Association of a Favorable Cardiovascular Health Profile With the Presence of Coronary Artery Calcification

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Background—To examine the association between the American Heart Association's 7 metrics of ideal cardiovascular health (ICH) and the presence of subclinical coronary atherosclerosis as assessed by coronary artery calcification (CAC) using electron-beam computed tomography.

Methods and Results—This study is a cross-sectional analysis of data obtained on 3121 male and female patients evaluated at the Cooper Clinic in Dallas, Texas, between 1997 and 2007. We included men aged ≥45 and women aged ≥55 without known cardiovascular disease and for whom information on all ICH metrics and a CAC score were available. Patients were grouped into 3 categories according to their number of ICH metrics: favorable (4–7 ICH metrics), intermediate (3 metrics), and unfavorable (0–2 metrics). Patients with favorable ICH profiles had a lower prevalence and severity of subclinical atherosclerosis than those with unfavorable or intermediate ICH profiles as estimated by CAC. This inverse association of CAC with ICH metrics was evident whether the presence of coronary calcium was defined as CAC score >0, CAC score >100, or CAC score >400. Patients with favorable ICH profiles had odds of coronary calcium (CAC>0) less than half of those for patients with unfavorable profiles (odds ratio 0.41; 95% confidence interval, 0.34–0.50) and patients with intermediate ICH profiles had odds of detectable CAC 32% lower (odds ratio 0.68; 95% confidence interval, 0.57–0.82).

Conclusions—A statistically significant association was found between a favorable level of ICH metrics and less or absent subclinical atherosclerosis as measured by CAC underscoring the importance of primordial prevention. **(*Circ Cardiovasc Imaging*. 2015;8:e001851. DOI: 10.1161/CIRCIMAGING.114.001851.)**

Key Words: coronary vessels ■ prevention and control ■ risk factors ■ vascular diseases

In 2010, the American Heart Association Strategic Planning Task Force and Statistics Committee established the 2020 Strategic Impact Goals, which were to improve the cardiovascular health of all Americans by 20%, at the same time reducing deaths from cardiovascular diseases and stroke by 20%.[1] To achieve these goals, the American Heart Association highlighted the importance of primordial prevention, which is the prevention of the initial development of risk factors. Based on an extensive body of evidence, the Committee defined ideal cardiovascular health (ICH) as the simultaneous presence of 7 health behaviors and health factors with the absence of clinical cardiovascular disease (CVD). The 7 ICH metrics are abstinence of smoking within the past year, ideal body mass index (BMI), physical activity at goal levels, consumption of a dietary pattern that promotes cardiovascular health, untreated total cholesterol <200 mg/dL (5.17 mmol/L), untreated blood pressure <120/80 mm Hg, and absence of diabetes mellitus.[1] The prevalence of individuals having all 7 ICH metrics is exceedingly low in several US cohorts.[2–4]

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Several studies have examined the relationship between the metrics included in ICH and clinical CVD,[3–6] but only a few evaluated the relationship between these ICH metrics and subclinical CVD as assessed by coronary artery calcification (CAC).[7–9] CAC is an established marker of subclinical atherosclerosis, which can precede the occurrence of clinical events by years to decades.[10–12] Noninvasive imaging detects CAC in minute amounts and, thus, is a valuable early indicator of preclinical disease. The relationship between CAC and coronary atherosclerosis has been confirmed both by histopathology and intravascular ultrasound.[12,13] Numerous studies on CAC have shown its prognostic value in coronary heart disease risk assessment in asymptomatic patients.[14–16] If a significant association can be demonstrated between favorable ICH metrics and a reduction in or absence of subclinical atherosclerosis (CAC), the benefits of ICH will potentially extend to abrogating the underlying disease process itself, namely atherogenesis. In addition, such an association would strengthen the emphasis on modifiable health behaviors, such as

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physical activity, in addition to treatment of risk factors, such as high cholesterol, as both types of factors are components of ICH.

The purpose of this study is to examine the association between the 7 metrics of ICH and the presence of CAC as detected by electron-beam computed tomography.

