) from the Jackson, Mississippi, metropolitan area. The goal of the study was to examine factors that influence the development of CVD in black men and women to learn how to prevent this group of diseases in this population. Two subsequent in-person follow-up visits have been completed since baseline (2005–2008 and 2009–2013). Details about the study design and recruitment process have been published.[13,14]

Data Collection

Baseline information, including demographics, socioeconomic status, lifestyle data, and medication use, was obtained by study personnel through interviews during clinic visits or at home. Medication use in the 2 weeks preceding each clinic visit was assessed at the time of the clinic visit. Blood samples were collected according to standard procedures and metabolic variables (glucose, insulin, and lipids) were analyzed at a central laboratory (University of Minnesota).[15]

Ascertainment of Incident Type 2 Diabetes Mellitus

At baseline, fasting plasma glucose was measured by the glucose oxidase colorimetric method using a Vitros 950 or 250 (Ortho Clinical Diagnostics analyzer; Ortho Clinical Diagnostics, Raritan, NJ), and at visits 2 and 3, it was measured using a Roche Modular P Chemistry analyzer

(Roche Diagnostics, Indianapolis, IN). Glycated hemoglobin was measured using a Tosoh high-performance liquid chromatography system (Tosoh Corporation, Tokyo, Japan). We defined type 2 diabetes mellitus as having either: (1) fasting glucose ≥126 mg/dL; (2) glycated hemoglobin ≥6.5%; (3) use of diabetes mellitus medication; or (4) a physician diagnosis of the condition. We assessed incident type 2 diabetes mellitus at follow-up visits 2 and 3. For each incident case of type 2 diabetes mellitus, time to event was considered as midpoint between last exam without diabetes mellitus and the exam at which diabetes mellitus developed. For participants who remained event free, follow-up time was censored at their last available visit.

AHA's CVH Metrics

Blood pressure

Resting blood pressure (BP) was measured twice at 5-minute intervals, the average of which was used in our analysis. Ideal BP was defined as a systolic BP of <120 mm Hg and a diastolic BP of <80 mm Hg if untreated; intermediate BP was defined as a systolic BP of 120 to 139 mm Hg or a diastolic BP of 80 to 89 mm Hg, of if treated to goal; and poor BP was defined as a systolic BP of ≥140 mm Hg or a diastolic BP ≥90 mm Hg.[6]

Physical activity

Participants completed an interviewer-administered physical activity (PA) questionnaire at baseline, modified from the Baeke PA survey,[16] which was also the parent document for the ARIC (Atherosclerosis Risk in Communities Study) study's survey.[17,18] This instrument was identical to the one used during the Kaiser PA survey, which showed good validity and reliability in a multiethnic sample.[19] Exercise was reported by the average amount of time per week spent, and metabolic equivalent levels were defined for each activity. Moderate activity was defined as 3 to 6 metabolic equivalents and vigorous activity as >6 metabolic equivalents. Ideal PA was defined as ≥150 minutes of moderate-intensity activity or ≥75 minutes of vigorous activity or ≥150 minutes of combined moderate-intensity and vigorous activity per week; intermediate PA was defined as 1 to 149 minutes of moderate-intensity activity or 1 to 74 minutes of vigorous activity or 1 to 149 minutes of combined moderate-intensity and vigorous activity per week; poor PA was defined as no amount of activity (0 minutes per week).[6]

Body Mass Index

BMI was determined as weight (in kilograms) divided by the square of height (in meters). BMI was defined as ideal, <25 kg/m^2; intermediate, 25 to 29.9 kg/m^2; and poor, ≥30 kg/m^2.[6]

Smoking

Cigarette smoking was as self-reported and participants were asked about the quantity and duration of smoking. Ideal smoking was defined as participants who had never smoked or who quit smoking more than 12 months preceding the clinic visit; intermediate was defined as former smokers who quit smoking within 12 months of the clinic visit; and poor was defined as a current smoker.[6]

Total cholesterol

Total cholesterol was measured by the cholesterol oxidase method (Roche COBAS Fara analyzer; Roche Diagnostics), as previously described.[15] Ideal total cholesterol was defined as a level of <200 mg/dL if untreated; intermediate total cholesterol defined by a level of 200 to 239 mg/dL or if treated to goal; and poor was defined by a level of ≥240 mg/dL.[6]

