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Comparing Coronary Artery Calcium Scoring With Cardiac Risk Scores for Predicting Cardiovascular Events in Primary Care Patients in Saudi Arabia

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Amani A. Alsulami [1] , Abdullah H. Alkhenizan [1] , Kossay Elabd [1] , Yaser Alendijani [2] , Nora Alalem [1]

1. Family Medicine, King Faisal Specialist Hospital and Research Centre, Riyadh, SAU 2. Family Medicine and Polyclinics, King Faisal Specialist Hospital and Research Centre, Riyadh, SAU

Corresponding author: Amani A. Alsulami, amanisulami@gmail.com

Abstract

Background

Cardiovascular diseases are the leading cause of death in Saudi Arabia, and cardiac risk-stratification scoring methods are critical in the primary healthcare setting to predict and potentially prevent the fatal outcomes of CVD. Therefore, this study aimed to examine the prognostic value of coronary artery calcium scoring (CACS) and other cardiac risk-stratification scores: arteriosclerotic cardiovascular disease (ASCVD) risk estimator, cardiovascular risk score (QRISK2), and triglyceride glucose index (TyG) in primary healthcare facilities in Riyadh, Saudi Arabia.

Methods

A retrospective cohort study was conducted at Family Medicine Clinics, and data on patient's demographics, medical records, and chronic illnesses obtained from the Integrated Clinical Information System (ICIS) database that were recorded between 2010 and 2019 were analyzed. We performed descriptive statistics, student's t-test, analysis of variance (ANOVA), Pearson correlation, Cohen's Kappa, and regression analyses.

Results

QRISK ($p<0.001$) and ASCVD ($p<0.05$) risk estimators positively correlated with the CACS score in predicting fatal and non-fatal cardiac outcomes while the TyG score had the lowest prediction ability among all the other risk estimators. CACS (OR = 1.003; 95% CI: 1.005 -1.002) ($p<0.001$), ASCVD (OR = 18.177; 95%CI: 214.578 - 1.540) ($p=0.021$), and QRISK2 (OR=154.796; 95%CI: 4137.356 - 5.792) ($p=0.003$) significantly predict stenosis unlike the TyG score's statistically insignificant prediction ($p>0.05$).

Conclusion

These findings show that ASCVD and QRISK2 are consistent with CACS and are effective risk indicators that could be used to predict cardiac-associated fatal and non-fatal cardiac events among primary care patients. This indicates that the integration of multiple risk scores, as necessary, can all contribute to more effective risk assessment and prevention of coronary artery diseases and related cardiovascular events.

Categories: Family/General Practice, Internal Medicine, Cardiology
Keywords: coronary artery calcium scoring, primary healthcare, cardiovascular diseases, triglyceride glucose index, arteriosclerotic cardiovascular disease

Introduction

Cardiovascular diseases (CVDs) are the leading cause of mortality globally [1]. In Gulf Cooperation Council (GCC) countries, especially in the Kingdom of Saudi Arabia (KSA), coronary heart disease (CHD) is the leading cause of death, with a prevalence previously reported to be 5.5% [2-4]. A previous report indicated that the prevalence of CHD in Saudi Arabia is 5.5%. CVDs are reported to account for over 45% of the mortality rate in Saudi Arabia [5]. Coronary artery calcification (CAC), which is the buildup of calcium in the arteries [6], is highly prevalent in patients with CHD and is associated with significant adverse cardiovascular events and the development of advanced atherosclerosis [4,7]. The prevalence of CAC in Saudi Arabia is high in patients with normal myocardial perfusion imaging (MPI) and is associated with risk factors such as age, male sex, and diabetes [8]. CHD risk stratification methods, such as atherosclerotic cardiovascular disease (ASCVD) score, cardiovascular risk score (QRISK2), and triglycerides glucose (TyG) index [9,10] are used to predict CHD and CVD risks. However, while it is still a relatively new method compared to other risk estimators, the coronary artery calcium score (CACS) is considered the gold-standard method to assess CAC [4,9,11-14]. Additionally, CACS is considered an independent indicator of cardiovascular events and superior to the other available risk estimators [11,15,16]. The Framingham Risk

Score (FRS) predicts the risk of coronary disease based on age, gender, smoking history, blood pressure, cholesterol, high-density lipoprotein cholesterol (HDL-C), and blood glucose levels or diabetes history [17,18]. Combined with the FRS, it was found that high CACS can alter predicted risk based on FRS alone, particularly in patients with intermediate risk, where clinical decision-making is most uncertain [17]. It has been reported that a combined CAC and ASCVD risk assessment can guide systolic blood pressure control measures, particularly among individuals with an ASCVD risk of 5-15% and pre-hypertension or mild hypertension [19].

It was previously reported that asymptomatic Saudis, especially women, who underwent CACS screening had a higher chance of developing a heart attack than the rest of the world population [20,21], which highlights the vital need to utilize the currently available and non-invasive screening methods to predict and prevent fatal and non-fatal cardiac events in Saudi Arabia. Therefore, this study examined CACS and other cardiac risk stratification scores, comparing their prediction of fatal and non-fatal cardiac events among primary care patients in King Faisal Specialist Hospital (KFSH), Family Medicine Department, in Riyadh, Saudi Arabia.

