Exercise Testing, Family History, and Subclinical Atherosclerosis Markers for Cardiovascular Risk Reclassification in Middle-Aged Women

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Abstract

Background: Cardiovascular diseases are the main cause of death in women and the accuracy of currently available risk scores is questionable.

Objective: To reclassify the risk estimated by the Framingham Risk Score (FRS) in asymptomatic middle-aged women by incorporating family history, exercise testing variables, and subclinical atherosclerosis markers.

Methods: This cross-sectional study included 509 women (age range, 46-65 years) without cardiovascular symptoms. Those at low or intermediate risk by the FRS were reclassified to a higher level considering premature family history of acute myocardial infarction and/or sudden death; four variables from exercise testing; and two variables related to subclinical atherosclerosis markers. The homogeneity of these variables according to the FRS was verified by Pearson chi-square test (p<0.05).

Results: According to the FRS, 80.2%, 6.2%, and 13.6% of the women were classified as low (<5%), intermediate (5-10%), and high (>10%) risks, respectively. The intermediate-risk stratum showed the highest increase (from 6.2% to 33.3%) with addition of family history; followed by addition of chronotropic index <80% (to 24.2%); functional capacity <85% (22.2%), coronary calcium score >0 (20.6%); decreased one-minute heart rate recovery ≤12 bpm (15.2%); carotid intima-media thickness >1 mm and/or carotid plaque (13.8%) and ST-segment depression (9.0%). The high-risk stratum increased to 14.4% with the addition of reduced heart rate recovery and to 17.1% with the coronary calcium score.

Conclusion: Incorporation of premature family history of cardiovascular events, exercise testing abnormal parameters, and subclinical atherosclerosis markers into the FRS led to risk reclassification in 3.0-29.7% of asymptomatic middle-aged women, mainly by an increase from low to intermediate risk.

Keywords: Exercise Test; Heredity; Atherosclerosis; Women; Middle Aged; Estrogens; Risk Factor; Obesity; Hypertension; Myocardial Infarction; Sudden death.

Introduction

In middle-aged women, estrogen deficiency and the high prevalence of traditional risk factors such as obesity, sedentary behavior and hypertension can cause significant changes in the cardiovascular risk profile.1,2 Although approximately 90% of these women are classified
as “low risk” based on the Framingham Risk Score (FRS), events such as acute myocardial infarction and sudden death are common in this group,\(^3,4\) suggesting that traditional cardiovascular risk scores may not be accurate.\(^3,5\) Thus, variables not included in the traditional scores, such as a premature family history of cardiovascular events,\(^3,4\) exercise testing variables,\(^4,5-10\) and subclinical atherosclerosis markers have been considered for risk reclassification in women.\(^8,9,11,12\) In addition, a history of infarction or death from cardiovascular disease in first-degree male relatives before 55 years of age and female relatives before 60 years of age has been considered in this regard.\(^1,10,13\) The prevalence of subclinical atherosclerosis is found to be high in women with a family history of cardiovascular events, even in those at low risk according to the FRS.\(^3,12\)

Among the markers of subclinical atherosclerosis, coronary calcium score has been of increasing interest, especially in asymptomatic individuals deemed to be at intermediate risk by the FRS,\(^3,14,15\) since it is able to detect coronary calcifications that correlate with disease extent and cardiovascular events.\(^16,17\) Another marker of subclinical atherosclerosis, carotid intima-media thickness (CIMT), assessed by ultrasonography, is associated with the presence and extent of disease in both men and women, and a predictor of myocardial infarction and stroke.\(^11,18,19\)

Exercise testing, a non-invasive functional method established in the field of cardiology, is not only of high diagnostic value, but also of prognostic value, including in asymptomatic women.\(^20-23\) In this sense, valuable information can be obtained regarding the prediction of cardiovascular risk when exercise parameters — functional capacity, chronotropic response, chronotropic index, heart rate (HR) recovery, and ventricular ectopy after exercise — are assessed.\(^24-30\)

Studies have demonstrated the prognostic role of imaging and functional tests, alone but especially in combination, to identify which women are at greatest risk for cardiovascular events.\(^31-33\) Thus, markers of subclinical atherosclerosis and exercise testing variables may contribute to the adoption of earlier and more effective preventive measures,\(^8,9,18,33,34\) especially in those initially classified as low or intermediate risk by the FRS.

