Original Article

# Estimation of the 10-Year Risk of Cardiovascular Diseases: Using the SCORE, WHO/ISH, and Framingham Models in the Shahrekord Cohort Study in Southwestern Iran

Pooneh Samaniyan Bavarsad, MSc[1], Solieman Kheiri, PhD[1,2], Ali Ahmadi, PhD[1,2*]

[1]*Department of Epidemiology and Biostatistics, School of Public Health, Shahrekord University of Medical Sciences, Shahrekord, Iran.*
[2]*Modeling in Health Research Center, Shahrekord University of Medical Sciences, Shahrekord, Iran.*

Received 22 June 2019; Accepted 30 March 2020

## Abstract

***Background:*** *Predicting the risk of cardiovascular diseases (CVDs) helps the management of high-risk individuals by the health system. We sought to determine the 10-year risk of CVDs in the Shahrekord Cohort Study (SCS).*

***Methods:*** *In this cross-sectional study based on the SCS in the southwest of Iran, the demographic, anthropometric, clinical, and laboratory data of 5152 persons recruited in the SCS by census method from 2016 to 2017 were used. R software was utilized to calculate the 10-year risk of CVDs according to the World Health Organization/International Society of Hypertension (WHO/ISH) chart, the Framingham Risk Score (FRS) model, and the Systematic Coronary Risk Evaluation (SCORE) model.*

***Results:*** *The mean age of the participants was 49.49±9.40 years, and 50.3% of them were female. According to the WHO/ISH chart, 94.1% of the participants were in the low-risk class, 4.1% in the moderate-risk class, and 0.4% in the high-risk class. Based on the FRS model, 72.2% of the participants were in the low-risk class, 18% in the middle-risk class, and 9.8% in the high-risk class. On the basis of the SCORE model for low-risk areas, 55.3% of the participants were in the low-risk class, 39.6% in the moderate-risk class, and 5.1% in the high-risk class. The agreement concerning risk estimation between the models was approximately 70%.*

***Conclusion:*** *The risk estimated in this study was higher than that in other similar studies. For monitoring risk trends over time, it is essential to nativize a valid risk function, including ethnicity and geographical characteristics, for the Iranian population.*

*J Teh Univ Heart Ctr 2020;15(3):105-112*

***This paper should be cited as:*** Samaniyan Bavarsad P, Kheiri S, Ahmadi A. Estimation of the 10-Year Risk of Cardiovascular Diseases: Using the SCORE, WHO/ISH, and Framingham Models in the Shahrekord Cohort Study in Southwestern Iran. J Teh Univ Heart Ctr 2020;15(3):105-112.

***Keywords:*** *Risk assessment; Heart diseases; Cohort studies*

## Introduction

Cardiovascular diseases (CVDs) are the most common cause of death and disabilities and the gravest comorbidity in most countries, including Iran. These diseases are, however, among the most preventable noncommunicable diseases.[1]

[*]**Corresponding Author:** ***Ali Ahmadi,*** *Associate Professor of Epidemiology, Modeling in Health Research Center, Kashani Hospital, Parastar Street, Shahrekord, Iran. 8815918459. Tel: +98 3832221164. Fax: +98 3832253742. E-mail: ahmadi@skums.ac.ir.*

Forty-six percent of all deaths and 27.2% of the years of life lost in Iran are due to CVDs. Our previous study sought to determine the epidemiological patterns of CVD risk factors in Iran.[2] The age-standardized prevalence of CVDs in various countries is significantly different. Iran is among the countries with a high age-standardized prevalence of CVDs, especially myocardial infarction, which is deemed an important priority by the country's health system.[3]

To estimate CVD risk over a period of 5 or 10 years, epidemiologists measure absolute, relative, lifetime, and repeated risks.[4] There are over 100 models to assess the risk of CVDs.[5] The most common and validated models include the Framingham Risk Score (FRS) model, the World Health Organization/International Society of Hypertension (WHO/ISH) chart, the Systematic Coronary Risk Evaluation (SCORE) model, and the American College of Cardiology/ American Heart Association (ACC/AHA) Pooled Cohort Equation.[6]

The purpose of the evaluation of CVD risk is to help provide documentation for implementing a second-level prevention plan, in conjunction with screening and identifying high-risk individuals, by a country's health system. The planners can evaluate the risk factors in the population by assessing the risk of CVDs and the cost-effectiveness of interventions to reduce the risk of their development.[7] The risk assessment model for CVDs has not yet been nativized to the Iranian population and, as a result, reliable Western models are employed in the country. In addition, for better and more accurate planning for population-based prevention plans, managers and health authorities need to have a proper view of the status of the risk factors and the future of CVDs in the community.

Therefore, utilizing the FRS model, the WHO/ISH chart, and the SCORE model, we strove to provide a basis for scientific evidence-based documentation of CVD risk over the next 10 years in the cohort urban community of the Iranian province of Chaharmahal and Bakhtiari.

