

Original article

Validity Assessment of Low-risk SCORE Function and SCORE Function Calibrated to the Spanish Population in the FRESCO Cohorts



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ABSTRACT

Introduction and objectives: To assess the validity of the original low-risk SCORE function without and with high-density lipoprotein cholesterol and SCORE calibrated to the Spanish population.

Methods: Pooled analysis with individual data from 12 Spanish population-based cohort studies. We included 30 919 individuals aged 40 to 64 years with no history of cardiovascular disease at baseline, who were followed up for 10 years for the causes of death included in the SCORE project. The validity of the risk functions was analyzed with the area under the ROC curve (discrimination) and the Hosmer-Lemeshow test (calibration), respectively.

Results: Follow-up comprised 286 105 persons/y. Ten-year cardiovascular mortality was 0.6%. The ratio between estimated/observed cases ranged from 9.1, 6.5, and 9.1 in men and 3.3, 1.3, and 1.9 in women with original low-risk SCORE risk function without and with high-density lipoprotein cholesterol and calibrated SCORE, respectively; differences were statistically significant with the Hosmer-Lemeshow test between predicted and observed mortality with SCORE ($P < .001$ in both sexes and with all functions). The area under the ROC curve with the original SCORE was 0.68 in men and 0.69 in women.

Conclusions: All versions of the SCORE functions available in Spain significantly overestimate the cardiovascular mortality observed in the Spanish population. Despite the acceptable discrimination

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capacity, prediction of the number of fatal cardiovascular events (calibration) was significantly inaccurate.

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Evaluación de la validez de las funciones SCORE de bajo riesgo y calibrada para población española en las cohortes FRESCO

RESUMEN

Palabras clave:

Enfermedades cardiovasculares
Mortalidad cardiovascular
Funciones de riesgo
Ictus
Enfermedad coronaria
Prevención

Introducción y objetivos: Estudiar la validez de la función SCORE original de bajo riesgo sin y con colesterol unido a lipoproteínas de alta densidad y SCORE calibrada en población española.

Métodos: Análisis agrupado con datos individuales de 12 estudios de cohorte de base poblacional. Se incluyó a 30.919 participantes de 40-64 años sin enfermedades cardiovasculares en el momento del reclutamiento, que se siguieron durante 10 años para la mortalidad cardiovascular contemplada en el proyecto SCORE. La validez de las funciones se analizó mediante el área bajo la curva ROC (discriminación) y el test de Hosmer-Lemeshow (calibración), respectivamente.

Resultados: Se dispuso de 286.105 personas/año. La mortalidad a 10 años por causas cardiovasculares fue del 0,6%. La razón de casos esperados/observados fue de 9,1, 6,5 y 9,1 en varones y de 3,3, 1,3 y 1,9 en mujeres con las funciones SCORE original de bajo riesgo sin y con colesterol unido a lipoproteínas de alta densidad y SCORE calibrada, respectivamente; diferencias estadísticamente significativas con el test de calibración de Hosmer-Lemeshow entre la mortalidad predicha con SCORE y la observada ($p < 0,001$ en ambos sexos y en todas las funciones). Las áreas bajo la curva ROC con SCORE original fueron 0,68 en varones y 0,69 en mujeres.

Conclusiones: Todas las versiones de las funciones SCORE disponibles en España sobreestiman significativamente la mortalidad cardiovascular observada en la población española. A pesar de la aceptable capacidad de discriminación, la predicción del número de acontecimientos cardiovasculares mortales (calibración) fue significativamente imprecisa.

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Abbreviations

HDL-C: high-density lipoprotein cholesterol
SCORE-C: calibrated Systematic COronary Risk Evaluation
SCORE-LOW: original low-risk Systematic COronary Risk Evaluation
SCORE-LOW-HDL: original low-risk Systematic COronary Risk Evaluation with high-density lipoprotein cholesterol

INTRODUCTION

Any tool that helps to prevent cardiovascular diseases is welcome because these conditions are still the main cause of death in Spain, with little change in their incidence in the last 30 years.^{1,2} Primary prevention identifies populations at high risk of cardiovascular disease to enable at-risk individuals to be treated with intensive measures—both pharmacological and lifestyle—that reduce and delay the incidence of cardiovascular disease.³ Risk functions have been designed to estimate global coronary risk and have improved upon the simple individual approach of cardiovascular risk factors. These instruments were developed from cohort studies with follow-up durations of 10 or more years and enable estimation of the risk of coronary disease development during this period.⁴

The SCORE (Systematic COronary Risk Evaluation) function, recommended in the European and Spanish guidelines,^{3,5–7} calculates the 10-year risk of cardiovascular death. Developed using European cohorts, there is an original version differentiated for high-risk and low-risk countries (SCORE-LOW),⁵ another original version that includes the total cholesterol/high-density lipoprotein cholesterol ratio (SCORE-LOW-HDL), and a version calibrated for use in the Spanish population (SCORE-C).⁸ The latter

2 versions are available online at HeartScore.⁹ The performance of these 3 versions of the SCORE function have not been evaluated in a Spanish population cohort.

