Therapeutics and Clinical Risk Management

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REVIEW

Exploring the Current Tools in Cardiovascular Risk Assessment in the Middle East and the Need for Region-Specific Models - A Scoping Review

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Background: Cardiovascular diseases (CVDs) are a major contributor to premature mortality, disability, and reduced quality of life globally. Assessing CVD risks is central to primary prevention, prompting the development of numerous tools to predict CVD risks for the general population. However, it is unclear which tools are recommended in clinical practice in the Middle East region.

Aim: This scoping review aims to identify, review, and summarize the available literature on CVD risk assessment tools recommended for the general population in the Middle East region.

Methods: The scoping review synthesized the literature on CVD risk assessment tools recommended for the general population in the Middle East region. It followed PRISMA-ScR guidelines, covering searches in the Web of Science (WOS), Medline, and Scopus databases. English-language articles published between 2015 and 2024 that focused on the primary prevention of CVDs in sixteen Middle Eastern countries were included.

Results: Seventeen articles met the inclusion criteria. The studies were distributed over Cyprus (n=1), Iran (n=7), Saudi Arabia (n=4), Qatar (n=1), the United Arab Emirates (n=3), and Egypt (n=1). Various tools are recommended in these countries, including validated Western tools such as ACC/AHA Pooled-Cohort Equations (PCE), Systematic Coronary Risk Evaluation 2 (SCORE 2), World Health Organization charts (WHO/ ISH) for the Eastern Mediterranean region (EMR), Cardiovascular Disease Risk Algorithm (QRISK3), and PREDICT. Some studies in Iran, Saudi Arabia, the United Arab Emirates, and Egypt focused on developing new CVD risk tools tailored for national use.

Conclusion: Current studies on CVD risk assessment are limited and have been conducted in six Middle Eastern countries. These studies recommend various tools, including both validated Western models and locally developed frameworks. However, the limitations of existing tools and the gaps in current research underscore the need for further studies to develop or recalibrate models that account for country-specific CVD risk factors across the region.

Keywords: CVD risk assessment tools, general population, Middle East region, primary prevention, scoping review

Introduction

Cardiovascular diseases (CVDs), the primary cause of mortality, disability, and reduced quality of life globally, have become the most important medical problem in the last few decades. Worldwide, the age-standardized disability-adjusted life years (DALYs) of CVDs are nearly 5078.4 per 100,000 individuals, and the age-standardized CVD mortality rates in North Africa and the Middle East countries ranged from 132.5 to 578.7 per 100,000 in 2022.[1] Moreover, the prevalence of CVDs in the Middle East region is high at 10.1%, with significant rates of associated risk factors, including dyslipidemia (43.3%), hypertension (26.2%), and diabetes (16%).[2]

Received: 19 May 2025
Accepted: 30 September 2025
Published: 10 October 2025

Assessment of CVD risk factors is the cornerstone of primary prevention. Consequently, numerous tools have been developed to predict 10-year CVDs, mainly created for people without prior CVD events, and focus on primary prevention.[3] They are intended to assist healthcare professionals in their clinical decision-making process for many preventive interventions, including lipid management (statin), BP management, or aspirin, to improve patient self-management, and improve overall clinical outcomes.[4,5] Moreover, using these tools led to better control of blood pressure, total cholesterol, and smoking cessation, especially in high-risk populations.[6]

Various CVD prediction tools have been developed, most of which were primarily created for use in Western populations, such as the Framingham Risk Score (FRS),[7] ACC/AHA Pooled-Cohort Equations (PCE),[8] and Cardiovascular Disease Risk Algorithm (QRISK®).[9] Since most prediction models were developed in Western countries, they should be validated (external validation) before being used in new populations to avoid underestimating or overestimating the risk of developing CVDs.[10] Consequently, many studies have focused on validating these prediction tools in different populations.[11–14] The validation of prediction models is essential before using them in a new population with similar conditions and outcomes, as these models often perform poorly during external validation.[15]

Rationale

Cardiovascular risk assessment tools are considered one of the preventive strategies for CVDs. Consequently, several CVD prediction tools have been developed worldwide. Discrepancies among international and regional clinical practice guidelines regarding recommended cardiovascular disease (CVD) risk assessment tools necessitate a critical evaluation of their applicability.[16–20] It remains unclear which tool is most suitable for clinical practice in the Middle East, or whether a single, universal tool can be effectively implemented across the region. Therefore, this scoping review aimed to comprehensively synthesize the literature on CVD risk assessment tools recommended for the general population in the Middle East region over the last decade and to identify potential literature gaps in this region.

Methods

To report the findings of the current review, the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews (PRISMA-ScR) were utilized.[21] This study did not have a pre-registered review protocol.

Eligibility Criteria

Published observational studies, including cohort and cross-sectional studies as well as reviews of CVD risk tools for the general population involving participants aged eighteen and above, were included. English articles focusing on CVD risk assessment tools for primary prevention in sixteen countries of the Middle East region, including Bahrain, Cyprus, Egypt, Iraq, Iran, Jordan, Kuwait, Lebanon, Oman, Palestine, Qatar, Saudi Arabia, Syria, Turkey, United Arab Emirates (UAE), and Yemen[22] were included. Articles published within a 10-year interval (2015–2024) were included to capture the most recent advancements in CVD risk assessment tools. Letters, commentaries, editorials, and AI-based risk assessment studies were excluded from this scoping review.

Information Sources

The database searches were conducted during September 2024 to capture potentially relevant articles. The databases included in the search were Web of Science, Medline (EBSCOhost), and Scopus. The search terms and strategy were developed and applied consistently across all the selected databases.

Search Strategies

Two key concepts were used in the database search: Cardiovascular disease risk assessment tools and Middle Eastern countries. Synonymous key terms were connected using the Boolean operator "OR", while the two main concepts were linked using "AND". The keywords were searched within the titles and abstracts of articles and reviews. Where applicable, search filters, limits, or refines were applied to narrow down the search results. Table 1 provides a complete search strategy for all selected databases.

