Scandinavian Cardiovascular Journal

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/icdv20

# Validation of the cardiovascular risk model NORRISK 2 in South Asians and people with diabetes

Kjersti Stormark Rabanal , Jannicke Igland , Grethe Seppola Tell , Anne Karen Jenum , Tor Ole Klemsdal , Inger Ariansen , Haakon Eduard Meyer & Randi Marie Selmer

**To cite this article:** Kjersti Stormark Rabanal , Jannicke Igland , Grethe Seppola Tell , Anne Karen Jenum , Tor Ole Klemsdal , Inger Ariansen , Haakon Eduard Meyer & Randi Marie Selmer (2020): Validation of the cardiovascular risk model NORRISK 2 in South Asians and people with diabetes, Scandinavian Cardiovascular Journal, DOI: 10.1080/14017431.2020.1821909

**To link to this article:** https://doi.org/10.1080/14017431.2020.1821909

SCANDINAVIAN CARDIOVASCULAR JOURNAL
https://doi.org/10.1080/14017431.2020.1821909

Taylor & Francis
Taylor & Francis Group

ORIGINAL ARTICLE



# Validation of the cardiovascular risk model NORRISK 2 in South Asians and people with diabetes

Kjersti Stormark Rabanal[a,b], Jannicke Igland[c], Grethe Seppola Tell[c,d], Anne Karen Jenum[e], Tor Ole Klemsdal[f], Inger Ariansen[d], Haakon Eduard Meyer[d,g] and Randi Marie Selmer[d]

[a]Department of Public Health, Faculty of Health Sciences, University of Stavanger, Stavanger, Norway; [b]Research Department, Stavanger University Hospital, Stavanger, Norway; [c]Department of Global Public Health and Primary Care, University of Bergen, Bergen, Norway; [d]Division of Mental and Physical Health, Norwegian Institute of Public Health, Oslo, Norway; [e]General Practice Research Unit (AFE), Department of General Practice, Institute of Health and Society, Faculty of Medicine, University of Oslo, Oslo, Norway; [f]Preventive cardiology, Oslo University Hospital, Oslo, Norway; [g]Department of Community Medicine and Global Health, Institute of Health and Society, University of Oslo, Oslo, Norway

**ABSTRACT**

*Objectives.* To evaluate the predictive ability of the previously published NORRISK 2 cardiovascular risk model in Norwegian-born and immigrants born in South Asia living in Norway, and to add information about diabetes and ethnicity in an updated model for South Asians and diabetics (NORRISK 2-SADia). *Design.* We included participants (30–74 years) born in Norway ($n = 13,885$) or South Asia ($n = 1942$) from health surveys conducted in Oslo 2000–2003. Cardiovascular disease (CVD) risk factor information including self-reported diabetes was linked with information on subsequent acute myocardial infarction (AMI) and acute cerebral stroke in hospital and mortality registry data throughout 2014 from the nationwide CVDNOR project. We developed an updated model using Cox regression with diabetes and South Asian ethnicity as additional predictors. We assessed model performance by Harrell's C and calibration plots. *Results.* The NORRISK 2 model underestimated the risk in South Asians in all quintiles of predicted risk. The mean predicted 13-year risk by the NORRISK 2 model was 3.9% (95% CI 3.7–4.2) versus observed 7.3% (95% CI 5.9–9.1) in South Asian men and 1.1% (95% CI 1.0–1.2) versus 2.7% (95% CI 1.7–4.2) observed risk in South Asian women. The mean predictions from the NORRISK 2-SADia model were 7.2% (95% CI 6.7–7.6) in South Asian men and 2.7% (95% CI 2.4–3.0) in South Asian women. *Conclusions.* The NORRISK 2-SADia model improved predictions of CVD substantially in South Asians, whose risks were underestimated by the NORRISK 2 model. The NORRISK 2-SADia model may facilitate more intense preventive measures in this high-risk population.