In this context, the purpose of this study was to reclassify the risk estimated by the FRS in asymptomatic middle-aged women with the incorporation of a premature family history of cardiovascular events, exercise testing variables, and subclinical atherosclerosis markers.

### Materials and methods

#### Study design and participants

It was a cross-sectional study with women aged 46-65 years selected by convenience sampling at two women’s health outpatient clinics. The sample studied (n=509) was greater than the calculated sample size (n=384), obtained by the method recommended when the frequency of the event in an infinite population is unknown.\(^35\) For sample calculation, we used: estimated frequency in the population (proportion of women whose cardiovascular risk was assessed by the two methods) equal to 50%, using the maximum possible variability; 95% confidence interval; 5% margin of error; and infinite population size. The following exclusion criteria were adopted: history or clinical evidence of cardiovascular disease, except hypertension; diagnosis of liver or kidney disease; use of corticosteroids or hormone replacement therapy; pregnancy; use of intrauterine device; use of hormonal contraceptives for at least one year; and contraindication to exercise testing according to the III Brazilian Society of Cardiology Guideline for Exercise Testing.\(^20\)

#### Variables and data collection

Of all women participating in the study, the following data were collected — age, weight, height, smoking habit, history of diabetes and systemic arterial hypertension, use of HR-reducing medication, and history of parents and siblings (<60 years of age for female relatives and <55 years of age for male relatives) with acute myocardial infarction and/or sudden death. Measurement of blood pressure, serological tests (fasting glycemia, total cholesterol and fractions, triglycerides), exercise testing, carotid artery ultrasound (for determination of CIMT), and chest tomography (to determine the coronary calcium score) were performed.

The FRS was obtained from variables including age, total cholesterol and fractions, blood pressure, and smoking. The FRS was categorized into three strata of cardiovascular risk, low (<5%), intermediate (5-10%), and high (>10%), according to the American Heart Association\(^7\) and the Brazilian Society of Cardiology\(^8\) recommendations for female patients. All diabetic women were classified as “high risk”.

Exercise testing was performed by the principal investigator following the symptom-limited Bruce protocol\(^26\) (Inbramed® treadmill, using the ErgoPc® exercise testing program and a Unitec® mercury manometer). Interpretation of the exercise testing results...
was made according to the parameters established by the Brazilian Society of Cardiology. For calculation of the exercise testing variables considered predictors of mortality, the following formulae were used: (a) Functional capacity = (maximum VO$_2$ reached × 100)/VO$_2$ predicted considering the predicted VO$_2$ = 14.7 × (0.13 × age); (b) chronotropic index = (maximum HR - resting HR) × 100/(predicted HR - resting HR). The predicted HR was considered as (220 - age) as recommended by Karmonen et al., and (c) decrease in HR recovery at 1 minute = maximum HR - HR recovery at 1 minute.

CIMT was measured by carotid artery ultrasound (12-3-MHz EnVisor Ultrasound System; Philips Ultrasound, Bothell, WA, USA) by the same technician. The average of maximum CIMT was obtained from the right and left carotid segments. CIMT values >1 mm and the presence of atheroma plaque in the carotid artery were used as indicators of subclinical carotid atherosclerosis. Carotid plaque was defined as the presence of focal wall thickening at least 50% greater than the wall thickness of the surrounding vessel or as a focal region with an intima-media thickness >1.5 mm projecting to the lumen distinct from the adjacent contour.