Diet

In the JHS, dietary intake was assessed using the Delta NIRI food frequency questionnaire with 158 items.[20,21] The 5 components used to compute the AHA score, based on a 2000-kcal diet, were: (1) ≥4.5 cups daily of fruits and vegetables; (2) >3.5 ounces, twice per week, of fish; (3) <450 kcal per week of sugary beverages; (4) ≥3 daily servings of whole grains; and (5) <1500 mg daily of sodium. Ideal diet was defined by a diet including 4 to 5 components; intermediate diet, 2 to 3 components; and poor diet, 0 to 1 component.[6]

Measurement of Covariates

Baseline waist circumference was the average of 2 measurements about the umbilicus and in the upright position. Current alcohol drinking was defined as alcohol use in the past 12 months. Education level was dichotomized as having at least a college education or higher versus no college education. Income status was divided into 3 categories based on family size and income: low income, middle income, and affluent income groups. Fasting insulin concentration was measured on a Vitros 950 or 250, Ortho Clinical Diagnostics analyzer (Ortho Clinical Diagnostics) using standard procedures that met the College of American Pathologists accreditation requirement.[15] Insulin resistance was estimated using the homeostasis model assessment for insulin resistance (HOMA-IR)=(fasting plasma insulin [μU/mL])×(fasting plasma glucose [mmol/L])÷22.5.[22] hs-CRP was measured by the immunoturbidimetric CRP-Latex

assay (Kamiya Biomedical Company, Seattle, WA) using a Hitachi 911 analyzer (Roche Diagnostics).[23]

Statistical Analysis

Our analyses were performed using SAS software (version 9.3; SAS Institute Inc, Cary, NC). Using 6 of the 7 AHA health metrics (BMI, diet, smoking status, BP, total cholesterol, and PA), for each participant, and for each health metric, presence of ideal health was scored as 1 and absence as 0. A summary AHA CVH score was computed ranging from 0 (least ideal CVH) to 6 (most ideal CVH).

We compared differences in baseline characteristics by categories of the CVH score using the analysis of variance test or appropriate nonparametric tests for continuous variables, and the chi-square test for categorical variables. Categories of the CVH score were defined based on the distribution of participants in each score group. Variables with non-normal distributions were log-transformed as required.

Using Cox regression analysis, we assessed the prospective graded association between the CVH score (modeled as a continuous variable) and the risk of incident diabetes mellitus. Hazard ratios (HRs) for each additional ideal health metric were estimated. We also examined the association of categories of the CVH score (≤1, 2, and ≥3) and incident diabetes mellitus. A sequential modeling approach was used as follows: model 1 (base model) was unadjusted; model 2 was adjusted for age, sex, education, and income; model 3 was further adjusted for hs-CRP; and model 4 was additionally adjusted for HOMA-IR.

Because of a previous report of effect modification of the association between low-grade systemic inflammation and incident diabetes mellitus by BMI,[24] we also assessed for interaction by waist circumference in our analysis. Interactions were assessed by including an interaction term in the regression model. Finally, based on a 5-year risk, we estimated the number of participants who need to have increments of the ideal CVH score in order to prevent 1 case of incident diabetes mellitus. For all analyses, a *P* value of ≤0.05 was considered statistically significant.

Results

After exclusions, our final sample size was 2668 adults. The proportions of participants with an ideal health score of 0, 1, 2, 3, 4, 5, and 6 were 3%, 36.1%, 39.9%, 16.1%, 4.5%, 0.4%, and 0%, respectively. Table 1 shows baseline characteristics of participants across categories of the ideal health summary score; score ≤1 (least ideal), score 2 to 3, and score ≥4 (most ideal). Compared with participants in the most ideal category, those in the least ideal category were older, less likely to have completed college with higher waist circumference, glycated

Table 1. Baseline Characteristics of Participants by Categories of the AHA CVH Score

Characteristic	Categories of AHA CVH Score			*P* Value
	Scores ≤1 (n=1042)	Score=2 (n=1065)	Score ≥3 (n=561)	
Age, y	57±11	55±12	50±13	<0.0001
Men, n, %	359 (34.5)	366 (34.4)	198 (35.3)	0.9
Waist circumference, cm	103±15	99±15	92±14	<0.0001
Current alcohol drinker, n, %	467 (45.0)	482 (45.3)	307 (55.1)	<0.001
At least college education, n, %	561 (53.8)	660 (62.0)	409 (73.2)	<0.0001
Income status, n, %				
Low	105 (11.9)	99 (10.9)	50 (10.3)	<0.001
Middle	501 (56.6)	477 (52.7)	220 (45.2)	
Affluent	279 (31.5)	329 (36.4)	217 (44.6)	
Incident diabetes mellitus, n, %	235 (22.6)	191 (17.9)	66 (11.8)	<0.0001
Family history of diabetes mellitus, n, %	482 (46.4)	502 (47.3)	232 (41.4)	0.07
Lipid-lowering medication, n, %	157 (17.4)	69 (6.8)	15 (2.7)	<0.0001
HOMA-IR*	3.4 (2.3)	3.1 (2.2)	2.5 (1.6)	<0.0001
HbA1c, %	5.6±0.5	5.5±0.5	5.4±0.4	<0.0001
hs-CRP*, mg/L	3.1 (4.5)	2.6 (4.7)	1.7 (3.6)	<0.0001