The aim of the present study was to analyze the validity of the 3 SCORE functions recommended in Spain by comparing their predictions with the 10-year rate of fatal cardiovascular disease observed in a general Spanish population cohort.

METHODS

Design and Participants

The present study involved pooled analysis of individual data from 12 population-based Spanish cohort studies performed from 1991 onward¹⁰ and with follow-up until 2005 aggregated in the FRESCO study¹¹ (Table 1 of the supplementary material). All cohort participants were randomly selected, were aged between 35 and 79 years, had no cardiovascular disease at the start of follow-up, and had signed an informed consent form. The FRESCO study was authorized by the Ethics Committee of the *Parc de Salut Mar*, Barcelona (2009/3391/I).

Measures

Age, sex, and the other risk factors considered in the SCORE functions (smoking, systolic blood pressure, total cholesterol, and high-density lipoprotein cholesterol [HDL-C]) were known for all cohorts and had been collected using the standardized methodology recommended by the World Health Organization.¹⁰ Participants were classified as smokers (if they were smoking at the time of examination or had quit smoking ≤ 1 year previously) or nonsmokers (exsmokers since > 1 year previously or never smoked). Systolic and diastolic blood pressure readings were determined via the mean of 2 determinations obtained at least 5 minutes apart. Analytical determinations were performed after

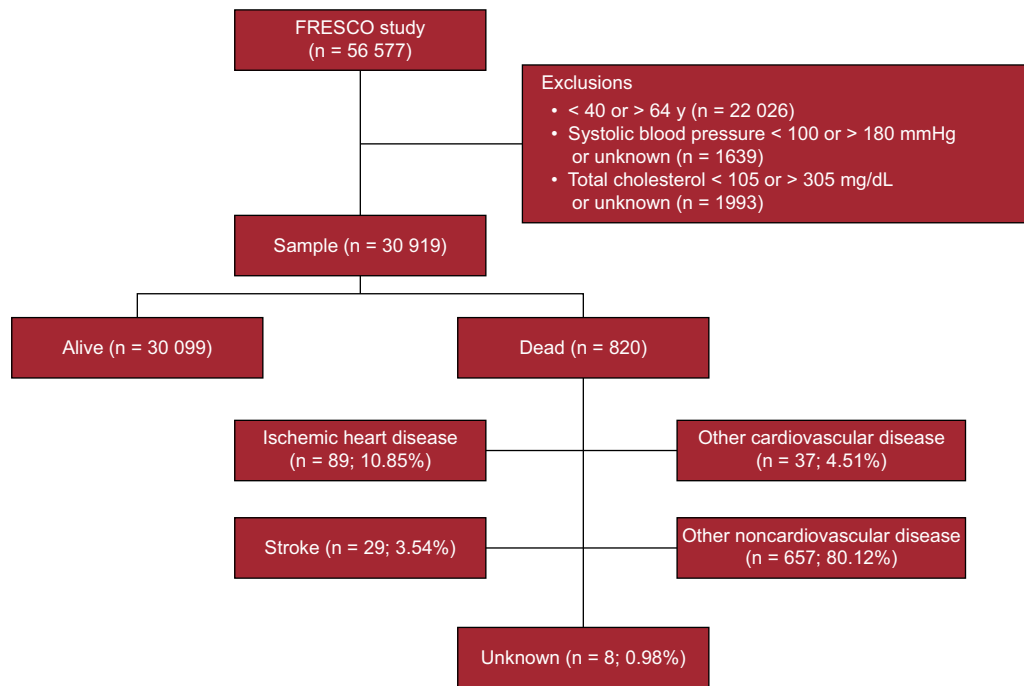


Figure 1. Flow diagram of participants in the FRESCO study.

participants fasted for 10 to 14 hours. Diabetes mellitus diagnosis was established from a previous diagnosis or a baseline blood glucose level > 125 mg/dL. In 9 of the 12 cohorts, a concordance study of total cholesterol and HDL-C was performed, with satisfactory results.¹² The present validation assessment specifically considered the population for whom the SCORE function was designed: age 40 to 64 years, systolic blood pressure \geq 100 and \leq 180 mmHg, and total cholesterol \geq 105 mg/dL (3 mmol/L) or \leq 305 mg/dL (8 mmol/L) (Figure 1).