## *Methods*

In the present population-based, cross-sectional study, demographic, anthropometric, clinical, and laboratory data of the Shahrekord Cohort Study (SCS) in the southwest of Iran were used. The SCS, a high-quality and population-based study, was designed as one of the centers of the Prospective Epidemiological Research Studies in IrAN (PERSIAN) Cohort. The protocol of this study has been previously published.[8, 9] In the current study, 5152 patients, comprised of 2558(49.7%) men and 2594 (50.3%) women, were recruited from the SCS by census method from September 2016 to October 2017. In the SCS, the data were collected by observation, interviews, and measuring variables by trained interviewers after informed consent to participate in the study was obtained from the participants. Blood biochemical variables including fasting blood sugar, triglyceride, cholesterol, low-density lipoprotein (LDL), and high-density lipoprotein (HDL) were measured by specific laboratory experts of the SCS using calibrated and standardized equipment.[8, 9]

In the present study, after the raw data were provided, the following steps were carried out: programming was performed in R software to calculate the risk according to the WHO/ISH chart and the 10-year risk of CVDs according to the FRS and SCORE models.

The model presented by the WHO/ISH includes charts for assessing the overall risk of CVDs and for delivering relevant screening and prevention services. In this model, the 10-year assessment of CVD risk is accomplished in the age group of 40 to 79 years in 14 regions. This model uses the variables of gender, age, smoking, diabetes, total cholesterol, and the systolic blood pressure to calculate the risk. The charts of this model are used to estimate the approximate risk of CVDs. By identifying individuals at high risk of CVDs, healthcare staff can also recommend certain interventions such as antihypertensive medications, hypolipidemic drugs, and aspirin, as well as behavioral changes. In this model, if a person has diabetes, the diabetes table is used. Subsequent calculations are gender-based. Then, the risk level is calculated given the individual's smoking status and age. Blood pressure (mmHg) and blood cholesterol (mmol/L) are used to measure the risk. The charts of this model contain colorful squares to represent the level of risk. The proposed activities in this model are provided for each risk level for each of the groups at risk for CVDs. In this model, individuals are classified into low-risk (<10%), moderate-risk (10–19%), relatively high-risk (20–29%), high-risk (30–39%), and very high-risk (≥40%).[10]

The FRS model is a guideline to assess the risk of CVDs in North America with the primary aim of prevention. This model, which evaluates the 10-year CVD risk in the age group of 30 to 75 years, was obtained from and introduced by the Framingham prospective cohort study. The FRS model performs a multivariable function. This model combines data on smoking, HDL, and CVD risk factors such as gender, age, total cholesterol, diabetes development status, and the systolic blood pressure to calculate cardiovascular risk in a specific period (eg, 10 y). Based on the FRS model, individuals are divided into 3 groups of high-, moderate-, and low-risk. Group 1 consists of persons at over 20% risk of developing CVDs (high-risk), group 2 at 10 to 20% of developing CVDs (moderate-risk), and group 3 at less than 10% of developing CVDs (low-risk) over the next 10 years.[11]

The SCORE model is a guide for the assessment of cardiovascular mortality risk in Europe for the prevention of CVDs. It evaluates the 10-year risk of cardiovascular death in the age group of 49 to 65 years. To use this model, investigators need gender, age, smoking status, total

cholesterol or the total cholesterol/HDL cholesterol ratio, and the systolic blood pressure. The SCORE model can be separately used for high-risk and low-risk countries.[12] Risk calculation first requires the selection of high- or low-risk areas. Thereafter, based on the gender of a person (male or female) that smokes and does not consume, considering the age group and the inclusion of the systolic blood pressure (mm Hg) and the total cholesterol level (mmol/L), there is a 10-year cardiovascular risk. The scoring system is divided into 3 groups of high-risk (>10%), moderate-risk (5–9%), and low-risk (0–4%).

The $\chi^2$ test was used to compare the qualitative variables and the t-test to compare the blood biochemical variables. The data were analyzed based on gender. The correlation and degree of agreement between the studied risk assessment models were calculated using the Spearman and Kendall correlation coefficients. A P value of less than 0.5 was considered statistically significant. The data were analyzed using Stata software, version14, and R software.

## Results

The mean age of the participants was 49.49±9.40 years. The mean levels of fasting blood sugar, cholesterol, LDL, and HDL were higher in women than in men. Blood glucose, cholesterol, and LDL did not differ significantly between men and women, but the triglyceride and HDL levels were significantly different between men and women, such that the mean HDL level was higher in women and the mean triglyceride level was higher in men. The descriptive data on blood biochemical variables are presented in Table 1. Apropos the frequency and prevalence of cardiovascular risk factors, high systolic blood pressure was reported in 1526 (29.6%) persons, high diastolic blood pressure in 1324 (25.7%), high cholesterol in 558 (10.8%), overweight in 2439 (47.3%), obesity (degree I) in 1075 (20.9%), and smoking in 848 (16.5%). The prevalence of CVD risk factors in terms of gender is presented in Table 2.

