Discordance between 10-year cardiovascular risk estimates using the ACC/AHA 2013 estimator and coronary artery calcium in individuals from 5 racial/ethnic groups: Comparing MASALA and MESA

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HIGHLIGHTS

- The performance of the pooled cohort equations (PCE) among South Asians (SAs) is uncertain.
- In the absence of 10-year follow-up for ASCVD events, coronary artery calcium may be used as a surrogate outcome.
- We studied the prevalence of CAC across strata of ASCVD risk in SAs as well as in other 4 races/ethnicities.
- There was a higher odds of CAC = 0 among low and intermediate risk SAs as compared to NHWs.
- The PCE may overestimate risk in low and intermediate risk in SAs living in the US even to a greater extent than in NHWs.

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ABSTRACT

Background and aims: South Asian (SA) individuals are thought to represent a group that is at high-risk for atherosclerotic cardiovascular disease (ASCVD). However, the performance of the Pooled Cohort Equations (PCE) remains uncertain in SAs living in the US. We aimed to study the interplay between predicted 10-year ASCVD risk and coronary artery calcium (CAC) in SAs compared to other racial/ethnic groups.

Methods: We studied 536 SAs from the Mediators of Atherosclerosis in South Asians Living in America (MASALA) study, and 2073 Non-Hispanic Whites (NHWs), 1514 African Americans (AAs), 1254 Hispanics, and 671 Chinese Americans (CAs) from the Multi-Ethnic Study of Atherosclerosis (MESA) who were not currently on statins. We used logistic regression models to assess the association between race/ethnicity and CAC within each ASCVD risk stratum.

Results: SAs at low and at intermediate estimated ASCVD risk were more likely to have CAC = 0 compared to...
1. Introduction

South Asian (SA) individuals currently represent the second fastest growing ethnic group in the US, with nearly 5 million residents [1]. Several studies have reported a high prevalence of cardiovascular risk factors and atherosclerotic cardiovascular disease (ASCVD) in this group, the latter being higher among SAs than any other racial/ethnic group living in North America or Europe [2-6].

SAs therefore represent a group in whom ASCVD prevention efforts should be intensified [7,8]. However, in the US there is no specific guidance for ASCVD risk assessment in these individuals. The 2013 American College of Cardiology/American Heart Association (ACC/AHA) ASCVD risk assessment guidelines included the pooled cohort equations (PCE), which allow estimating 10-year ASCVD risk by race/ethnicity [non-Hispanic Whites (NHWs) and African Americans (AAs)] and sex. For other racial/ethnic groups living in the US, including individuals of SA ancestry, the ACC/AHA recommends using the equations for NHWs [9]. However, the performance of the equations and their potential for over- or underestimation of ASCVD risk in this group remains unknown [10].

To date, there is no study on SAs living in the US with sufficient follow-up length to allow a formal 10-year validation of the 2013 ACC/AHA PCE. The Mediators of Atherosclerosis in South Asians Living in America (MASALA) study [11] enrolled individuals of SA ancestry in the US and assessed coronary artery calcium (CAC) burden [11,12]. CAC is a robust predictor of ASCVD events [13-16] and, in the absence of prospective ASCVD outcomes, provides an opportunity to conduct a preliminary evaluation of the performance of the risk estimator in SA individuals [17].

The aim of our study was therefore to evaluate, in a representative population of SAs in the US, the interrelationship between 10-year ASCVD risk estimates (using the 2013 ACC/AHA PCE for NHWs) and CAC burden. Specifically, we assessed the prevalence of clinically relevant CAC categories such as a CAC score of 0 (which is known to be associated with very low event rates) [18] and a CAC score > 100 (which is associated with high ASCVD event rates approaching secondary prevention populations) [16]. For comparison, we performed the same analysis among the 4 racial/ethnic groups included in the similarly-designed Multi-Ethnic Study of Atherosclerosis (MESA) [19].