Participant follow-up was at least 10 years for the following fatal cardiovascular disease codes of the ICD-9 (International Classification of Diseases, Ninth Edition), or their equivalents in the 10th revision, considered in the SCORE function⁵: from 401 to 414 and from 426 to 443, excluding 426.7, 429.0, 430.0, 432.1, 437.3, 437.4, and 437.5. In addition, death from cardiovascular causes⁵ was classified according to the following ICD-9 codes: 798.1 (instantaneous death) and 798.2 (sudden death occurring less than 24 hours after symptom onset). Cause of death was ascertained from medical records, hospital discharge sheets, and the national death registry and that of each autonomous community.

Statistical Analysis

Analyses were stratified by sex. Continuous variables are reported as mean \pm standard deviation and categorical variables as proportions. Overall mortality rates and those according to cause (cardiovascular, noncardiovascular) were estimated using Kaplan-Meier analysis.

The 10-year risk of cardiovascular death was estimated with the SCORE-LOW function with Weibull model coefficients.⁵ The risk was also estimated with the SCORE-LOW-HDL and SCORE-C functions⁸ using the HeartScore calculator of the European Society of Cardiology⁹ because their coefficients are no longer published.⁷ The free software Autolt¹³ was used to automatically add to the corresponding field of the calculator the values of the variables—sex, age, smoking, systolic blood pressure, total cholesterol, and

HDL-C (when necessary)—taken from the database. The same program captured the risk estimated by the calculator for the SCORE-LOW-HDL and SCORE-C functions and incorporated this value into the database.

To validate the functions, the observed-to-expected mortality ratio was first estimated with each of the 3 risk functions. To determine the reliability of the SCORE-LOW function,⁵ its discrimination capacity was analyzed using the area under the ROC (receiver operating characteristic) curve.¹⁴ Accuracy was evaluated via a comparison of the risks observed in the cohort and those estimated by the SCORE functions using the Hosmer-Lemeshow test modified for cohort studies with SCORE-LOW risk sextiles (calibration).¹⁵ No ROC curves could be evaluated for the SCORE-LOW-HDL and SCORE-C because the HeartScore calculator rounds risk figures to whole numbers.⁹ Nonetheless, the calibration was analyzed by comparing the observed events and those predicted with 3 whole cutoff points (1%, 2%, and 3%).

The risk estimated with the 3 functions was multiplied by 3 and 5 in men and women with diabetes, respectively, according to the indications of the most recent clinical practice guidelines of the European Society of Cardiology.³ In addition, in a sensitivity analysis, the cardiovascular risk estimated with the SCORE-LOW function was multiplied by 2 and 4 in men and women with diabetes, respectively, as indicated in the reference publication.⁵

The population distribution was calculated in 4 risk groups defined by 1%, 5%, and 10% cutoff points with the 3 versions of the SCORE function and the percentage of cardiovascular deaths observed in each group.

All analyses were performed using R statistical software version 2.10 (R Foundation for Statistical Computing, Vienna, Austria).

RESULTS

Of the 56 577 participants in the FRESCO study, 22 026 were excluded for being younger than 40 years or older than 64 years, as well as 3632 for having systolic blood pressure and total cholesterol values outside of the range considered by SCORE.

Table

Participants' Baseline Characteristics, Cardiovascular Risk Estimated With the SCORE-LOW, SCORE-LOW-HDL, and SCORE-C Functions (Risk Multiplied by 3 and 5 in Men and Women, Respectively), and Outcome Variables Stratified by Sex

	Men (n = 14 661)	Women (n = 16 258)
Age, y	52 ± 7	52 ± 7
Smoker	4891 (33.7)	2284 (14.2)
Total cholesterol, mg/dL	220 ± 36	221 ± 37
HDL-C, mg/dL	49 ± 13	59 ± 15
Diabetes mellitus	2393 (16.4)	1818 (11.2)
Systolic blood pressure, mmHg	134 ± 16	129 ± 16
SCORE-LOW ×3/×5 (%)	3.50 ± 4.56	1.27 ± 2.44
SCORE-LOW ×3/×5		
< 1%	4037 (28.0)	10 756 (67.3)
≥ 1% to 5%	7560 (52.4)	4394 (27.5)
≥ 5%	2829 (19.6)	822 (5.1)
SCORE-LOW-HDL	3.47 ± 4.73	0.74 ± 1.29
SCORE-LOW-HDL		
< 1%	5601 (41.6)	13 368 (89.1)
≥ 1% to 5%	6137 (45.6)	1219 (8.1)
≥ 5%	1714 (12.7)	421 (2.8)
SCORE-C	2.48 ± 3.22	0.51 ± 0.86
SCORE-C		
< 1%	4926 (35.8)	12 472 (81.5)
≥ 1% to < 5%	6005 (43.6)	2278 (14.9)
≥ 5%	2833 (20.6)	555 (3.6)
10-year overall mortality	545 (3.7)	275 (1.7)
Cause of death*		
Cardiovascular	103 (0.7)	52 (0.3)
Noncardiovascular	439 (3.0)	218 (1.3)
Unknown	3 (< 0.1)	5 (< 0.1)