Data are means±SD or numbers (percentages). Scores are the sum of the individual points for each CVH metric and for each individual. A score of zero (0) indicates poor overall CVH, and a score of 6 indicates ideal overall CVH. AHA indicates American Heart Association; CVH, cardiovascular health; HbA1c, glycosylated hemoglobin; HOMA-IR, homeostasis model assessment of insulin resistance; hs-CRP, high-sensitivity C-reactive protein.
*Results are median (interquartile range).

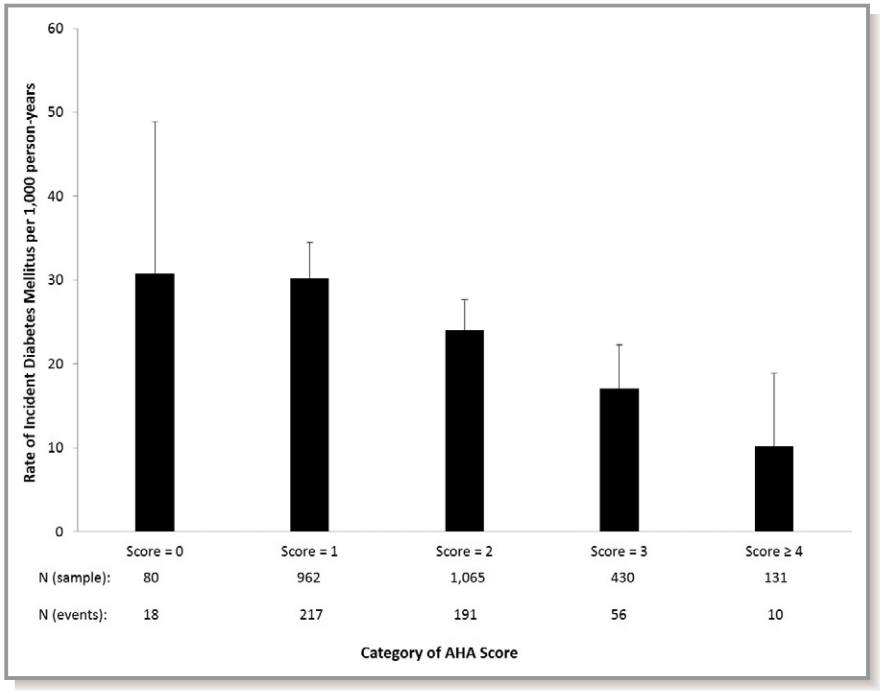

Figure. Crude rates (per 1000 person-years) of incident diabetes mellitus across categories of the American Heart Association cardiovascular health summary score. Error bars represent the 95% CIs about the rates. AHA indicates American Heart Association.

hemoglobin, markers of systemic inflammation (hs-CRP), and insulin resistance (as measured by HOMA-IR). There were no differences in family history of diabetes mellitus or sex between categories.

Incident type 2 diabetes mellitus occurred in 492 persons (rate, 24.6 per 1000 person-years) during a median follow-up of 7.6 years (range, 3.5–12.2). Rates of diabetes mellitus decreased across increasing categories of ideal CVH score (Figure). Rates were highest among those with a score of 0 (30.8 events per 1000 person-years; 95% CI, 19.4–48.9) and those with a score of 1 (30.2; 95% CI, 26.4–34.5). Rates among those with scores of 2 and 3 were (24.0; 95% CI, 20.9–27.7) and (17.1; 95% CI, 13.2–22.3), respectively. The lowest rate was observed among those with an ideal CVH score of 4 or more (10.2; 95% CI, 5.5–18.9).

Multivariable Analysis

The HR of incident diabetes mellitus per each additional ideal CVH metric in the unadjusted model was 0.77 (95% CI, 0.69–0.85; Table 2). The HR for incident diabetes mellitus was mildly attenuated, but remained significant after adjustment for age, sex, education, and income (HR, 0.80; 95% CI, 0.71–0.90) and for hs-CRP (HR, 0.83; 95% CI, 0.74–0.93). With additional adjustment for HOMA-IR (HR, 0.89; 95% CI, 0.79–1.00), the association was no longer significant.