2. Materials and methods

2.1. Study design

Full details of the design and methods of the MASALA and MESA studies have been reported elsewhere [11,20]. Briefly, MASALA is a community-based prospective cohort study of 906 asymptomatic US adults of SA ancestry free from clinical CAC, who were enrolled from two clinical sites (San Francisco Bay Area at the University of California, San Francisco (UCSF) and the greater Chicago area at Northwestern University (NWU)). MASALA investigators recruited participants of SA ancestry, defined as having at least 3 grandparents born in India, Pakistan, Bangladesh, Nepal, or Sri Lanka. The first study examination began in October 2010, and final participant enrollment was concluded in March 2013. The study protocol was designed to be similar to MESA, and was approved by the institutional review boards of University of California, San Francisco and Northwestern University. All participants provided written informed consent [11].

MESA is a multi-ethnic, community-based, prospective cohort study of 6814 men and women aged 45–84 years who were free from clinical ASCVD at the time of recruitment. Study participants were enrolled between July 2000 and September 2002 at six field centers in the US and identified themselves as NHW, AA, Hispanic (Latino) or Chinese American (CA). The study was approved by the institutional review boards at each center and all MESA participants provided written informed consent [20].

2.2. Study population

All participants from MASALA and MESA with information on baseline CAC burden were included. Participants from both studies were free of clinical ASCVD at the time of study entry. To assess the performance of the PCE specifically in the population they are intended to be used [9], we excluded participants older than 80 years and those already taking statins. To allow direct comparisons between the two studies, MASALA participants aged < 45 years were also excluded from the analysis as the minimum age of MESA participants at enrollment was 45 years. Finally, individuals with missing information on any of the variables used by the 2013 ACC/AHA PCE were excluded.

2.3. 10-Year ASCVD risk estimation

In each study participant, 10-year ASCVD risk was estimated using the ACC/AHA 2013 PCE [9]. Risk estimates for NHWs, Latinos, CA and SAs were calculated using the equations for NHWs men and women, and the corresponding PCE for AA men and women were used for ASCVD risk estimates in AAs [9].

2.4. Assessment of coronary artery calcium

Details on the CAC quantification methods implemented in each of the two studies have been reported elsewhere. In MESA, CAC was measured using either an electron-beam CT (at the Chicago, Los Angeles, and New York centers) or a multidetector CT (at the Baltimore, Forsyth County, and St. Paul centers). All images were interpreted at the Los Angeles Biomedical Research Center, Torrance, CA. In MASALA, CAC was assessed using a cardiac-gated electron-beam computed tomography scanner [21]. All images were analyzed at the Los Angeles Biomedical Research Center according to MESA study methods [11]. In both studies CAC scans were interpreted blinded to race/ethnicity and quantified using the Agatston scoring system [12]. In MESA, both intraobserver and interobserver agreement for CAC were excellent (kappa statistics, 0.93 and 0.90, respectively). These estimates are expected to be similar for MASALA given that identical scanning protocols were used and images were interpreted at the same reading center.

2.5. Assessment of traditional cardiovascular risk factors

Information on sociodemographic characteristics, tobacco use, family history of coronary heart disease, medication use, and physical activity was collected using validated questionnaires that were similar for both studies. The body mass index was calculated as weight in kilograms divided by height in meters squared. Systolic and diastolic blood pressures were measured three times using an automated
sphygmomanometer and the mean of the last two measurements was used. Lipid profile and plasma glucose levels were measured in blood samples collected at baseline and after a 12-hour overnight fast.

2.6. Statistical analyses

Baseline demographics, cardiovascular risk factors and 10-year ASCVD risk estimates of the study participants were described for each race/ethnicity, both overall and further stratified by ASCVD risk score categories. Categorical variables were presented as number (%), and continuous variables as mean (SD) or median (IQR) depending on the distribution of the data. Differences between racial/ethnic groups were assessed using chi-square tests, t-tests, and nonparametric tests as appropriate.

The frequency of ASCVD risk categories (low: < 5%, intermediate: 5 to < 7.5%, and high: ≥7.5%) and the proportion of key, clinically relevant CAC score categories (0 and ≥100) were described for each racial/ethnic group adjusted for age. To study the interplay between 10-year ASCVD risk estimates and CAC burden, we also described the distribution of clinically relevant age-adjusted CAC categories (0, 1–100, and ≥100) across ASCVD risk categories (< 5%, ≥5–7.5%, and ≥7.5%), for each racial/ethnic group. Chi-square tests were used to compare these proportions across each racial/ethnic group.

