Ideal Cardiovascular Health and the Prevalence and Progression of Coronary Artery Calcification in Adults With and Without Type 1 Diabetes

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CARDIOVASCULAR AND METABOLIC RISK

OBJECTIVE

In 2010, the American Heart Association defined seven metrics (smoking, BMI, physical activity, diet, total cholesterol, blood pressure, and fasting plasma glucose) for ideal cardiovascular health (ICH). Subsequent studies have shown that the prevalence of achieving these metrics is very low in the general population. Adults with type 1 diabetes are at increased risk of cardiovascular disease (CVD), but no studies to date have been published on the prevalence of ICH in this population.

RESEARCH DESIGN AND METHODS

Data for this analysis were collected as part of the prospective Coronary Artery Calcification in Type 1 Diabetes study. This analysis involved 546 subjects with type 1 diabetes and 631 subjects without diabetes who had complete information for calculating the ICH metrics.

RESULTS

Overall, the prevalence of ICH was low in this population, with none meeting the ideal criteria for all seven metrics. The prevalence of ideal physical activity (10.0%) and diet (1.1%) were particularly low. ICH was significantly associated with both decreased prevalence (odds ratio [OR] 0.70; 95% CI 0.62–0.80) and progression (OR 0.77; 95% CI 0.66–0.90) of coronary artery calcification (CAC).

CONCLUSIONS

ICH is significantly associated with decreased prevalence and progression of CAC; however, prevalence of ICH metrics was low in adults both with and without type 1 diabetes. Efforts to increase the prevalence of ICH could have a significant impact on reducing the burden of CVD.

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Cardiovascular disease (CVD) is the leading cause of morbidity and mortality in the U.S., with an estimated prevalence of one in three and accounting for more deaths than any other cause (1). The incidence of type 1 diabetes worldwide is increasing (2), with variations in geographic distribution that are unexplained by racial/ethnic composition (3). Considering that people with type 1 diabetes are at increased risk of CVD compared with the general population (4), prevention of CVD in this high-risk population is a clinical and research priority (5).

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In 2010, the American Heart Association (AHA) defined parameters for poor, intermediate, and ideal cardiovascular health (ICH) in seven modifiable metrics (6). This was done to increase focus on primordial prevention of risk factors to prevent the atherosclerotic disease processes that lead to CVD events years later. The seven metrics include smoking, BMI, physical activity, diet, total cholesterol, blood pressure, and fasting plasma glucose (6). Nationally, the prevalence of achieving ICH is quite low in the general population, with fewer than 1% of adults meeting the criteria in all seven metrics (7).

Since the AHA published their definition of ICH, several studies have reported the prevalence of these metrics in different populations (8–10). No studies published to date have reported on the prevalence of ICH factors in type 1 diabetes. Several studies have reported on the association between ICH metrics and CVD outcomes (8,9,11), and only one prior report has looked at ICH metrics and subclinical CVD (12). While these metrics are well-defined risk factors for CVD, it is relevant to determine whether achievement of ICH as defined by the AHA is associated with reduced subclinical CVD, as these measures may be used for clinical benchmarks. The purpose of this report is to describe the prevalence of ICH metrics in a population of adults with and without type 1 diabetes and to examine the association with the prevalence and progression of coronary artery calcification (CAC), an established measure of subclinical CVD.

RESEARCH DESIGN AND METHODS

Study Design and Subjects

Data for this analysis were collected as part of the prospective cohort study Coronary Artery Calcification in Type 1 Diabetes (CACTI). CACTI was designed to examine the prevalence of subclinical atherosclerosis in adults with type 1 diabetes and a comparable group of controls without any diabetes. Detailed descriptions of the study design have been published elsewhere (13). There were 1,420 subjects enrolled, but 4 subjects (2 with type 1 diabetes and 2 without diabetes) were found to not meet study inclusion criteria and were dropped, leaving 1,416 (652 subjects with type 1 diabetes and 764 subjects without diabetes) who were clinically free of CVD at enrollment. A matched study design was not used in order to observe factors related to CVD that differed between the groups. Of the 1,416 subjects enrolled at baseline, 106 subjects with type 1 diabetes and 133 subjects without diabetes were missing data on physical activity and diet. This leaves 546 subjects with type 1 diabetes and 631 subjects without diabetes who had complete information at the baseline exam for the assessment of ICH metrics. An additional 148 subjects with type 1 diabetes and 173 subjects without diabetes did not have information on progression of CAC over the average of 6.1 years between exams, which were not included in the models for progression. Supplementary Table 1 compares baseline characteristics of participants with and without data on CAC progression, demonstrating that the groups were similar other than for age (35.1 vs. 39.2 years; $P < 0.001$).