According to the WHO/ISH chart, 4847 (94.1%) persons were in the low-risk class, 210 (4.1%) in the moderate-risk class, and 21 (0.4%) in the high-risk class.

On the basis of the FRS model, 3718 (72.2%) persons were in the low-risk class, 927 (18.0%) in the middle-risk class, and 504 (9.8%) in the high-risk class.

Based on the SCORE model for low-risk areas, 2848 (55.3%) persons were in the low-risk class, 2042 (39.6%) in the moderate-risk class, and 262 (5.1%) in the high-risk class. As was demonstrated by the SCORE chart for high-risk areas, 2170 (42.1%) persons were in the low-risk class, 2367 (45.9%) in the moderate-risk class, and 615 (11.9%) in the high-risk class.

A significant difference was observed in the 10-year risk assessment of CVDs between men and women based on

Table 1. Biochemical characteristics of the participants (n=5152)*

| Total Population | Variable | Gender | | P |
|---|---|---|---|---|
| | | Male | Female | |
| FBS (mg/dL) | 102.41±25.88 | 102.95±25.46 | 101.85±26.30 | 0.126 |
| Chol (mg/dL) | 190.02±42.98 | 191.01±44.48 | 189.03±41.39 | 0.097 |
| TG (mg/dL) | 167.35±100.15 | 164.25±108.42 | 170.48±90.90 | <0.001 |
| HDL (mg/dL) | 52.99±14.02 | 54.39±15.98 | 51.58±11.52 | <0.001 |
| LDL (mg/dL) | 103.58±32.75 | 104.06±32.64 | 103.10±32.86 | 0.153 |

*Date are presented as mean±SD
FBS, Fasting blood sugar; Chol, Cholesterol; TG, Triglyceride; HDL, High-density lipoprotein; LDL, Low-density lipoprotein

Table 2. Cardiovascular risk factors in the participants (N=5152)*

| Total Population | Frequency | Gender | | P |
|---|---|---|---|---|
| | | Male | Female | |
| High Systolic Blood Pressure | 29.6 (1526) | 35.8 (930) | 596 (23.2) | <0.001 |
| High Diastolic Blood Pressure | 25.7 (1324) | 30.7 (797) | 527 (20.6) | <0.001 |
| High FBS | 8.2 (425) | 7.4 (190) | 235 (9.1) | 0.038 |
| High LDL | 9.3 (484) | 9.3 (243) | 9.4 (241) | 0.609 |
| Low HDL | - | 41.9 (2155) | 11.4 (588) | <0.001 |
| High Cholesterol | 10.8 (558) | 10.6 (274) | 9.6 (248) | 0.328 |
| High Triglyceride | 27.1 (1395) | 29.1 (755) | 25.0 (640) | <0.001 |
| Overweight | 47.3 (2439) | 50.4 (1308) | 44.2 (1131) | <0.001 |
| Obesity Grade I | 20.9 (1075) | 15.9 (415) | 25.8 (660) | <0.001 |
| Obesity Grade II | 5.1 (262) | 2.1 (53) | 8.1 (209) | <0.001 |
| Obesity Grade III | 1.3 (65) | 0.5 (12) | 2.0 (53) | <0.001 |
| Smoking | 16.5 (848) | 32.2 (837) | 0.4 (11) | <0.001 |

*Data are presented as n (%)
FBS, Fasting blood sugar; LDL, Low-density lipoprotein; HDL, High-density lipoprotein

Table 3. Estimation of the 10-year risk of cardiovascular diseases using the SCORE, WHO/ISH, and FRS models in the Shahrekord Cohort Study*

| Models | Frequency | Gender | | P |
|---|---|---|---|---|
| | | Male | Female | |
| WHO | | | | <0.001 |
| Low | 4847 (94.1) | 2376 (92.9) | 2471 (95.3) | |
| Intermediate | 210 (4.1) | 123 (4.8) | 87 (3.4) | |
| Relatively High | 57 (1.1) | 35 (1.4) | 22 (0.8) | |
| High | 17 (0.3) | 12 (0.5) | 5 (0.2) | |
| Very High | 21 (0.4) | 12 (0.5) | 9 (0.3) | |
| FRS | | | | <0.001 |
| Low | 3718 (72.2) | 1464 (57.2) | 2254 (86.9) | |
| Intermediate | 927 (18.0) | 679 (26.5) | 248 (9.6) | |
| High | 504 (9.8) | 415 (16.2) | 89 (3.4) | |
| Low SCORE | | | | <0.001 |
| Low | 2848 (55.3) | 952 (37.2) | 1896 (73.1) | |
| Intermediate | 2042 (39.6) | 1368 (53.5) | 674 (26) | |
| High | 262 (5.1) | 238 (9.3) | 24 (0.9) | |
| High SCORE | | | | <0.001 |
| Low | 2170 (42.1) | 508 (19.9) | 1662 (64.1) | |
| Intermediate | 2367 (45.9) | 1490 (58.2) | 887 (33.8) | |
| High | 615 (11.9) | 560 (21.9) | 55 (2.1) | |