Methods

Design

This study is a cross-sectional analysis of data obtained during a preventive medicine examination, including electron-beam computed tomography to assess CAC, of patients evaluated at the Cooper Clinic in Dallas, Texas, between 1997 and 2007, the time period that CAC assessment was done by electron-beam computed tomography. These data were collected as part of the Cooper Center Longitudinal Study, a large prospective observational study established in 1970. Patients are either self-referred or sent by their employers. Cooper Clinic patients are predominantly white, well-educated and with access to preventive health care. All participants gave informed consent to participate in the study. The Cooper Institute Institutional Review Board reviewed and approved the study protocol annually.

Study Population

The present study included men ≥45 years of age and women ≥55 years of age with complete information on all ICH metrics (smoking, BMI, physical activity, diet, total cholesterol concentration, blood pressure, and glucose concentration) and a CAC score. These age groups allowed a focus on individuals at higher, age-related risk for CAC among both men and women. We excluded those participants with a history of stroke, myocardial infarction, cancer, and those who were underweight (BMI <18.5 kg/m^2). 3121 participants fulfilled our inclusion and exclusion criteria.

Baseline Examination

The baseline evaluation at the Cooper Clinic comprised a detailed medical history, physical examination, and a variety of clinical and laboratory measurements. Participants completed a standardized medical history questionnaire that included personal history, family history, cigarette smoking status, and detailed physical activity questions. Participants also completed a 3-day diet record. BMI was calculated as weight in kilograms divided by height in meters squared, measured using a standard clinical scale and stadiometer. Resting systolic and diastolic blood pressure was measured with the individual in the seated position. After a 12 hour fast, venous blood was assayed for serum cholesterol and glucose using standard, automated techniques in the Cooper Clinic laboratory.[17]

Physical Activity

As cited previously, leisure time physical activity over the past 3 months was assessed via questionnaire.[18] Physical activity categories were created based on participant responses for 10 specific physical activities: walking, jogging, running, treadmill exercise, cycling, stationary cycling, swimming, racquet sports, aerobic dance, and other sports- related activities (eg, basketball and soccer). The intensity of each activity was estimated via a speed-specific or activity-specific metabolic equivalent (MET) value derived from the Compendium of Physical Activities.[19] The MET value for a given activity was multiplied by the frequency and the duration and then summed over all activities, which resulted in total MET-minutes per week of physical activity. All participants were classified into 3 categories based on the 2008 Physical Activity Guidelines for Americans: inactive (0 MET-min/week), insufficient (1–499 MET-min/week), and recommended (≥500 MET-min/week).[20] Five hundred MET-minutes per week are equivalent to 150 minutes per week of moderately intense activity or 75 minutes per week of vigorous activity.

Diet

The 3-day dietary assessment required participants to keep a detailed record of all food and beverages consumed over 2 preassigned week days and 1 weekend day. Participants were provided written instructions on how to accurately describe foods and estimate portion sizes. These diet records included foods consumed during and between meals and recorded portion sizes in common household measures. Dietary records were analyzed using the Food Intake Analysis System (versions 3.00 and 3.99; University of Texas-Houston School of Public Health, Houston, TX, 1996, 2000), and intake of fruits, vegetables, whole grains, and sodium was estimated.[21,22]

In accordance with the American Heart Association recommendations, dietary goals were defined as follows: ≥4.5 servings per day of fruits and vegetables; ≥2 3.5 oz servings per week of fish, shellfish, or other seafood; ≥3 servings per day of whole grains; and <1500 mg/day of sodium. Information on sugar-sweetened beverage was not available. Each dietary metric was assigned a value of either 0 (absent or inadequate) or 1 (present in the ideal range), which allowed for a cumulative dietary score that ranged from 0 to 4. Thus, for the dietary component, the highest score would be 4 instead of 5 because adequate sugar-sweetened beverage data were not available.

Ideal Cardiovascular Health

For the other metrics that are included in ICH, we used the definitions set forth by the ICH writing group as published in *Circulation*, February 2010.[1]

Each individual was categorized into 1 of 3 health levels based on the number of ICH metrics in the ideal range. The healthiest level (favorable ICH score) was defined as having 4 to 7 metrics in the ideal range, with the intermediate level having 3 metrics in the ideal range and the unfavorable level having 0 to 2 metrics ideal. These cut points were used because they resulted in a distribution of the sample cohort into approximately equal groups, with 29% in the favorable category, 28% in the intermediate, and 43% in the unfavorable group. A similar distribution was used in a prior study involving the entire cohort when comparing ICH and mortality.[4]

