Original Article:

Correlation of Agatston Score With Coronary Artery Calcium Data Reporting System (CAC-DRS), Body Mass Index (BMI) and Body Surface Area (BSA) In Asymptomatic South Indian Patients Using 128-Slice Multi-Slice Computed Tomography (MDCT)

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Abstract

Background and aim:
Coronary artery disease (CAD) is a leading cause of morbidity and mortality worldwide. Coronary artery calcium (CAC) scoring, particularly the Agatston score, serves as a non-invasive biomarker for subclinical atherosclerosis. The CAC Data Reporting System (CAC-DRS) enables standardized risk classification. Body Mass Index (BMI) and Body Surface Area (BSA) are commonly used anthropometric indices; however, their association with coronary calcification remains uncertain. This study aims to evaluate the relationship between CAC scores and anthropometric markers in an asymptomatic South Indian cohort using computed tomography (CT).

Methods:
This retrospective observational study included 250 asymptomatic adults (162 males, 88 females) aged 20–90 years who underwent CT-based CAC scoring at a tertiary care center. Patients with prior cardiac symptoms or interventions were excluded. BMI and BSA were calculated using standard formulas. Data analysis was performed using SPSS v23.0, employing Spearman's rank correlation, Kruskal-Wallis test, Pearson Chi-Square, ANOVA, and multivariate logistic regression.

Results:
The Agatston score showed a strong positive correlation with CAC-DRS ($r = 0.885$, $p < 0.0001$). Age correlated moderately with the Agatston score ($r = 0.540$, $p < 0.001$). Males had significantly higher CAC scores than females ($p = 0.004$). In contrast, BMI ($r = 0.013$, $p = 0.842$) and BSA ($r = 0.067$, $p = 0.291$) had weak, non-significant correlations. Multivariate analysis identified age ($p < 0.001$) as independent predictors of elevated CAC and male sex ($p = 0.001$) to have higher scores.

Conclusion:
While CAC-DRS strongly reflects coronary calcification burden, anthropometric indices like BMI and BSA are poor standalone predictors. These findings underscore the clinical utility of Agatston scoring in cardiovascular risk stratification beyond traditional anthropometric parameters.

Keywords:
Coronary Artery Disease, Coronary Artery Calcium, Multidetector Computed Tomography, Agatston Score, Body Mass Index, Body Surface Area, Risk Assessment

Introduction:

Coronary artery disease (CAD) is one of the major causes of death and disability. CAD has been known to have a long asymptomatic latent period and mortality, and morbidity which can be decreased if detected early followed by a targeted preventive therapy [1]. A major epidemiological transition from underweight to overweight/obese population has been observed in India. Obesity is a major risk factor for type2 diabetes and cardiovascular diseases. These levels are remarkably high across all zones in India, with the highest being in the south and lowest in the eastern India, with a prevalence of 40.3% [2]. Obesity is an independent predictor of atherosclerotic plaque formation and mortality. It is also one of the most important chronic health problems worldwide [3]. The most commonly used measure of obesity in Body Mass Index (BMI) and the lesser-known measure is Body Surface Area (BSA)[4].

Elevated BSA has been found to be associated with increased Coronary Artery Calcium (CAC), particularly in men, whereas BMI is not associated with CAC score in an American population. BSA is a better predictor of obesity than BMI; therefore, it is likely to be a better predictor of CAD, particularly more useful in males than in females [4].

The CAC score is a marker of coronary plaque burden and cardiovascular risk factors [4,5]. Patients with a CAC score of 0 may have noncalcified plaques with low rates of cardiovascular events [4]. Obesity is associated with a higher risk of CAC development [5]. Future cardiovascular events and their severity can be predicted based on the presence of CAC and can be used for risk stratification. The extent of CAC is associated with the risk of heart failure (HF) in elderly patients [6]. Few studies in the past have shown inverse associations between BMI and CAC, suggesting that larger body morphology may not always correspond to greater calcification. However, this relationship has not been thoroughly investigated in the Indian population, nor has it been studied in conjunction with body surface area (BSA).[7]

The coronary artery calcium data reporting system (CAC-DRS) combined with the Agatston score and the number of vessels with CAC provides better stratification of risk for chronic heart disease (CHD), cardiovascular disease (CVD), and all-cause death than the Agatston score alone. These prognostic data strongly support the new Society of Cardiovascular Computed Tomography (SCCT) guidelines recommending the use of CAC-DRS scoring [8]. The CAC-DRS is a recently introduced method for

standardized reporting of calcium scoring on computed tomography (CT), providing four risk categories (CAC-DRS-0, CAC-DRS-1, CAC-DRS-2, and CAC-DRS-3) along with treatment recommendations for each risk category [1].