HDL-C, high-density lipoprotein cholesterol; SCORE-C, calibrated Systematic COronary Risk Evaluation; SCORE-LOW, original low-risk Systematic COronary Risk Evaluation; SCORE-LOW-HDL, original low-risk Systematic COronary Risk Evaluation with HDL-C.

Unless otherwise indicated, the data represent No. (%) or mean ± standard deviation.

* Estimated by the Kaplan-Meier method.

Finally, 30 919 individuals were included in the validation (Figure 1). The median follow-up time was 10.0 years, with a total of 286 105 persons/y. The 10-year mortality rate was 3.0% for all-cause death but was 0.6% for the cardiovascular causes included in the SCORE function. The cause of death was unknown in 8 participants (0.98%).

The participants' characteristics by sex are detailed in Table. The cardiovascular risk profile was more unfavorable in men. The mean risk calculated with the 3 functions was always higher in men than in women, as well as the percentage of men classified in the high-risk group (≥ 5%). SCORE-LOW-HDL classified the fewest people in the high-risk group (≥ 5%) (12.7% of men and 2.8% of women). The ratio between estimated/observed cases was 9.1, 6.5, and 9.1 in men and 3.3, 1.3, and 1.9 in women with the SCORE-LOW, SCORE-LOW-HDL, and SCORE-C functions, respectively.

The discrimination capacity of the original SCORE function is shown in Figure 2. The area under the ROC curve was 0.68 in men and 0.69 in women.

The accuracies of the SCORE-LOW function estimates are presented in Figure 3. Both sexes showed significant differences between the percentages of observed and estimated deaths in the risk sextiles. There were also significant differences for both sexes among the 4 risk groups analyzed with the SCORE-C and SCORE-LOW-HDL functions (Figure 4).

The percentage of cohort participants included in the 4 risk groups and the percentage of deaths in each group are shown in Figure 5. About 80% of the fatal cardiovascular events occurred in approximately 80% of the female population with low risk (< 1% at 10 years) with SCORE-C and SCORE-LOW-HDL. In men, with the same functions, about 40% of events occurred in approximately 60% of the low-risk population. With the SCORE-LOW function, more than 50% of the events occurred in the 1.1% to 5% risk group (intermediate risk) in both sexes.

Sensitivity analysis of the SCORE-LOW estimates—by applying a correction factor of 2 and 4 to men and women with diabetes, respectively—showed similar results (Table 2 of the supplementary material and Figure 1, Figure 2, and Figure 3 of the supplementary material).

DISCUSSION

The present study is the first to analyze the validity components (reliability and accuracy) of the cardiovascular risk estimates of the

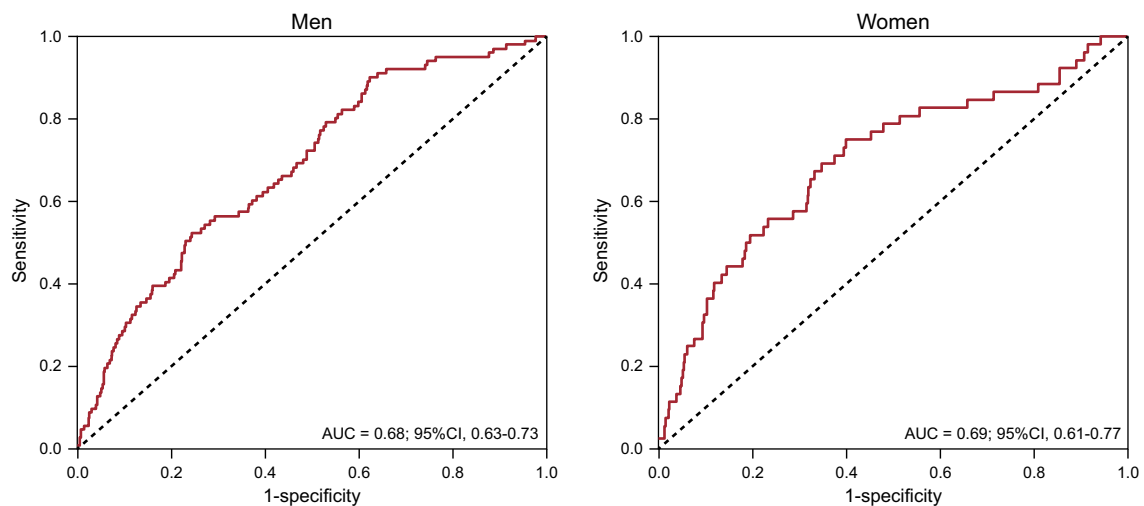


Figure 2. Area under the curve of the original low-risk SCORE function. The risk is multiplied by 3 and 5 in men and women with diabetes, respectively. 95%CI, 95% confidence interval; AUC, area under the curve.