To compare CAC group distribution within similar risk groups across race/ethnicity, logistic regression was used to evaluate the associations between racial/ethnic groups (NHWs as the reference category) and CAC burden categories within each ASCVD risk group. For these analyses, dependent variables were CAC = 0 (vs. CAC > 0), and CAC > 100 (vs. CAC ≤100). Analyses were conducted both unadjusted and adjusting for age and sex.

Two sensitivity analyses were conducted. First, we repeated the analyses using alternative cutpoints for ASCVD risk categories: low (< 5%), intermediate (5–15%), and high (> 15%) [22]. Second, we excluded individuals considered to benefit from statin therapy by the ACC/AHA 2013 guidelines (LDL cholesterol ≥190 mg/dL, and individuals with diabetes and LDL cholesterol ≥70 mg/dL) despite the fact that they were not being treated with statins at baseline [9,23]. Third we further adjusted for family history of CHD and education.

A p value < 0.05 was considered statistically significant. All analyses were performed using Stata version 13 (StataCorp. 2011, College Station, TX).

3. Results

3.1. Study population

We included 536 SAs participants from MASALA, and 5512 participants from MESA (2073 NHW [37.6%], 1514 AA [27.5%], 1254 Hispanics [22.8%], and 671 CA [12.2%]), all of whom were not taking statins at baseline and had ages ranging 45–80 years (Fig. 1).

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**Fig. 1.** Flowchart diagram demonstrating inclusion/exclusion criteria in each cohort to derive the final study population. We excluded participants older than 80 years and those already taking statins. To allow direct comparisons between the two studies, MASALA participants aged < 45 years were also excluded from the analysis as the minimum age of MESA participants at enrollment was 45 years. Finally, individuals with missing information on any of the variables used by the 2013 ACC/AHA PCE were excluded. In a sensitivity analysis we further excluded individuals considered to benefit from statin therapy by the ACC/AHA 2013 guidelines (LDL cholesterol ≥190 mg/dL, and individuals with diabetes and LDL cholesterol ≥70 mg/dL) despite the fact that they were not being treated with statins at baseline.
Table 1 presents the characteristics of the study participants by racial/ethnic group. MASALA participants were on average younger, had a higher educational level, lower estimated ASCVD risk, were less likely to smoke, and were less active compared to the racial/ethnic groups in MESA (all \( p < 0.05 \)). No clear differences were observed in the prevalence of other cardiovascular risk factors between SAs and the other racial/ethnic groups.

Supplementary Tables 1-5 display the characteristics of the study participants further stratified by baseline 10-year ASCVD estimated risk. Among those at low (< 5%) 10-year risk similar patterns were noted in the distribution of risk factors as in the overall group presented in Table 1. Among higher risk strata the following differences were noted: SAs at intermediate risk (5 to < 7.5%) were more likely to be male, diabetic, and have higher triglyceride levels, while those at high risk (≥7.5%) were also more likely to be male compared to MESA participants (all \( p < 0.05 \)).

### 3.2. Distribution of estimated 10-year ASCVD risk

Fig. 2A displays the age-adjusted distribution of 10-year ASCVD risk categories across racial/ethnic groups. The prevalence of low, intermediate, and high ASCVD risk was almost identical comparing SAs and NHWs.

### 3.3. Burden of CAC in the study population

Fig. 2B displays the age-adjusted distribution of key clinically relevant CAC burden categories across racial/ethnic groups. The prevalence of CAC was very similar comparing SAs to NHWs, with nearly 50% CAC = 0 and 25% for CAC 1–100 and > 100.

### 3.4. Interplay between 10-year ASCVD risk estimates and CAC burden

Table 2 and Fig. 2C present age-adjusted proportions of CAC burden categories by ASCVD risk strata and racial/ethnic groups. Among SAs the prevalence of CAC = 0 was inversely proportional to ASCVD risk (prevalence of CAC = 0: 86%, 62%, and 34% for low, intermediate and high ASCVD risk groups respectively; \( p < 0.001 \)). Similar trends were noted among other race/ethnicities. In contrast, the prevalence of CAC > 100 among SAs was correlated with estimated ASCVD risk (prevalence of CAC > 100: 3%, 6%, and 31% for low, intermediate, and high ASCVD risk groups respectively; \( p < 0.001 \)). The same was true for other race/ethnicities. Supplementary Table 6 presents these results using alternative ASCVD risk cutpoints (< 5%, 5–15%, and > 15%).