Coronary Artery Calcification

CAC was assessed by the Imatron C-150XP or C-300 electron beam tomography scanner (GE Imatron, San Francisco, California). Three-millimeter-thick slices were obtained with 2-mm table increments during a breath-holding protocol. Agatston score calculation and the related method for quantifying CAC score has been previously described.[23] CAC scores were categorized into 4 levels: 0, 1 to 99, 100 to 399, and ≥400 to evaluate the prevalence of clinically relevant CAC categories. Clinical practice commonly identifies patients with high CAC using thresholds of 0, 100, or 400 Agatston units. To demonstrate that our findings were not sensitive to which threshold is used, we present results based on analysis for all 3 cut points. The proportion of individuals in each of these CAC score groups was calculated for each ICH metrics level. For the logistic regression models, CAC was dichotomized at clinical cut points of >0 versus 0, ≥100 versus <100, and ≥400 versus <400.

Statistical Analysis

Descriptive statistics for baseline characteristics were calculated for continuous and categorical variables. Measures of baseline characteristics were calculated for each health level and compared using the Jonckheere–Terpstra test for trend. Multivariable logistic regression was used to estimate odds ratios for health levels with prevalent CAC as the outcome. Separate models were constructed for CAC>0 versus 0, CAC≥100 versus <100, and CAC≥400 versus <400 and were adjusted for age and sex. *P* values <0.05 (2-sided) were considered statistically significant. All analyses were performed using SAS for Windows, release 9.2 (SAS Institute, Inc.).

Table 1. Baseline Characteristics of Women and Men With an EBCT Scan and Data for all 7 ICH Metrics Between 1997 and 2007

Variable*	Women (n=538, 17%)	Men (n=2583, 83%)
Age, y	61.7 (6.3)	53.9 (7.3)
Body mass index, kg/m²	25.6 (4.4)	28.1 (3.9)
Total cholesterol, mmol/L	5.6 (0.9)	5.1 (1.0)
Fasting plasma glucose, mmol/L	5.4 (1.0)	5.6 (1.0)
Systolic blood pressure, mm Hg	124.3 (17.6)	126.4 (14.6)
Diastolic blood pressure, mm Hg	79.9 (9.7)	84.2 (9.7)
Hypercholesterolemia, n (%)	204 (37.9%)	835 (32.3%)
Hypertension, n (%)	225 (41.8%)	1264 (48.9%)
Diabetes mellitus, n (%)	21 (3.9%)	150 (5.8%)
Physical activity, MET-min/week	922.5 (1295.7)	1120.9 (1492.9)
Healthy diet score	0.8 (0.6)	0.6 (1.0)
Smoking, n (%)	22 (4.1%)	351 (13.6%)

EBCT indicates electron-beam computed tomography; ICH, ideal cardiovascular health; and MET, metabolic equivalent.

*Values shown are for mean (standard deviation) unless otherwise noted.

Results

Baseline characteristics of the study population stratified by sex are presented in Table 1. Men had higher fasting plasma glucose levels and blood pressure as well as greater prevalence of smoking compared with women. Table 2 describes the characteristics of the study population stratified by ICH metric scores categories. The overall prevalence of a favorable ICH score was 29%, and no participant reached the ideal range for all 7 metrics. The prevalence of intermediate and unfavorable scores was 28% and 43%, respectively. Each factor and behavior demonstrated a significant linear trend across the ICH metric score categories with the exception of age (*P*=0.09). Participants with a favorable ICH score had lower baseline values of BMI, total cholesterol, fasting plasma glucose, blood pressure, and CAC scores, as well as a lower prevalence of self-reported diabetes mellitus and hypertension (*P* value <0.0001). With respect to healthy behaviors, those with a favorable ICH score had higher baseline physical activity levels and healthy diet scores than those with a less favorable ICH score (*P*<0.001) and a lower prevalence of smoking.

Figure 1 shows the distribution of ICH metrics in the study population. The most common number of metrics per individual was 3 (28%). Among the study participants, 2% had zero favorable metrics whereas only 2% had 6 favorable metrics, the maximum number of ICH metrics achieved by the patients in this sample. Figure 2 depicts the distribution of CAC scores based on the number of favorable ICH metrics (ICH score categories). Of those with more favorable cardiovascular health (4–7 ICH metrics), 61% have no detectable CAC, whereas only 7% had CAC≥400. Conversely, unfavorable health (0–2 ICH metrics) was associated with a higher prevalence of CAC≥400.