Given these considerations, our study aims to directly assess the correlation between the Agatston score, CAC-DRS, and the traditional anthropometric measures of BMI and BSA in an asymptomatic South Indian population to better understand their predictive power in coronary artery disease risk assessment.

Materials and methods:

The data were collected for a period of one year after institutional ethical approval. CT coronary calcium score studies were performed using multi-detector computed tomography (MDCT) 128 slice Evolution, and the images were stored in PACS in the Department of Radio Diagnosis and Imaging, Father Muller Medical College, and Hospital, Kankanady, Mangalore.

The participants in the study were asymptomatic individuals between the ages of 20 and 90 years who had never experienced symptoms of cardiovascular disease. Age, sex, height, weight, BMI, and BSA were among the demographic information documented. Individuals with a history of myocardial infarction, angina, coronary revascularization, heart failure, or known coronary artery disease (CAD) were excluded. However, as long as they remained asymptomatic, individuals with cardiovascular risk factors, such as dyslipidemia, diabetes mellitus, and hypertension, were included. To evaluate the independent associations of these risk factors with the Agatston score, CAC-DRS, BMI, and BSA, adjustments were made during statistical analysis. To assess any possible confounding effects, patients taking drugs known to affect calcium scoring, such as statins, were listed separately.

The patients were given β-blockers as required for a target heart rate of less than 60 beats per minute. Calcification analysis was performed as previously described by Agatston et al [9]. The total CAC score, which is the sum of the lesion scores from the major coronary arteries, was analyzed using the Agatston method.

An experienced radiologist with 10 years of cardiovascular imaging experience interpreted all scans based on the commercially available software (Smart Score Version SS 4.0_203) on the GE Advanced Workstation (AW) at the time of the study, and the report was sent to PACS. To ensure measurement consistency, intra-observer reliability was evaluated by having the same radiologist review a subset of randomly selected scans, with intra-class correlation coefficient (ICC) analysis

conducted. The ICC for the Agatston score was 0.92, indicating excellent reliability. CAC scores were not re-measured in this study.

The following protocol was used for scanning.

Scout Scan:

Scout planes: Acquired at 90 and 180, Tube voltage (kV) : 120, Tube current (mA): 40 mA for the 90˚ scout and 20 mA for the 180˚ scout, Scout Window Setting: Window Width (WW)/Window Level (WL): 500/50

Smart Scoring:

Thickness: 2.5 mm, Interval: 20 mm, Gantry tilt: S0.0, Scan Field of View (SFOV): small body, kV: 120, mA: 215, Prep Group: 5.2s, Cine duration: 0.2s.

Anthropometric measurements:

Body Surface Area (BSA) was calculated using the Du Bois formula (BSA = 0.007184 × W0.425 × H0.725), where BSA is represented in m2, W is weight in kg, H is height in m with a cutoff of 1.71 m^2.[10] BMI was calculated using the formula (weight in kg / height in m^2) which was further classified as normal weight, BMI: 18.0 to 24.9 kg/m^2; overweight, BMI:25.0 to 29.9 kg/m^2; obese, BMI: ≥30.0 kg/m^2; and underweight, BMI <18.0 kg/m^2.

CAC/Agatston scoring & CAC-DRS:

The CAC/Agatston scores were classified as no evidence of CAD (0), minimal: 1-10, mild: 11-100, moderate: 101-400, extensive (> 400). CAC-DRS was classified into 4 risk categories, (CAC-DRS-0: Low, CAC-DRS-1: Mild, CAC-DRS-2: Moderate, CAC-DRS-3: Severe) [1].