We examined the association between ideal CVH summary score and incident diabetes mellitus across categories of the score (Table 3): score ≤1, score=2, and score ≥3. In the unadjusted model, compared with participants with 1 or no CVH metric (reference category, score ≤1), the HR for incident diabetes mellitus was 0.82 (95% CI, 0.67–0.99) for those with a score of 2, and 0.51 (95% CI, 0.39–0.68) for those with a score ≥3 (P for trend, <0.0001). The HR for incident diabetes mellitus for those with a score ≥3 was 0.58 (95% CI, 0.43–0.77; P for trend, <0.001) when adjusted for age, sex, education, and income and 0.63 (95% CI, 0.47–0.85; P for trend=0.002) when further adjusted for hs-CRP. The association was no longer significant when adjusted for HOMA-IR (HR, 0.74; 95% CI, 0.55–0.99; P for trend=0.06).

We did not formally test for mediation effects of HOMA-IR. However, when only HOMA-IR was added to the unadjusted model with ideal CVH score modeled as a continuous variable (Table 2), there was a substantial decrease in the HR for incident diabetes mellitus, from HR 0.77 (CI, 0.69–0.85) to HR 0.85 (CI, 0.76–0.94). Similarly, when only HOMA-IR was added to the model containing categorical ideal CVH score (Table 3), the HR decreased from 0.51 (CI, 0.39–0.68) to 0.64 (CI, 0.49–0.84) for those with a score ≥3. These represented similar magnitudes in attenuation of effects compared to when both demographic factors and hs-CRP were adjusted for.

The association between ideal CVH and incident diabetes mellitus was modified by central obesity (measured by waist circumference; $P_{interaction}$<0.001 in the demographic model). We stratified our analysis by the median waist circumference (98.0 cm). Compared with the upper median of waist

Table 2. Unadjusted and Adjusted HRs and 95% CIs for Incident Diabetes Mellitus Per Unit Increase in the AHA CVH Score

Model	HR	95% CI	*P* Value
CVH score	0.77	0.69 to 0.85	<0.0001
CVH score+demographic factors*	0.80	0.71 to 0.90	<0.001
CVH score+demographic factors+hs-CRP	0.83	0.74 to 0.93	0.002
CVH score+demographic factors+Hs-CRP+HOMA-IR	0.89	0.79 to 1.00	0.06
CVH Score+HOMA-IR	0.85	0.76 to 0.94	0.002

AHA indicates American Heart Association; CVH, cardiovascular health; HOMA-IR, homeostasis model assessment for insulin resistance; HR, hazard ratio; hs-CRP, high-sensitivity C-reactive protein.
*Demographic factors include age, sex, education, and income.

circumference, the lower median had significantly higher proportions of participants with ideal BMI (28.6% versus 0.7%), ideal BP (21.4% versus 10.5%), and ideal PA level (24.1% versus 18.6%; Table 4). There were no differences in ideal diet and ideal total cholesterol between these 2 groups. In analysis adjusted for age, sex, education, income, and hs-CRP, among participants in the lower median of waist circumference, increasing ideal CVH score was significantly associated with a 21% decrease in risk of incident diabetes mellitus (HR, 0.79; 95% CI, 0.66–0.97; Table 5). Accounting for the effects of HOMA-IR attenuated this relationship (HR, 0.83; 95% CI, 0.68–1.02). Among participants in the upper median, there was no association between ideal CVH score and incident diabetes mellitus even in the unadjusted model (HR, 0.96; 95% CI, 0.84–1.10).

Association Between Individual Ideal CVH Metrics and Diabetes Mellitus

Table S1 displays the results of multivariable analysis for each individual CVH metric with incident diabetes mellitus. Only BMI and BP were associated with diabetes mellitus after adjustment for demographic factors and hs-CRP. The association between ideal PA and diabetes mellitus was significant in the unadjusted model, but this association was totally explained by age, sex, education, and income. Smoking status, total cholesterol, and diet were not associated with diabetes mellitus.

Number Needed to Prevent

Based on a 5-year risk, we estimated the number of participants who need to have increments of the ideal CVH score in order to prevent 1 case of incident diabetes mellitus. In the unadjusted model, compared to participants with no ideal CVH metric, the number of participants needed to have 1, 2, 3, and ≥4 ideal CVH metrics to prevent 1 case of incident diabetes mellitus were 167, 56, 29, and 20, respectively. After accounting for age, sex, education, income, hs-CRP, and HOMA-IR, the number of participants needed to have 1, 2, 3, and ≥4 ideal CVH metrics to prevent 1 case of incident diabetes mellitus were 279, 156, 55, and 49, respectively.