### 3.5. Associations between race/ethnicity and CAC burden within estimated ASCVD risk strata

Table 3 presents the associations between race/ethnicity and CAC categories across estimated 10-year ASCVD risk strata. In the low and intermediate ASCVD risk strata, SAs had a higher odds of CAC = 0 compared to NHWs (ORs 1.26, 95% CI 0.91–1.76 and 1.73, 95% CI 1.00–2.99, respectively). In the high ASCVD risk group, SAs had similar odds of CAC = 0 and CAC > 100 compared to NHWs (OR 0.95, 95% CI 0.65–1.38 and 0.86, 95% CI 0.61–1.22 respectively).

Among other racial/ethnic groups, AAs and Hispanics considered at low ASCVD risk had lower odds than NHWs of having CAC > 100. Among individuals considered at intermediate ASCVD risk, AA and Hispanic ancestries were associated with higher odds of having CAC = 0 compared to NHWs (ORs 2.23, 95% CI 1.51–3.30 and 1.74, 95% CI 1.14–2.66, respectively). In the high-risk stratum, AAs, Hispanics and CAs had higher odds of having CAC = 0 than NHWs.

Supplementary Table 7 presents the results using alternative ASCVD risk cutpoints (< 5%, 5–15%, and > 15%). Similar results were observed in analyses further excluding individuals with LDL cholesterol > 190 mg/dL and diabetic patients with LDL cholesterol > 70 mg/dL (Table 4, Supplementary Table 8). We also obtained similar results after additionally adjusting for family history of coronary heart disease and education (Supplementary Table 9).

### 4. Discussion

In two community-based study populations of adults living in the US comprising 5 racial/ethnic groups, a SA ancestry was associated with higher odds of having CAC = 0 compared to NHWs in the low and in the intermediate risk groups, while SAs in the high risk group had a similar distribution of CAC compared to NHWs. These findings have implications for the interpretation of ASCVD risk estimates and for the utility of CAC scoring in SAs, a large group living in the US in whom optimal ASCVD risk estimation strategy is currently uncertain.

Our study has important clinical implications. In the absence of 10-year longitudinal data and therefore of specific ASCVD risk equations for SAs in the US, the ACC/AHA currently recommends using the 2013 PCE for NHWs to assess 10-year ASCVD risk in this group [9]. Nevertheless, two considerations lead to great uncertainty when following this strategy. First, release in 2013 of the ACC/AHA PCE was followed...
by concerns regarding their potential for global ASCVD risk overestimation [24–26]. Second, a number of studies have shown SAs having higher event rates than NHWs in almost every country where this has been evaluated [5,6,27–29]. In this context, the performance of the 2013 PCE specifically in SAs is unclear. Based on our preliminary results, we posit that the PCEs may overestimate risk in low and intermediate risk SAs even to a greater extent than they do in NHWs [24,25].

Previous reports comparing MASALA and MESA cohorts have shown SAs from MASALA and NHWs from MESA having a similar...
Hispanic Whites (reference category).

Results presented as odds ratios (95% confidence intervals) of each of the CAC endpoints comparing individuals from each of the racial/ethnic groups to Non-Hispanic Whites (reference category).

ACC = American College of Cardiology; AHA = American Heart Association; ASCVD = atherosclerotic cardiovascular disease; CAC = coronary artery calcium.

Table 2
The prevalence of CAC by 10-year ASCVD risk categories and racial/ethnic group.