Table 3 shows the odds ratios (OR) for CAC presence after adjusting for age and sex. For patients with favorable ICH profiles, odds of CAC>0 were less than half of those for patients with unfavorable profiles (OR 0.41; 95% confidence interval [CI], 0.34–0.50). For patients with intermediate ICH profiles, odds of CAC>0 were 32% lower than those with unfavorable profiles (OR 0.68; 95% CI, 0.57–0.82). A similar pattern was evident in those with a CAC score ≥100 for both the favorable (OR 0.44; 95% CI, 0.35–0.56) and intermediate groups (OR 0.56; 95% CI, 0.46–0.70). When a CAC score ≥400 was the considered outcome, once again there was a significant

Table 2. Baseline Characteristics of Participants With an EBCT Scan and Data for All 7 Ideal Cardiovascular Health Metrics From 1997 to 2007 Grouped by Number of Metrics in the Ideal Range

	Number of Ideal Cardiovascular Health Metrics			
	0–2 (n=1334, 43%)	3 (n=881, 28%)	4–7 (n=906, 29%)	*P* Value*
Age, y	55.5 (7.8)	55.2 (7.8)	54.9 (7.5)	0.09
Female, n (%)	170 (13%)	150 (17%)	218 (24%)	<0.001
Body mass index, kg/m²	29.6 (3.9)	27.5 (3.6)	25.0 (3.6)	…
Total cholesterol, mmol/L	5.5 (1.0)	5.2 (0.9)	4.9 (0.8)	…
Fasting plasma glucose, mmol/L	5.9 (1.1)	5.4 (0.8)	5.2 (0.7)	…
Systolic blood pressure, mm Hg	129.9 (14.9)	126.6 (14.2)	119.9 (14.4)	…
Diastolic blood pressure, mm Hg	86.0 (9.8)	83.9 (9.2)	79.4 (9.2)	…
Hypercholesterolemia, n (%)	636 (47.7%)	267 (30.3%)	136 (15.0%)	…
Hypertension, n (%)	829 (62.1%)	420 (47.7%)	240 (26.5%)	…
Diabetes mellitus, n (%)	144 (10.8%)	20 (2.3%)	7 (0.8%)	…
Physical activity, MET-min/week	636.3 (1114)	1241.8 (1583)	1625.2 (1582)	…
Healthy diet score	0.57 (0.57)	0.64 (0.58)	0.72 (0.56)	…
Smoking, n %	291 (21.8%)	51 (5.8%)	31 (3.4%)	…
CAC score, Agatston units	230.9 (566.2)	190.6 (627.1)	108.3 (368.6)	<0.0001†

Values shown are for mean (standard deviation) unless otherwise noted.

CAC indicates coronary artery calcification; EBCT indicates electron-beam computed tomography and MET, metabolic equivalent.

*Trend tests across ordered cardiovascular health categories are not conducted on variables that are used to define those categories.

†*P* value for trend.

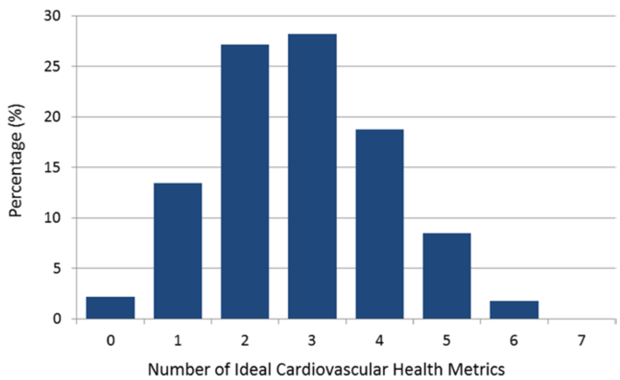

Figure 1. Distribution of cardiovascular health metric scores in 3121 men and women. Health metric score is the total number of ideal cardiovascular health metrics in the ideal range, including smoking, body mass index, physical activity, diet, total cholesterol concentration, blood pressure, and glucose concentration. Percentage of the sample having the total health metric score 0 to 7.

reduction in the odds of CAC for the favorable ICH group (OR 0.55; 95% CI, 0.40–0.75) as well as the intermediate group (OR 0.71; 95% CI, 0.53–0.95).