Participants underwent a physical exam to obtain anthropometric measurements and blood pressure readings and to obtain a fasting blood sample. Each participant also completed a standardized questionnaire to obtain demographics, medical history, medication inventory, smoking status, physical activity, food frequency, daily insulin dose, and family medical history. Electron-beam computed tomography was used to measure CAC at baseline and follow-up exams. Informed consent was provided by all study participants, and the protocol was reviewed and approved by the Colorado Multiple Institutional Review Board.

ICH Metrics

We used the definitions for ideal, intermediate, and poor cardiovascular health from the AHA's Strategic Impact Goal Statement, published in 2010 (6), for five of the seven metrics (blood pressure, total cholesterol, BMI, physical activity, and diet). For smoking, we had insufficient information on smoking history to determine how recently former smokers had quit. Therefore, for this metric, we deviated from the published definition by defining never smoking as ideal, former smoking as intermediate, and current smoking as poor.

The guideline for ideal fasting plasma glucose was not intended to include those with diabetes, as this metric imperfectly captures CVD risk in type 1 diabetes. Instead, we substituted HbA_{1c} for plasma glucose, utilizing the following cut points: <5.7, 5.7 to <6.5, and ≥6.5%. These cut points have been used previously (11) and reflect the American Diabetes Association recommendations for HbA_{1c} diagnostic criteria for diabetes (≥6.5%) and prediabetes (5.7–6.4%) (14). We chose to use the same criteria for both those with and without diabetes for consistency. Definitions for the remaining metrics can be found in Table 2.

Health Factors

Blood pressure measurements, resting systolic blood pressure (SBP), and fifth-phase diastolic blood pressure (DBP) were taken in triplicate while the subject was seated, following a 5 min rest. The average of the second and third readings was used for the study.

Separated plasma samples were obtained from whole blood after an overnight fast. Samples were stored at 4°C until the assays were performed using standard methods to determine total cholesterol and HbA_{1c} levels. HbA_{1c} levels were determined using high-performance liquid chromatography. As noted above, we replaced the fasting plasma glucose metric with one using HbA_{1c}.

Health Behaviors

BMI was calculated as kilograms of body weight per meters squared of height. Smoking history was obtained from a validated questionnaire developed for the Insulin Resistance Atherosclerosis Study (15). Smoking status was defined as never smoking (<100 cigarettes in lifetime), past, and current.

Physical activity was obtained from the validated Modifiable Activity Questionnaire designed for the Pima Indian study (16). Previous validation of this instrument found correlations with activity monitor counts for leisure activities over the prior week ranging from 0.50–0.80 ($P < 0.05$) (16). Activities were defined as moderate, vigorous, or low intensity, and the number of minutes per week for each activity level was calculated.

The validated, self-administered food frequency questionnaire (Harvard, 1988) asked participants to indicate how often (never to 6+ times per day) on average over the previous year they had consumed the indicated foods in commonly used portion sizes (17). A previous validation study of this instrument found that the mean correlation of nutrient intakes estimated from the questionnaire with diet records over the previous year, after adjusting for week-to-week variation, was $r = 0.65$ (17). Nutrient intake was estimated from the diet assessment to calculate the sodium consumption per day. The food frequencies for fruits and vegetables, fish, and grains were converted to U.S. Department of Agriculture MyPyramid equivalents (18) in order to calculate comparable equivalents for summing across food groupings and to estimate the whole-grain equivalents. Based on the reported frequency of consumption, the servings per day were calculated.

CAC Measurement

CAC measurements were obtained in duplicate using an ultrafast Imatron C-150XLP electron-beam computed tomography scanner (Imatron, San Francisco, CA). The average of the two scores was used as the CAC score for that visit. Scans were repeated on follow-up an average of 6.1 years after the baseline exam. Presence of CAC was defined as a CAC score >0. Progression of CAC was defined as an increase in volume of CAC of ≥2.5 square root transformed units. This definition of progression has previously been shown to represent significant progression of CAC (19,20).