Discussion

In this contemporary middle-aged black cohort, we found that the AHA-defined ideal CVH metrics for CVD and stroke prevention are associated with a decreased risk of incident type 2 diabetes mellitus. Specifically, the risk of developing diabetes mellitus decreased by 17% for each additional baseline ideal CVH metric that a participant had, and participants with at least 3 CVH metrics had a 37% risk reduction, after accounting for demographic risk factors and systemic inflammation. Our findings also suggest that the association between the ideal CVH metrics and incident diabetes mellitus is, in large part, explained by insulin resistance (measured by HOMA-IR) and may differ according

Table 3. Unadjusted and Adjusted HRs and 95% CIs for Incident Diabetes Mellitus by Category of the AHA CVH Score

Models	Categories of AHA CVH Score			*P* Trend
	Score ≤1 HR (95% CI)	Score=2 HR (95% CI)	Score ≥3 HR (95% CI)	
N/events	1042/235	1065/191	561/66	
CVH score	1.0	0.82 (0.67–0.99)	0.51 (0.39–0.68)	<0.0001
CVH score+demographic factors*	1.0	0.83 (0.68–1.02)	0.58 (0.43–0.77)	<0.001
CVH score+demographic factors+hs-CRP	1.0	0.85 (0.69–1.04)	0.63 (0.47–0.85)	0.002
CVH score+demographic factors+hs-CRP+HOMA-IR	1.0	0.95 (0.77–1.17)	0.74 (0.55–0.99)	0.06
CVH score+HOMA-IR	1.0	0.92 (0.76–1.11)	0.64 (0.49–0.84)	0.003

AHA indicates American Heart Association; CVH, cardiovascular health; HOMA-IR, homeostasis model assessment for insulin resistance; HR, hazard ratio; hs-CRP, high-sensitivity C-reactive protein.
*Demographic factors include age, sex, education, and income.

Table 4. Ideal CVH Metrics by Median Waist Circumference

CVH Metric	Median WC <98.0 cm	Median WC ≥98.0 cm	*P* Value
Ideal CVH score	2.1±1.0	1.6±0.8	<0.0001
Categories ideal CVH score, n (%)			<0.0001
≤1	406 (30.7)	636 (47.2)	
2	523 (39.6)	542 (40.2)	
≥3	392 (29.7)	169 (12.6)	
AHA body mass index category, n (%)			<0.0001
Not ideal, ≥25 kg/m^2	943 (71.4)	1338 (99.3)	
Ideal, <25 kg/m^2	378 (28.6)	9 (0.7)	
AHA blood pressure category, n (%)			<0.0001
Not ideal, ≥120/ or ≥80 mm Hg	1038 (78.6)	1206 (89.5)	
Ideal, <120/<80 mm Hg without treatment	283 (21.4)	141 (10.5)	
AHA total cholesterol category, n (%)			0.45
Not ideal, ≥200 mg/dL	742 (56.2)	776 (57.6)	
Ideal, <200 mg/dL without treatment	579 (43.8)	571 (42.4)	
AHA diet category, n (%)			0.079
Not ideal, <4 components	1306 (98.9)	1340 (99.5)	
Ideal, 4 to 5 components	15 (1.1)	7 (0.5)	
AHA smoking category, n (%)			0.024
Not ideal, current or former smoker or quit less ≤12 months ago	169 (12.8)	135 (10.0)	
Ideal, never smoker or quit >12 months ago	1152 (87.2)	1212 (90.0)	
AHA physical activity category, n (%)			<0.001
Not ideal, none or <150 mod. or <75 vig. or <150 mod. +vig.	1002 (75.9)	1096 (81.4)	
Ideal, ≥150 mod. or ≥75 vig. or ≥150 mod. +vig.	319 (24.1)	251 (18.6)	

Data for ideal CVH score are presented as mean±SD. AHA indicates American Heart Association; CVH, cardiovascular health.

to a participant's waist circumference. Our findings differ from those in the MESA study, in which the association was less robust among blacks. The MESA study did not take into account the effects of systemic inflammation and insulin resistance, which we found to play a significant role in the association between ideal CVH and incident diabetes mellitus.