Discussion

There are 2 main findings of this study. First, among middle-aged men and women enrolled in the Cooper Center Longitudinal Study between 1997 and 2007 who had an electron-beam computed tomography examination and data available on all 7 ICH metrics, none had ICH. Second, those with a favorable ICH score had a lower prevalence and severity of subclinical atherosclerosis as estimated by CAC.

Our finding that more favorable ICH categories were associated with less CAC is consistent with previous studies evaluating the association between individual health risk factors or health behaviors and CAC. In the CARDIA cohort, prehypertension and suboptimal lipids in young adulthood was associated with the development of CAC 20 years later.[24,25] In a study of subjects with normal glucose tolerance, impaired glucose tolerance (impaired fasting glucose), or type 2 diabetes mellitus, subjects with diabetes mellitus were significantly more likely to have CAC.[26] In Framingham Heart Study participants, obesity was associated with high CAC in multivariable models that included impaired fasting glucose.[27] Studies of the association of CAC with physical activity have yielded conflicting results.[28] In the Multi Ethnic Study of Atherosclerosis, only walking pace was associated with a lower prevalence of CAC in men, although the associations were modest at best.[28] Also in Multi Ethnic Study of Atherosclerosis, Ahmed et al[29] found lower incidence of CAC with less progression and less all-cause mortality in participants who had a low risk profile of lifestyle risk factors. Desai et al[30] found long duration physical activity to be inversely related to CAC independent of other confounding variables. On the contrary, Taylor et al[31] found no significant relationship between physical activity, particularly high-intensity physical activity and the extent of CAC.

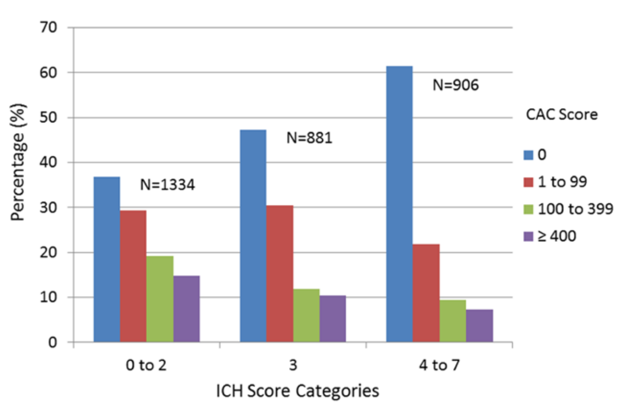

Figure 2. Distribution of CAC scores by cardiovascular health profile categories. Cardiovascular health profile categories: 0 to 2 ideal cardiovascular health (ICH) metrics in the ideal range, unfavorable; 3 ICH metrics in the ideal range, intermediate; 4 to 7 metrics in the ideal range, favorable. ICH metrics include smoking, body mass index, physical activity, diet, total cholesterol concentration, blood pressure, and glucose concentration. CAC indicates coronary artery calcification in Agatston units.

Rather than looking at a single health metric, other studies have evaluated the relationship between multiple risk factors and CAC. Daviglus et al[7] showed that individuals with favorable risk factor profiles had less CAC. However, this group did not consider physical activity or diet. In 2008, Michos et al[9] examined the association between CAC and favorable levels of systolic blood pressure, triglycerides, glucose, waist circumference, and nonsmoking in 440 asymptomatic middle-aged Brazilian men and found significantly less CAC in those with a favorable risk profile. Michos reported on 1824 men and women aged ≥70 and showed a significant association between normal BMI, lipids, blood pressure, and nonsmoking status and lower CAC scores.[8]

An important strength of our study is a population with information on all 7 ICH metrics, CVD risk factors, and concurrent CAC measurements. We excluded subjects with a history of stroke, CVD, cancer, or a BMI <18.5 kg/m^2. Thus, our population was healthy and well suited to evaluate the effect of primordial prevention on subclinical CVD. Our study is the largest to date with both men and women and includes subjects over a broad age range.