*Data are presented as n (%)
SCORE, Systematic Coronary Risk Evaluation; WHO, World Health Organization; ISH, International Society of Hypertension; FRS, Framingham Risk Score

Table 4. Correlation coefficients between the models for the risk assessment of cardiovascular diseases*

| Model | FRS | Low SCORE | High SCORE | WHO/ISH |
|---|---|---|---|---|
| FRS | - | 0.84 (<0.001) | 0.89 (<0.001) | 0.37 (<0.001) |
| Low SCORE | 0.84 (<0.001) | - | 0.90 (<0.001) | 0.40 (<0.001) |
| High SCORE | 0.89 (<0.001) | 0.90 (<0.001) | - | 0.37 (<0.001) |
| WHO/ISH | 0.37 (<0.001) | 0.40 (<0.001) | 0.37 (<0.001) | - |

*Date are presented as correlation coefficients (p values)
FRS, Framingham Risk Score; SCORE, Systematic Coronary Risk Evaluation; WHO, World Health Organization; ISH, International Society of Hypertension

the WHO/ISH chart, the SCORE model for low-risk and high-risk areas, and the FRS model. The highest estimated risk of CVDs in the middle-aged population was obtained by the WHO/ISH chart in the low-risk group (99.3%). The highest risk of CVDs in the elderly for low-risk areas was obtained by the SCORE model in the moderate-risk population (72.9%). Significant differences were observed in the 10-year risk for CVDs between elderly and middle-aged individuals according to the WHO/ISH chart, the SCORE model for low- and high-risk areas, and the FRS model. The 10-year risk of CVDs estimated for the studied population is presented in Table 3.

The Spearman correlation coefficient between the 3 models of the assessment of CVD risk was significant, signifying a good correlation between these risk-estimation models. In this study, the greatest correlation was obtained between the SCORE model for low- and high-risk areas and the lowest correlation between the WHO/ISH chart and the FRS model. The Kendall correlation coefficient between the reported risk rates was significant (69.7%), indicating a relatively good correlation between the studied models (Table 4).

## *Discussion*

The current study aimed to investigate the prevalence of the risk factors and 10-year risk assessment of CVDs based on the FRS, WHO/ISH, and SCORE models in the study population of the SCS on health and noncommunicable diseases in Iran.

Possible explanations for the differences in the prevalence of risk factors between our study and the cited studies are gender-sensitive differences in lifestyle in Iran and genetic factors. Dissimilarities in social determinants of health constitute another reason for inconsistency between the results of the current investigation and the previously reported ones. By way of example, in a study by Schargrodsky et al.[13] in Latin America, the prevalence rates of hypertension, hypercholesteremia, diabetes, metabolic syndrome (MetS), obesity, and smoking were 18%, 14%, 7%, 20%, 23%, and 30%, respectively. By comparison, the prevalence of hypertension is higher but the prevalence of smoking, high cholesterol, and obesity is lower in the current study.

Chia et al.[14] conducted an investigation in Asia from 1998

to 2007 and reported prevalence rates of smoking (6.1%), diabetes (43.3%), blood pressure (59.7%), and smoking which are lower than those in the present study. The prevalence of some risk factors in the study by Selvarajah et al.[15] in Asia in 2006 is higher than that in our investigation. In the study of Gutierrez et al.[16] in 2016 in Saudi Arabia, the prevalence of obesity and overweight is higher than that in our study. In the study of Awad et al.[17] in Kuwait in 2014, the prevalence rates of smoking, obesity, and hypercholesterolemia are higher than the figures that we obtained in the present study. In the study of Mazaherinejad et al.[18] in Iran from 2014 to 2015, the prevalence of overweight and high LDL is higher but the prevalence of high cholesterol is lower than our findings. In the study of Beigi Davarani et al.[19] in Kerman in 2015, the prevalence of overweight is low by comparison with that in our investigation.

The points to bear in mind when comparing the results of previous studies and ours are that we recruited a larger sample volume, included more reliable risk factors, utilized a relatively better methodology to measure biochemical factors with high-quality tools, and had higher precision and lower random error.