Statistical Analysis:

Data were analysed using Statistical Package for the Social Sciences (SPSS): Statistics for Windows, Version 23.0.(Armonk, NY: IBM Corp). Kolmogorov-Smirnov test was conducted to assess the normality of continuous variables. Spearman's rank correlation coefficient was applied to evaluate correlations between continuous variables. This assessed the relationships between the Agatston score and variables such as age, BMI, and BSA. Kruskal-Wallis test was employed to compare median Agatston scores across different BMI categories. Association between categorical variables, such as sex and CAC-DRS categories, were examined using the Pearson Chi-Square test. In instances where expected cell counts were less than five, the Fisher's Exact Test was utilized to ensure accurate p-values. To compare mean BSA across CAC-DRS categories, a One-Way Analysis of Variance (ANOVA) was conducted. Despite the general non-normality of data, BSA was normally distributed, justifying the use of ANOVA for this variable. Univariate and multivariate logistic regression analyses were performed to identify predictors of elevated Agatston scores and higher CAC-

DRS categories. Variables with a p-value < 0.05 in univariate analysis were included in the multivariate model to adjust for potential confounders.

Results:

Participant characteristics, CAC score and CAC-DRS:

The data of 250 asymptomatic patients referred for CT calcium scoring at our center were analyzed, in which 162 (64.8%) were male and 88 (35.2%) were female of the age group of 20 to 90, and a median (IQR)(75p,25p) age of 59 years, (67,49).

After computing BMI 3 (1.2%) were found to be underweight, median 55 (0,0), 77 (30.8%) were normal, median14 (93.5,0) ,124 (49.6%) i.e. majority were overweight, median 16.5(148.25,0) and 46 (18.4%) were obese, median 15.5(266.5,0). The median BMI was 26.56 kg/m2 (28.8,23.8). The mean BSA was 1.8 m2 with a standard deviation of 0.2 m2. Of the 250 participants, 81 (32.4%) had a BMI <1.71 m2 and 169 (67.6%) had a BMI ≥1.71 m2.

Agatston Score & CAC DRS: Distribution and Correlation:

After Agatston scoring we found no evidence of CAD in 96 (38.4%) patients, minimal in 2 (0.8%), 79 (31.6%) mild, 41 (16.4%) moderate, and 32 (12.8%) had extensive CAD. The median CAC score was 15.5, (143,0). In CAC-DRS scoring we found 96 (38.4%), median 0 (0,0) with low risk, 80 (32%) with Mild risk, median 27 (46.5,10), 36 (14.4%) with moderate risk, median 166.5 (234.5,123.25) & 38 (15.2%) with severe risk, median 637 (1253.25,455.5).

Kolmogorov-Smirnov test of normality was conducted, we found all values deviated from normality except BSA (0.2). Nonparametric Spearman's rank correlation was performed for BSA and Agatston score, and a weak positive correlation was found of 0.067 and p-value of 0.291, which showed no significant relationship as demonstrated in Figure 1.

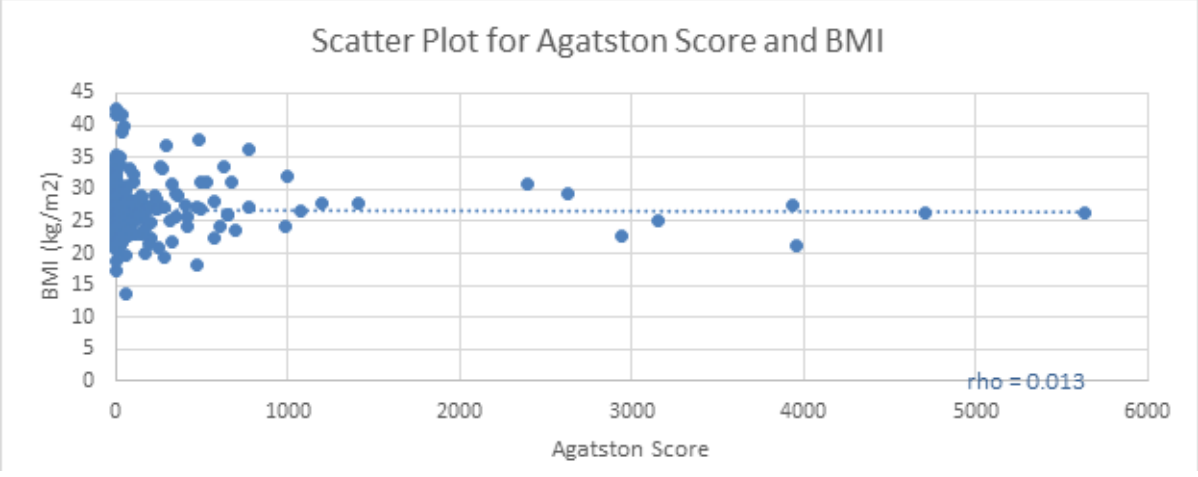


Figure 1: Scatter Plot for Agatston Score & BSA.