**ARTICLE HISTORY**
Received 18 December 2019
Revised 1 July 2020
Accepted 3 September 2020

**KEYWORDS**
Cardiovascular disease; risk prediction; South Asians; country of birth; diabetes; ethnicity

## Introduction

International guidelines for prevention of cardiovascular disease (CVD) recommend the estimation of an individual's total risk of CVD to inform treatment decisions [1,2]. The recent Norwegian guidelines recommend risk calculation by the NORRISK 2 model, which predicts an individual's 10-year risk of incident fatal or non-fatal acute myocardial infarction (AMI) or cerebral stroke [3,4]. The NORRISK 2 model has not been validated among immigrants in Norway. Migrants originating from South Asia (India, Pakistan, Sri Lanka, Bangladesh, Nepal and Bhutan) have higher risk of CVD compared to other ethnic groups in several countries, including the United Kingdom (UK), Denmark, Sweden, Italy, the United States, New Zealand and Norway [5–11]. In 2019, immigrants and Norwegian-born to immigrant parents with a country background from South Asia living in Norway counted 75,227 individuals [12]. We previously reported that immigrants from South Asia have an increased risk of CVD compared to ethnic Norwegians after adjustment for traditional risk factors [13].

Norwegian guidelines recommend adding a factor of 1.5 to the predicted risk score in South Asians to account for possible underestimation of risk [4]. The prevalence of type 2 diabetes is considerably higher in immigrants from South Asia than in the general Norwegian population [13,14]. Furthermore, South Asian migrants living in high-income countries are diagnosed with diabetes at a younger age than Europeans [15]. The NORRISK 2 model did not include diabetes because there are separate guidelines for CVD prevention in diabetics advising preventive medication (statins) to all diabetic patients, provided LDL-cholesterol is >2.5 mmol/L and age >40 years [4]. However, when estimating the burden of CVD in a given population (i.e. a city or community) the exclusion of diabetes and ethnicity

CONTACT Kjersti Stormark Rabanal kjersti.s.rabanal@uis.no Department of Public Health, Faculty of Health Sciences, University of Stavanger, Stavanger, Norway

Supplemental data for this article can be accessed here.

would give invalid and underestimated cardiovascular risk estimates in South Asians and people with diabetes. The purpose of this study was to evaluate the NORRISK 2 model in men and women born in Norway and South Asia, and to include South Asian ethnicity and diabetes as additional predictors in an updated model called NORRISK 2-SADia.

## Materials and methods

### Study population

We included participants from health examination surveys; The Oslo Health Study (HUBRO), The Oslo Immigrant Health Study (I-HUBRO) and the Romsås in Motion Study (MoRo II) ($N = 26{,}884$), all conducted in Oslo during 2000–2003 and part of Cohort of Norway (CONOR) [16]. Participation rates were 40–48%. All surveys followed standard data collection procedures. Self-reported questionnaires included questions about self-reported health and disease, family history of disease, medication use and lifestyle [16]. Participants underwent a clinical examination and non-fasting blood samples were analyzed for serum lipids by standard methods [16]. Systolic blood pressure (SBP) was measured using an automatic device. Further details on data collection are given elsewhere [16].

We included participants aged 30–74 years at examination. The final study population included 7574 women and 6311 men born in Norway, and 795 women and 1147 men born in South Asia. See Appendix Figure 1 in supplementary materials for details. About 3.9% of South Asians and 2.7% of Norwegians emigrated during follow-up.

Participants signed a written informed consent. The Regional Committee for Medical and Health Research Ethics approved the study.

### Cardiovascular outcomes

An endpoint was defined as the first occurrence of hospitalization with AMI (ICD10 I21-22) or acute cerebral stroke (ICD10 I60-61, I63-I64 except I63.6) as main or secondary diagnosis or death with CHD (ICD10 I20-25) or cerebral stroke as the underlying cause. The CVDNOR project includes hospitalizations retrieved from patient administrative systems during 1994–2009, and from the Norwegian Patient Registry from 2008 to 2014 [17,18]. Fatal events were retrieved from the Cause of Death Registry. Follow-up time was calculated from the CONOR participation date until date of hospitalization, death or end of follow-up (31 December 2014), whichever occurred first.