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<tr>
<td>&lt; 5% ASCVD risk</td>
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<tr>
<td>CAC = 0</td>
<td>237 (86)</td>
<td>628 (70)</td>
<td>326 (90)</td>
<td>422 (82)</td>
<td>212 (70)</td>
</tr>
<tr>
<td>CAC 1-100</td>
<td>48 (11)</td>
<td>166 (23)</td>
<td>47 (9)</td>
<td>68 (16)</td>
<td>55 (19)</td>
</tr>
<tr>
<td>CAC &gt; 100</td>
<td>10 (3)</td>
<td>48 (7)</td>
<td>7 (1)</td>
<td>15 (2)</td>
<td>16 (11)</td>
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<tr>
<td>5 to 7.5% ASCVD risk</td>
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<tr>
<td>CAC = 0</td>
<td>43 (62)</td>
<td>120 (48)</td>
<td>141 (65)</td>
<td>87 (63)</td>
<td>36 (46)</td>
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<tr>
<td>CAC 1-100</td>
<td>22 (33)</td>
<td>93 (37)</td>
<td>45 (21)</td>
<td>41 (28)</td>
<td>30 (42)</td>
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<tr>
<td>CAC &gt; 100</td>
<td>6 (6)</td>
<td>40 (14)</td>
<td>21 (14)</td>
<td>13 (9)</td>
<td>10 (11)</td>
</tr>
<tr>
<td>≥ 7.5% ASCVD risk</td>
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<tr>
<td>CAC = 0</td>
<td>48 (34)</td>
<td>260 (31)</td>
<td>445 (55)</td>
<td>229 (44)</td>
<td>106 (42)</td>
</tr>
<tr>
<td>CAC 1-100</td>
<td>56 (35)</td>
<td>265 (30)</td>
<td>266 (27)</td>
<td>202 (31)</td>
<td>112 (36)</td>
</tr>
<tr>
<td>CAC &gt; 100</td>
<td>66 (31)</td>
<td>453 (38)</td>
<td>216 (18)</td>
<td>177 (25)</td>
<td>93 (22)</td>
</tr>
<tr>
<td>p value</td>
<td>&lt; 0.001</td>
<td>&lt; 0.001</td>
<td>&lt; 0.001</td>
<td>&lt; 0.001</td>
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Data presented as n (%).
Percentages may not add 100% due to rounding.

ACC = American College of Cardiology; AHA = American Heart Association; ASCVD = atherosclerotic cardiovascular disease; CAC = coronary artery calcium.

* Results are age-standardized.

profile in terms of age-standardized CAC burden at baseline [21,30]. Similar results have been reported in European studies as well [31]. This appears to be true particularly among high risk SAs based on results of our study. This may seem in contradiction with prior studies conducted in Europe and Canada, which consistently showed higher ASCVD event rates in SAs compared to NHWs [5,6,27–29]. Nevertheless, while SAs migrants included in those studies tended to have low income, low education, and a high burden of cardiovascular risk factors, SAs from MASALA represent a highly educated and high income group consistent with the immigration patterns of SAs in the US compared to Europe and Canada [11].

It is therefore possible that MASALA comprised a lower-risk SA subgroup compared to the aforementioned studies. MASALA also excluded SAs with a history of clinical ASCVD and we further excluded those on statins at baseline enriching our study population with healthy SAs. Furthermore, MASALA was initiated 10 years later than MESA, when key prevention programs such as anti-tobacco laws had already been instituted [32], and statin therapies were more commonly prescribed for primary prevention [33,34]. The latter is consistent with our finding of a larger proportion of individuals excluded due to baseline statin use in MASALA (30%) than in MESA (12–17%). The combination of these factors may explain the greater similarity between SAs and NHWs when comparing MESA and MASALA than that observed in prior multi-ethnic evaluations.

4.1. Study limitations

Our study has some limitations that are worth discussing. First, the key limitation of our analysis is the lack of longitudinal data for SAs, which precluded performing a formal validation study of the PCE. Nevertheless, CAC is considered a robust predictor of CVD events, and the CAC burden categories used in our analyses (CAC = 0 and CAC > 100) have shown strong associations with very low and very high ASCVD event rates, respectively [16,18]. Therefore, until 10-year follow-up data is available for SAs, our analysis provides valuable preliminary insights on the potential performance that the PCE may have in this important group.