The prevalence of ideal CVH in our sample was very low. No participant met all 6 ideal CVH goals and less than 1% of them met 5 of the goals used in our analyses. Three quarters of participants met only 1 or 2 ideal CVH metrics goals. Previous studies have reported lower prevalence values especially for persons with 1 or 2 ideal CVH metrics.[7,25–27] Folsom et al, using data from the ARIC study,[9] reported that around 54% of black men and 55% of black women had between 1 and 2 ideal CVH metrics. Prevalence values in our study may be higher because of the fact that we used 6 of the 7 CVH metrics in defining ideal health. A previous report from the JHS cohort, using all 7 CVH metrics, showed a prevalence of around 56% among those with 1 or 2 ideal CVH metrics, similar to previous studies.[8]

Our findings support a protective role of ideal CVH, as defined by the AHA, on diabetes mellitus risk among blacks and are consistent with previous reports on this association in other populations using data from the SHFS[10] and MESA.[11] In the SHFS, a lower odds of developing diabetes mellitus was reported among American Indians who met at least 2 of the ideal CVH goals, compared with those who met only 1 ideal CVH goal or none. In MESA, an interaction by race/ethnicity was found. Ideal CVH was associated with incident diabetes mellitus in the general MESA study population, but when stratified by race/ethnicity, the association was less robust among blacks and Hispanics compared with whites and Chinese. Findings from our study showed that the association between ideal CVH and incident diabetes mellitus is, in fact, robust and consistent among blacks and independent of age, sex, socioeconomic status, and the presence of systemic inflammation. The magnitude of risk reduction differs across studies; compared with our study where participants with 3 or more ideal CVH metrics had a 37% reduction in risk of diabetes mellitus, in the SHFS and in MESA, American Indians,

Table 5. Unadjusted and Adjusted HRs and 95% CIs for Incident Diabetes Mellitus Per Unit Increase in the AHA CVH Score, Stratified by Median WC

Model	Hazard Ratio	95% CI	*P* Value
Waist circumference <98.0 cm	0.67	0.57 to 0.82	<0.0001
CVH score	0.75	0.62 to 0.92	0.006
CVH score+demographic factors*	0.79	0.66 to 0.97	0.022
CVH score+demographic factors+hs-CRP	0.83	0.68 to 1.02	0.081
CVH score+demographic factors+hs-CRP+HOMA-IR	0.67	0.57 to 0.82	<0.0001
Waist circumference ≥98.0 cm	0.96	0.84 to 1.10	0.56
CVH score	0.97	0.84 to 1.13	0.71
CVH score+demographic factors	0.97	0.84 to 1.13	0.70
CVH score+demographic factors+hs-CRP	1.01	0.87 to 1.17	0.92
CVH score+demographic factors+hs-CRP+HOMA-IR	0.96	0.84 to 1.10	0.56

P interaction, <0.001 in demographic model. CVH indicates cardiovascular health; HOMA-IR, homeostasis model assessment for insulin resistance; HR, hazard ratio; hs-CRP, high-sensitivity C-reactive protein; WC, waist circumference.
*Demographic factors include age, sex, education, and income.

non-Hispanic whites, and Chinese Americans with 4 or more ideal CVH metrics had an 89%, 87%, and 88% reduction in risk, respectively. These differences may be explained, in part, by differences in methodology across studies, but may also reflect potential race/ethnic differences in the association between ideal CVH and incident diabetes mellitus. In recent genetic studies, single-nucleotide polymorphism variants in the APOE locus, which has been associated with clinical ideal CVH,[28] were found to be associated with multiple components of metabolic syndrome in blacks.[29]

When the CVH metrics were considered individually, the association between ideal CVH and incident diabetes mellitus appeared to be driven primarily by BMI, which could explain why insulin resistance plays a significant role in the association. There were no apparent PA/diabetes mellitus, diet/diabetes mellitus, smoking/diabetes mellitus, and total cholesterol/diabetes mellitus associations. Similar findings were reported in the SHFS and MESA.[10,11] Given that less than 1% of our participants met the dietary targets for ideal CVH, we had limited power to adequately examine the association between diet and diabetes mellitus. As such, our results for healthy diet need to be interpreted with caution. The effects of diet and PA may not have been adequately captured in our sample by questionnaires, and their true effects may not be independent of BMI. There is evidence that adherence to the Dietary Approach to Stop Hypertension diet reduces insulin resistance[30] and the risk of incident diabetes mellitus.[31] Although only 2 (BMI and BP) of 6 CVH metrics were individually associated with diabetes mellitus risk, the finding of a significant trend in the association between categories of the CVH score (0–1, 2, and 3+) and incident diabetes mellitus suggests that the beneficial effects of the CVH metrics on diabetes mellitus risk is synergistic and cumulative. In fact, when compared with those with 0 to 1 ideal CVH metric, having 3 or more ideal CVH metrics was associated with a 37% reduction in diabetes mellitus risk. Other risk factors taken into account, 55 people in the population would need to meet 3 AHA ideal CVH targets to prevent 1 case of diabetes mellitus, and 49 people would need to meet 4 or more AHA ideal CVH targets to prevent 1 case of diabetes mellitus.