Materials And Methods

Study design and data source

We retrospectively retrieved 2010-2019 electronic health records from the Integrated Clinical Information System (ICIS) database of all adult patients (n=404) who were regularly seen at Family Medicine & Polyclinics clinics at King Faisal Specialist Hospital and Research Centre (KFSH&RC) in Riyadh. ICIS is a comprehensive digital patient-care system that automates and connects all patient-related information. ICIS possesses a local electronic client care record that contains comprehensive operational and strategic information. This record has the capability to access information from other important information systems through various system interfaces that are linked to specific client identifiers.

Participants

This retrospective cohort study included asymptomatic patients without known coronary heart disease who had been referred for CAC screening because of the presence of one or more coronary artery disease (CAD) risk factors (diabetes, hypertension (HTN), hypercholesterolemia, family history of CAD, and obesity). We excluded patients below the age of 18, patients with myocardial infarction or coronary revascularization, patients on dialysis, patients with elevated triglyceride levels (⩾400 mg/dL), patients taking cholesterol-lowering medications, patients with known peripheral vascular disease, heart failure, and familial hypercholesterolemia.

Asymptomatic patients were defined as individuals who did not exhibit any clinical manifestations, such as chest pain, dyspnea, or other associated symptoms and did not have a documented history or previous diagnosis of CVD, indicating that their condition remains undetectable through standard clinical assessments.

We recorded all data on demographic factors, such as age, gender, nationality, weight, height, body mass index (BMI), and smoking history from medical records. The age was calculated in years, gender was binary (male and female), weight was calculated in kilograms (kg), height in meters (m), and BMI was calculated as a ratio of weight over height squared (kg/m^2).

Patients' medical history of chronic illness

We recorded data on the medical history of patients with chronic illnesses known to be risk factors for CAD, and medication history. High blood pressure (HTN), which was defined by either self-reporting HTN, currently taking anti-hypertensive drugs, or recorded systolic blood pressure (SBP) ⩾140 mmHg, and/or diastolic blood pressure (DBP) ⩾90 mmHg for three or more consecutive times or based on ambulatory BP (24hr BP) [22].

We recorded patients' history of CAD prior to and after CACS as well as fatal and non-fatal myocardial infarction, family history of ischemic heart disease, premature cardiac death in a first-degree relative (women less than 65 and men less than 55), chronic kidney disease (CKD) and stage assessed based on estimated glomerular filtration rate (eGFR) (CKD stages: 1. Normal: >90, 2. Mild CKD: 60-89 ml/min, 3A. Moderate CKD: 45-59 ml/min, 3B. Moderate CKD: 30-44 ml/min, 4. Severe CKD: 15-29 ml/min, end-stage CKD, 5: <15 ml/min) [23], rheumatoid arthritis, atrial fibrillation, primary vessel affected identified by CACS, and degree of occlusion. In addition, obesity was assessed and defined as BMI > 30. Abnormal lipids (higher triglycerides, low-density lipoprotein, lower high-density lipoprotein), and diabetes mellitus type 2 were measured either as fasting serum glucose ⩾7.0 mmol/L, two-hour serum glucose using oral glucose tolerance test ⩾11.1 mmol/L, or HbA1c ⩾6.5 currently using hypoglycemic drugs or are taking daily insulin injections.

Risk score measurements

At the time of visits, all patients' blood samples were taken after 8-12 hours of fasting. Data of fasting plasma glucose (FPG), hemoglobin A1C, total cholesterol (TC), high-density lipoprotein cholesterol (HDL-C), triglyceride (TG), and low-density lipoprotein cholesterol (LDL-C) that had been collected at the time of the visits for CACS were retrieved from laboratory records. The TyG index was calculated as follows: [fasting triglycerides (mg/dL) × fasting plasma glucose (mg/dL)/2] [24], and the TyG index cutoff was 4.49. ASCVD and QRISK2 scores were calculated using commercially available calculators on their websites.

Computed tomography (CT) calcium scoring measurement

The extent of calcification was quantified using the Agatston score, which was calculated by multiplying the area of calcification by the corresponding density [25]. An Agatston score of >0 reported CAC presence. A CACS between 0 and 100 (mild disease), 101 and 400 (moderate disease), and more than 400 (severe disease) [4,6,7,10,26].

Statistical analysis

SAS software, version 9.4 (Statistical Analysis System, SAS Institute Inc., Cary, NC, USA), was used to perform all the statistical analyses reported in this study. Descriptive statistics were summarized as frequencies and percentages. The primary outcome variables, including CAC scoring, ASCVD, QRISK2, and TyG, were comparatively analyzed using the chi-square and Fisher-Freeman-Halton exact tests. Pearson correlation was used to measure the strength of the linear relationship between the CAC score and the other cardiac risk stratification scores while Cohen's Kappa was used to assess the level of agreement. Logistic regression was used to assess the effect of risk factors on the possibility of developing cardiac events. The level of statistical significance was set at $p<0.05$.

Ethical considerations

This study is non-interventional, and it did not cause any harm to the patients. Ethical approval was obtained from the Office of Research Affairs (ORA) at KFSH&RC before the initiation of the study (RAC# 2211013), and a waiver of consent was granted.

Results

Patients' demographics and medical history

Of all records obtained between January 2010 and December 2019, only 404 patients were eligible and included in this study. As shown in Table *1*, the included patients were predominantly male (n=262; 64.9%). About half of the responders (n=192; 47.5%) suffered from cardiac symptoms, with chest pain being the most common symptom (n=123; 30.4%). Most patients (n=165; 65.6%) had a desirable amount of cholesterol while only 44 (10.9%) had high cholesterol levels. Surprisingly, there was about equal distribution of patients with (n=206; 51%) and without (n=198; 49%) HTN, as well as with (n=175; 43.3%) and without (n=227; 56.2%) clinical obesity. Nevertheless, most patients had DLD (n=274; 67.8%).