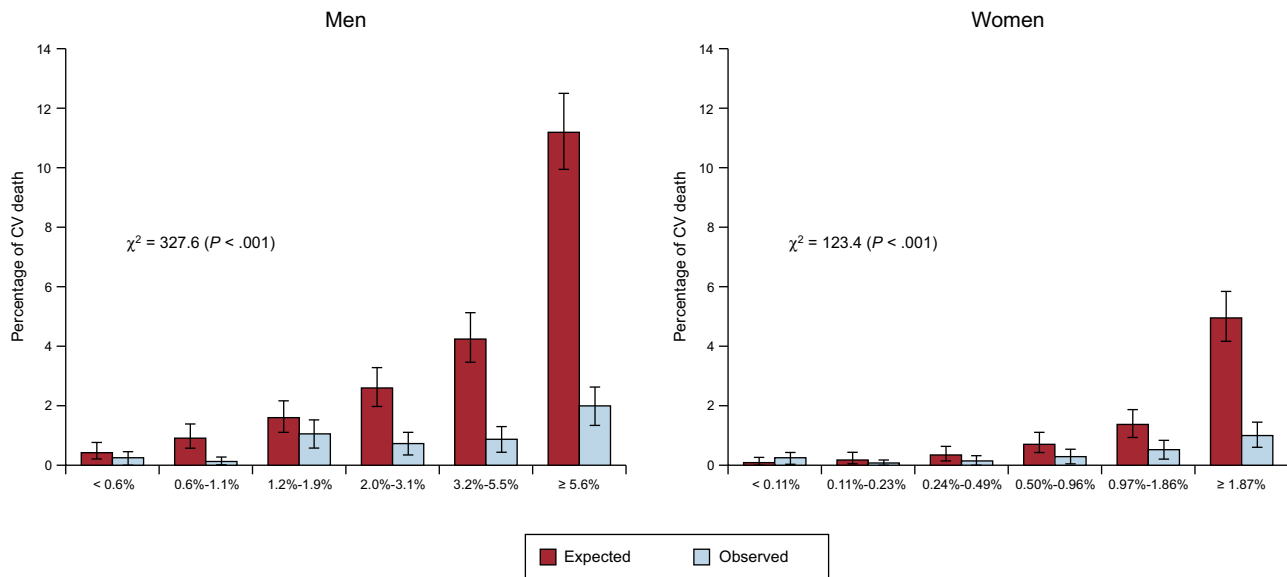


Figure 3. Calibration according to sextile of risk of CV death using the original low-risk SCORE function. Error bars indicate the 95% confidence interval. The risk is multiplied by 3 and 5 in men and women with diabetes, respectively. CV, cardiovascular.

original SCORE function with and without HDL-C^{5,9} and of its calibrated version^{8,9} in a Spanish cohort with a population base of more than 30 000 participants followed up for 10 years. The 3 functions predicted significantly higher cardiovascular mortality rates (from 6.5 to 9.1 times in men and from 1.3 to 3.3 in women) than those observed in this period (accuracy). The discrimination (reliability) of the SCORE functions was acceptable and similar to that of most cardiovascular risk functions.^{4,11,16,17}

Comparison With Other Studies

Most European population-based studies analyzing the validity of the high-risk SCORE function indicate that estimates of risk of cardiovascular death are significantly higher in both sexes than the observed rates in the Netherlands,¹⁸ Denmark,¹⁹ Norway,²⁰ Germany (2 studies),^{21,22} Iceland,²³ and the United Kingdom.²⁴ In all of these studies, SCORE approximately doubled the true risk of cardiovascular death. In an Australian population, who are mainly of European origin, the risk was overestimated by 75% in women.²⁵

The risk estimation with SCORE-LOW was 40% higher than that observed in the nondiabetic population in Extremadura, Spain.²⁶ This function has also been evaluated in high-risk countries such as the Netherlands¹⁸ and Iceland,²³ where the risk of cardiovascular death was correctly estimated. However, in Germany²¹ and the United Kingdom,²⁴ this function overestimated the risk by 31% and 25%, respectively. In Norway,²⁰ the results were acceptable in men, but the risk was overestimated in women (observed-to-expected mortality ratio: 0.69 in patients 50 to 59 years old and 0.56 in those 60 to 69 years old), with similar findings from Australia (16% overestimation).²⁵