Our results suggest that less-than-ideal levels of AHA CVH may reflect a state of insulin resistance, which would promote the occurrence of not only diabetes mellitus, but also probably of CVDs. Although there was no apparent association between ideal PA and ideal diet with incident diabetes mellitus in our analysis, both have been associated with a reduction in diabetes mellitus risk in previous studies.[32–35] Data from the Diabetes Prevention Program showed that weight loss achieved through PA and a healthy low-fat, low-calorie diet reduced the incidence of diabetes mellitus by 61% in blacks, when compared with placebo.[5] Diabetes mellitus risk reduction was greatest in the lifestyle group, compared with the other groups. The reduction in diabetes mellitus risk is thought to be mediated by improvements in insulin sensitivity, as a result of weight loss and PA. Although there were no differences in CVD events (myocardial infarction, stroke, and coronary revascularization) after 3 years between treatment arms in the Diabetes Prevention Program, there were significant reductions in cardiometabolic risk factors in the lifestyle arm, including high triglyceride levels, hypertension, low high-density lipoprotein, and small dense low-density lipoprotein.[36] In other clinical trials with longer durations of follow-up, such cardiometabolic risk factor reductions have

resulted in reductions in both fatal and nonfatal CVD events.[37,38]

The association between CVH metrics and diabetes mellitus differed according to waist circumference levels. The finding of a significant association among participants in the lower median of waist circumference, but not among those in the upper median, may simply reflect a greater heterogeneity in the distribution of ideal CVH metrics as indicated by the differences observed in the proportions of ideal CVH between participants in the lower and upper median of waist circumference. This pattern warrants further investigation and replication in other cohorts.

The strengths of our analysis include the use of a sizable cohort of blacks with more incident diabetes mellitus events compared to previous reports in the same population.[11] Not only were we able to more robustly assess the extent of the associations between ideal CVH and diabetes mellitus, we also conducted a more comprehensive ascertainment of diabetes mellitus (using the American Diabetes Association 2010 criteria, including HbA1c level), thus reducing the potential for misclassifications. Furthermore, in contrast to previous studies, we explored the potential role of insulin resistance, measured by HOMA-IR, on the observed association between CVH metrics and diabetes mellitus. Some limitations of the present study should be addressed. Because of the small number of participants and events for some CVH metrics (diet and smoking), we were unable to fully explore the individual effects of these health behaviors on incident diabetes mellitus. Also, it is difficult to assess the true independent effects of inter-related parameters such as BMI, PA, diet, BP, and HOMA-IR. In addition, although validated instruments were used in the JHS to measure PA[39] and diet,[40] an association between PA and diet with diabetes mellitus may not have been apparent owing to the self-reported nature of these measures. Because some of the CVH metrics were self-reported (PA, diet, and smoking), residual confounding could be present. Time to incident diabetes mellitus was interval-censored and the midpoint between 2 study visits was imputed as the time to incident diabetes mellitus. This approach of imputing time to event has been validated in previous studies.[41,42]

Conclusion

Our study showed that each additional ideal AHA CVH metric was associated with a 17% reduction in the risk of incident diabetes mellitus in blacks, after accounting for demographic factors and systemic inflammation. The association between the ideal CVH metrics and incident diabetes mellitus may be synergistic and cumulative and was largely explained by insulin resistance. These data support the application the concept of ideal CVH as defined by the AHA in diabetes mellitus prevention in this population.

Implications

Our findings, which support a protective role of ideal CVH metrics (healthy BMI, healthy diet, nonsmoking status, normal total cholesterol, normal BP, and PA) have implications from a primary prevention standpoint. The overall low prevalence of higher levels of ideal CVH, as defined by the AHA, among blacks is alarming and calls for targeted public health interventions to improve on disparities for CVD and diabetes mellitus among blacks, a population that is disproportionately affected by these 2 conditions.

Our study has shown that if people meet increasing targets of AHA ideal CVH metrics, diabetes mellitus can be prevented. It would need 55 people in the population to meet 3 AHA ideal CVH targets to prevent 1 case of diabetes mellitus and 49 people to meet 4 or more AHA ideal CVH targets to prevent 1 case of diabetes mellitus. Interventions with a primary focus of improving health behaviors so that more blacks achieve the AHA targets for ideal CVH are important and may have a significant impact in reducing diabetes mellitus risk. Our findings suggest that the effects of these ideal CVH metrics may be cumulative and synergistic. In this light, future lifestyle or behavioral interventions should take into account as many AHA ideal CVH metrics as possible, and not just 1 particular metric, to potentially increase the impact of the interventions on reducing diabetes mellitus risk. Also, future joint efforts for CVD and diabetes mellitus prevention among blacks may provide 1 effective and cost-efficient strategy for public health experts and policy makers to tackle the growing challenge of diabetes mellitus and CVD.