Variables	Frequency (%)
Gender	
Male	262(64.9)
Female	142(35.1)
Nationality	
Saudi	256(63.4)
Non-Saudi	148(36.6)
Smoking history	
Yes	79(19.6)
No	312(77.2)
Undocumented	13(3.2)
Cardiac symptoms history	
Yes	192(47.5)
No	210(52.0)
Not documented	2(0.5)

Symptoms category (194(48.0))	
Chest pain	123(30.4)
Dyspnea	32(7.9)
Palpitation	9(2.2)
Other	6(1.5)
Combination of the above	24(5.9)
Total cholesterol	
Desirable	265(65.6)
Borderline high	95(23.5)
High	44(10.9)
Low-density lipoprotein cholesterol (LDL-C)	
Optimal	100(24.8)
Near-optimal	128(31.7)
Borderline	88(21.8)
High	72(17.8)
Very high	16(4.0)
Hypertension history	
Yes	206(51.0)
No	198(49.0)
Obesity (BMI>30)	
Yes	175(43.3)
No	227(56.2)
Dyslipidemia	
Yes	274(67.8)
No	130(32.2)
Diabetes mellitus type 2	
Yes	155(38.4)
No	249(61.6)
Chronic kidney disease	
Yes	12(3.0)
No	392(97.0)
Coronary revascularization or stroke	
Yes	40(9.9)
No	363(89.9)
History of atrial fibrillation	
Yes	7(1.7)
No	397(98.3)
History of rheumatoid arthritis	
Yes	4(1)
No	400(99.0)

Family history of ischemic heart disease	
Yes	83(20.5)
No	208(51.5)
Family history of premature cardiac death in a first-degree relative	
Yes	25(6.2)
No	239(59.2)

TABLE 1: Overall patients' demographics and medical health history

Demographic and baseline characteristics among different CAC scores

This study evaluated the relationship between CAC scores and the participants' demographics and medical history. As shown in Table *2*, the CAC scoring system compares mild, moderate, and severe risks to predict the patients' cardiac outcomes and guide the intensity of their medical management. There were significant differences ($p<0.05$) between risk levels (shown by CACS gradings) and levels of LDL, HTN, and DLD, previous history of heart disease, arterial fibrillation, cardiac disease history, stenosis, and CAD. However, the CAC scoring system could not detect any significant difference in total cholesterol levels, obesity, or diabetes mellitus (Type 2) among the three groups based on demographics.

Variables	CACS			P-value
	Mild	Moderate	Severe	
Gender				
Male	85.9%	8.8%	5.3%	0.277
Female	85.9%	5.6%	8.5%	
Nationality				
Saudi	83.6%	9.8%	6.6%	0.107
Non-Saudi	89.9%	4.1%	6.1%	
Smoking				
Yes	84.8%	10.1%	5.1%	0.642
No	85.9%	7.4%	6.7%	
Cardiac symptoms				
Yes	82.8%	8.3%	8.9%	0.131
No	89.0%	6.7%	4.3%	
Total cholesterol grade				
Desirable	83.0%	9.4%	7.5%	0.183
Borderline high	89.5%	5.3%	5.3%	
High	95.5%	2.3%	2.3%	
LDL grade				
Optimal	76.0%	14.0%	10.0%	0.012*
Near-optimal	82.8%	8.6%	8.6%	
Borderline	92.0%	3.4%	4.5%	
Presence of hypertension				
Yes	76.7%	14.1%	9.2%	0.000*

No	95.5%	1.0%	3.5%	
Presence of obesity				
Yes	82.3%	9.1%	8.6%	0.183
No	88.5%	6.6%	4.8%	
Presence of dyslipidemia				
Yes	81.4%	10.2%	8.4%	0.001*
No	95.4%	2.3%	2.3%	
Presence of diabetes mellitus				
Yes	81.3%	10.3%	8.4%	0.110
No	88.8%	6.0%	5.2%	
Presence of chronic kidney disease (CKD)				
Yes	75.0%	8.3%	16.7%	0.335
No	86.2%	7.7%	6.1%	
If CKD is present, was the patient on dialysis				
Yes	100.0%	0.0%	0.0%	0.982
No	96.6%	1.7%	1.7%	
History of previous heart diseases				
Yes	62.5%	20.0%	17.5%	0.000*
No	88.7%	6.1%	5.2%	
Presence of arterial fibrillation				
Yes	42.9%	28.6%	28.6%	0.004*
No	86.6%	7.3%	6.0%	
Presence of rheumatoid arthritis				
Yes	100.0%	0.0%	0.0%	0.718
No	85.8%	7.8%	6.5%	
Family history of cardiac disease				
Yes	85.5%	4.8%	9.6%	0.026*
No	92.3%	5.3%	2.4%	
Presence of coronary stenosis after the CAC study				
Yes	15.0%	60.9%	0.0%	0.000*
No	85.0%	39.1%	0.0%	
If the patient had CAD after the CAC study				
Yes	3.8%	26.7%	53.8%	0.000*
No	96.2%	73.3%	46.2%	
If the patient had a stroke after the CAC study				
Yes	0.6%	0.0%	0.0%	0.847
No	99.4%	100.0%	100.0%	

TABLE 2: Relationship between baseline characteristics of the study population and CACS

*Statistically significant, p<0.05

The data have been represented as %.