In agreement with our results, a cross-sectional study performed in the Catalan population showed that the SCORE-C function (particularly in men) classified a higher percentage of patients as high risk vs the SCORE-LOW and SCORE-LOW-HDL functions.²⁷ In addition, a risk overestimation was seen with the SCORE function calibrated for the Netherlands¹⁸ (approximately double), whereas the estimate was adequate in Germany.²² In Denmark, the calibrated function failed to improve the validity of the SCORE-LOW function.¹⁹

Implications for Clinical Practice

Overall, the 3 versions of the SCORE function analyzed provided significantly different cardiovascular risk estimates from those actually observed in the Spanish population. In women, 80% of fatal cardiovascular events were concentrated in the low-risk groups of the SCORE-C and SCORE-LOW-HDL functions and in the intermediate- and low-risk groups of SCORE-LOW, whereas 80% of events in men were concentrated in low- and intermediate-risk groups with SCORE-C and SCORE-LOW-HDL and 65% with SCORE-LOW. This observation indicates that the cutoff points defining low, intermediate, and high risk should be revised downward. Definition of the cutoff points is limited by the absence of decimal places in the estimates of the European Society of Cardiology calculator for the SCORE-C and SCORE-LOW-HDL functions.⁹

The results of the present study suggest that all SCORE versions^{5,8,9} have significant limitations in the accuracy of the estimates obtained in the Spanish population. It was additionally confirmed that most cardiovascular events occurring in Spain are not fatal.¹¹ The accuracy of tables based solely on cardiovascular mortality can vary over time, given that this type of mortality has greatly decreased in the 3 decades since the development of the SCORE cohorts.^{2,5} Similarly, the exclusion of individuals aged from 65 to 74 years is also clinically relevant because the rate of death from cardiovascular causes in this population is double that of the individuals included in our cohort (40–64 years). In a Danish study, the authors suggested that future guidelines should focus on individuals older than 65 years because most fatal cardiovascular events occur in this population.¹⁹ Recently, a version of SCORE Older People was published, which permits estimation of the risk of cardiovascular death in individuals 65 to 74 years.²⁸ For its derivation, the authors used the SCORE cohorts of Norway (mainly; 86.9% of the sample included in the derivation), Italy, Belgium, and Denmark. In Spain, the SCORE Older People tables showed a lower risk than that estimated using SCORE for persons older than 65 years.²⁹ It is thus reasonable to also promote the use of the functions validated in Spain: the Framingham-Wilson calibrated by REGICOR^{4,16,17} and by FRESCO,¹¹ which also increases the upper age limit to 79 years.

To perform effective prevention of cardiovascular diseases, the models for predicting individual risk should follow the TRIPOD