Table 1 Search Strategies

Database	Search Words	Limits/Filter/ Refine	Number of Records
Web of Science	(Concept 1 AND Concept 2)*	Advance Search: Topic	**351 records**
		Published Date: 2015–2024	
		Articles and review articles	
		English Language	
		Web of Science categories (medical/pharmacy-related categories)	
Scopus	(Concept 1 AND Concept 2)*	Advanced Search: (article title, abstract, keywords)	**617 records**
		Published Date: 2015-2024	
		Medicine	
		Articles and review articles	
		English Language	
Medline: EBSCOhost	(Concept 1 AND Concept 2)*	Advance Search: Abstract & title	**173 records**
		Full text	
		Published Date: 2015-2024	
		Academic journal	
		English Language	

Notes: *((“cardiovascular risk assessment tools” OR “cardiovascular risk assessment” OR “CVD risk assessment” OR “cardiovascular disease risk assessment” OR “cardiovascular disease risk assessment tools” OR “cardiovascular risk assessment instruments” OR “cardiovascular risk score” OR “cardiovascular disease risk score” OR “cardiovascular risk scoring” OR “CVD risk score” OR “cardiac risk scores” OR “cardiovascular risk prediction scores” OR “cardiovascular risk calculator” OR “cardiovascular disease risk calculator” OR “CVD risk calculator” OR “cardiovascular risk prediction tools” OR “cardiovascular risk prediction” OR “cardiovascular risk equation” OR “CVD risk equation” OR “cardiovascular risk charts” OR “CVD risk charts” OR “cardiovascular risk algorithms” OR “CVD risk algorithms” OR “coronary risk score” OR “risk equation” OR “risk scoring method” OR “risk score” OR “risk prediction” OR “risk algorithms” OR “risk assessment tool” OR “risk assessment charts” OR “risk charts” OR “risk assessment/methods”)) AND ((“Middle East countries” OR “Middle East nations” OR “Arab countries” OR “the Arabian Gulf countries” OR “Levantine countries” OR “United Arab Emirates” OR “Saudi Arabia” OR Bahrain* OR Kuwait* OR Qatar* OR Oman* OR Yemen* OR Iraq* OR Jordan* OR Lebanon* OR Palestinian* OR Syria* OR Egypt* OR Iran* OR Turkey* OR Cyprus* OR “United Arab Emirates population” OR “Emirati population” OR “Saudi population”)).

Selection of Evidence Sources

After completing the database search, the resulting citations were exported and uploaded to Rayyan Web[23] to manage the records systematically, remove the duplicated articles, and facilitate screening titles and abstracts by grouping them based on decisions (included, excluded, or maybe). After removing duplicate articles, the titles and abstracts were screened for eligibility. In the case of doubt, the articles were grouped into “maybe” in Rayyan, whereby the second and third reviewers made the final decisions. After excluding irrelevant articles, one reviewer screened and assessed the full text of the relevant studies to determine their eligibility based on the review criteria. The second and third reviewers approved the finalized articles before data extraction.

Data Charting Process

The data-charting process was started by categorizing the identified studies according to the countries in the Middle East. The lead reviewer extracted data using a charting table designed specifically for the research objectives. The data items charted were the authors, date of publication, related countries, study population, sample size, CVD risk assessment tools used, study design, study aims, and study conclusion or results.

Synthesis Of results

The data were analyzed thematically according to the distribution of studies by country, CVD risk assessment tools, validation of CVD risk assessment tools, and development of new CVD risk assessment tools in the Middle East.

Results

Study Selection

A total of 1141 records were identified from databases, Web of Science (n=351), Scopus (n=617 and Medline (n=173). Of 1141 identified records, 386 duplicate records were removed. The screening process involved reviewing 755 titles and abstracts, of which 712 were excluded for not being relevant to the topic of this review. Reasons for exclusion included studies with inappropriate designs, a lack of focus on Middle Eastern countries, and those addressing secondary prevention of CVDs. Subsequently, 43 reports were assessed during the full-text screening to evaluate their eligibility, and 26 were excluded due to having different outcomes. Ultimately, 17 articles met the inclusion criteria of the scoping review. The details of the selection process are summarized in Figure 1.[24]