CACS: coronary artery calcium score

Next, the study assessed the relationship between ASCVD scores and the participants' demographics and medical history. Baseline demographic and clinical data variables of the study participants were stratified into groups according to ASCVD scores, with four scales (low, borderline, intermediate, and high) (Table 3). There was a significant relationship between ASCVD scores and grades of LDL, HTN, DLD, diabetes mellitus (Type 2), family history of cardiac disease, stenosis, and CAD (p<0.05).

Variables	ASCVD				P-value
	Low	Borderline	Intermediate	High	
Gender					
Male	22.4%	14.7%	41.7%	21.2%	0.000*
Female	53.5%	9.9%	30.3%	6.3%	
Nationality					
Saudi	27.6%	13.4%	40.9%	18.1%	0.011*
Non-Saudi	43.5%	12.2%	32.0%	12.2%	
Smoking					
Yes	19.0%	11.4%	43.0%	26.6%	0.002*
No	37.5%	13.3%	35.9%	13.3%	
Cardiac symptoms					
Yes	30.7%	11.6%	37.6%	20.1%	0.173
No	35.7%	14.3%	37.6%	12.4%	
Total cholesterol grade					
Desirable	30.5%	13.0%	40.1%	16.4%	0.252
Borderline high	36.8%	13.7%	37.9%	11.6%	
High	43.2%	11.4%	22.7%	22.7%	
LDL grade					
Optimal	18.6%	18.6%	45.4%	17.5%	0.022*
Near-optimal	37.5%	11.7%	32.0%	18.8%	
Borderline	36.4%	10.2%	43.2%	10.2%	
High	43.1%	9.7%	34.7%	12.5%	
Presence of hypertension					
Yes	21.1%	9.8%	44.6%	24.5%	0.000*
No	46.2%	16.2%	30.5%	7.1%	
Presence of obesity					
Yes	29.5%	13.3%	41.0%	16.2%	0.504
No	36.3%	12.8%	35.0%	15.9%	
Presence of dyslipidemia					
Yes	25.4%	14.3%	41.9%	18.4%	0.000*
No	50.4%	10.1%	28.7%	10.9%	

Diabetes mellitus					
Yes	16.3%	11.1%	41.8%	30.7%	0.000*
No	44.0%	14.1%	35.1%	6.9%	
Chronic kidney disease					
Yes	16.7%	16.7%	50.0%	16.7%	0.643
No	33.9%	12.9%	37.3%	15.9%	
Dialysis					
Yes	0.0%	100.0%	0.0%	0.0%	0.139
No	47.0%	14.8%	31.3%	7.0%	
History of heart disease					
Yes	17.9%	15.4%	38.5%	28.2%	0.056
No	35.2%	12.7%	37.7%	14.4%	
Arterial fibrillation					
Yes	0.0%	28.6%	28.6%	42.9%	0.069
No	34.0%	12.7%	37.8%	15.5%	
Rheumatoid arthritis					
Yes	50.0%	0.0%	50.0%	0.0%	0.645
No	33.2%	13.1%	37.5%	16.1%	
Family history of cardiac disease					
Yes	45.8%	16.9%	21.7%	15.7%	0.021*
No	31.1%	13.6%	39.8%	15.5%	
Stenosis					
Yes	14.3%	30.0%	21.3%	48.6%	0.001*
No	85.7%	70.0%	78.7%	51.4%	
if the patient has CAD after CACS					
Yes	4.5%	5.8%	8.7%	19.0%	0.006*
No	95.5%	94.2%	91.3%	81.0%	
if the patient has a stroke after CACS					
Yes	0.7%	0.0%	0.0%	1.6%	0.452
No	99.3%	100.0%	100.0%	98.4%	

TABLE 3: Relationship between baseline characteristics of the study population and ASCVD scores

* Statistically significant, p<0.05

The data have been represented as %.

ASCVD: arteriosclerotic cardiovascular disease; CACS: coronary artery calcium score

In addition, the relationship between QRISK2 and patients' demographics and medical history is shown in Table *4*. Like the CAC scoring system, the QRISK2 estimator uses a low, moderate, and high scaling system. We found a statistically significant relationship between QRISK2 scores and cardiac symptoms, total cholesterol grade, HTN, DLD, diabetes mellitus (Type 2), previous history of heart disease, arterial

fibrillation, stenosis, and CAD.

Variables	QRISK2			P-value
	Low	Moderate	High	
Gender				
Male	52.9%	30.7%	16.5%	0.001*
Female	66.2%	29.6%	4.2%	
Nationality				
Saudi	48.2%	36.5%	15.3%	0.000*
Non-Saudi	73.6%	19.6%	6.8%	
Smoking				
Yes	44.9%	33.3%	21.8%	0.005*
No	61.2%	28.8%	9.9%	
Cardiac symptoms				
Yes	51.0%	32.8%	16.1%	0.019*
No	63.2%	28.2%	8.6%	
Total cholesterol grade				
Desirable	54.5%	32.2%	13.3%	0.329
Borderline high	66.3%	23.2%	10.5%	
High	56.8%	34.1%	9.1%	
LDL grade				
Optimal	49.0%	34.0%	17.0%	0.150
Near-optimal	55.1%	32.3%	12.6%	
Borderline	64.8%	30.7%	4.5%	
High	65.3%	20.8%	13.9%	
Very high	56.2%	31.2%	12.5%	
Prescence of hypertension				
Yes	42.7%	38.8%	18.4%	0.000*
No	73.1%	21.3%	5.6%	
Presence of obesity				
Yes	50.9%	34.9%	14.3%	0.068
No	62.4%	27.0%	10.6%	
Presence of dyslipidemia				
Yes	50.0%	36.1%	13.9%	0.000*
No	73.6%	17.8%	8.5%	
Presence of diabetes mellitus				
Yes	36.1%	39.4%	24.5%	0.000*
No	71.0%	24.6%	4.4%	
Presence of chronic kidney disease				
Yes	33.3%	50.0%	16.7%	