Conducting a systematic search into databases, we found similar studies in middle-income countries including Nigeria, Iran, China, Pakistan, Georgia, Nepal, Cuba, Sri Lanka, and Bangladesh.[20-26] Our study in southwestern Iran is the first of its kind to report a 10-year risk estimate using 3 models. Given the different risk estimates for CVDs by different models among countries and even within countries, it is essential to nativize a valid risk function for each population, including ethnicity and geographical characteristics, in Iran and other countries. Different populations, lifestyles, social determinants of health, and type of study can explain some inconsistencies in research findings.

In a study by Khanal et al.[22] in Nepal in 2014, age, education, and occupation were significantly associated with an increase in CVD incidence. In their investigation, similar to our study, the majority of the participants were at low risk; nonetheless, the percentage of the persons in the low-risk class (7.7%) in our study is lower, whereas the percentage of persons in the high-risk class is significantly higher (by approximately 4%) in the study by Khanal and colleagues. This work is also another reason for the difference in the outcome of the application of the WHO/ISH chart in different populations and highlights the need for the nativization of models in different populations. However, there are limitations to these models. For instance, the FRS model may overestimate or underestimate the risk in some populations and concentrates on cardiac infarction and coronary artery disease without addressing the family history; additionally, the 10-year period is also somewhat short for the model. One of the most important limitations of the SCORE model is its non-inclusion of triglycerides and fibrinogen, as well as a family history of CVDs.[20]

According to the FRS categorization, the predictive value of low, intermediate, and high CVD risk in patients with MetS in Iran was 77.5%, 16.3%, and 6.3%, respectively.[27]

Yousefzadeh et al.28 performed a study on patients with MetS and individuals without the syndrome in Kerman in 2014 and reported that 74.3% of the patients with MetS were low-risk, 18.1% were intermediate-risk, and 7.6% were high-risk for 10-year CVDs. Additionally, the 10-year risk for CVDs according to the FRS model was significantly lower in those without MetS insofar as 86.4% of them were low-risk, 12.3% were intermediate-risk, and only 1.3% were high-risk for cardiovascular disorders. These figures are lower than what we obtained in the current investigation.

Based on the FRS model, our study reported a high percentage of high-risk population compared with the studies of Jahangiry et al.[27] and Yousefzadeh et al.[28] Be that as it may, our study recruited the general population, whereas the aforementioned authors enrolled patients with MetS, who are generally expected to be at higher risk than are the general population. Contrary to our study, where the proportion of the high-risk population was 9.8%, the proportion of the high-risk population was 6.3% in the study of Jahangiry and colleagues and 1.3% in the study of Yousefzadeh and coworkers. Jahangiry and coworkers included persons with 6 input FRS risk factors commonly found in patients with MetS, whose prevalence was low at the time of 10-year risk calculations. In other words, the prevalence of risk factors is greater in the population of the SCS than in the population studied in the Iranian city of Tabriz.

The estimated low and intermediate 10-year risk fraction in the population of the SCS is greater than the population studied in Kerman.[28] The varied proportions may be due to the different tools used and also the differences in genetic predisposition, lifestyle patterns, and nutritional behaviors.28

In the studied population (ie, individuals over 30 years), 77.8%, 13.4%, and 8.8% were found to be at low, intermediate, and high risk of CVDs, correspondingly. Compared with a similar study in a 40- to 65-year-old population from Asia (based on the National Health Measurement Study [NHMS] information, 2006), 48%, 29%, and 23% of the individuals were reported to be at low, intermediate, and high risk of CVDs, respectively.15 Based on a study using the data from the surveillance system on risk factors for noncommunicable diseases (The WHO STEPwise approach to Surveillance [STEPS]) in the 25- to 64-year-old population of Iran in 2011, 51.6%, 25.8%, and 22.6% faced low, intermediate, and high risk of CVDs, respectively.[29] According to another investigation using data from a cross-sectional population-based study performed in 2015 on 2976 adults living in the Iranian city of Mashhad, 82.9%, 10.1%, and 6.8% of the study participants were found to be at low, intermediate, and high risk of CVDs, respectively.[30]

The percentages of the subjects at intermediate and high risks of CVDs are higher in the study of Amiri et al.[29] and

STEPS than in the present study. Given the fact that the present study differs in terms of time and age range, this could indicate a lower frequency of risk factors among our participants and differences in lifestyles.[29, 30] In line with our study, most of the participants were in the low-risk class, and the percentages of individuals in all classes were almost similar to our findings. Still, in our risk assessment in the high-risk group, the risk is lower than that in a previous study in another population in Iran.[23] The mentioned study also posited that even the application of the WHO/ISH chart could lead to a different estimate in different populations in the same country and, therefore, recommended that models become appropriate for and nativized to each population. Put another way, that study concluded that the use of a model for the entire population of a country might be inappropriate.[23]