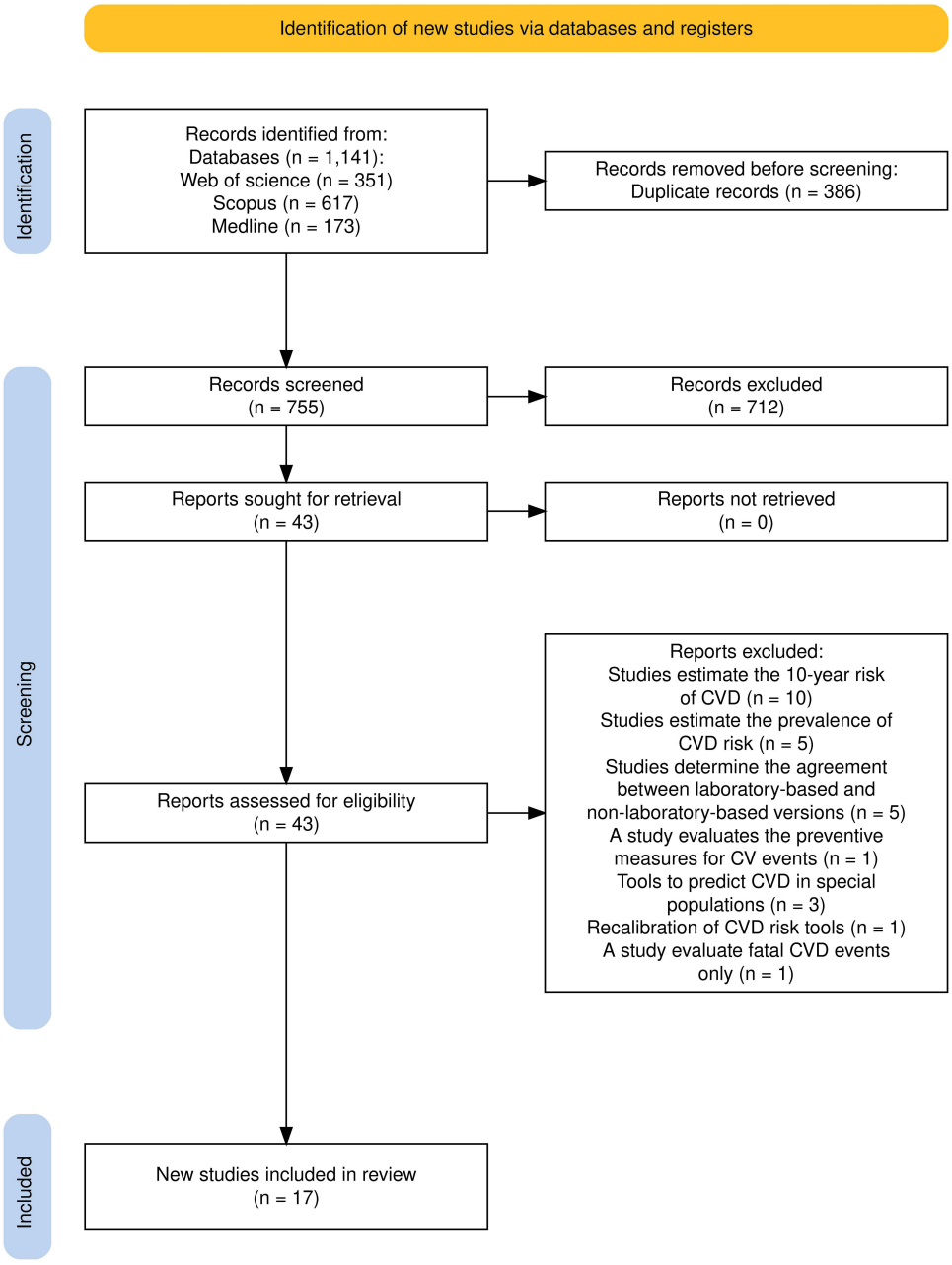

Figure 1 PRISMA flowchart of identified studies via the database.

Studies Characteristics

Forty-three relevant articles were identified, of which seventeen studies were eligible for inclusion in this scoping review. The studies have been conducted only in six out of sixteen countries: Saudi Arabia, the United Arab Emirates (UAE), Qatar, Egypt, Iran, and Cyprus, with Iran leading in publications. Of seventeen studies, nine employed cohort designs (prospective studies n=4, retrospective studies n=5), five employed cross-sectional designs, one used a retrospective cross-sectional design, one employed a cross-sectional followed by a retrospective design, and one was a systematic review. The participants in the included studies ranged from 129 to 5432, with ages ranging from 18 to 79 years old, all without a CVD history. Table 2 provides the key characteristics of the included studies.

Middle East Countries

The included studies were distributed over Cyprus (n=1), Iran (n=7), Saudi Arabia (n=4), Qatar (n=1), UAE (n=3), and Egypt (n=1) Figure 2. All observational studies incorporated the national population of each country, except for one conducted in Saudi Arabia, which included populations from the East Mediterranean (Jordan, Saudi Arabia, Kuwait, Egypt, Yemen, and Sudan) and South Asians (Bangladesh, India, Pakistan, and Sri Lanka).[26]

Table 2 Characteristics of Included Studies

No	Study	Country	Sample Size/ Population	CVD Risk Tools	Study Design	Study Aims	Study Result/ Conclusion
1	[25]	Saudi Arabia	462 Saudi patients 40 years of age and above with a high risk of ASCVD (having excessive coronary calcification)	ACC/AHA/PCE FRS SCORE	A cross-sectional study	To compare and identify the accuracy of three scores in identifying higher-risk Saudi patients for ASCVD	The ACC/AHA has a higher sensitivity (65%) than FRS (55%) and SCORE (40%) in predicting CVD among the high-risk Saudi population
2	[14]	Saudi Arabia	129 Saudi patients 40 years of age and above and diagnosed with ACS	FRS SCORE ACC/AHA/ ASCVD QRISK®	A cross-sectional study	To compare and identify the accuracy of four scores in the predictability of CVD in the Saudi population	The most applicable was QRISK® with 95.3% among the total sample; however, the ACC/AHA was better in predicting CVDS with 66.7% in the high-risk group than other scores
3	[26]	Saudi Arabia	139 patients, 90 from the East Mediterranean (Saudi Arabia, Egypt, Jordan, Sudan, Yemen, Kuwait) and 49 from South Asians (India, Pakistan, Bangladesh, Sri Lanka) aged between 40–70 years and diagnosed with MI	FRS SCORE ACC/AHA/ASCVD WHO/ISH	A retrospective study	To compare the accuracy of four tools used to measure the CVD risk among the populations from East Mediterranean and South Asian	The ACC/AHA has a higher CVD risk prediction with 54.44% for the East Mediterranean population and 46.93% for the South Asian population than other scores
4	[27]	Saudi Arabia	451Saudi patients 18 to 75 years of age	A new CVD risk prediction model	A retrospective study	To create a 10-year CVD risk prediction model tailored for the Saudi population	The first 10-year CVD risk prediction model was created for the Saudi population
5	[28]	United Arab Emirates (UAE)	554 UAE participants 30–79 years of age without CVD and diabetes history	FRS (NCEP-ATP-III)	A10-year retrospective cohort study	To test the performance of the FRS in predicting CHD risk in UAE nationals	The FRS showed good predictive accuracy of coronary risk among UAE nationals with discrimination ability (AUROC: 0.83) and good calibration (Hosmer-Lemeshow χ^2 statistic 11.2, P = 0.191)

(*Continued*)

https://doi.org/10.2147/TCRM.S520628

Table 2 (Continued).