Statistical Analyses

Differences were compared by diabetes status. Parametric continuous data were presented as means ± SD or as least squares means adjusted for age, sex, and race since subjects with and without diabetes differed significantly for these variables (Table 1). Triglyceride and plasma glucose values were not normally distributed and so are presented as the geometric mean. Categorical data were presented as the number of subjects and the percentage. Statistical testing to detect differences between groups included the *t* test for parametric continuous data, the χ^2 test for categorical data, and the ANCOVA to compare least squares adjusted means.

Logistic regression was used to examine the association between the individual metrics as well as the number of metrics that met the criteria for ICH as a continuous variable (0–7) and the presence and progression of CAC. Potential confounding variables were

Table 1—Characteristics of the study population

Characteristic	Type 1 diabetes (*n* = 546)	No diabetes (*n* = 631)	*P* value*
Age at baseline, mean (SD)	37.0 (9.1)	39.0 (9.1)	<0.001
Males, *N* (%)	236 (43.2)	312 (49.5)	0.033
White, *N* (%)	521 (95.8)	533 (84.7)	<0.001
Hispanic, *N* (%)	13 (2.4)	55 (8.8)	<0.001
Duration of diabetes, mean (SD)	23.7 (9.0)	NA	—
HbA_{1c} (%), adjusted mean (95% CI; mmol/mol)†	8.0 (7.9–8.1; 64)	5.5 (5.4–5.6; 37)	<0.001
Insulin dose (units/kg/day), mean (SD)	0.63 (0.25)	NA	—
BMI (kg/m^2), adjusted mean (95% CI)†	26.8 (26.3–27.4)	26.5 (26.0–27.0)	0.275
Waist circumference (cm), adjusted mean (95% CI)†	86.3 (84.9–87.8)	85.9 (84.6–87.1)	0.489
Waist-to-hip ratio, adjusted mean (95% CI)†	0.83 (0.82–0.84)	0.83 (0.82–0.83)	0.986
SBP (mmHg), adjusted mean (95% CI)†	119 (117–120)	114 (113–116)	<0.001
DBP (mmHg), adjusted mean (95% CI)†	78 (77–79)	79 (78–80)	0.028
Total cholesterol (mg/dL), adjusted mean (95% CI)†	176 (172–181)	191 (187–194)	<0.001
HDL (mg/dL), adjusted mean (95% CI)†	57 (55–58)	51 (50–53)	<0.001
LDL (mg/dL), adjusted mean (95% CI)†	101 (97–104)	113 (110–117)	<0.001
Non-HDL (mg/dL), adjusted mean (95% CI)†	119 (115–124)	139 (135–142)	<0.001
Triglycerides (mg/dL), adjusted geometric mean (95% CI)†	85 (80–91)	111 (106–117)	<0.001
Plasma glucose (mg/dL), adjusted geometric mean (95% CI)†	169 (161–177)	89 (85–92)	<0.001
Albumin excretion rate (μg/min), adjusted geometric mean (95% CI)†	12.6 (10.8–14.6)	4.8 (4.2–5.5)	<0.001
Albuminuria			<0.001
Macroalbuminuria, *N* (%)	47 (9.1)	3 (0.49)	
Microalbuminuria, *N* (%)	69 (13.4)	13 (2.1)	
Normoalbuminuria, *N* (%)	398 (77.4)	599 (97.4)	
Presence of CAC at baseline, *N* (%)	210 (38.5)	158 (25.0)	<0.001
Progression of CAC, *N* (%)	173 (43.5)	134 (29.3)	<0.001

NA, not applicable. **P* value obtained from *t* test for continuous parametric data, χ^2 for categorical data, and ANCOVA for adjusted means. †Least squares means adjusted for age, sex, and race.

considered for inclusion in the models based on a priori criteria: significance in previous work, significant contribution to the model fit (P value of the Wald X^2 $<$0.05), or confounding the association between the main variable of interest and the outcome by $>$10%. Interaction terms for each individual health metric as well as the number of metrics that met ICH and sex, age, race, and diabetes status were tested for the presence of effect modification. Age at baseline (continuous), sex, log triglycerides, and diabetes status were included in the final models for the presence of CAC. The same variables with the addition of the baseline CAC score were included in the final models for the progression of CAC. Additional variables considered for inclusion in the model but not found to meet the a priori criteria for inclusion were race, Hispanic ethnicity, plasma glucose, and albumin excretion rate. HDL cholesterol, LDL cholesterol, and non-HDL cholesterol were not included in the models since these measures are components of total cholesterol, which was already considered in the model.