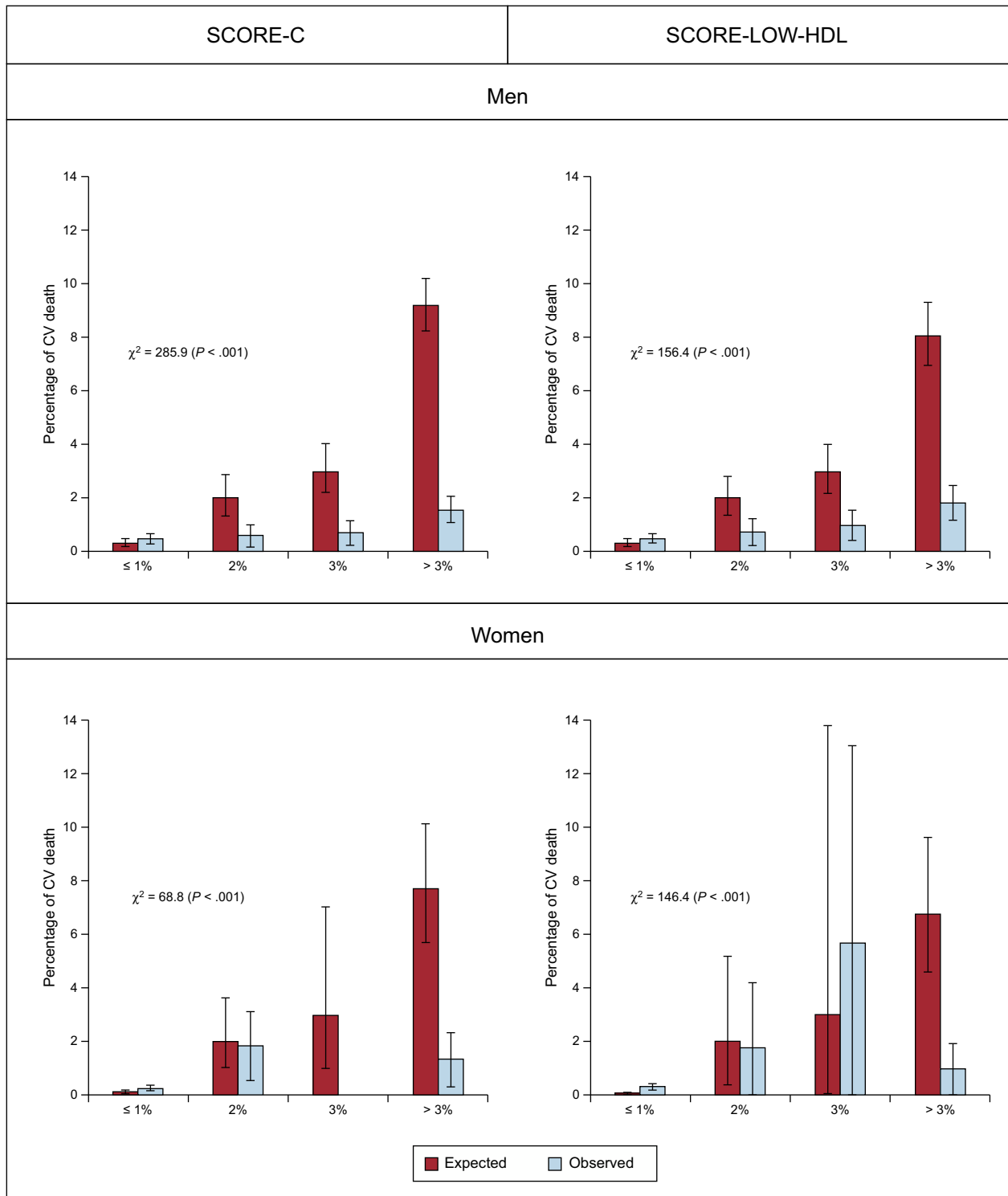


Figure 4. Calibration according to risk group for CV death of the SCORE-C and SCORE-LOW-HDL functions. Error bars indicate the 95% confidence interval. The risk is multiplied by 3 and 5 in men and women with diabetes, respectively. CV, cardiovascular; SCORE-C, calibrated Systematic COronary Risk Evaluation; SCORE-LOW-HDL, original low-risk Systematic COronary Risk Evaluation with high-density lipoprotein cholesterol.

guidelines.³⁰ These recommendations promote transparency in the publication of the methods used in order to facilitate their evaluation.

Study Limitations

The FRESCO study combines data from 12 Spanish cohorts that are representative of the populations of different reference areas recruited between 1991 and 2004. The study has a large sample

size, exhaustive 10-year follow-up of cardiovascular events, standardized data collection methodology for component cohorts, and broad representativeness of the Spanish population.¹¹ Despite the robustness of these characteristics, there may be some residual heterogeneity among study components. First, the coefficients of the SCORE-C and SCORE-LOW-HDL functions were not available because they have not been published.⁸ Accordingly, the use of the online HeartScore calculator was required, even though it was