No	Study	Country	Sample Size/ Population	CVD Risk Tools	Study Design	Study Aims	Study Result/ Conclusion
6	[29]	United Arab Emirates	1041 UAE nationals 30–79 years of age without CVD history	2008 FRS 2008 FRS (office-based) 2013 ACC/AHA/PCE	A10-year retrospective cohort study	To evaluate the accuracy and usefulness of two FRS models and the 2013 PCE in the UAE populations	All models overestimated CVD risk and showed moderate discriminative performance with C-statistics ranging from 0.69 to 0.74 across the models; the models were not accurate for prediction in the UAE populations
7	[30]	United Arab Emirates	1245 Emiratis 18 years and above of age without CVD history	A novel 10-year cardiovascular risk prediction nomogram	A 10-year retrospective cohort study	To create and validate a novel 10-year ASCVD risk nomogram for Emiratis	The nomogram was developed, provides an accurate 10-year ASCVD risk prediction in Emiratis with good discrimination (C- statistic: 0.826) and calibration (GND χ^2 2.83, P=0.830)
8	[31]	Qatar	Individuals of all ages and from any geographical area	41 studies compared 116 models for the primary prevention of ASCVD	A systematic review	To identify, assess, and compare the characteristics of existing and established ASCVD risk prediction models for the Qatari population	No existing ASCVD is especially appropriate for the multi-ethnic nature of Qatar's population and PREDICT and QRISK3 seem to be the most suitable models because they include ethnicity
9	[32]	Egypt	350 Egyptian 35 years and above of age diagnosed with CHD or other conditions	WHO/ISH for EMR	A cross-sectional screening survey combined with a retrospective analysis	To identify the accuracy of WHO/ISH risk prediction charts in predicting and detecting high-risk people for developing CHD	The WHO/ISH showed good accuracy with a sensitivity of 60.0% and specificity of 93.2% in CHD predicting risk for the EMR
				An alternative CHD risk assessment instrument		To propose CHD risk assessment models tailored for Egyptian	A different CHD risk assessment model was proposed for general practice with or without laboratory test
10	[33]	Cyprus	908 Cypriot population 40 to 89 years of age without ASCVD or diabetes at baseline	SCORE2 SCORE2-OP (moderate-risk algorithms and high-risk algorithms)	A prospective cohort study	To assess the accuracy of SCORE2 and SCORE2-OP algorithms for the 10-year risk of MI, stroke, fatal CVD, and for all ASCVD events, including MI, onset of angina, coronary artery revascularization, ischemic stroke, TIA, onset of claudication, or critical limb ischemia in the Cypriot population	SCORE2 and SCORE2-OP algorithms of moderate risk demonstrated good performance with a discrimination ability (C-statistic: 0.76) and the observed 10-year event rate was like the predicted one for predicting MI, stroke, and fatal CVD disease; while high-risk algorithms showed good discrimination abilities (C-statistic: 0.73) and better calibration for predicting all ASCVD events than moderate risk algorithms

(*Continued*)

Table 2 (Continued).

No	Study	Country	Sample Size/ Population	CVD Risk Tools	Study Design	Study Aims	Study Result/ Conclusion
11	[34]	Iran	3086 Iranians 40–74 years of age without CVD and DM history	ACC/AHA/PCE SCORE (low and high-risk algorithms) FRS-ATP III	A cross-sectional study	To evaluate and compare CVD risk assessment tools and their associated guidelines in the estimation of 10-year CVD risk and resulting therapeutic recommendations	The ACC/AHA provided better risk prediction than other risk assessment tools, with a mean cardiovascular risk of 12.96% in men and 5.87% in women. The ACC/AHA guideline recommends significantly more individuals for statin therapy (men: 58.2% and women: 39.7%)
12	[35]	Iran	5432 Iranian 35 years and above of age without CVD history	Persian Atherosclerotic Cardiovascular Disease Risk Stratification (PARS)	A prospective study	To develop a 10-year laboratory CVD risk assessment chart tailored for the Iranian population	A 10-year laboratory-based risk prediction chart was created (PARS) for fatal and non-fatal CVD with good discrimination (AUROC: 0.74, Harrell's C: 0.73) and calibration (Nam-D'Agostino χ^2 = 10.82, p = 0.29)
13	[36]	Iran	5432 Iranian adults 35 years and above of age without CVD history	Simplified Persian Atherosclerotic Cardiovascular Disease Risk Stratification (SPARS)	A prospective study	To create a simplified, 10-year non-laboratory CVD risk assessment chart tailored for Iranians and validate PARS and SPARS models	A 10-year non-laboratory-based risk prediction chart was created (SPARS) for fatal and non-fatal with good discrimination (Harrell's C: 0.73) and good calibration (Nam-D'Agostino χ^2:11.01, p = 0.27) SPARS and PARS showed good discrimination in the external validation with Harrell's C of 0.77 and 0.78 respectively
14	[37]	Iran	2883 Iranians 40–74 years of age without CVD history	ACC/AHA/PCE FRS SCORE (low and high-risk algorithms)	A prospective study	To evaluate and compare the predictive accuracy of the four risk assessment tools for the estimation of CVD risks in Northern Iran	The ACC/AHA and SCORE tools showed an almost similar result and ACC/AHA had slightly better performance with discriminative abilities of (AUC: 0.6625 in men, 0.7722 in women for non-fatal), and (AUC: 0.8614 in men, 0.8779 in women for fatal CVD events)
15	[38]	Iran	284 Iranians 30–79 years of age with cardiac symptoms and without a history of CVD	ACC/AHA/ASCVD WHO/ISH	A cross-sectional study	To compare the 10-year CVD risk among symptomatic individuals without cardiac disease using two CVD risk tools	The ASCVD risk score stratified more subjects as high risk with 95.3% sensitivity and 75.1% specificity when compared with the WHO risk equation

(*Continued*)

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Table 2 (Continued).

No	Study	Country	Sample Size/ Population	CVD Risk Tools	Study Design	Study Aims	Study Result/ Conclusion
16	[39]	Iran	289 obese Iranians without a CVD history	FRS ACC/AHA/ASCVD	A Retrospective Cross-sectional Study	To determine the more accurate calculator for the prediction risk of heart disease among Iranian people with obesity	The ASCVD risk score identified more obese individuals (14.9%) at high risk of CVDs than FRS (1%)
17	[40]	Iran	1827 Iranians 40–80 years of age with cardiac event (MI or HF)	FRS ACC/AHA/ASCVD	A cross-sectional study	To compare the performance of ASCVD and FRS in the south of Iran	ASCVD identified a greater portion of patients as high-risk compared to FRS (28.7% vs 15.7%) and the discriminative ability of ASCVD (AUC:0.794) was higher than FRS (AUC:0.746)

Abbreviations: ACC/AHA, the American College of Cardiology/American Heart Association; ACS, Acute Coronary Syndrome; ASCVD, Atherosclerotic Cardiovascular Disease; ATP III, Adult Treatment Panel III; AUC, Areas Under Curve; AUROC, Area Under the Receiver Operating Characteristic; CHD, Coronary heart disease; CVD, Cardiovascular Disease; DM, Diabetes Mellites; EMR, Eastern Mediterranean region; FRS, Framingham Risk Score; GND, Greenwood- Nam- D'Agostino; HF, Heart Failure; MI, Myocardial Infarction; NCEP, National Cholesterol Education Program; PARS, Persian Atherosclerotic Cardiovascular Disease Risk Stratification; PCE, Pooled Cohort Risk Equations [atherosclerotic cardiovascular disease (ASCVD) score]; QRISK, Cardiovascular Disease Risk Algorithm; SCORE, Systematic Coronary Risk Evaluation; SCORE2-OP, Systematic Coronary Risk Evaluation old-Population; SPARS, Simplified Persian Atherosclerotic Cardiovascular Disease Risk Stratification; TIA, Transient ischemic attack; UAE, United Arab Emirates; WHO/ISH, World Health Organization / International Society of Hypertension.