### Statistical analyses

The NORRISK 2 model [3] predicts 10-year risk of CVD based on continuous (age, serum total cholesterol and SBP (per 10 mmHg)) and categorical risk factors (low high-density lipoprotein (HDL)-cholesterol ($<1.3$ mmol/L in women, $<1.0$ mmol/L in men), daily smoking, current use of antihypertensive medication and family history (first-degree family member) of CHD before the age of 60). The NORRISK 2 model predicts 10-year risk by the Fine and Gray competing risk model [19]. In the current study, we evaluate 13-year risk because of few cases in the South Asian group. In the 13-year risk calculation, we used the sub-distribution hazards at 13 years instead of 10 years. We calculated the observed cumulative 13-year incidence of CVD using life table methods.

We validated the model by Harrell's C and calibration plots based on observed cumulative 13-year risk within quintiles of predicted risk by NORRISK 2.

The NORRISK 2 model was intended for individuals aged 40–79 years. Due to few participants at higher ages in the South Asian group, we included individuals aged 30–74 years. Competing risk is small in these age groups; we, therefore, used Cox regression to develop an updated NORRISK 2 model (NORRISK 2-SADia) including diabetes and South Asian region of birth in addition to the NORRISK 2 predictors.

## Results

Norwegian-born participants were on average 3 years older than South Asians, had higher mean levels of SBP and a higher proportion reported family history of AMI or stroke (Table 1). However, the proportion reporting diabetes was 5–8 times higher in South Asians who also had considerably lower HDL-cholesterol. Only 1.6% of South Asian women reported daily smoking.

During 13 years of follow-up, we observed 621 endpoints (Table 2). The observed cumulative incidence of CVD ranged from 2.3% in Norwegian women to 7.3% in South Asian men. Predicted 13-year risk by NORRISK 2 was considerably higher in Norwegians compared to South Asians. NORRISK 2 underestimated 13-year risk in South Asian men and women, with and without known diabetes and in Norwegian born men with diabetes (Table 2). NORRISK 2 underestimated risk in all quintiles of predicted risk in South Asians, most pronounced in the two highest quintiles (Figure 1 and Appendix Table 1 in supplementary materials). The discriminative ability of NORRISK 2 was good in both sexes and ethnic groups with Harrell's C estimates from 0.79 to 0.81 (Appendix Table 2 in supplementary materials).

We developed a new sex-specific model, NORRISK 2-SADia, adding diabetes and ethnicity to the NORRISK 2 predictors (Table 3, Appendix Table 3 in supplementary materials). Use of anti-hypertensive medications, low HDL-cholesterol and family history of CHD were not significant predictors in women and included as predictors in the final model for men only. A model with all predictors included also for women is shown in Supplementary materials (Appendix Table 4). The adjusted hazard ratios (HRs) for CVD events in South Asians versus Norwegians in the NORRISK 2-SADia model were 1.7 in men and 2.7 in women, whereas the HR for diabetes was 2.0 in both sexes (Table 3). The mean 13-year risk score based on the updated model was close to the observed cumulative risk,