The underestimation of the SCORE model compared with the FRS model in our study is related to the objective of the SCORE model, which covers only fatal cardiovascular events to predict the 10-year risk of CVDs, while the FRS model incorporates both fatal and nonfatal events. Other studies have also shown that the FRS model usually estimates a higher risk for each individual than does the SCORE model.[22] Although the SCORE model yields lower risk estimates than do the other tools, it should be noted that these equations predict only fatal CVDs. As a result, an estimation of risk using these equations should approximately be multiplied by 3 and 4 (3 in men, 4 in women, and slightly lower in the elderly) to obtain an equivalent risk to the ACC/AHA or FRS approaches. A cohort study performed in the northern Iranian city of Amol reported data on 3086 subjects aged between 40 and 74 years. According to the results,[31] the percentage of persons at high risk in the FRS model was 8.8% in men and 2.1% in women, which is in agreement with the findings of our study.

In an investigation conducted in the Iranian city of Isfahan, Alaei Faradonbeh et al.[32] reported that the proportion of low, intermediate-, and high-risk patients with diabetes mellitus according to the FRS model was 30.4%, 40.9%, and 28.7%, respectively. In our study, the 10-year risk according to the 3 models in the moderate- and high-risk classes was higher in men than in women and higher than the figure obtained in the study by Alaei Faradonbeh and colleagues. This inconsistency could be related to the target population, place and time of the study, the effects of sex hormones, and the protective role of the female gender against CVDs. In addition, different gender-sensitive lifestyles in Iran and genetics lead to notable differences. The present findings appear to be consistent with those reported by Khalili et al.,[33] who found that the FRS model was able to differentiate between low- and high-risk individuals but was not applicable to clinical settings at high cut points (eg, 20%), which are considered for more aggressive risk factor modification. Khalili and colleagues posited that gender played an essential role in predicting risk in Tehran based on the FRS model. According to the authors, in both genders, the usefulness of the FRS model was as good as the function derived directly from Tehran data with the same variables; however, it could be useful in low thresholds for treatment. The 10-year CVD risk assessment by using well-known models for the assessment of the global risk of CVDs, including the FRS and SCORE models, is widely used across the world and recommended for all adult populations. Nevertheless, this recommendation may suffer from certain limitations. As was stated above, not only is the FRS model liable to overestimate or underestimate the risk in some populations but also it focuses primarily on cardiac infarction and coronary artery disease without considering the family history; what is more, the 10-year period is also relatively short for the model. One of the most important shortcomings of the SCORE model is its non-inclusion of triglyceride and fibrinogen levels and a family history of CVDs. The WHO/ISH chart is recommended for risk classification in countries with limited resources, but it underestimates the risk in comparison with the other risk scores. The heterogeneity of a population, along with cardiovascular risk factors, may cause underestimation of the risk by the WHO/ISH chart. The graphs from the WHO/ISH chart have not been derived from prospective cohort studies but from hypothetical data from each region based on the prevalence of the risk factors in that region. This can be because this chart is not consistent with the FRS and SCORE models. Additionally, the WHO/ISH chart has low sensitivity and underestimates the 10-year risk in comparison with the SCORE and FRS models in moderate- and high-risk populations. The respective outcomes of the SCORE model, the WHO/ISH chart, and the FRS model are cardiovascular mortality, hard CVDs, and total CVDs. Thus, caution should be exercised when comparing the risks derived from these models. In the present study, the Spearman correlation coefficient between the 3 models of CVD risk assessment was significant, which indicates a good correlation between the models with respect to risk estimation. We found the highest correlation between the SCORE model for low- and high-risk areas and the least correlation between the WHO/ISH chart and the FRS model. The Kendall correlation coefficient between the reported risk rates was significant (69.7%), signifying a good correlation between the models. In all 3 models, the highest risk level was estimated in the low-risk group, but in the SCORE model for high-risk areas, the highest risk was estimated in the moderate-risk class. We observed the highest correlation between the SCORE model for low- and high-risk areas and the lowest correlation between the WHO/ISH and FRS models. The correlation and agreement between the risk-estimation models was approximately 70%.

The salient limitation of the present investigation is that our recruitment of the study sample from an urban population precludes the generalization of the results to rural areas. Additionally, the fact that we extended the risk models of other countries to a sample of the Iranian population is

another weakness of note.

## Conclusion

The highest correlation was found between the SCORE model for low- and high-risk areas and the lowest correlation between the WHO/ISH chart and the FRS model. The consequences of cardiovascular risk can serve as a screening tool to detect high-risk individuals and monitor trends over time. The risk factors for CVDs can also be used as a screening tool for detecting high-risk individuals and monitoring trends over time. Given the diversity of risk estimates from cardiovascular risk assessment models, we suggest that feasible and economical models be employed. Because the prevalence of CVDs and resultant mortality in the Iranian province of Chaharmahal and Bakhtiari (our study sitting) are high, the WHO/ISH chart is not suitable for this population. In light of the results of numerous prospective cohort studies in Iran, we recommend that the models be further studied in each of the Iranian subpopulations with different ethnicities and in different geographical regions. The effectiveness of the proposed models should be compared with the results of the current study in future studies.