CVD Risk Assessment Tools

The CVD risk assessment tools that have been externally validated in Middle Eastern countries were Framingham Risk Score (FRS), FRS (office-based),[7] FRS (ATP-III),[41] ACC/AHA Pooled-Cohort Equations (PCE),[8] Systematic Coronary Risk Evaluation (SCORE),[42] Systematic Coronary Risk Evaluation 2 (SCORE 2),[43] Systematic Coronary Risk Evaluation old-Population (SCORE2-OP),[44] Cardiovascular Disease Risk Algorithm (QRISK2),[9] and World Health Organization charts (WHO/ ISH) for the Eastern Mediterranean region (EMR).[45] Characteristics of validated cardiovascular risk assessment tools, including the corresponding guidelines, parameters, population, and outcomes, are detailed in Table 3.

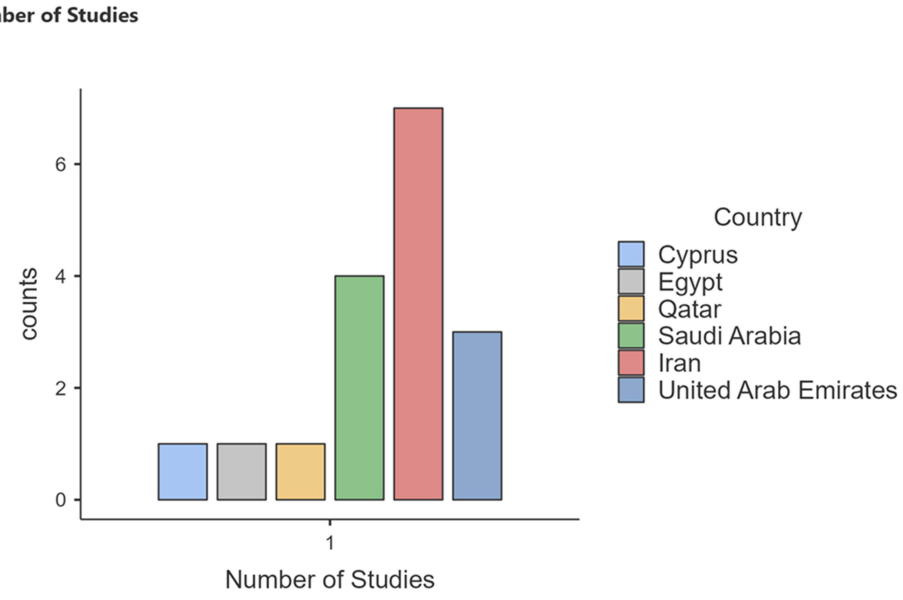

Figure 2 Distribution of studies over the Middle East countries.

Table 3 Characteristics of Cardiovascular Risk Assessment Tools

Risk Tools	Guideline	Parameters	Population	Outcomes
PCE	ACC/AHA	Age, sex, race, SBP, DBP, TC, HDL-C, LDL-C, DM, smoking, on a statin, aspirin, or hypertension treatment	Individuals aged 20 to 79 years without CVD history at the baseline	10-year risk for ASCVD, which is defined as coronary death, nonfatal MI, or fatal or nonfatal stroke
SCORE	ESC	Age, sex, TC, HDL cholesterol, SBP, smoking status, and region based on European country	Individuals aged 40 to 65 years without CVD history at the baseline	10-year risk of fatal CVD events
SCORE2	ESC	Age, sex, SBP, TC, HDL-C, LDL-C, smoking, and region based on European country	Individuals aged 40 to 69 years without CVD history at the baseline or other high-risk conditions	10-year fatal and non-fatal CVD risk
SCORE2-OP	ESC	Age, sex, SBP, total cholesterol, HDL-C, LDL-C, smoking, and region based on European country	Individuals aged over 70 years without pre-existing CVD	5- and 10-year risk of incident CVD
QRISK2	NICE	Age, sex, SBP, HTN treatment, ethnicity, cholesterol/HDL ratio, BMI, smoking status, CKD (stage 4, 5), AF, DM, RA, and angina or heart attack in a first-degree relative younger than 60 years old	Individuals aged 35–74 years free from CVD and diabetes at baseline.	10-year risk of CVD (heart attack or stroke)
WHO/ISH	WHO	Age, sex, BP, smoking status, TC, and DM, WHO epidemiological sub-region	Individuals aged 40 to 74 years without CVD history at the baseline.	10-year risk of a fatal or non-fatal major cardiovascular event (MI or stroke)
FRS (ATP-III)	NCEP-ATPIII	Age, sex, TC, smoking, HDL-C, SBP, HTN treatment	Individuals aged 20 to 79 years old and without CVD history and diabetes at baseline	10-year risk for MI and coronary death
FRS	CCS	Age, sex, SBP, HTN treatment, TC, HDL-C, DM, smoking	Individuals aged 30 to 74 years without CVD history at the baseline	10-year risk prediction of CVD (coronary death, MI, coronary insufficiency, angina, ischemic stroke, hemorrhagic stroke, TIA, PAD, HF)
FRS (office-based)	CCS	Age, sex, SBP, HTN treatment, DM, smoking, and BMI	Individuals aged 30 to 74 years without CVD history at the baseline	10-year risk prediction of CVD (coronary death, MI, coronary insufficiency, angina, ischemic stroke, hemorrhagic stroke, TIA, PAD, HF)