As the intended purpose of this report was to compare the prevalence of ICH in those with and without diabetes and to examine the association of ICH with the prevalence and progression of CAC, we have dichotomized continuous predictors for the purposes of these analyses. Dichotomizing continuous predictors can lead to a loss of statistical power and an inflation of residual confounding (21). We compared models of the continuous predictors with the dichotomized ICH metric (Supplementary Table 2), and demonstrate that use of continuous variables would not alter the conclusions of this report.

Stratified analyses by diabetes status are presented in Supplementary Table 3. In order to examine graded effects of intermediate and poor cardiovascular health on the prevalence and progression of CAC, a model of the individual health metrics with intermediate and poor cardiovascular health relative to ideal is presented in Supplementary Table 4. Scores were constructed by assigning a value for each metric (0 for poor, 1 for intermediate, and 2 for ideal) and summing across the metrics in order to assess all levels of cardiovascular health. All analyses were performed using SAS/STAT software, version 9.2 of the SAS System for Windows (SAS Institute Inc., Cary, NC).

RESULTS

Table 1 presents characteristics of the study population by diabetes status. Subjects with diabetes were younger, and a higher percentage were female and white, non-Hispanic. They also had higher HbA_{1c}, SBP, HDL cholesterol, plasma glucose, macroalbuminuria, microalbuminuria, and albumin excretion rate. Conversely, subjects with diabetes had lower DBP, total cholesterol, LDL cholesterol, non-HDL cholesterol, and triglyceride values. Subjects with diabetes were more likely to have CAC present at baseline and to experience significant progression of CAC over 6.1 years.

Table 2 presents the prevalence of the AHA ICH metrics by diabetes status. The distribution of subjects across ideal, intermediate, and poor categories was similar between those with diabetes and without for smoking, BMI, physical activity, healthy diet score, and total cholesterol. A smaller percentage of those with diabetes met the ideal category for blood pressure (31.1 vs. 44.4%; $P < 0.001$), and the majority of those with diabetes were in the poor category for HbA_{1c} (91.2%).

Overall, 67.9% of our study population met the ideal criteria for smoking, 45.2% for BMI, and 62.1% for total cholesterol. For physical activity, only 10.0% met the ideal criteria, and just 28.3% met the intermediate criteria. The majority, 61.7% reported no moderate or vigorous physical activity per week. For the healthy diet score, only 1.1% met the ideal criteria, while 42.5% met the intermediate criteria. The remainder, 56.4%, reported none or only one component of the healthy diet.

The number of ideal metrics achieved was significantly lower in those with diabetes compared with those without ($P < 0.001$). For the health behaviors, those with diabetes and those without were similar in the number that achieved the ideal criteria (P = 0.26). Figure 1 presents the number of ICH metrics by diabetes status, including HbA_{1c} in Fig. 1*A* and excluding HbA_{1c} in Fig. 1*B*. There were no subjects in either group that met the ideal criteria for all seven health factors and behaviors. Those with type 1 diabetes met fewer ICH metrics than those without diabetes, with significantly more subjects with type 1 diabetes meeting zero to two metrics and significantly fewer meeting four or five metrics, compared with those without diabetes (Fig. 1*A*). Few subjects in both groups met the ideal criteria for six of the health metrics (0.18 and 1.1%, respectively). Excluding HbA_{1c} (Fig. 1*B*), the distribution for the number of ICH metrics achieved in both groups was similar, with significantly fewer subjects with diabetes meeting four ICH metrics compared with those without diabetes.