No	58.3%	29.7%	12.0%	0.217
History of dialysis				
Yes	0.0%	100.0%	0.0%	0.051
No	81.9%	13.8%	4.3%	
History of heart diseases				
Yes	40.0%	32.5%	27.5%	0.003*
No	59.7%	30.1%	10.2%	
History of arterial fibrillation				
Yes	42.9%	14.3%	42.9%	0.041*
No	57.8%	30.6%	11.6%	
History of rheumatoid arthritis				
Yes	100.0%	0.0%	0.0%	0.328
No	57.2%	30.5%	12.2%	
Family history of cardiac disease				
Yes	70.7%	20.7%	8.5%	0.285
No	61.1%	26.0%	13.0%	
Stenosis				
Yes	18.7%	22.8%	51.6%	0.001*
No	81.3%	77.2%	48.4%	
If the patient had CAD after the CAC study				
Yes	5.2%	10.7%	20.8%	0.001*
No	94.8%	89.3%	79.2%	
If the patient had a stroke after the CAC study				
Yes	0.4%	0.0%	2.0%	0.225
No	99.6%	100.0%	98.0%	

TABLE 4: Relationship between baseline characteristics of the study population and QRISK2

*Statistically significant, p<0.05

The data have been represented as %.

QRISK2: cardiovascular risk score; CACS: coronary artery calcium score

Finally, we assessed the relationship between the TyG scoring system and the patient's demographics and medical history. As shown in Table *5*, this risk estimator has only a low and high grading scale. We found a significant relationship (p<0.05) between TyG scales, DLD levels, and type 2 diabetes mellitus.

Variables	TyG		P-value
	Low	High	
Gender			
Male	22.4%	14.7%	0.157

Female	53.5%	9.9%	
Nationality			
Saudi	25.0%	75.0%	0.113
Non-Saudi	18.4%	81.6%	
Smoking			
Yes	22.8%	77.2%	0.658
No	20.5%	79.5%	
Cardiac symptoms			
Yes	18.8%	81.2%	0.369
No	22.4%	77.6%	
Total cholesterol grade			
Desirable	20.0%	80.0%	
Borderline high	25.3%	74.7%	0.388
High	15.9%	84.1%	
LDL grade			
Optimal	29.0%	71.0%	
Near-optimal	17.2%	82.8%	0.158
Borderline	17.0%	83.0%	
High	22.2%	77.8%	
Presence of hypertension			
Yes	17.5%	82.5%	0.094
No	24.2%	75.8%	
Presence of obesity			
Yes	17.7%	82.3%	0.202
No	22.9%	77.1%	
Presence of dyslipidemia			
Yes	16.8%	83.2%	0.004*
No	29.2%	70.8%	
Presence of diabetes mellitus			
Yes	13.5%	86.5%	0.005*
No	25.3%	74.7%	
Presence of chronic kidney disease			
Yes	8.3%	91.7%	0.280
No	21.2%	78.8%	
Dialysis			
Yes	0.0%	100.0%	0.549
No	26.5%	73.5%	
Previous history of heart diseases			
Yes	25.0%	75.0%	0.495
No	20.4%	79.6%	

Arterial fibrillation			
Yes	28.6%	71.4%	0.609
No	20.7%	79.3%	
Rheumatoid arthritis			
Yes	50.0%	50.0%	0.148
No	20.5%	79.5%	
Family history of cardiac disease			
Yes	18.1%	81.9%	0.131
No	26.4%	73.6%	
Stenosis			
Yes	25.0%	24.3%	0.927
No	75.0%	75.7%	
If the patient had CAD after the CAC study			
Yes	7.1%	9.1%	0.568
No	92.9%	90.9%	
If the patient had a stroke after the CAC study			
Yes	1.2%	0.3%	0.309
No	98.8%	99.7%	

TABLE 5: Relationship between the baseline characteristics of the study population and TyG

* Statistically significant, p<0.05

The data have been represented as %.

TyG: triglyceride glucose index; CAC: coronary artery calcium

Level of agreement and correlation between CACS and the other cardiac risk scores

Cohen's Kappa coefficient revealed an almost perfect level of concordance between CACS and QRISK2, suggesting strong consistency between the two risk stratification tools. Additionally, a moderate level of agreement was observed between CACS and ASCVD, indicating a reasonable degree of alignment between these tools. Table *6* shows that QRISK2 (p<0.001) and ASCVD (P=0.003) significantly correlated with the CAC scores, which indicates that QRISK2 and ASCVD are consistent with CACS in risk prediction. There was no significant correlation detected between the CAC score and the TyG index. In addition, the CAC score had a significant level of agreement with both the ASCVD (P=0.011) and QRISK2 score (p=0.008), but not with the TyG index (Table *7*).