Abbreviations: ACC/AHA, the American College of Cardiology/American Heart Association; ASCVD, Atherosclerotic Cardiovascular Disease; AF, Atrial Fibrillation; ATP III, Adult Treatment Panel III; BMI, Body Mass Index; BP, blood Pressure; CCS, Canadian Cardiovascular Society; CKD, Chronic Kidney Disease; CVD, Cardiovascular Disease; DBP, diastolic blood pressure; DM, Diabetes Mellites; ESC, European Society of Cardiology; HF, Heart failure; HTN, Hypertension; HDL-C, High-Density Lipids-Cholesterol; ISH, International Society of Hypertension; LDL- C, Low-Density Lipids-Cholesterol; MI, Myocardial Infarction; NICE, National Institute for Health and Care Excellence; NCEP, National Cholesterol Education Program; PAD, Peripheral artery disease; PCE, Pooled Cohort Risk Equations [atherosclerotic cardiovascular disease (ASCVD) score]; QRISK, Cardiovascular disease risk algorithm; RA, Rheumatoid Arthritis; SBP, Systolic Blood Pressure; SCORE, Systematic Coronary Risk Evaluation; SCORE2-OP, Systematic Coronary Risk Evaluation old-Population; TIA, Transient Ischemic Attack; TC, Total Cholesterol; WHO/ISH, World Health Organization/ International Society of Hypertension.

Validation of CVD Risk Assessment Tools

Several studies were carried out to evaluate the performance of Western CVD risk assessment tools in predicting CVDs within 10 years in the Middle East region. The evaluation of CVD prediction models included head-to-head comparisons, comparing several models, or validating only one model.

In Saudi Arabia, three studies assessed the performance of the scores by comparing several models. The first study compared the FRS, ACC/AHA/PCE, and SCORE. It found that ACC/AHA has a higher sensitivity (65%) than FRS and SCORE in predicting patients at high risk of CVDs.[25] The second study compared the FRS, ACC/AHA, SCORE2, and QRISK2, it demonstrated that QRISK2 was the most applicable score (95.3%) among the total sample; however, the ACC/AHA was better in detecting the high-risk group (66.7%).[14] The third study compared the ACC/AHA, FRS, WHO/ISH, and SCORE, recommending ACC/AHA for the East Mediterranean populations because of its higher detection rate (54.44%) and suggesting that more research is necessary to determine the most appropriate tool for South Asian people.[26]

In the UAE, a study compared the 2008 FRS, FRS (office-based), and the 2013 PCE and found that none of these models accurately predict cardiovascular risk in the Emirati population, as all of them overestimated the risk.[29] Another study in the UAE recommended the FRS (ATP-III) for UAE populations without diabetes because it showed good discrimination (AUROC: 0.83) and calibration in predicting Coronary heart disease (CHD) (Hosmer-Lemeshow $\chi 2$ statistic 11.2, $P = 0.191$).[28]

A study in Egypt was carried out to validate the WHO/ISH chart of the EMR, finding good accuracy with a sensitivity of 60.0% and a specificity of 93.2% in detecting people at high-risk for CHD.[32]

In Cyprus, a study was conducted to identify the accuracy of SCORE2 and SCORE2-OP algorithms of moderate and high-risk regions in the prediction of 10-year risk for Myocardial Infarction (MI), stroke, or fatal CVDs, and all Atherosclerotic Cardiovascular Disease (ASCVD) events.[33] The result showed that the SCORE2 and SCORE2-OP moderate risk algorithms demonstrated good performance with a discrimination ability (C-statistic: 0.76). The observed 10-year event rate was like the predicted one (calibration) for predicting MI, stroke, and fatal CVDs only. While high-risk algorithms showed good discrimination abilities (C-statistic: 0.73) and better calibration for predicting all ASCVD events than moderate-risk algorithms.

Five studies have been conducted in Iran to evaluate the performance of different CVD risk scores. One study compared three scores (ACC/AHA, SCORE, FRS) and their associated guidelines, ACC/AHA, ESC, and NCEP-ATP-III.[34] Based on this study, the ACC/AHA approach provided significantly higher risk estimations with mean cardiovascular risks of 12.96% in men and 5.87% in women, and its guideline recommended significantly more individuals for statin therapy (men: 58.2%, women: 39.7%). Another study compared the ACC/AHA, SCORE (both low- and high-risk algorithms), and FRS. It was found that ACC/AHA & SCORE scores have similar prediction abilities; however, ACC/AHA had a slightly better performance based on areas under the curve (AUC) values. The AUC values for non-fatal CVD events were 0.6625 for men and 0.7722 for women, while the AUC values for fatal CVD events were 0.8614 for men and 0.8779 for women.[37] Two studies compared the ASCVD with the WHO[38] and once with FRS.[40] Both studies concluded that the ASCVD risk score had better performance in predicting CVDs, identifying more high-risk individuals than FRS (28.7% vs 15.7%) and achieving a sensitivity of 95.3% and specificity of 75.1% compared to the WHO equation. Another study compared the ASCVD algorithm with the FRS in Iranian subjects with obesity and found that the ASCVD identified more obese subjects (14.9%) at high risk of CVDs.[39] Figure 3 summarizes international CVD risk prediction models validated in Middle Eastern countries and the most accurate tools identified through local studies.

Development of New CVD Risk Assessment Tools in the Middle East

Several studies have been conducted in various Middle Eastern countries to develop new CVD risk assessment tools tailored to their national populations. The characteristics of new CVD risk tools are summarized in Table 4. For Saudi nationals, a 10-year CVD risk prediction model was developed, but pending validation.[27] Unlike most well-known CVD risk tools, the Saudi prediction tool surprisingly did not include sex and age as predictors of CVDs. However, it included heart failure, antihyperlipidemic, and antithrombotic therapy as predictors.

A novel 10-year cardiovascular risk prediction nomogram was developed specifically for UAE nationals.[30] This nomogram incorporated family history and estimated glomerular filtration rate (eGFR), like QRISK3. Unlike most CVD risk tools, it included individuals starting from 18 years old. The nomogram provided good performance accuracy with discrimination abilities (C-statistic: 0.826) and calibration (GND $\chi 2$ 2.83, P=0.830).