Table 3 presents the results of multivariable logistic regression models of ICH on prevalence and progression of CAC, adjusted for age, log-transformed triglycerides, sex, and diabetes status. Of the individual ICH metrics, having ideal BMI (odds ratio [OR] 0.41; 95% CI 0.30–0.56) and having ideal total cholesterol (OR 0.73; 95% CI 0.53–0.99) were protective for the prevalence of CAC. For progression, both having ideal BMI (OR 0.61; 95% CI 0.42–0.88) and ideal blood pressure (OR 0.49; 95% CI 0.33–0.72) were independently protective. Having a higher number of ICH behaviors was significantly associated with a lower odds of having prevalent CAC (OR 0.66; 95% CI 0.54–0.80), and having a higher number of ICH factors was significantly associated with lower odds of prevalence (OR 0.75; 95% CI 0.62–0.91) and progression (OR 0.76; 95% CI 0.61–0.95) of CAC. Overall, for each ICH goal met, the odds of CAC prevalence (OR 0.70; 95% CI 0.62–0.80) and progression (OR 0.77; 95% CI 0.66–0.90) were significantly lower. There was no evidence of effect modification by diabetes status on the relationship between the number of ICH factors and the prevalence or progression of CAC (P = 0.72 and 0.45, respectively; data not shown). While significant differences existed in the prevalence of ideal blood pressure and ideal HbA_{1c} between those with and without diabetes, significant

Table 2—Prevalence of AHA ICH metrics

Health metric	Category	Definition	All N (%)	Type 1 diabetes N (%)	No diabetes N (%)	P value*
Smoking	Ideal	Never	799 (67.9)	364 (66.7)	435 (68.9)	0.41
	Intermediate	Former	253 (21.5)	115 (21.1)	138 (21.9)	
	Poor	Current	125 (10.6)	67 (12.3)	58 (9.2)	
BMI	Ideal	$<$25 kg/m^2	532 (45.2)	238 (43.6)	294 (46.6)	0.30
	Intermediate	25–29.99 kg/m^2	431 (36.6)	220 (40.3)	211 (33.4)	
	Poor	$\geq$30 kg/m^2	214 (18.2)	88 (16.1)	126 (20.0)	
Physical activity	Ideal	$\geq$150 min/week moderate *or* $\geq$75 min/week vigorous *or* $\geq$150 min/week moderate + vigorous†	118 (10.0)	55 (10.1)	63 (10.0)	0.96
	Intermediate	1–149 min/week moderate *or* 1–74 min/week vigorous *or* 1–149 min/week moderate + vigorous†	333 (28.3)	140 (25.6)	193 (30.6)	
	Poor	None	726 (61.7)	351 (64.3)	375 (59.4)	
Healthy diet score‡	Ideal	4–5 components	13 (1.1)	6 (1.1)	7 (1.1)	0.99
	Intermediate	2–3 components	500 (42.5)	245 (44.9)	255 (40.4)	
	Poor	0–1 components	664 (56.4)	295 (54.0)	369 (58.5)	
Total cholesterol	Ideal	$<$200 mg/dL untreated	731 (62.1)	349 (63.9)	382 (60.5)	0.23
	Intermediate	200–239 mg/dL, or treated to goal	357 (30.3)	173 (31.7)	184 (29.2)	
	Poor	$\geq$240 mg/dL	89 (7.6)	24 (4.4)	65 (10.3)	
Blood pressure	Ideal	$<$120/$<$80 mmHg untreated	450 (38.2)	170 (31.1)	280 (44.4)	$<$0.001
	Intermediate	120–139 SBP, 80–89 DBP, or treated to goal	597 (50.7)	310 (56.8)	287 (45.5)	
	Poor	$\geq$140 SBP, $\geq$90 DBP	130 (11.1)	66 (12.1)	64 (10.1)	
HbA_{1c}	Ideal	$<$5.7%	488 (41.8	6 (1.1)	482 (77.1)	$<$0.001
	Intermediate	5.7–$<$6.5%	177 (15.2)	42 (7.7)	135 (21.6)	
	Poor	$\geq$6.5%	503 (43.1)	495 (91.2)	8 (1.3)	
Number of ideal health factors (blood pressure, cholesterol, and HbA_{1c})	0		216 (18.5)	154 (28.4)	62 (9.9)	$<$0.001
	1		413 (35.4)	257 (47.3)	156 (25.0)	
	2		369 (31.6)	130 (23.9)	239 (38.2)	
	3		170 (14.6)	2 (0.37)	168 (26.9)	
Number of ideal health behaviors (smoking, BMI, physical activity, and diet)	0		203 (17.3)	93 (17.0)	110 (17.4)	0.26
	1		538 (45.7)	266 (48.7)	272 (43.1)	
	2		384 (32.6)	164 (30.0)	220 (34.9)	
	3		52 (4.4)	23 (4.2)	29 (4.6)	
	4		0 (0.0)	0 (0.0)	0 (0.0)	