For coronary calcium score, non-contrast chest computed tomography with low effective radiation dose (1.7-2.5 mSv) was performed by multi-channel detector computed tomography (Philips Brilliance CT-10; Philips, Amsterdam, The Netherlands). Images were prospectively obtained using the single 20-second acquisitions of deep-inspiration breath-hold technique and synchronized with electrocardiogram to obtain 3-mm cuts from the level of the carina to the level of the diaphragm. Coronary calcification was defined as a plaque of at least three consecutive pixels (area = 1.03 mm$^2$) with density ≥130 Hounsfield units (HU). The coronary calcium score was calculated according to the method described by Agatston, i.e., multiplying the area of calcification in square millimeters by a factor of 1, 2, 3, or 4 depending on attenuation coefficients determined by calcium. Factor 1 was used when the coefficients were 130-199 HU; factor 2, 200-299 HU; factor 3, 300-399 HU; and factor 4, >400 HU.

**Statistical analysis**

Continuous variables are presented as mean and standard deviation, and categorical variables as absolute and relative frequencies. Homogeneity of the variables used for cardiovascular risk reclassification was verified by the Pearson chi-square test ($p < 0.05$).

Women classified as “low” or “intermediate” cardiovascular risk based on the FRS were reclassified to “high” risk if they had one or more of the following parameters: (a) premature family history of acute myocardial infarction and/or sudden death; (b) chronotropic index <80% or <62% if using HR-lowering medication; (c) functional capacity <85%; (d) decrease in HR recovery at 1 minute ≤12 bpm; (e) ST-segment depression; (f) CIMT >1 mm and/or presence of carotid plaque; or (g) coronary calcium score >0.

With the incorporation of premature family history of cardiovascular events, exercise test variables, and atherosclerosis markers into the FRS, the increase in cardiovascular risk corresponded to the proportion of participants who were reclassified to a higher risk level. The database was built in the Microsoft Office Access program and analysis was performed using the SPSS program (version 21.0).

**Results**

More than one-third of the middle-aged women participating in the study (mean age, 56.4 ± 4.8 years; body mass index, 27.8 ± 4.9 kg/m$^2$) had systemic arterial hypertension, dyslipidemia, and obesity (Table 1). Among them, 11.2% were diabetic and 7.7% reported smoking. Approximately 11.0% were using HR-reducing medication to control systemic arterial hypertension. In the exercise testing (Table 1), mean values of maximal HR, exercise time, and VO$_2$ were adequate for test interpretation.

Among the variables incorporated into the FRS for cardiovascular risk reclassification (Table 2), premature family history of acute myocardial infarction and/or sudden death was the most frequent (more than one-third of participants), followed by chronotropic index, with almost one-third of participants with values below 80% or 62% (in users of HR-lowering drugs). The lowest frequency was related to ST-segment depression, observed in 22 women (4.4%), of whom only 11 (2.2% of the total sample) had a horizontal or descending pattern (>1 mm), suggestive of myocardial ischemia. According to the FRS strata, differences ($p<0.05$) were observed only in the distribution of the chronotropic index and carotid calcium score.

As shown in Figure 1, about 6% of the women were classified as intermediate risk by the FRS. After the variables of interest were added, the percentage of women at this stratum increased, with the highest increment (to 33.3%) after the addition of premature family history of cardiovascular events, followed by low chronotropic index (24.2%) and impairment in functional capacity (22.2%) (Figure 1).
Regarding the percentage of women at high risk based on the FRS (13.6% of the women), after reclassification, it increased to 14.4% with the addition of one-minute HR recovery ≤12 bpm and to 17.1% with the addition of a calcium score >0. The percentage of women at low risk based on the FRS (80.2%) decreased due to the migration of women to the strata of higher risk, from 80.2% to 50.6% when considering a premature family history of a cardiovascular event, and to 77.2% when considering the ST-segment depression. The total increase in risk (low to intermediate and intermediate to high) ranged from 3.0% (ST-segment depression) to 29.7% (premature family history of cardiovascular event). For all variables considered, the highest increment occurred in the intermediate-risk stratum.