Second, the sample size of the SA population was relatively small, particularly after excluding individuals using statins, which likely limited statistical power. This may be particularly true for low risk SAs who tend to have CAC = 0. Nevertheless, we were able to identify statistically significant differences in the intermediate risk stratum, which is indeed the most likely to benefit from further testing using tools such as CAC. Important differences between MESA and MASALA must be acknowledged with direct comparisons between the two cohorts. Despite rigorous adjustment for potential confounders, there

Table 3
Age- and sex-adjusted associations between race/ethnicity and CAC categories across 10-year ASCVD risk categories.

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<tr>
<td>Age- and sex-adjusted</td>
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<tr>
<td>&lt; 5% ASCVD risk</td>
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<tr>
<td>CAC = 0</td>
<td>1.26 (0.91, 1.76)</td>
<td>1.00 (Ref)</td>
<td>1.76 (1.26, 2.45)</td>
<td>1.67 (1.25, 2.22)</td>
<td>1.02 (0.74, 1.40)</td>
</tr>
<tr>
<td>CAC &gt; 100</td>
<td>0.67 (0.33, 1.35)</td>
<td>1.00 (Ref)</td>
<td>0.39 (0.17, 0.88)</td>
<td>0.55 (0.30, 0.99)</td>
<td>1.00 (0.56, 1.81)</td>
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<tr>
<td>5 to &lt; 7.5% ASCVD risk</td>
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<tr>
<td>CAC = 0</td>
<td>1.73 (1.00, 2.99)</td>
<td>1.00 (Ref)</td>
<td>2.23 (1.51, 3.30)</td>
<td>1.74 (1.14, 2.66)</td>
<td>1.03 (0.61, 1.72)</td>
</tr>
<tr>
<td>CAC &gt; 100</td>
<td>0.53 (0.21, 1.32)</td>
<td>1.00 (Ref)</td>
<td>0.68 (0.38, 1.21)</td>
<td>0.58 (0.30, 1.14)</td>
<td>0.79 (0.37, 1.67)</td>
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<tr>
<td>≥ 7.5% ASCVD risk</td>
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</tr>
<tr>
<td>CAC = 0</td>
<td>0.95 (0.65, 1.38)</td>
<td>1.00 (Ref)</td>
<td>1.97 (1.61, 2.40)</td>
<td>1.47 (1.18, 1.85)</td>
<td>1.47 (1.11, 1.95)</td>
</tr>
<tr>
<td>CAC &gt; 100</td>
<td>0.86 (0.61, 1.22)</td>
<td>1.00 (Ref)</td>
<td>0.44 (0.35, 0.54)</td>
<td>0.52 (0.42, 0.65)</td>
<td>0.47 (0.36, 0.62)</td>
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Results presented as odds ratios (95% confidence intervals) of each of the CAC endpoints comparing individuals from each of the racial/ethnic groups to Non-Hispanic Whites (reference category).

ACC = American College of Cardiology; AHA = American Heart Association; ASCVD = atherosclerotic cardiovascular disease; CAC = coronary artery calcium.
remains the possibility for residual confounding. While the high SES among SAs in the MASALA study is consistent with national survey data, it is possible that non-responders or those who declined to participate in the study had lower SES thus potentially limiting generalizability of the study to SAs of lower SES in the US or SA globally [11]. Finally, as discussed above, the exclusion of individuals with a history of ASCVD and those taking statins, as well as the 10-year lag between MASALA and MESA initiation may have resulted in a healthy SA population and thus results may not be generalizable to all SAs. However, our study population is a true primary prevention cohort in whom ASCVD risk estimation is used to guide the decision to initiate lipid-lowering therapy [9,23]. Therefore, our results may be used to guide clinicians when interpreting risk estimations and prescribing lipid-lowering therapies in this group.

4.2. Conclusion

Until prospective information on cardiovascular outcomes becomes available for SA individuals living in the US, understanding the relationship between 10-year cardiovascular risk estimates and CAC burden provides preliminary insights on the potential performance of the PCE in this important racial/ethnic group. Our findings suggest that risk overestimation among low and intermediate-risk SAs may be even greater than among their NHW counterparts. In this context, CAC may be a very valuable tool to help further refine risk estimations in SAs considered at intermediate risk. Validation studies are needed to confirm these preliminary findings.

Conflict of interest

The authors declared they do not have anything to disclose regarding conflict of interest with respect to this manuscript.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.atherosclerosis.2018.09.015.

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