Variables				
		TyG index N=404	QRISK2 N=401	ASCVD N=397
CACS	r	0.074	0.247	0.147
	P-value	0.136	<0.001*	0.003*

TABLE 6: Correlations between CACS and risk estimators

* Statistically significant, p<0.05

CACS: coronary artery calcium score

Variables compared to CACS	Kappa	P-value
TyG	-0.002	0.880
QRISK2	0.080	0.008*
ASCVD	0.049	0.011*

TABLE 7: Level of agreement between CACS and risk estimators

*Statistically significant, p<0.05

CACS: coronary artery calcium score

Cardiac risk scores in predicting stenosis

The ability of cardiac risk estimators to predict stenosis was assessed using univariate logistic regression analysis (Table *8*) and found that CACS (OR= 1.003; 95% CI: 1.005 -1.002) (p<0.001), ASCVD (OR= 18.177; 95%CI: 214.578 -1.540) (p=0.021), and QRISK2 (OR= 154.796; 95%CI: 4137.356 - 5.792) (p=0.003) were able to predict stenosis. However, based on the analysis, the TyG Index did not independently predict stenosis (p=0.231).

Risk Estimators	Univariate	
	OR (95% CI)	P-value
TyG index	1.853 (5.085 - 0.675)	0.231
QRISK2	154.796 (4137.356 - 5.792)	0.003*
ASCVD	18.177 (214.578 - 1.540)	0.021*
CACS	1.003 (1.005 -1.002)	0.000*

TABLE 8: Univariate analysis evaluating the association between stenosis and risk estimators

* Statistically significant, p<0.05

TyG: triglyceride glucose index; QRISK2: cardiovascular risk score; ASCVD: arteriosclerotic cardiovascular disease; CACS: coronary artery calcium score

Discussion

This retrospective cohort study evaluated the prognostic gold-standard CAC scoring method known as CACS and compared it with other risk estimators in primary health care in Riyadh, Saudi Arabia. Although the CACS score is considered the gold-standard method to detect CAC events in patients [4,9,11-14], it is still unknown whether the combination of CACS and other risk scores can improve fatal and non-fatal cardiac

events associated with CAC. To the best of our knowledge, this is the first study to compare CACS with other risk scores, such as ASCVD, QRISK2, and the TyG index, in their ability to predict CAC events.

Several studies have evaluated each score individually or in combination with other risk estimators. Pereira et al. demonstrated that when the CAC score was combined with other scores, such as QRISK2 and FRS, they improved the risk assessment in HIV patients [27]. Likewise, others have demonstrated that using the ASCVD score can improve CAC prediction and thus enhance the type of treatment provided to CAC patients [28]. Kapelios et al. reported that CACS was a highly effective indicator for identifying various levels of subclinical CAD in asymptomatic people living with HIV without CVD [29]. CACS proved to be a highly effective indicator for identifying various levels of subclinical CAD. Given these observations, it is evident that using multiple risk scores and estimators enhances the detection and prediction of fatal and non-fatal cardiovascular events in CAC patients [9,21,27].

The current study evaluated the relationship between the baseline characteristics and CACS, ASCVD, QRISK2, and TyG index. We found that the CACS scores were significantly associated with LDL, HTN, DLD, heart disease history, arterial fibrillation, cardiac disease history, stenosis, and CAD. This means that CACS could predict the risks of these conditions. However, CACS was not associated with diabetes mellitus, which was otherwise associated with the ASCVD score. There was no relationship between the ASCVD score and heart disease history or arterial fibrillation. Nevertheless, the TyG index could only detect a significant difference in DLD levels and type 2 diabetes mellitus. These results indicate that the TyG index is the least informative in predicting cardiac outcomes out of the four scores assessed in this study. Previous studies have indicated that the TyG index predictive value varies across populations (highly predictive among morbidly obese individuals than other categories [30,31]. Our findings showed that the CAC score positively correlated and highly agreed with the ASCVD score and QRISK2 score but not with the TyG index. This observation could be explained by the fact that the TyG index predominantly detects insulin resistance in patients [32]. However, some studies argue that the TyG index could be used to predict cardiovascular events [9].

Identifying severe occult coronary artery stenosis helps improve the prevention of cardiac events [33]. Thus, the current study demonstrated that stenosis could be predicted using CACS, ASCVD, and QRISK2 but not the TyG index. This suggests that TyG is the least informative stratification strategy when predicting stenosis in CAC patients. Additionally, this study showed that CACS, ASCVD, and QRISK2 risk estimators complement each other to predict CAC events in patients in primary healthcare settings. These observations are consistent with previous studies, which reported that using the CACS score improves stenosis prediction in patients and thus can be used to prevent the progression to developing severe cardiac events such as heart attack [29,33]. This is an additional study comparing CACS scores with other risk scores (ASCVD, QRISK) and their ability to prevent cardiovascular events. The finding that the TyG index was the least predictive of all was also reported by a previous study [34].

The findings highlight that the integration of multiple risk scores, careful consideration of baseline characteristics, and recognition of specific indices' limitations can all contribute to more effective risk assessment and prevention strategies in the context of coronary artery calcification and related cardiovascular events. This study used a clinical and local database, which is vital to local data use and enhancing locally contextualized evidence from understudied populations.