**Discussion**

This study demonstrated that adding the variables premature family history of cardiovascular events, exercise test parameters, and markers of subclinical

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value (n = 509)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age group [n (%)], years</td>
<td></td>
</tr>
<tr>
<td>46-55</td>
<td>231 (46.1%)</td>
</tr>
<tr>
<td>56-60</td>
<td>147 (29.3%)</td>
</tr>
<tr>
<td>61-65</td>
<td>123 (24.6%)</td>
</tr>
<tr>
<td>Age (mean ± SD), years</td>
<td>56.4 ± 4.8</td>
</tr>
<tr>
<td>BMI (mean ± SD), kg/m²</td>
<td>27.8 ± 4.9</td>
</tr>
<tr>
<td>Obesity [n (%)]</td>
<td>158 (31.1%)</td>
</tr>
<tr>
<td>Diabetes [n (%)]</td>
<td>57 (11.2%)</td>
</tr>
<tr>
<td>Systemic arterial hypertension [n (%)]</td>
<td>247 (48.5%)</td>
</tr>
<tr>
<td>Dyslipidemia [n (%)]</td>
<td>211 (41.5%)</td>
</tr>
<tr>
<td>Smoking [n (%)]</td>
<td>39 (7.7%)</td>
</tr>
<tr>
<td>Coronary calcium score (mean ± SD)</td>
<td>21.4 ± 89.7</td>
</tr>
<tr>
<td>CIMT (mean ± SD), mm</td>
<td>0.6 ± 0.1</td>
</tr>
<tr>
<td>HR-lowering medication [n (%)]</td>
<td>57 (11.2%)</td>
</tr>
<tr>
<td>Exercise testing</td>
<td></td>
</tr>
<tr>
<td>HR response (mean ± SD), bpm</td>
<td>74.4 ± 13.3</td>
</tr>
<tr>
<td>Maximum HR (mean ± SD), bpm</td>
<td>152.5 ± 19.6</td>
</tr>
<tr>
<td>HR recovery at 1 minute (mean ± SD), bpm</td>
<td>130.7 ± 19.3</td>
</tr>
<tr>
<td>Chronotropic index (mean ±SD), %</td>
<td>88.4 ± 20.8</td>
</tr>
<tr>
<td>Decreased HR recovery at 1 minute (mean ± SD), bpm</td>
<td>21.8 ± 9.1</td>
</tr>
<tr>
<td>Functional capacity (mean ± SD), %</td>
<td>104.1 ± 26.9</td>
</tr>
<tr>
<td>Exercise time, (mean ±SD), minutes</td>
<td>7.4 ± 2.1</td>
</tr>
<tr>
<td>VO₂ (mean ± SD), METs</td>
<td>7.6 ± 2.0</td>
</tr>
<tr>
<td>Arrhythmia [n (%)]</td>
<td>43 (9.9%)</td>
</tr>
</tbody>
</table>

**Table 1 – Characteristics of participants and exercise testing parameters**

BMI: body mass index; CIMT: carotid intima-media thickness; HR: heart rate; METs: metabolic equivalents; SD: standard deviation; VO₂: oxygen uptake
Atherosclerosis to the FRS provided a cardiovascular risk reclassification in asymptomatic, middle-aged women. Among the seven variables used, ST-segment depression contributed to the smallest increase (3%) in cardiovascular risk when added to the FRS, while other variables like premature family history of cardiovascular events (about 30%) and altered chronotropic index (about 21%) contributed to the largest increases.

Despite the recognized importance of the FRS, studies\(^3,27,29\) have drawn attention to the use of some variables for reclassification of the cardiovascular risk in middle-aged women, since although most of them are classified as low risk by the FRS, some are affected by acute myocardial infarction, even without previous symptoms. Thus, for women at low or intermediate risk based on the FRS, with one or more risk factors or