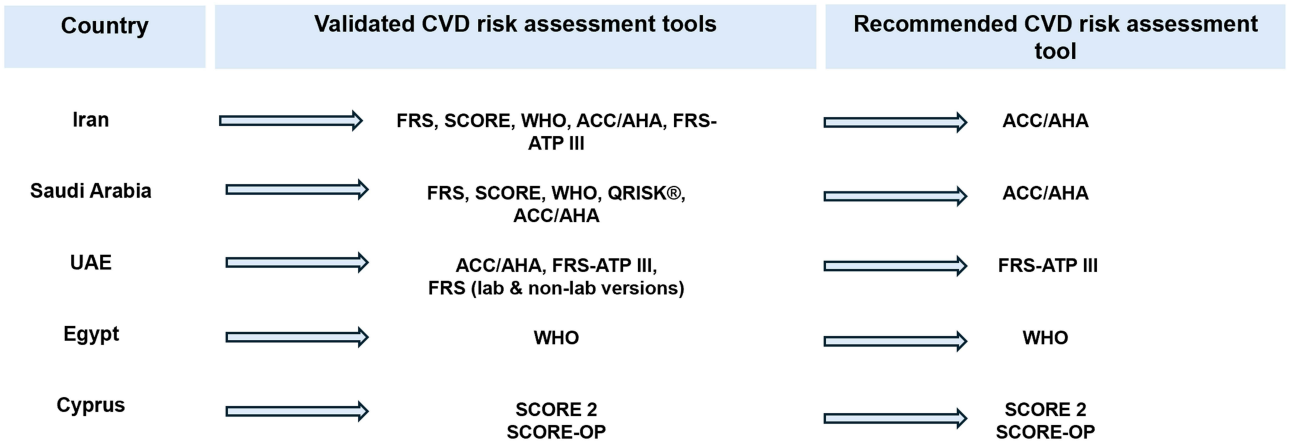

Figure 3 International CVD risk prediction models validated in Middle Eastern countries and their recommendations.

In Egypt, a study was performed to propose CHD risk assessment models tailored for Egyptians. Two models were developed: in model 1, standard CVD risk factors without laboratory tests were included, while in model 2, the parameters were derived from a logistic regression analysis, including laboratory tests.[32]

The Persian Atherosclerotic Cardiovascular Disease Risk Stratification (PARS) model, developed by Sarrafzadegan et al, predicts the 10-year risk of fatal and non-fatal CVDs based on laboratory factors in the Iranian population.[35] The model demonstrated good discrimination (AUROC: 0.74, Harrell's C: 0.73) and calibration (Nam-D'Agostino $\chi^2 = 10.82$, $p = 0.29$). Additionally, Hassannejad et al developed a Simplified Persian Atherosclerotic Cardiovascular Disease Risk Stratification (SPARS) model, which is based on non-laboratory risk factors, for use in an environment with limited resources or limited availability of laboratory tests.[36] It showed good discrimination (Harrell's C: 0.73) and calibration (Nam-D'Agostino χ2:11.01, $p = 0.27$). Unlike most CVD risk tools, the PARS and SPARS models included a high waist-to-hip ratio (WHR) as a predictor for CVDs. Additionally, CVD family history was included in the PARS as a predictor.

Table 4 CVD Risk Assessment Tools in Middle East Countries

Country	Model	Age	Predictors	Outcome
Iran	PARS risk chart	≥ 35 years	Age, Sex, SBP, TC, WHR, diabetes, smoking status, and CVD family history	10-year risk of fatal and non-fatal CVD
Iran	SPARS risk chart	≥ 35 years	Age, sex, WHR, smoking status, SBP, and self-reporting history of diabetes	10-year risk of fatal and non-fatal CVD
Egypt	Model 1 (Non-lab)	≥ 35 years	Age, BP, smoking status, medical and family history of DM and CV morbidities, physical activity, and poor dietary habits	Predict CHD event
	Model 2 (lab- Model)	≥ 35 years	Age, HTN, DM, DBP, and high LDL-C: HDL-C ratio	
United Arab Emirates	A novel nomogram	≥ 18 years	Age, sex, HTN treatment, SBP, TC, HbA1c, eGFR, and CVD family history	10-year ASCVD risk prediction
Saudi Arabia	Saudi Cardiovascular Disease Risk Prediction Model	18 - 75 years	FBS, HDL, heart failure, antithrombotic treatment, antihyperlipidemic treatment, and antihypertension treatment	10-year risk of cardiovascular disease (CVD) events

Abbreviations: ALT, Alanine aminotransferase; AST, Aspartate aminotransferase; ASCVD, Atherosclerotic Cardiovascular Disease; BP, Blood pressure; CHD, Coronary heart disease; CVD, Cardiovascular disease; DM, Diabetic mellitus; DBP, Diastolic blood pressure; eGFR, Estimated glomerular filtration rate; FBS, Fasting blood sugar; HbA1c, glycosylated hemoglobin A1c; HDL-C, high-density lipoprotein cholesterol; HTN, Hypertension; Lab, laboratory; LDL-C, Low-density lipoprotein cholesterol; WHR, High waist-to-hip ratio; TC, Total cholesterol; SBP, Systolic blood pressure.

https://doi.org/10.2147/TCRM.S520628

Discussion

This scoping review highlighted CVD risk assessment tools recommended for primary CVD prevention in the general population in the Middle East region over the past decade. Seventeen studies were identified in the current scoping review, including sixteen primary studies and one secondary study. The studies were conducted in six countries, including Saudi Arabia, the UAE, Qatar, Egypt, Iran, and Cyprus, with Iran leading in publications. Various tools are recommended in these countries, including both validated Western tools and nationally developed models. The validated tools were FRS (lab and non-lab), FRS (ATP-III), SCORE, SCORE2, SCORE2-OP, ACC/AHA, QRISK2, and WHO/ISH. New CVD models were developed in Saudi Arabia, the UAE, Egypt, and Iran.