This study was limited to a single healthcare facility in Riyadh, Saudi Arabia, with a small sample size relative to Riyadh’s population. Additionally, it was a retrospective study, which is prone to selection bias and missing or inaccurate information. Thus, further extensive longitudinal studies with a larger and more diverse population are recommended. Moreover, future research should look into applying our findings in different healthcare settings and populations to strengthen the evidence base for risk assessment and prevention strategies.

Conclusions

This study identified that combined with the gold-standard CAC score, the ASCVD and QRISK scores are valid indicators of fatal and non-fatal cardiac events among primary care patients. QRISK2 and ASCVD are consistent with CACS in predicting the risks. ASCVD and QRISK2 (but not TyG) can also assess and detect stenosis. These findings indicate that a combination of CACS and other risk scores can improve fatal and non-fatal cardiac events. This study could guide primary healthcare providers in a better choice of risk estimation methods to assess coronary artery plaque and predict their patients’ cardiac outcomes to guide medical management and improve the quality of care. Future studies could use the findings of this study as a baseline and further explore the different risk indicators among demographically different populations to further inform measures designed to optimize health outcomes among CVD patients.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the

work.

Concept and design: Amani A. Alsulami, Abdullah H. Alkhenizan, Kossay Elabd, Yaser Alendijani, Nora Alalem

Acquisition, analysis, or interpretation of data: Amani A. Alsulami, Abdullah H. Alkhenizan, Kossay Elabd, Yaser Alendijani, Nora Alalem

Drafting of the manuscript: Amani A. Alsulami, Abdullah H. Alkhenizan, Kossay Elabd, Yaser Alendijani, Nora Alalem

Critical review of the manuscript for important intellectual content: Amani A. Alsulami, Abdullah H. Alkhenizan, Kossay Elabd, Yaser Alendijani, Nora Alalem

Supervision: Amani A. Alsulami

Disclosures

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References

1. WHO. Cardiovascular diseases (CVDs). Accessed: September 23, 2023: https://www.who.int/news-room/fact-sheets/detail/cardiovascular-diseases-(cvds).
2. Aljefree N, Ahmed F: Prevalence of cardiovascular disease and associated risk factors among adult population in the Gulf region: a systematic review. Adv Public Health. 2015, 2015:1-23. 10.1155/2015/235101
3. Al-Nozha MM, Al-Mazrou YY, Al-Maatouq MA, et al.: Obesity in Saudi Arabia. Saudi Med J. 2005, 26:824-9.
4. Liu W, Zhang Y, Yu CM, Ji QW, Cai M, Zhao YX, Zhou YJ: Current understanding of coronary artery calcification. J Geriatr Cardiol. 2015, 12:668-75. 10.11909/j.issn.1671-5411.2015.06.012
5. Tash AA, Al-Bawardy RF: Cardiovascular disease in Saudi Arabia: facts and the way forward . J Saudi Heart Assoc. 2023, 35:148-62. 10.37616/2212-5043.1336
6. Nakahara T, Dweck MR, Narula N, Pisapia D, Narula J, Strauss HW: Coronary artery calcification: from mechanism to molecular imaging. JACC Cardiovasc Imaging. 2017, 10:582-93. 10.1016/j.jcmg.2017.03.005
7. Mori H, Torii S, Kutyna M, Sakamoto A, Finn AV, Virmani R: Coronary artery calcification and its progression: what does it really mean?. JACC Cardiovasc Imaging. 2018, 11:127-42. 10.1016/j.jcmg.2017.10.012
8. Fathala AL, Bukhari SQ, Shoukri M, El Sergani H, Al-Ghamdi B, Al-Sugair A: High prevalence of coronary artery calcification in Saudi patients with normal myocardial perfusion. Ann Saudi Med. 2017, 37:154-60. 10.5144/0256-4947.2017.154
9. Sánchez-Íñigo L, Navarro-González D, Fernández-Montero A, Pastrana-Delgado J, Martínez JA: The TyG index may predict the development of cardiovascular events. Eur J Clin Invest. 2016, 46:189-97. 10.1111/eci.12583
10. Neves PO, Andrade J, Monção H: Coronary artery calcium score: current status. Radiol Bras. 2017, 50:182-9. 10.1590/0100-3984.2015.0235
11. Budoff MJ, Shaw LJ, Liu ST, et al.: Long-term prognosis associated with coronary calcification: observations from a registry of 25,253 patients. J Am Coll Cardiol. 2007, 49:1860-70. 10.1016/j.jacc.2006.10.079
12. Chaikriangkrai K, Palamaner Subash Shantha G, Jhun HY, et al.: Prognostic value of coronary artery calcium score in acute chest pain patients without known coronary artery disease: systematic review and meta-analysis. Ann Emerg Med. 2016, 68:659-70. 10.1016/j.annemergmed.2016.07.020
13. Pletcher MJ, Tice JA, Pignone M, Browner WS: Using the coronary artery calcium score to predict coronary heart disease events: a systematic review and meta-analysis. Arch Intern Med. 2004, 164:1285-92. 10.1001/archinte.164.12.1285
14. Hou ZH, Lu B, Gao Y, Jiang SL, Wang Y, Li W, Budoff MJ: Prognostic value of coronary CT angiography and calcium score for major adverse cardiac events in outpatients. JACC Cardiovasc Imaging. 2012, 5:990-9. 10.1016/j.jcmg.2012.06.006
15. Hisamatsu T, Liu K, Chan C, et al.: Coronary artery calcium progression among the US and Japanese men.