**Table 1.** Baseline characteristics of participants born in Norway and in South Asia. Participants free of prior CVD.

| | Men | | Women | |
|---|---|---|---|---|
| | Norwegian | South Asian | Norwegian | South Asian |
| N | 6311 | 1147 | 7574 | 795 |
| Age (years), mean (SD) | 44 (11.5) | 41.3 (7.8) | 43.8 (10.8) | 40.4 (8.1) |
| Age range (years) | 30–74 | 30–67.8 | 30–74.9 | 30–65.5 |
| Serum total cholesterol (mmol/L), (mean (SD) | 5.61 (1.04) | 5.48 (0.97) | 5.40 (1.01) | 5.02 (0.89) |
| HDL-cholesterol (mmol/L), mean (SD) | 1.31 (0.34) | 1.08 (0.25) | 1.62 (0.40) | 1.23 (0.29) |
| Low HDL-cholesterol (men < 1mmol/L, women < 1.3 mmol/L) (%) | 15.9 | 41.9 | 20.9 | 63.5 |
| Systolic blood pressure (mm Hg), mean (SD) | 132.8 (14.4) | 126.8 (12.9) | 124.4 (15.2) | 120.5 (14.7) |
| Diastolic blood pressure (mm Hg), mean (SD) | 77.8 (10.8) | 77.0 (9.8) | 71.7 (10.1) | 70.8 (9.7) |
| Hypertension[a] (%) | 31.3 | 22.1 | 19.0 | 16.9 |
| Diabetes (%) | 1.7 | 8.5 | 1.4 | 11.2 |
| Former smokers (%) | 27.8 | 15.8 | 26.0 | 1.6 |
| Current smokers (%) | 26.0 | 24.5 | 31.4 | 1.6 |
| Family history of AMI before age 60 (%): | 12.0 | 7.0 | 12.8 | 8.2 |
| One family member (%) | 11.3 | 6.3 | 11.8 | 6.9 |
| At least two family members (%) | 0.7 | 0.7 | 1.0 | 1.3 |
| Family history of stroke (%) | 11.0 | 2.7 | 13.6 | 4.7 |
| Antihypertensive treatment (%) | 7.1 | 7.6 | 5.8 | 8.7 |
| Lipid-lowering treatment (%) | 4.4 | 6.2 | 2.9 | 6.7 |
| Endpoints: *n* (%) | 391 (6.2) | 80 (7.0) | 188 (2.5) | 21 (2.6) |
| AMI/death from CHD: *n* (%) | 235 (3.7) | 60 (5.2) | 87 (1.2) | 16 (2.0) |
| Acute cerebral stroke : *n* (%) | 175 (2.8) | 27 (2.4) | 109 (1.4) | 5 (0.6) |
| Follow-up time (years), mean (SD) | 13.2 (2.3) | 12.4 (2.1) | 13.4 (1.7) | 12.9 (1.3) |

SD: standard deviation; HDL: high-density lipoprotein; AMI: acute myocardial infarction; CHD: coronary heart disease.
[a]Hypertension: systolic blood pressure >=140 mmHg or diastolic blood pressure >=90 mmHg or using blood pressure medication.

**Table 2.** Observed and predicted cumulative 13-year risk of CVD according to NORRISK2, original and updated (NORRISK2-SADia).

| | Men | | Women | |
|---|---|---|---|---|
| | Norwegian | South Asian | Norwegian | South Asian |
| Total | | | | |
| *N* | 6311 | 1147 | 7574 | 795 |
| No. of events | 355 | 77 | 170 | 19 |
| Observed cumulative incidence, percent (95% CI) | 5.8 (5.2–6.4) | 7.3 (5.9–9.1) | 2.3(2.0–2.7) | 2.7 (1.7–4.2) |
| Predicted NORRISK2, percent (95% CI) | 6.3 (6.2–6.5) | 3.9 (3.7–4.2) | 2.7 (2.6–2.8) | 1.1 (1.0–1.2) |
| Predicted NORRISK2*1.5, percent (95% CI) | – | 5.9 (5.5–6.3) | – | 1.7 (1.5–1.9) |
| Predicted NORRISK2-SADia, percent (95% CI) | 5.9 (5.8–6.1) | 7.2 (6.7–7.6) | 2.4 (2.3–2.4) | 2.7 (2.4–3.0) |
| Not known diabetes | | | | |
| *N* | 6201 | 1050 | 7469 | 706 |
| No. of events | 325 | 62 | 165 | 13 |
| Observed cumulative incidence, percent (95% CI) | 5.4 (4.8–6.0) | 6.5 (5.0–8.3) | 2.3 (2.0–2.6) | 2.1 (1.2–3.7) |
| Predicted NORRISK2, percent (95% CI) | 6.2 (6.0–6.4) | 3.7 (3.4–3.9) | 2.7 (2.6–2.8) | 1.0 (0.9–1.1) |
| Predicted NORRISK2*1.5, percent (95% CI) | – | 5.5 (5.1–5.9) | – | 1.5 (1.3–1.7) |
| Predicted NORRISK2-SADia, percent (95% CI) | 5.6 (5.5–5.8) | 5.9 (5.6–6.3) | 2.3 (2.2–2.4) | 2.1 (1.9–2.3) |
| With known diabetes | | | | |
| *N* | 110 | 97 | 105 | 89 |
| No. of events | 30 | 15 | 5 | 6 |
| Observed cumulative incidence, percent(95% CI) | 29.6 (21.6–39.7) | 16.5 (10.2–26.1) | 5.0 (2.1–11.7) | 6.8 (3.1–14.6) |
| Predicted NORRISK2, percent (95% CI) | 13.3 (11.4–15.1) | 6.9 (5.6–8.2) | 5.7 (4.2–7.1) | 2.1 (1.6–2.6) |
| Predicted NORRISK2*1.5, percent (95% CI) | – | 10.4 (8.5–12.4) | – | 3.1 (2.4–3.9) |
| Predicted NORRISK2-SADia, percent (95% CI) | 22.8 (19.9–25.8) | 20.3 (17.3–23.4) | 7.1 (5.5–8.7) | 7.4 (5.8–9.0) |