The studies that were conducted in Iran and Saudi Arabia recommended the ACC/AHA in the prediction of cardiovascular events in high-risk patients, as it performed better compared to other models.[14,25,26,34] However, a study in the UAE found that FRS-ATP III is appropriate to use in the estimation of coronary risk without diabetes for the UAE population.[28] In Egypt, a study recommended the WHO in predicting CHD among Egyptians.[32] Meanwhile, a study conducted in Cyprus suggested that SCORE2 and SCORE2-OP (moderate- and high-risk algorithms) for use in CVDs prediction among the Cypriot population.[33] Additionally, a systematic review concluded that none of the available ASCVD risk tools are suitable for use in Qatar due to the variety of ethnic populations. However, PREDICT and QRISK3 appear to be the most appropriate because they include ethnicity.[31]

Based on the validation studies, the results of studies done in one country of the Middle East cannot be generalized to others. Iran and Saudi Arabia studies recommended ACC/AHA in the stratification of CVDs. However, a study in the UAE showed that the ACC/AHA model performed poorly in predicting CVDs for UAE nationals.[29] Furthermore, a systematic review that sought to assess the appropriateness of existing ASCVD risk assessment scores for Qatari nationals concluded that none of the current ASCVD risk scores were appropriate for use in Qatar.[31] This discrepancy may be attributed to unique cardiovascular risk factors in each country and the limitations of current tools to account for these risk factors.

The variations in some CVD risk factors across countries in the Middle East region and the lack of consideration for these factors by current tools have led to the development of various new CVD risk assessment tools tailored to national use. For example, a family history of CVD and central obesity are considered prominent risk factors for CVDs in the Iranian population.[35] Therefore, the PARS risk chart included both factors.[35] In the UAE, the novel nomogram included a low estimated glomerular filtration rate (eGFR) because it is considered an independent risk factor for CVDs among UAE nationals, although it is a non-traditional CVD risk factor.[30,46] In Saudi Arabia, heart failure, antihyperlipidemic, and antithrombotic therapy were considered risk factors for CVD, which led to the consideration of these factors during the creation of a national CVD risk prediction model.[27] In Egypt, physical activity and poor dietary habits are considered prominent risk factors for the development of CHD, which prompted the development of an alternative risk assessment instrument.[32] Accordingly, when developing or recalibrating a tool for the Qatari population, the inclusion of various ethnicities as risk factors should be considered.[31] This underscores the importance of tailoring CVD risk assessment tools to reflect these differences accurately.[47]

Overall, the number of research articles on CVD risk assessment is limited compared to the number of countries in the Middle East. Studies focusing on the validation or development of CVD risk assessment tools for primary prevention in the general population are particularly scarce in countries such as Bahrain, Iraq, Kuwait, Lebanon, Oman, Palestine, Syria, Yemen, Jordan, and Turkey. Most of these countries are classified as low- and middle-income, which may contribute to the lack of studies in these regions.[48,49] Moreover, the absence of studies in some countries, including Lebanon, Iraq, Palestine, Yemen, and Syria, may be attributed to political instability.[50] The increasing prevalence of CVDs in the Middle East region[2] emphasizes the importance of preventive strategies, including the use of CVD risk scores.

No unified CVD risk score is recommended for use in Middle Eastern countries; however, different tools are recommended depending on the geographical region. This variation within the region is due to a variety of factors. Notably, this region encompasses diverse populations, including Arabs, Persians, Turks, and Kurds, each with distinct racial and genetic profiles that significantly influence CVD risks. Genetic predispositions, such as variations in lipid metabolism, hypertension susceptibility, and inflammatory markers, differ among races and underscore the importance of tailoring CVD risk assessment tools to reflect these differences accurately. Furthermore, the region comprises 16 countries with varying income levels—ranging from

low- to high-income,[49] which impacts healthcare infrastructure, clinical practices, and the feasibility of implementing specific CVD risk tools. Additionally, variations in each country's unique CVD risk profiles, such as a higher prevalence of chronic kidney disease or central obesity, further highlight the need for customized approaches to risk assessment. Moreover, these variations can be influenced by differences in the tools themselves, particularly in their inclusion of risk factors and areas of focus. For example, QRISK incorporated additional risk factors such as ethnicity and body mass index, while SCORE focused only on fatal CVD events. These considerations are critical for ensuring the accuracy and applicability of CVD risk prediction models across this diverse region.

Nontraditional risk factors such as metabolic syndrome, inflammatory markers, and autoimmune diseases should be prioritized in future studies to provide a more comprehensive understanding of cardiovascular risk.[51] Furthermore, incorporating novel markers of atherosclerotic disease, along with demographic factors such as income, employment history, education, and personal habits, could significantly enhance the accuracy and applicability of prediction models.

Advances in computer science and information technology have opened new avenues for using artificial intelligence (AI), particularly machine learning (ML), in predicting and detecting CVD risk profiles. This approach holds significant potential for application in the Middle East, offering the possibility of more accurate and individualized CVD risk prediction. For example, a study by Esmaeili et al demonstrated the effectiveness of ML algorithms in predicting atherosclerotic cardiovascular disease risk among 500 participants in Iran, achieving an impressive accuracy range of 95.7% to 98.1%.[52] While these results are promising, it is important to note that the success of ML applications depends on access to high-quality, well-curated datasets that accurately reflect the unique epidemiological and genetic characteristics of the population.[53,54] In addition to the ML technology, mobile health applications have been shown to improve healthy lifestyle behaviors, increase medication adherence, and help control cardiovascular risk factors.[55,56] Future research should investigate the incorporation of these digital interventions among Middle Eastern populations to enhance preventive strategies and improve cardiovascular outcomes.

The findings from the current study will lay a critical foundation for future regional research efforts. These endeavors will focus on validating and implementing tailored CVD risk assessment models in clinical practice. By achieving greater specificity and sensitivity for the Middle Eastern population, these tools will allow for more precise stratification of CVD risk factors. Ultimately, this approach will not only improve the accuracy of CVD risk prediction but also enhance preventive and therapeutic strategies, ensuring they are better aligned with the needs of the target population.

Strengths and Limitations

The review is considered the first one that focuses on CVD risk prediction models in the Middle East region. It was strengthened by including sixteen countries in the Middle East region, implementing comprehensive search strategies, and transparent selection criteria. On the other hand, this scoping review has some limitations. The database search was restricted to English studies only and focused on three major international databases: Web of Science, Scopus, and Medline. Grey literature with unpublished articles was not included in this review.

Conclusion

This scoping review gave an overall picture of recommended CVD risk tools in the Middle East region. Currently, no unified CVD risk assessment tool is recommended for use in all Middle Eastern countries. Instead, a range of risk tools is recommended, including validated Western tools and nationally developed models. The limitations of existing CVD risk assessment tools and the gaps in current research underscore the need for further studies to develop or recalibrate models that account for country-specific CVD risk factors across the region.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Disclosure

All authors declare no conflicts of interest related to this work.

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