A weak positive relationship was also found between the Agatston score and BMI (0.013) and p-value (0.842), which showed no significant relationship, indicating a weak direct correlation between these factors in the population under study as demonstrated in Figure 2.

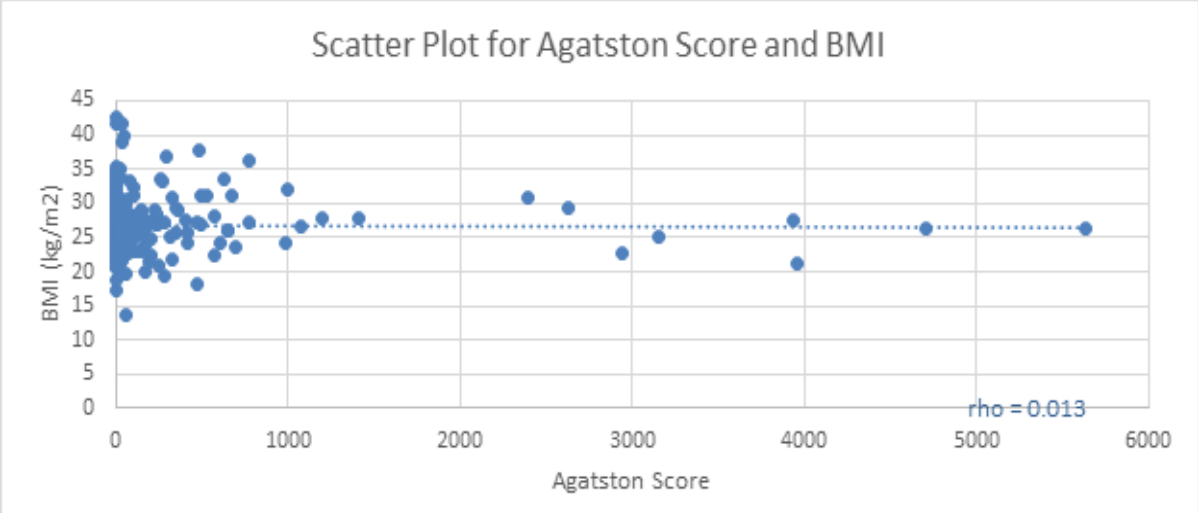


Figure 2: Scatter Plot for Agatston score and BMI.

This result is consistent with earlier research suggesting that coronary artery calcium level may not be well predicted by BMI alone. The involvement of metabolic variables other than BMI, such as lipid profiles and visceral fat distribution, is a possible explanation. The correlation coefficient for the Agatston score vs. age showed a moderate relationship (0.540) and a significant relationship ($p < 0.0001$). This indicates a positive relationship between the two variable as demonstrated in Figure 3.