## Acknowledgments

This work was obtained from the MS thesis of P. Samaniyan Bavarsad (first author) in Shahrekord University of Medical Sciences. We thank the staff of the Shahrekord Cohort Study (SCS). May thanks are also due to the School of Health, Modeling in Health Research Center, the Heart Department, and the Research and Technology Deputyship of Shahrekord University of Medical Sciences for their support of the research. This study was approved and funded by the Research and Technology Deputyship of Shahrekord University of Medical Sciences (No. 3166; Ethics code: IR.SKUMS.REC.1396.35).

## References

1. Ahmadi A, Soori H, Sajjadi H. Modeling of in hospital mortality determinants in myocardial infarction patients, with and without type 2 diabetes, undergoing pharmaco-invasive strategy: the first national report using two approaches in Iran. Diabetes Res Clin Pract 2015;2:216-222.
2. Ahmadi A, Soori H, Mehrabi Y, Etemad K, Khaledifar A. Epidemiological pattern of myocardial infarction and modelling risk factors relevant to in-hospital mortality: the first results from the Iranian myocardial infarction registry. Kardiol Pol 2015;6:451-457.
3. Ahmadi A, Soori H, Mehrabi Y, Etemad K. Spatial analysis of myocardial infarction in Iran: national report from the Iranian myocardial infarction registry. J Res Med Sci 2015;5:434-439.
4. Ruwanpathirana T, Owen A, Reid CM. Review on cardiovascular risk prediction. Cardiovasc Ther 2015;2:62-70.
5. Allan GM, Garrison S, McCormack J. Comparison of cardiovascular disease risk calculators. Curr Opin Lipidol 2014;4:254-265.
6. Goh LGH, Welborn TA, Dhaliwal SS. Independent external validation of cardiovascular disease mortality in women utilising Framingham and SCORE risk models: a mortality follow-up study. BMC Womens Health 2014;1:118-129.
7. Cooney MT, Cooney HC, Dudina A, Graham IM. Assessment of cardiovascular risk. Am J Epidemiol 2010;5:384-393.
8. Khaledifar A, Hashemzadeh M, Solati K, Poustchi H, Bollati V, Ahmadi A, Kheiri S, Banitalebi M, Sedehi M, Malekzadeh R. The protocol of a population-based prospective cohort study in southwest of Iran to analyze common non-communicable diseases: Shahrekord cohort study. BMC public health 2018;1:660-670.
9. Poustchi H, Eghtesad S, Kamangar F, Etemadi A, Keshtkar AA, Hekmatdoost A, Mohammadi Z, Mahmoudi Z, Shayanrad A, Roozafzai F. Prospective epidemiological research studies in Iran (the PERSIAN Cohort Study): rationale, objectives, and design. Am J Epidemiol 2018;187:647-55.
10. WHO/ISH risk prediction charts for 14 WHO epidemiological subregions. World Health Organization, Geneva 2007. https://www.who.int/cardiovascular_diseases/guidelines/Chart_predictions/en. (23 Jun 2019).
11. D'Agostino Sr RB, Pencina MJ, Massaro JM, Coady S. Cardiovascular disease risk assessment: insights from Framingham. Glob Heart 2013;1:11-23.
12. Versteylen MO, Joosen IA, Shaw LJ, Narula J, Hofstra L. Comparison of Framingham, PROCAM, SCORE, and Diamond Forrester to predict coronary atherosclerosis and cardiovascular events. J Nucl Cardiol 2011;5:904-915.
13. Schargrodsky H, Hernández-Hernández R, Champagne BM, Silva H, Vinueza R, Ayçaguer LCS, Touboul PJ, Boissonnet CP, Escobedo J, Pellegrini F . CARMELA: assessment of cardiovascular risk in seven Latin American cities. Am J Med 2008;1:58-65.
14. Chia YC, Gray SYW, Ching SM, Lim HM, Chinna K. Validation of the Framingham general cardiovascular risk score in a multiethnic Asian population: a retrospective cohort study. BMJ Open 2015;5:e007324.
15. Selvarajah S, Kaur G, Haniff J, Cheong KC, Hiong TG, van der Graaf Y, Bots M. Comparison of the Framingham Risk Score, SCORE and WHO/ISH cardiovascular risk prediction models in an Asian population. Int J Cardiol 2014;1:211-218.
16. Gutierrez J, Alloubani A, Mari M, Alzaatreh M. Cardiovascular disease risk factors: hypertension, diabetes mellitus and obesity among Tabuk Citizens in Saudi Arabia. Open Cardiovasc Med J 2018;4:41-49.
17. Awad A, Al-Nafisi H. Public knowledge of cardiovascular disease and its risk factors in Kuwait: a cross-sectional survey. BMC Public Health 2014;1:1131-1141.
18. Mazaherinejad A, Angorani H, Tamannaie Z, Parsa HM, Parsa HM. Prevalence of atherosclerotic cardiovascular risk factors among Iranian football referees 2014-2015. MJMS 2016;3:188-195.
19. Rezabeigi Davarani E, Iranpour A, Khanjani N, Mohseni M, Nazari Robati F. Cardiovascular diseases risk factors and the relationship between knowledge level and preventive behaviors for cardiovascular diseases among women in kerman. J Res Health Sci 2016;2:119-132.
20. Conroy RM, Pyörälä K, Fitzgerald Ae, Sans S, Menotti A, De Backer G, De Bacquer D, Ducimetiere P, Jousilahti P, Keil U . Estimation of ten-year risk of fatal cardiovascular disease in Europe: the SCORE project. Eur Heart J 2003;11:987-1003.
21. Fatema K, Zwar NA, Milton AH, Rahman B, Ali L. Application of two versions of the WHO/international society of hypertension absolute cardiovascular risk assessment tools in a rural Bangladeshi population. BMJ Open 2015;10:e008140.
22. Khanal MK, Ahmed MM, Moniruzzaman M, Banik PC, Dhungana R R, Bhandari P, Devkota S, Shayami A . Total cardiovascular risk for next 10 years among rural population of Nepal using WHO/ISH risk prediction chart. BMC Res Notes 2017;1:120-127.
23. Mendis S, Lindholm LH, Anderson SG, Alwan A, Koju R, On-