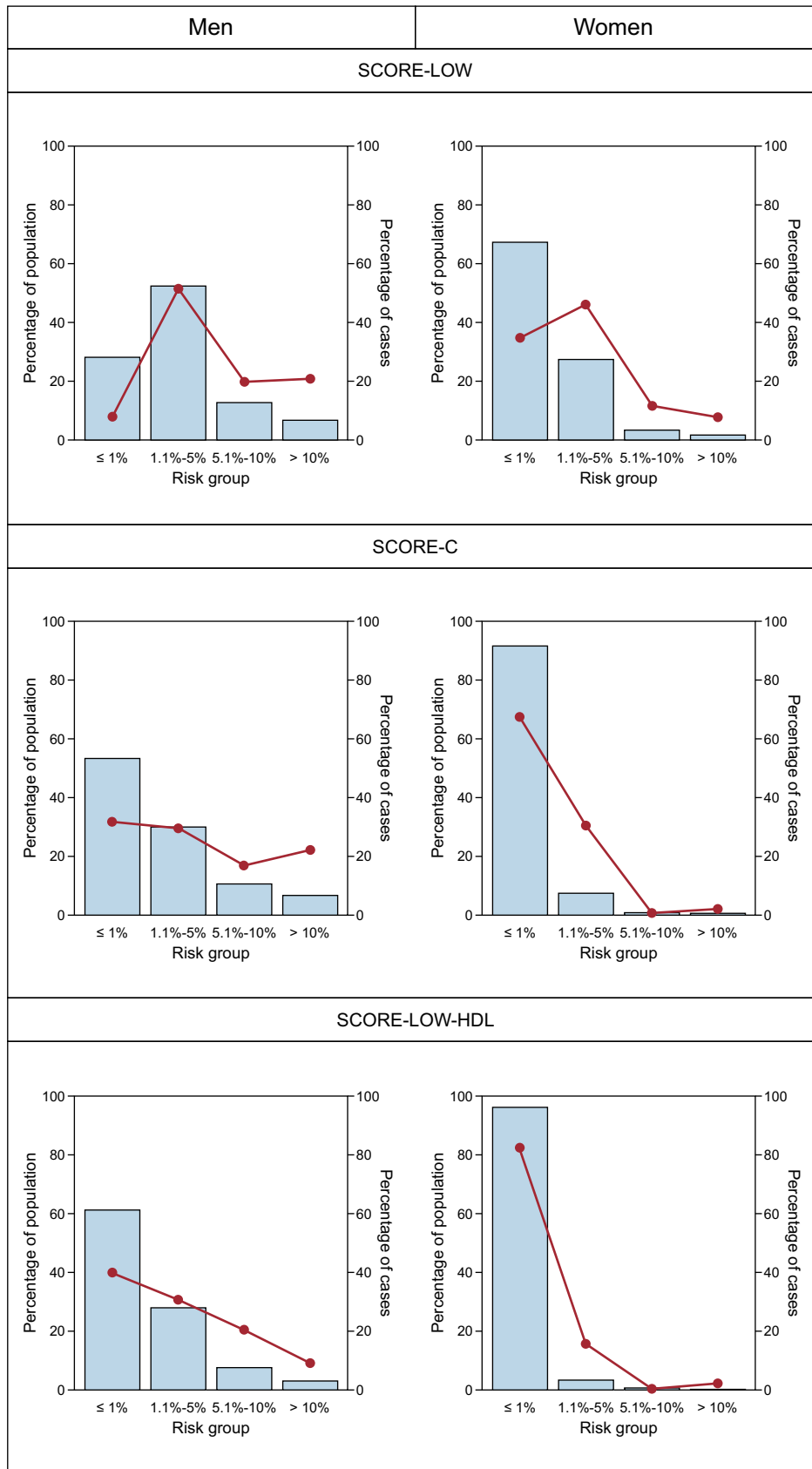


Figure 5. Population proportion in different risk of cardiovascular death groups according to the SCORE-LOW, SCORE-C, and SCORE-LOW-HDL functions (bars) and proportion of cases over the total in each group (lines and dots). The risk is multiplied by 3 and 5 in men and women with diabetes, respectively. SCORE-C, calibrated Systematic COronary Risk Evaluation; SCORE-LOW, original Systematic COronary Risk Evaluation; SCORE-LOW-HDL, original low-risk Systematic COronary Risk Evaluation with high-density lipoprotein cholesterol.

designed for the health care setting⁹ and rounds results to whole numbers. The absence of decimal places prevented calculation of the area under the curve of the 2 functions. This limitation also affected the calibration analysis, which was restricted to 4 risk groups instead of the risk sextiles and deciles (such as in the case of the SCORE-LOW function) used classically to evaluate the accuracy of the cardiovascular risk functions.^{15,16}

CONCLUSIONS

The risk predictions of all SCORE functions significantly differed from the 10-year incidence rates in a contemporary Spanish population eligible for primary cardiovascular prevention. Because the SCORE functions considerably overestimated the true risk of cardiovascular death, their recalibration is required to better adjust their predictions to the actual rates of cardiovascular mortality.

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CONFLICTS OF INTEREST

None declared.

WHAT IS KNOWN ABOUT THE TOPIC?

- Cardiovascular risk calculation through cardiovascular risk functions is key to primary prevention strategies.
- The European guidelines for cardiovascular disease prevention and the Spanish Interdisciplinary Committee for Cardiovascular Prevention recommended the use of the SCORE function, among other tools.
- The sole cardiovascular risk function validated in Spain is the Framingham-Wilson function calibrated by the REGICOR group and the FRESKO function.

WHAT DOES THIS STUDY ADD?

- SCORE functions were not valid in a contemporary Spanish population.
- SCORE functions significantly overestimate the true risk of cardiovascular death, even in the version calibrated for the Spanish population.
- The cutoff points of the SCORE functions should be redefined to achieve efficient stratification of cardiovascular prevention in clinical practice.

SUPPLEMENTARY MATERIAL



Supplementary material associated with this article can be found in the online version available at <http://dx.doi.org/10.1016/j.rec.2017.03.030>.

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