Our study participants were predominantly white, well educated, from middle to upper socioeconomic strata, and were not randomly selected from the general population. However, these characteristics make our study cohort more homogeneous and reduce confounding caused by unmeasured factors. Also, previous studies have demonstrated that the Cooper Center Longitudinal Study cohort is similar to other well defined population-based cohorts in terms of CVD outcomes in the presence of known risk factors.[32] Third, our study included fewer women (17% of the total sample), although the concept of ICH as defined by the American Heart Association is not sex-specific, and appropriate adjustment for sex was made in our analyses. Additionally, we had insufficient information on sugar-sweetened beverages and did not have information on the length of time since a former smoker quit. Nevertheless, we still had useful and well validated nutritional information to include in the healthy dietary score metric. Constructing an ICH metric as a count of prevalent factors assumes that each

Table 3. Odds Ratios (OR) for a Subclinical CAC>0 Versus 0, ≥100 Versus <100, and ≥400 Versus <400 Based on the Number of ICH Metrics in the Ideal Range and Adjusted for Age and Sex

	CAC Score Categories, OR (95% CI)		
Number of ICH Metrics	>0 Versus 0	≥100 Versus <100	≥400 Versus <400
0–2 (referent)	1.0 (referent)	1.0 (referent)	1.0 (referent)
3	0.68 (0.57–0.82)	0.56 (0.46–0.70)	0.71 (0.53–0.95)
4–7	0.41(0.34–0.50)	0.44 (0.35–0.56)	0.55 (0.40–0.75)

CAC indicates coronary artery calcification; CI, confidence interval; ICH, ideal cardiovascular health; and OR: odds ratio.

factor contributes equally to cardiovascular health; this is a question that should be investigated with further research. A limitation of observational data, such as ours, is that the component factors are not independent but instead can be highly correlated. We were therefore not able to extend our study to cover this point. On the other hand, it was not our objective to justify the ICH concept, but rather to demonstrate its association with CAC. Finally, this study evaluated the relationship to preclinical disease and did not assess the interplay with the burden of actual clinical atherosclerotic disease.

We have demonstrated an inverse association between the number of ICH metrics and CAC, a preclinical marker of CVD, among middle-aged adults. With fewer cardiovascular risk factors or unhealthy behaviors, there is less CAC. Identifying and addressing the earliest departure from normal of a given risk factor would seem to provide a clear advantage. It has been stated that the majority of CVD occurs in individuals with only mildly adverse levels of risk factors because this is where the majority of the population lies.[1] Thus, a population-wide effort at risk factor reduction rather than simply targeting prevention efforts at individuals with abnormal risk profiles seems prudent.

Our findings also suggest that achieving ICH is difficult. No one subject in our population had achieved ICH as defined. Even in our seemingly healthy, asymptomatic population, only 30% had favorable ICH scores. Moreover, given that 36% of our subjects in the favorable ICH category had some evidence of calcified coronary artery atherosclerosis (CAC>0), ideal ICH metrics may truly be the goal rather than settling for moderate or average.

These findings also suggest that there is much work to do in the medical community and beyond to screen, treat, and educate the population at large about the targets for achieving ICH. Importantly, patients need to be provided practical strategies to achieve these ideal targets, including how to embrace opportunities to become physically active and nutritionally mindful. Additional studies evaluating the effect of risk factor and lifestyle interventions and their effect on ICH metrics and clinical disease are clearly needed.

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Disclosures

None.

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CLINICAL PERSPECTIVE

The American Heart Association's 2020 Strategic Impact Goals aim to improve the cardiovascular health of all Americans by 20% and reduce deaths from cardiovascular diseases and stroke by 20%. To achieve these goals, the American Heart Association highlighted the importance of primordial prevention or preventing the initial development of risk factors. Ideal cardiovascular health (ICH) was defined as the simultaneous presence of 7 health behaviors and health factors in the absence of clinical cardiovascular diseases. The 7 metrics are abstinence of smoking within the past year, ideal body mass index, physical activity at goal levels, dietary pattern that promotes cardiovascular health, untreated total cholesterol <200 mg/dL (5.17 mmol/L), untreated blood pressure <120/80 mm Hg, and absence of diabetes mellitus. In this generally healthy population, we have demonstrated an inverse association between the number of ICH metrics and coronary artery calcium, a preclinical marker of cardiovascular diseases, among middle-aged adults. Our findings also suggest that achieving ICH is difficult as no one in our population achieved ICH as defined by American Heart Association and only 30% had favorable ICH scores. Moreover, given that 36% of our subjects in the favorable ICH category had some evidence of CAC (>0), ideal ICH metrics may truly be the goal rather than settling for moderate or average. These findings suggest that there is much work to do in the medical community and beyond to screen, treat, and educate the population at large about the targets for achieving ICH.

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