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Disclosures

None.

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SUPPLEMENTAL MATERIAL

Table S1. Unadjusted and Adjusted Hazard Ratios and 95% Confidence Intervals for Incident Diabetes for each Individual American Heart Association Cardiovascular Health Metric.

Cardiovascular Health Metric	N/events	Model 1	Model 2	Model 3	Model 4
		Hazard Ratio (95% Confidence interval)			
Body Mass Index, kg/m^2					
Poor, ≥ 30	1,365/336	1.0	1.0	1.0	1.0
Intermediate, 25 – 29.9	916/126	0.55 (0.44 – 0.67)	0.50 (0.40 – 0.63)	0.54 (0.43 – 0.69)	0.76 (0.60 – 0.96)
Ideal, < 25	387/30	0.30 (0.20 – 0.44)	0.29 (0.19 – 0.43)	0.32 (0.22 – 0.49)	0.58 (0.38 – 0.88)
Blood Pressure, mmHg					
Poor, ≥ 140 / or ≥ 90	358/77	1.0	1.0	1.0	1.0
Intermediate, 120-139 / or 80-89 or <120/< 80 with treatment	1,886/369	0.94 (0.74 – 1.21)	0.90 (0.69 – 1.17)	0.91 (0.69 – 1.18)	0.95 (0.73 – 1.24)
Ideal, < 120/< 80 without treatment	424/46	0.51 (0.35 – 0.73)	0.56 (0.37 – 0.84)	0.58 (0.39 – 0.87)	0.72 (0.48 – 1.08)
Total Cholesterol, mg/dl					
Poor, ≥ 240	411/90	1.0	1.0	1.0	1.0
Intermediate, 200 – 239 or < 200 with treatment	1,107/200	0.87 (0.68 – 1.12)	0.90 (0.68 – 1.17)	0.89 (0.68 – 1.17)	0.94 (0.71 – 1.23)
Ideal, < 200 without treatment	1,150/202	0.83 (0.65 – 1.06)	0.88 (0.67 – 1.15)	0.86 (0.65 – 1.12)	0.92 (0.70 – 1.20)
Dietary Measures					
Poor, 0-1 component	1,644/306	1.0	1.0	1.0	1.0
Intermediate, 2-3 components	1,002/183	1.08 (0.90 – 1.30)	1.15 (0.94 – 1.40)	1.14 (0.93 – 1.39)	1.15 (0.94 – 1.40)
Ideal, 4-5 components	22/3	N/A	N/A	N/A	N/A
Smoking					

Poor, current smoker	284/54	1.0	1.0	1.0	1.0
Intermediate, former smoker or quit less ≤ 12 months ago	20/3	N/A	N/A	N/A	N/A
Ideal, never smoker or quit less >12 months ago	2,364/435	1.04 (0.78 – 1.38)	1.08 (0.79 – 1.47)	1.13 (0.83 – 1.55)	0.93 (0.69 – 1.28)
Physical Activity, minutes/week					
Poor, None	1,203/240	1.0	1.0	1.0	1.0
Intermediate, < 150 mod. or < 75 vig. or < 150 mod. + vig.	895/161	0.85 (0.69 – 1.04)	0.88 (0.71 – 1.10)	0.90 (0.72 – 1.13)	0.94 (0.75 – 1.18)
Ideal, ≥ 150 mod. or ≥ 75 vig. or ≥ 150 mod. + vig.	570/91	0.78 (0.61 – 0.99)	0.82 (0.63 – 1.07)	0.85 (0.65 – 1.11)	0.92 (0.70 – 1.20)

Model 1: unadjusted. Model 2: model 1, age, sex, education and income. Model 3: model 2, high-sensitivity C-reactive protein. Model 4: model 3, HOMA-IR. Mod. indicates moderate; vig., vigorous. Dietary components: Fruits and vegetables: ≥4.5 cups per day; Fish: ≥two 3.5-oz servings per week; Fiber-rich whole grains (≥1.1 g of fiber per 10 g of carbohydrate): ≥three 1-oz-equivalent servings per day; Sodium: <1500 mg per day; Sugar-sweetened beverages: ≤450 kcal (36 oz) per week.