*P value from χ^2 test of ideal versus intermediate and poor combined or logistic regression of number of ideal health factors and ideal health behaviors. †Minutes of vigorous activity were doubled when combined with moderate activity. ‡Dietary components were as follows: $\geq$4.5 cups of fruits and vegetables per day; two or more 3.5-ounce servings of fish per week; three 1-ounce equivalents of whole grains per day; $<$1,500 mg of sodium per day; and $\leq$36 ounces of sugar-sweetened beverages per week, scaled to a 2,000 kcal/day diet.

interactions with diabetes status were not found on the relationship with prevalence (P = 0.66 and 0.95, respectively; data not shown) and progression of CAC (P = 0.93 and 0.92, respectively; data not shown). In addition, no significant effect modification was found with age, sex, or race. Results from regression models by diabetes status are available in Supplementary Table 3. The results from these analyses support the use of a pooled analysis combining those with and without diabetes in one model. Intermediate and poor cardiovascular health were associated with more prevalence and progression of CAC, relative to ideal, but the cardiovascular health scores revealed that even incremental improvements in cardiovascular health were associated with decreased prevalence (OR 0.80; 95% CI 0.74–0.87) and progression (OR 0.85; 95% CI 0.78–0.93) of CAC (Supplementary Table 4).

CONCLUSIONS

We found that higher numbers of ICH metrics were significantly associated with decreased CAC prevalence and progression in a population of adults with and without type 1 diabetes. The groups were similar for all of the metrics except blood pressure and HbA_{1c}. This was likely driven by treatment, as significantly more subjects with type 1 diabetes in this cohort were on dyslipidemia (36 vs. 9%; $P < 0.0001$) (22) and antihypertensive medications