<table>
<thead>
<tr>
<th>Variable</th>
<th>Framingham Risk Score(^*)</th>
<th>(p)^†</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
<td>Intermediate</td>
</tr>
<tr>
<td></td>
<td>(N)</td>
<td>%</td>
</tr>
<tr>
<td>Premature family history of AMI and/or sudden death</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>146</td>
<td>37.0</td>
</tr>
<tr>
<td>Not</td>
<td>249</td>
<td>63.0</td>
</tr>
<tr>
<td>Chronotropic index</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Altered (&lt;62%/&lt;80%)</td>
<td>104</td>
<td>25.9</td>
</tr>
<tr>
<td>Normal</td>
<td>297</td>
<td>74.1</td>
</tr>
<tr>
<td>Decreased HR recovery at 1 minute</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Altered (&lt;12 bpm)</td>
<td>52</td>
<td>12.9</td>
</tr>
<tr>
<td>Normal</td>
<td>350</td>
<td>87.1</td>
</tr>
<tr>
<td>Functional capacity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Altered (&lt;85%)</td>
<td>90</td>
<td>22.4</td>
</tr>
<tr>
<td>Normal</td>
<td>312</td>
<td>77.6</td>
</tr>
<tr>
<td>ST-segment depression</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>15</td>
<td>3.7</td>
</tr>
<tr>
<td>Not</td>
<td>387</td>
<td>96.3</td>
</tr>
<tr>
<td>Coronary calcium score</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zero</td>
<td>264</td>
<td>76.5</td>
</tr>
<tr>
<td>1-99</td>
<td>68</td>
<td>19.7</td>
</tr>
<tr>
<td>≥ 100</td>
<td>13</td>
<td>3.8</td>
</tr>
<tr>
<td>CIMT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤ 1 mm and/or carotid plaque</td>
<td>360</td>
<td>89.6</td>
</tr>
</tbody>
</table>

AMI: acute myocardial infarction; HR: heart rate; CIMT: carotid intima-media thickness.

\(^*\)Framingham Risk Score: low (<5%), intermediate (5-10%), high (>10%); \(^\dagger\)p-value referring to the Pearson chi-square test; \(^\ddagger\)Chronotropic index <62% only in women using heart rate-lowering medication.

Note: Women with incomplete information were excluded from the analyses.

Table 2 – Prevalence of premature family history of cardiovascular events, exercise testing variables, and subclinical atherosclerosis markers in asymptomatic middle-aged women according to the Framingham Risk Score classification.
Figure 1 – Proportion of asymptomatic middle-aged women by Framingham Risk Score strata and by risk reclassification after addition of premature family history of cardiovascular event, exercise testing variables, and subclinical atherosclerosis markers

FRS: Framingham Risk Score; AMI: acute myocardial infarction; HR: heart rate; CIMT: carotid intima-media thickness.

*History of acute myocardial infarction (AMI) and/or sudden death in parents and/or siblings younger than 55 years (men) or 60 years (women);
†Chronotropic index <62% if using heart rate-lowering medication.

Figure 2 – Increase in cardiovascular risk by the addition of premature family history of cardiovascular events, exercise testing variables, and subclinical atherosclerosis markers to the Framingham Risk Score in asymptomatic middle-aged women

FRS: Framingham Risk Score; AMI: acute myocardial infarction; HR: heart rate; CIMT: carotid intima-media thickness

*FRS: Framingham Risk Score; †History of acute myocardial infarction (AMI) and/or sudden death in parents and/or siblings younger than 55 years (men) or 60 years (women); ‡Chronotropic index <62% if using heart rate-lowering medication.
a positive family history, the addition of other variables to the risk score may identify and benefit those most vulnerable to cardiovascular events.  

Several variables have been proposed for reclassification of cardiovascular risk estimated by the FRS, varying from simple clinical history to more complex methods that are expensive or require advanced technology, such as cardiac imaging tests. The variables analyzed in the present study were previously shown to be associated with severe outcomes, including death, acute myocardial infarction, and stroke. Five of the seven variables showed a homogeneous distribution between the FRS strata, which reinforces the possible benefit of their addition to this traditional risk score.  

A premature family history of cardiovascular events in parents and siblings has been independently associated with a higher incidence of cardiovascular events, even in women classified as low risk by the FRS. This is a class I variable in asymptomatic individuals obtained during the initial evaluation, regardless of other exams and at no additional cost.  