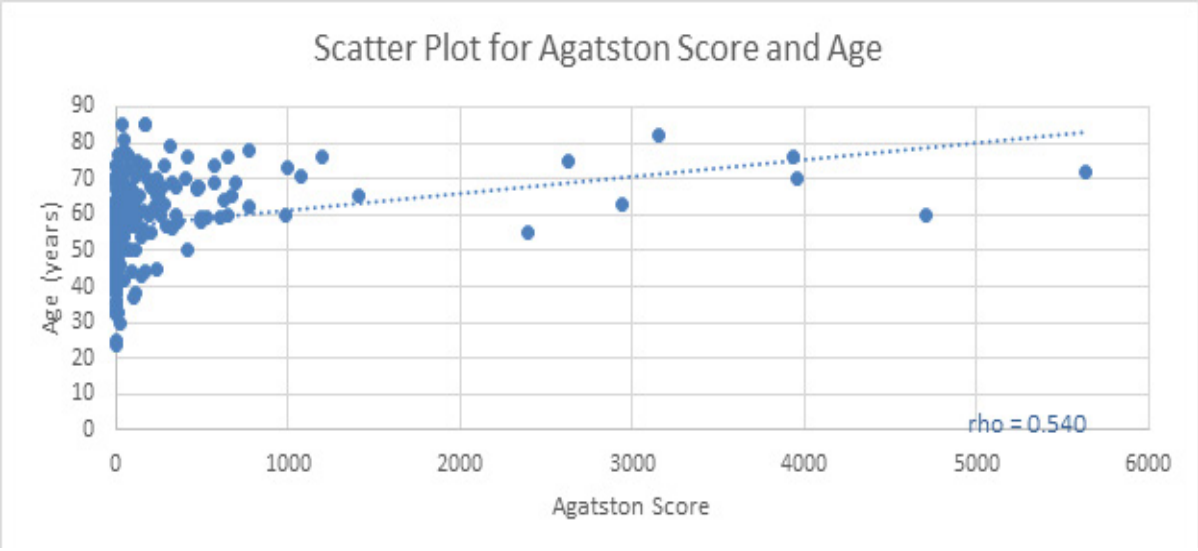


Figure 3 Scatter Plot for Agatston Score and Age.

The Kruskal-Wallis test was performed to determine the relationship between the Agatston score and BMI, and no significant difference was found (p = 0.778); a significant difference was found between the Agatston score and CAC DRS values (p < 0.0001), and between the Agatston score and sex (p = 0.004).A highly significant difference was also found between age and CAC-DRS scores (p < 0.001).

Group Comparisons:

Impact of Age and Gender on CAC Scores (Pearson Chi Square):

Among the male population (n=162, 64.8%), the majority had CAC-DRS scores of severe (n=29, 76.3%), median 29.5 (165.25,0) and females (n=88, 35.2%), and the median 1 (62.25,0) majority had CAC-DRS scores of low (n=43,44.8%). The proportion of males increased progressively across CAC-DRS categories (55.2% at CAC-DRS 0 vs. 76.3% at CAC-DRS 3). The Pearson Chi-Square test was performed, and no significant difference was found between sex and CAC-DRS (p = 0.073) as shown in Table 1.

Table 1: Sex Distribution Across CAC DRS Categories .

Sex	CACDRS 0 (n=96)	CACDRS 1 (n=80)	CACDRS 2 (n=36)	CACDRS 3 (n=38)	PValue
Male	53 (55.2%)	55 (68.8%)	25 (69.4%)	29 (76.3%)	0.073
Female	43 (44.8%)	25 (31.3%)	11 (30.6%)	9 (23.7%)	

Association of BMI with CAC Scores (Fishers Exact test):

By computing BMI results with CAC-DRS, we found that in underweight individuals, the majority (n=1, 2.6%) had severe scores, normal (n=28, 35%) had a mild score, overweight (n=20, 55.6%) had moderate scores, obese (n=9, 23.7%) had severe scores. Fisher's exact test did not show a significant difference between BMI and CAC-DRS scores (p = 0.802) as shown in Table 2.

Table 2: BMI Categories Across CAC DRS Categories .

BMI Category	CACDRS 0 (n=96)	CACDRS 1 (n=80)	CACDRS 2 (n=36)	CACDRS 3 (n=38)	PValue
Underweight	1 (1.0%)	1 (1.3%)	0 (0.0%)	1 (2.6%)	0.802
Normal weight	30 (31.3%)	28 (35.0%)	11 (30.6%)	8 (21.1%)	
Overweight	45 (46.9%)	39 (48.8%)	20 (55.6%)	20 (52.6%)	
Obese	20 (20.8%)	12 (15.0%)	5 (13.9%)	9 (23.7%)	

BSA & CAC-DRS (ANOVA):

One-way ANOVA was performed to determine the significance between the BSA and CAC-DRS scores, and no significant relationship was found between the two (p = 0.275).

Correlation Analyses:

CAC-DRS, BMI , AGE:

Median age rises from 51 years (IQR 44–58.8) in CAC DRS 0 to 68 years (IQR 60–73.3) in CAC DRS 3 presented in Table 3**.**

Table 3: Median Age (IQR) by CAC DRS Category .

CACDRS Category	n	Median Age (years)	IQR (25th–75th percentile)
0 (Low)	96	51	44 – 58.75
1 (Mild)	80	61	51.75 – 67
2 (Moderate)	36	63	56.25 – 70
3 (Severe)	38	68	60 – 73.25

BSA & CAC:

Among the low CAC scores (n=96), the mean was 1.8 and the standard deviation (SD) was 0.22. For mild scores (n = 80), the mean was 1.76 and the SD was 0.17. for moderate scores; n =36, the mean was 1.81 and SD was 0.2. for severe CAD score (n=38), the mean was 1.84 and SD was 0.18.