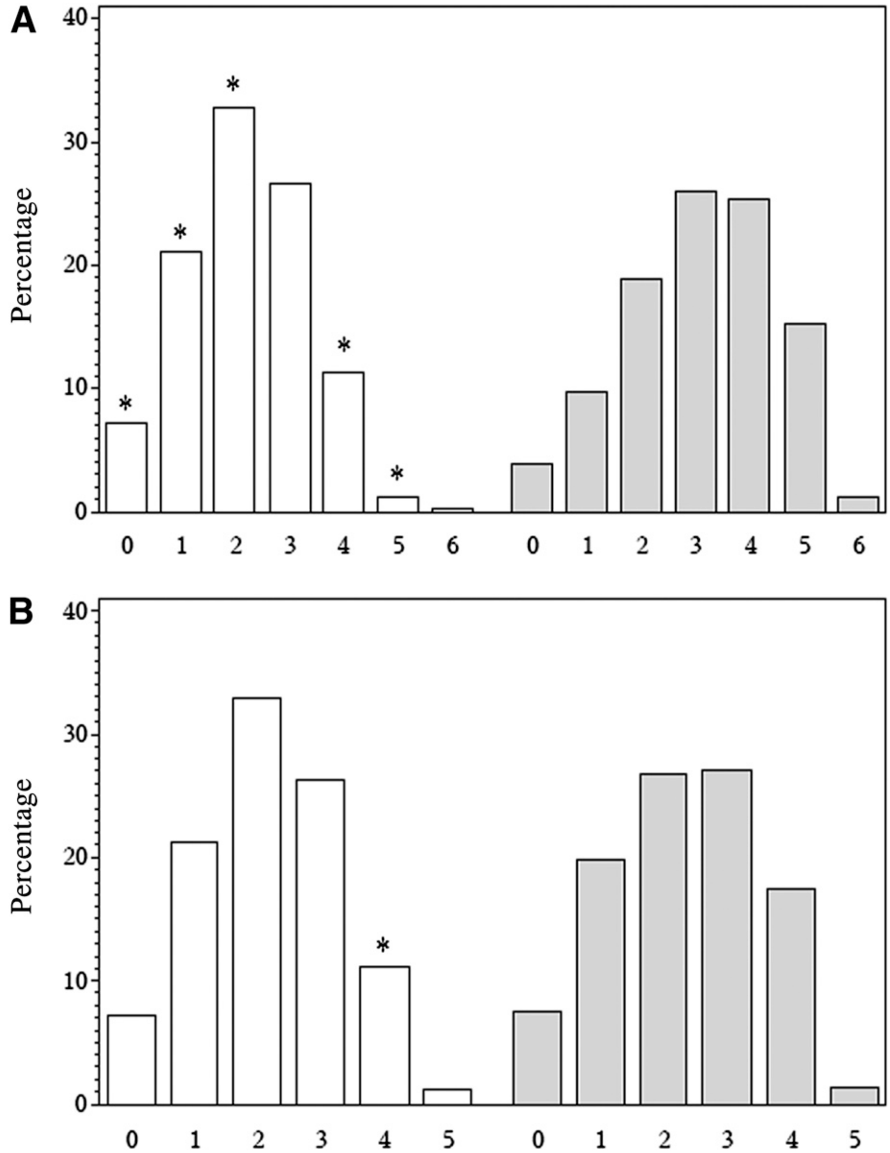

Figure 1—(*A*) Number of ICH metrics by diabetes status, including HbA_{1c}. (*B*) Number of ICH metrics by diabetes status, excluding HbA_{1c}. Significance was determined by χ^2 test with 3 as the referent category. White bars represent the number of ICH metrics for those with type 1 diabetes. Gray bars represent the number of ICH metrics for those without diabetes. *Significantly lower among those with type 1 diabetes than among those without diabetes ($P < 0.05$).

(87 vs. 47%; $P < 0.001$) (23). Overall, those with type 1 diabetes met fewer ICH metrics than those without, but prevalence of ICH was low, with no subjects in either group meeting all seven criteria and only 0.18 and 1.1%, respectively, meeting the ideal criteria in six. Among adults with diabetes, only 1.3% met the ideal criteria in five or more metrics, and among adults without diabetes, only 16.3% did.

This is the first study that we are aware of to report on the prevalence of ICH metrics in a population of adults with type 1 diabetes; however, these results confirm the low prevalence reported in other studies of adults without diabetes, with estimates ranging from <0.1–0.2% for ICH in all seven metrics. In an examination of data from survey years 2003 to 2008 of the National Health and Nutrition Examination Survey (NHANES), <1% of participants met all seven ICH metrics, and the prevalence of ICH declined with age (7).

The prevalence of ideal diet and physical activity was particularly low (1.1 and 10.0%, respectively). For diet, these results are very similar to those from the NHANES 2003 to 2008 data, where the estimate for 40–64-year-olds was 1.1% and the estimate for 20–39-year-olds was only 0.5% (7). In the current study, ideal diet was quite a bit lower than the estimate from Bambs et al. (10) (38.7%); however, their estimate was based solely on consumption of fruits and vegetables. Estimates from other studies ranged from 0.4 to 5.3% of the population (8,9,24). Additionally, a previous report on the CACTI study population showed that adults with type 1 diabetes reported higher than recommended consumption of fat and saturated fat (25).

Our estimate for physical activity was lower than many of the other published studies (range 23.8–60.3%) (7–10,24).

Table 3—Multiple* logistic regression of ICH on prevalence and progression of CAC

Variable	Prevalence of CAC OR (95% CI)	Progression of CAC OR (95% CI)
Model 1: ideal health metrics†		
Smoking	0.85 (0.62–1.15)	0.90 (0.62–1.30)
BMI	0.41 (0.30–0.56)	0.61 (0.42–0.88)
Physical activity	0.95 (0.57–1.57)	1.16 (0.66–2.04)
Diet	1.72 (0.43–6.86)	0.87 (0.15–5.02)
Total cholesterol	0.73 (0.53–0.99)	1.10 (0.76–1.58)
Blood pressure	0.74 (0.53–1.04)	0.49 (0.33–0.72)
HbA_{1c}	0.89 (0.57–1.41)	0.86 (0.51–1.44)
Model 2:		
Number of ideal health factors	0.75 (0.62–0.91)	0.76 (0.61–0.95)
Number of ideal health behaviors	0.66 (0.54–0.80)	0.79 (0.63–1.00)
Model 3:		
Number of ideal health metrics	0.70 (0.62–0.80)	0.77 (0.66–0.90)

*Adjusted for age, log triglycerides, sex, and diabetes status; additionally adjusted for baseline CAC in progression models. †Factors were included in a single model to test the independent effect of each.