The predictive factors of mortality, although easily assessed in exercise testing, are not always considered important in the interpretation of the test results, including in asymptomatic women, and are not considered for primary prevention. As noted in this study, about one-fifth of asymptomatic middle-aged women would be more closely monitored for their cardiovascular risk if abnormalities in the chronotropic index or functional capacity were added to the FRS. A low functional capacity is potentially reversible by physical activity programs aimed to reduce cardiovascular risk. On the other hand, a good functional capacity is indicative of better prognosis, even in the presence of ischemia, elevated calcium score, or anatomical coronary disease. Also, the finding of a good functional capacity, can avoid the overvaluation of eventual ST-segment depression and the subsequent performance of unnecessary or even harmful exams.  

In relation to the coronary calcium score and CIMT, studies have shown that they add independent prognostic information to the FRS. In the present study, the increment in cardiovascular risk by the addition of CIMT >1 mm and/or carotid plaque to the FRS was lower than that observed with the addition of a carotid calcium score >0. However, access to both tests may be costly and not possible in clinical practice. In this case, we consider the CIMT due to the higher feasibility and lack of radiation exposure.  

Among the strengths of the study, our study population consisted of middle-aged women whose complaints may go unmonitored and uninvestigated, despite the increase in the prevalence and severity of cardiovascular diseases in this group. Middle-aged women have relatively low participation rates in clinical trials and scientific guidelines. In addition, we analyzed variables that are easily measured by exercise testing but not always valued in clinical practice. It should be emphasized that exercise testing is a widespread, low-cost method, that does not involve radiation, with proven accuracy in different populations, including asymptomatic women. In this study, exercise testing was symptom-limited, rather than by maximal HR, which could have underestimated functional capacity.  

In the present study, we evaluated whether the addition of certain variables to the FRS would improve risk classification in asymptomatic middle-aged women, and propose that premature family history of cardiovascular events should be the first factor to be evaluated by clinicians in women classified at low or intermediate risk based on the FRS. Then, after risk reclassification, these women would undergo exercise testing and carotid artery ultrasound for assessment of markers of subclinical atherosclerosis, including the CIMT, and calcium score testing. In each stage, stricter recommendations for periodic follow-up and primary prevention strategies are recommended to early identify those women at higher risk of cardiovascular events.  

This study was limited by its cross-sectional design, and the absence of monitoring the effect of adding family history, exercise testing parameters and subclinical atherosclerosis markers on cardiovascular outcomes of these women over time. However, the selection of variables for risk reclassification was based on cohort studies that evaluated severe outcomes such as death, acute myocardial infarction, and stroke. It is also worth noting that all variables used in the present study to reclassify cardiovascular risk in asymptomatic middle-aged women are currently recommended in national and international guidelines as factors for consideration in risk assessments.  

Conclusions  

In asymptomatic middle-aged women, the study revealed an increase of 3.0-29.7% in cardiovascular risk estimated by the FRS with the addition of premature family history of acute myocardial infarction and/or
sudden death, mortality predictive factors assessed by exercise testing, and subclinical atherosclerosis markers. This enabled risk reclassification of women classified as low or intermediate risk based on the FRS, and the possibility for a more effective control and reduction of the risk for cardiovascular events in this group of asymptomatic women.

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Author contributions

Conception and design of the research: Coutinho RQ, Montarroyos UR, Barros IML, Guimarães MJB, Costa LOBF, Ferreira MNL, Chalela WA, Pedrosa RP. Acquisition of data: Coutinho RQ, Barros IML, Leão APD, Medeiros AKL, Monteiro MF. Analysis and interpretation of the data: Coutinho RQ, Montarroyos UR, Guimarães MJB, Pedrosa RP. Statistical analysis: Montarroyos UR. Obtaining financing: Barros IML. Writing of the manuscript: Coutinho RQ, Montarroyos UR, Guimarães MJB, Pedrosa RP. Critical revision of the manuscript for intellectual content: Coutinho RQ, Montarroyos UR, Guimarães MJB, Ferreira MNL, Chalela WA, Pedrosa RP.

Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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Study Association

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Ethics approval and consent to participate

This study was approved by the Brazilian National Ethics Committee Registry, CAAE n. 0159.0.106.106-11. The research was conducted according to the principles of the Declaration of Helsinki (2013). Written informed consent was obtained from all participants included in the study, who were assured of adequate symptom control or changes in subclinical atherosclerosis markers, if required.

References