Circ Cardiovasc Imaging. 2019, 12:e008104. 10.1161/CIRCIMAGING.118.008104
16. Raggi P, Callister TQ, Cooil B, et al.: Identification of patients at increased risk of first unheralded acute myocardial infarction by electron-beam computed tomography. Circulation. 2000, 101:850-5. 10.1161/01.cir.101.8.850
17. Greenland P, LaBree L, Azen SP, Doherty TM, Detrano RC: Coronary artery calcium score combined with Framingham score for risk prediction in asymptomatic individuals. JAMA. 2004, 291:210-5. 10.1001/jama.291.2.210
18. Aktas MK, Ozduran V, Pothier CE, Lang R, Lauer MS: Global risk scores and exercise testing for predicting all-cause mortality in a preventive medicine program. JAMA. 2004, 292:1462-8. 10.1001/jama.292.12.1462
19. McEvoy JW, Martin SS, Dardari ZA, et al.: Coronary artery calcium to guide a personalized risk-based approach to initiation and intensification of antihypertensive therapy. Circulation. 2017, 135:153-65. 10.1161/CIRCULATIONAHA.116.025471
20. Fathala A, Alreshoodi S, Rujaib MA, Shoukri M, Sergani HA, Buriki JA, Sugair AA: Coronary artery calcium score in high-risk asymptomatic women in Saudi Arabia. Ann Saudi Med. 2015, 35:298-302. 10.5144/0256-4947.2015.298
21. Abazid R, Al Saqqa H, Smettei O: Analysis of three risk stratification systems in a Saudi population . J Saudi Heart Assoc. 2017, 29:96-101. 10.1016/j.jsha.2016.06.002
22. Anota A, Nedi T: Blood pressure control and associated factors among hypertensive patients attending Shashemene Referral Hospital, Oromia, Ethiopia. Hosp Pharm. 2022, 57:555-63. 10.1177/00185787211061372
23. Mallappallil M, Friedman EA, Delano BG, McFarlane SI, Salifu MO: Chronic kidney disease in the elderly: evaluation and management. Clin Pract (Lond). 2014, 11:525-35. 10.2217/cpr.14.46
24. Tao LC, Xu JN, Wang TT, Hua F, Li JJ: Triglyceride-glucose index as a marker in cardiovascular diseases: landscape and limitations. Cardiovasc Diabetol. 2022, 21:68. 10.1186/s12933-022-01511-x
25. Gheorghe AG, Jacobsen C, Thomsen R, et al.: Coronary artery CT calcium score assessed by direct calcium quantification using atomic absorption spectroscopy and compared to macroscopic and histological assessments. Int J Legal Med. 2019, 133:1485-96. 10.1007/s00414-018-01998-8
26. Bachar GN, Atar E, Fuchs S, Dror D, Kornowski R: Prevalence and clinical predictors of atherosclerotic coronary artery disease in asymptomatic patients undergoing coronary multidetector computed tomography. Coron Artery Dis. 2007, 18:353-60. 10.1097/MCA.0b013e3281286529
27. Pereira B, Mazzitelli M, Milinkovic A, et al.: Use of coronary artery calcium scoring to improve cardiovascular risk stratification and guide decisions to start statin therapy in people living with HIV. J Acquir Immune Defic Syndr. 2020, 85:98-105. 10.1097/QAI.0000000000002400
28. Patel J, Pallazola VA, Dudum R, et al.: Assessment of coronary artery calcium scoring to guide statin therapy allocation according to risk-enhancing factors: the multi-ethnic study of atherosclerosis. JAMA Cardiol. 2021, 6:1161-70. 10.1001/jamacardio.2021.2321
29. Kapelios CJ, Masouris G, Argyris A, et al.: Detection of subclinical coronary artery lesions by Framingham Risk Score, peripheral artery atheromatosis and coronary artery calcium score: a pilot study in asymptomatic individuals living with HIV. AIDS Res Hum Retroviruses. 2021, 37:343-9. 10.1089/AID.2021.0015
30. Cho YK, Kim HS, Park JY, Lee WJ, Kim YJ, Jung CH: Triglyceride-glucose index predicts cardiovascular outcome in metabolically unhealthy obese population: a nationwide population-based cohort study. J Obes Metab Syndr. 2022, 31:178-86. 10.7570/jomes21086
31. Şaylık F, Çınar T, Selçuk M, Tanboğa İH: The predictive value of triglyceride-glucose index for in-hospital and one-year mortality in elderly non-diabetic patients with ST-segment elevation myocardial infarction. J Geriatr Cardiol. 2022, 19:610-7. 10.11909/j.issn.1671-5411.2022.08.006
32. Sánchez-García A, Rodríguez-Gutiérrez R, Mancillas-Adame L, et al.: Diagnostic accuracy of the triglyceride and glucose index for insulin resistance: a systematic review. Int J Endocrinol. 2020, 2020:4678526. 10.1155/2020/4678526
33. Beigneux Y, Sablayrolles JL, Varenne O, Mas JL, Calvet D: Coronary artery calcium score improves the prediction of occult coronary artery stenosis in ischemic stroke patients. J Am Heart Assoc. 2016, 5:e003770. 10.1161/JAHA.116.003770
34. Alalem N, Alkhenizan A, Basudan L, Amin F, Alsoghayer S: The prognostic value of coronary arteries calcium scoring in a primary health care setting in Riyadh, Saudi Arabia: a retrospective cohort study. Cureus. 2022, 14:e25623. 10.7759/cureus.25623