wubere B, Kayani AM, Abeysinghe N, Duneas A, Tabagari. Total cardiovascular risk approach to improve efficiency of cardiovascular prevention in resource constrain settings. J Clin Epidemiol 2011;12:1451-1462.
24. Ofori S, Dodiyi-Manuel S, Akpa MR. Comparison of 3 risk estimators to guide initiation of statin therapy for primary prevention of cardiovascular disease. J Clin Lipidol 2017;6:1441-1447.
25. 25. Otgontuya D, Oum S, Buckley BS, Bonita R. Assessment of total cardiovascular risk using WHO/ISH risk prediction charts in three low and middle income countries in Asia. BMC public Health 2013;1:539-551.
26. Van Der Heijden AA, Ortegon MM, Niessen LW, Nijpels G, Dekker JM. Prediction of coronary heart disease risk in a general, pre-diabetic, and diabetic population during 10 years of follow-up: accuracy of the Framingham, SCORE, and UKPDS risk functions: The Hoorn Study. Diabetes Care 2009;11:2094-2098.
27. Jahangiry L, Farhangi MA, Rezaei F. Framingham risk score for estimation of 10-years of cardiovascular diseases risk in patients with metabolic syndrome. J Health Popul Nutr 2017;1:36-42.
28. Yousefzadeh G, Shokoohi M, Najafipour H, Shadkamfarokhi M. Applying the Framingham risk score for prediction of metabolic syndrome: the Kerman coronary artery disease risk study, Iran. ARYA Atheroscler 2015;3:179-185.
29. Meysamie A, Salarvand F, Khorasanizadeh M, Ghalehtaki R, Eskian M, Ghodsi S, Ghalehtaki S, Abbasi M, Etemad K, Asgari F. Cardiovascular risk assessment by FRS and SCORE in Iranian adult population. J Diabetes Metab Disord 2017;10:35-43.
30. Amiri ZS, Khajedaluee M, Rezaii A, Dadgarmoghaddam M. The risk of cardiovascular events based on the Framingham criteria in adults living in Mashhad (Iran). Electron Physician 2018;8:7164-7173.
31. Motamed N, Rabiee B, Perumal D, Poustchi H, Miresmail S J H, Farahani B, Maadi M, Saeedian F S, Ajdarkosh H, Khonsari MR. Comparison of cardiovascular risk assessment tools and their guidelines in evaluation of 10-year CVD risk and preventive recommendations: A population based study. Int J Cardiol 2017;228:52-57.
32. Faradonbeh NA, Nikaeen F, Akbari M, Almasi N, Vakhshoori M. Cardiovascular disease risk prediction among Iranian patients with diabetes mellitus in Isfahan Province, Iran, in 2014, by using Framingham risk score, atherosclerotic cardiovascular disease risk score, and high-sensitive C-reactive protein. ARYA Atheroscler 2018;4:163-168.
33. Khalili D, Hadaegh F, Soori H, Steyerberg EW, Bozorgmanesh M, Azizi F. Clinical usefulness of the Framingham cardiovascular risk profile beyond its statistical performance: the Tehran Lipid and Glucose Study. Am J Epidemiol 2012;3:177-186.