This may be due to differences in how moderate and vigorous physical activity was defined. For example, Bambs et al. (10) reported that 23.8% of their population met the ideal criteria for physical activity. However, the amount of time performing moderate and vigorous activities could not be defined from the questionnaire that was used to assess physical activity (10). The report on the Aerobics Center Longitudinal Study reported that 60.3% of their population met the ideal criteria for physical activity, but they used metabolic equivalent values to assess intensity of activity (24). Physical activity in the current study population has previously been reported to not differ between adults with and without type 1 diabetes (26).

In the current study, the number of metrics meeting the criteria for ICH was significantly associated with both the prevalence and progression of CAC. These results confirm the findings from other studies that have shown an association between ICH metrics and measures of CVD. In the Cardiovascular Risk in Young Finns Study, the number of ICH metrics present in childhood was significantly associated with high-risk carotid intima-media thickness (OR 0.75; 95% CI 0.60–0.94) (12). In the ARIC study, CVD incidence rates were higher in those with zero ICH metrics (37.1 per 1,000 person-years) compared with those with six ICH metrics (3.9 per 1,000 person-years) (9). Similarly, the cumulative incidence of CVD in the Kailuan cohort in Northern China was significantly lower in those with six and seven ideal metrics (0.8%) compared with those with zero or one ideal metric (3.3%) (27). In the Northern Manhattan Study, a strong gradient relationship was found between increasing ICH metrics and decreasing incidence of CVD (P for trend <0.0001) (8). In a study of NHANES data, participants meeting ≥ 5 ICH metrics had a reduction in risk of mortality from circulatory system diseases (adjusted hazard ratio 0.12; 95% CI 0.03–0.57) compared with those who met none of the ideal criteria (11). In the Aerobics Center Longitudinal Study, mortality due to CVD was significantly lower in those who met five to seven ICH metrics (adjusted hazard ratio 0.37; 95% CI 0.15–0.95) compared with those who met the criteria in only zero to two metrics (24).

There are some limitations of this study. First, physical activity and diet were self-reported and could have been affected by poor recall but were reported at the time of the study visit. Variation in prevalence estimates evident in these various studies may represent geographic and population differences that affect generalizability. This study is similar to previous publications but is novel in that it includes a population at high risk for CVD (adults with type 1 diabetes) and examines the association between the AHA-defined ICH metrics with CAC prevalence and progression. Results from participants with type 1 diabetes are not generalizable to the general population because of inherent differences in HbA_{1c}, and in our population, they were more likely to be treated for hypertension; however, type 1 diabetes affects 1.5 million people in the U.S. and represents a group that is recognized for being at high risk for CVD. Despite these differences, the overall distribution (excluding HbA_{1c}) of ICH metrics was similar between those with diabetes and those without. Since the controls were generally friends, spouses, or neighbors of the cases, they may be more similar to cases in the ICH behaviors. However, our estimates of the prevalence of ICH were similar to other published studies.

Adults with type 1 diabetes are known to be at higher risk for CVD (4) and are not able to meet the fasting plasma glucose metric as defined by the AHA. The criteria we used for HbA_{1c} reflected American Diabetes Association diagnostic recommendations but do not have as much relevance for those already diagnosed with diabetes. However, use of higher cut points for those with diabetes did not alter the association with CAC prevalence and progression (data not shown). With the exception of having worse blood pressure and glycemic control, those with type 1 diabetes and those without were very similar in the prevalence that achieved ICH. These data demonstrate that the higher risk of CVD seen in those with type 1 diabetes is explained not by having worse health behaviors or measures, but instead by other factors influencing CVD risk in this group. Even those with type 1 diabetes that achieve ICH may remain at increased risk compared with those without diabetes; however, the significant association between ICH and prevalence and progression of CAC highlights the significance of incremental improvements in cardiovascular health in all sectors of the population, even in those at high risk of the disease.

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