A weak correlation was found between Agatston score and CAC-DRS with BSA and BMI; sex and CAC-DRS also showed a weak relationship. A strong relationship was found between the Agatston score and CAC-DRS and gender. The CAC-DRS also showed a strong relationship with age, while age showed a moderate relationship with the Agatston score. Our study found that BSA and BMI could not be used independently to predict CAC.

Logistic Regression:

In univariate models, both age and male sex were significant predictors of an elevated Agatston score (p < 0.001 and p = 0.013, respectively). In the multivariate model, adjusting for BMI and BSA, age (p < 0.001) and male sex (p = 0.001) remained independently associated, whereas neither overweight (p = 0.789) nor obesity (p = 0.773) reached significance. Full odds ratios (OR) and 95% confidence intervals (CI) are presented in Table 4.

Table 4: Univariate and Multivariate Logistic Regression for Elevated Agatston Score .

Predictor	Univariate OR (95% CI)	P-Value	Multivariate OR (95% CI)	P-Value
Age	1.111(1.077,1.145)	<0.001	1.123(1.086,1.160)	<0.001
Sex (male)vs female	1.965(1.155,3.344)	0.013	3.740(1.741,8.037)	0.001
Overweight vs normal BMI	2.478(1.368,4.486)	0.003	1.111(0.543,2.276)	0.773
Obese vs normal BMI	7.990(2.851,22.387)	<0.001	1.137(0.444,2.914)	0.789

Discussion:

This study evaluated the associations between Agatston score, CAC-DRS, and demographic factors such as BMI, BSA, sex, and age using 128-slice Multi-Detector CT in an asymptomatic South Indian population. Our findings contribute to the ongoing debate regarding the role of anthropometric parameters in predicting CAC.

Our key finding was the strong relationship between age and CAC-DRS, and a moderate correlation between age and Agatston score, confirming age as a major determinant of CAC burden. CAC scores increased progressively with age, supporting the role of age-based CAC screening, especially in individuals with additional cardiovascular risk factors.

In contrast, BMI and BSA demonstrated only weak correlations with Agatston and CAC-DRS scores. These results align with studies by Kovacic et al. [7]. and Dangas et al. [11], which reported limited or inverse associations between BMI and CAC. Though previous work, such as that by Syed M. Atique et al. [3], found BMI predictive of CAC in younger populations, our findings suggest that BMI and BSA alone may not be reliable predictors of coronary calcification. This may be due to underlying metabolic or inflammatory factors which are not captured by anthropometric measures.

While sex also showed a significant association with both Agatston score and CAC-DRS, male participants consistently exhibited higher CAC scores across categories. This is consistent with existing literature showing greater CAC burden in men and delayed onset in women, likely due to hormonal protection pre-menopause[12,13]. These sex-based disparities highlight the value of sex-specific approaches in cardiovascular risk assessment.

Notably, our findings support Roy et al. [4], who emphasized the role of BSA in CAC prediction in men, although this was not statistically significant in our cohort. The limited predictive power of BMI and BSA

in this study suggests the need to explore additional parameters such as visceral fat, lipid profiles, or genetic markers.

Importantly, CAC-DRS emerged as a reliable risk stratification tool, correlating strongly with Agatston score and demographic variables, highlighting its clinical utility.

Clinical Implications:

Our study highlights the need to prioritize age and sex in CAC-based cardiovascular risk assessment, while acknowledging the limited standalone predictive value of BMI and BSA. These insights can help refine individualized screening strategies and enhance prevention in asymptomatic populations.

Conclusion:

The Agatston score and CAC-DRS were strongly correlated, affirming their reliability in quantifying coronary artery calcification. Age and sex emerged as significant predictors of CAC, while BMI and BSA showed only weak associations, highlighting the limited independent utility of anthropometric measures in CAC risk assessment.

These results underscore the importance of prioritizing age, sex, and established cardiovascular risk factors over BMI and BSA when evaluating coronary artery disease risk. The strong correlation of CAC-DRS with both age and sex supports its value as a practical and effective tool for clinical risk stratification.

Future research should explore the role of metabolic, inflammatory, and genetic factors to enhance the predictive accuracy of CAC-based scori**ng systems across diverse populations.**

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Conflicts of interest: There are no conflicts of interest.

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