CI: confidence interval.

for both sexes, both ethnic groups and regardless of known diabetes status (Table 2). NORRISK 2 multiplied by 1.5, as recommended in Norwegian guidelines, gave similar predicted risk estimates as NORRISK 2-SADia among South Asian men without diabetes, but not in South Asian men with diabetes nor in South Asian women.

The calibration was good (Appendix Table 1 in supplementary materials and Figure 2). The discriminative ability was similar for NORRISK 2-SADia and NORRISK 2 (Appendix Table 1 in supplementary materials).

Appendix Table 5 in supplementary materials shows risk classifications in men and women without known diabetes, according to the Norwegian guidelines [4]. For Norwegian-born men and women, there is a change towards lower risk categories with NORRISK 2-SADia compared to NORRISK 2. Men and women born in South-Asia have a higher estimated risk by NORRISK 2-SADia when compared to the original model. However, NORRISK 2 multiplied by 1.5 and NORRISK 2-SADia gave similar percentages in the high-risk category for South-Asian men. The risk was low in South-Asian women according to both models.

## Discussion

NORRISK 2 underestimated the risk of incident AMI and stroke in South Asian men and women living in Norway with about a twofold difference between observed and predicted risk. As expected, the NORRISK 2 model also

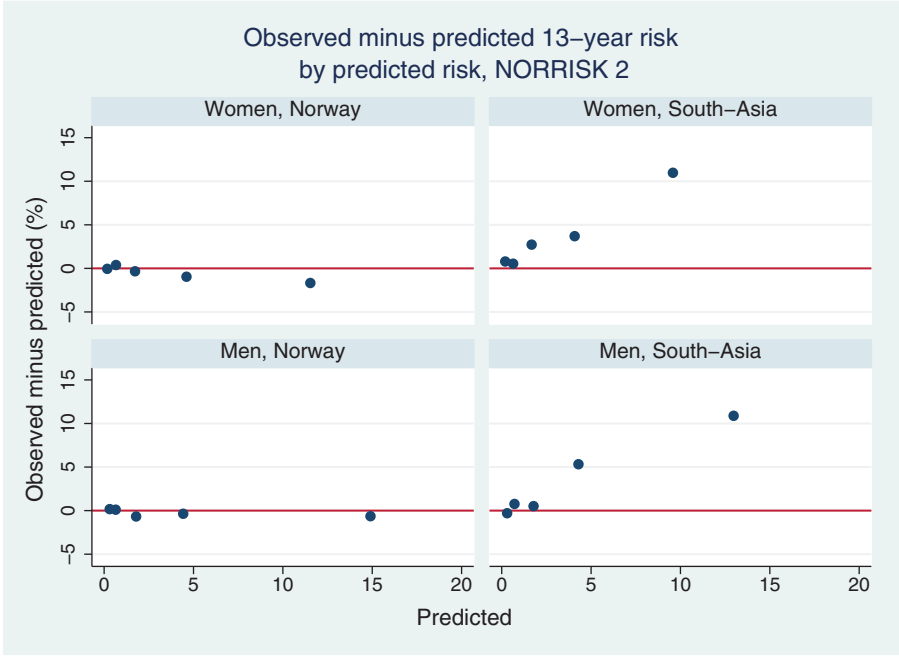


**Figure 1.** Calibration plots showing observed minus predicted 13-year risk for the previously published NORRISK 2 model.

underestimated the risk in Norwegian-born men with diabetes. We, therefore, updated the NORRISK 2 model with information about diabetes and South Asian ethnicity. The updated NORRISK 2-SADia model may be used to predict CVD risk in both South Asians and Norwegians in Norway with and without diabetes. However, the use of such algorithms is not recommended to make individual treatment decisions in patients with diabetes, who are better evaluated through separate diabetes guidelines [20]. We present details of our new risk equation that enable the calculation of 10- and 13-year predicted cardiovascular NORRISK 2-SADia risk, or external validation of the model.

South Asians worldwide have an increased risk of CVD, particularly CHD, compared with other ethnic groups [5–11,21]. In a previous Norway-New Zealand collaborative study, we found that South Asians in both countries had a higher risk of CVD than people of European origin after adjustment for SBP, TC/HDL-cholesterol ratio, smoking and diabetes [13]. Despite a high awareness of the increased cardiovascular risk in South Asians, few cardiovascular prediction models have been validated in South Asian populations [22]. As far as we know, only two studies have validated cardiovascular prediction models in South Asians reporting performance measures of both discrimination and calibration, one in the UK and our validation of the Framingham cardiovascular risk model among Indians and Europeans in New Zealand [23,24]. Validation of prognostic models is essential as the consequence of using models with poor performance could be either overtreatment of healthy individuals or undertreatment of high-risk individuals.

To account for the excess risk of CVD in South Asians, different adjustment methods have been recommended to lower the thresholds of existing risk scores in South Asians [25–27]. The Norwegian guidelines recommend to multiply the NORRISK 2 score by 1.5 in South Asian individuals [4], similar to the previous UK recommendation of adding a factor of 1.4 to the Framingham risk score for South Asian men [27]. A validation study from the UK found that Framingham multiplied by 1.4 predicted the risk reasonably well in South Asian men [23]. The Framingham model (without any adjustments) underestimated the risk in South Asian women [23]. The European Society of Cardiology (ESC) also suggests a correction factor of 1.4 when using the European SCORE model to assess CVD risk among first-generation immigrants from South Asia [1]. However, according to the ESC guidelines, this should be interpreted with caution as the underlying evidence is somewhat limited, and ethnicity-specific risk equations could be considered. The updated cardiovascular risk model for the UK, QRISK3, exists in different versions [28]. One of the comprehensive QRISK3 versions (Model B with 21 predictors) was validated in Indians, Pakistanis and Bangladeshis by the model developers, and showed good performance according to the D statistics, $R^2$ and Harrell's C [28].

Type 2 diabetes is an important factor for the high cardiovascular risk in South Asians [13,29], and models that do not take diabetes or South Asian ethnicity into account might underestimate their risk. Both the NORRISK 2 and NORRISK 2-SADia models discriminated well with similar Harrell's C-values. However, c-statistics are insensitive measures for model selection [30]. The calibration showed that our NORRISK 2-SADia model improved risk prediction in South Asians compared to NORRISK 2. However, we found similar predicted risk estimates from NORRISK 2-SADia and the NORRISK 2 model multiplied with 1.5 in South Asian men without diabetes (Table 2). This conforms to similar percentages categorized as being at high risk for South Asians without diabetes according to these two models (Appendix Table 5 in supplementary materials), suggesting that the Norwegian guidelines are reasonable in this

**Table 3.** The CVD risk model NORRISK 2-SADia, with inclusion of diabetes (yes/no) and region of birth (South Asia versus Norway) for prediction of 10- and 13-year risk of acute cerebral stroke or acute myocardial infarction in men and women born in Norway or South-Asia.

| | Men ($N = 7458$, endpoints $= 471$) | | | Women ($N = 8369$, endpoints $= 209$) | | |
|---|---|---|---|---|---|---|
| Covariate | HR | 95% CI | | HR | 95% CI | |
| Age-40 | 1.08 | 1.07 | 1.09 | 1.09 | 1.07 | 1.11 |
| Systolic blood pressure-120 (per 10 mmHg) | 1.15 | 1.09 | 1.21 | 1.18 | 1.09 | 1.27 |
| Serum total cholesterol − 4 (per 1 mmol/L) | 1.24 | 1.13 | 1.35 | 1.24 | 1.08 | 1.42 |
| Daily smoking (yes/no) | 2.04 | 1.52 | 2.72 | 2.69 | 2.02 | 3.57 |
| Antihypertensives (yes/no) | 1.40 | 1.09 | 1.79 | – | – | – |
| Low HDL-cholesterol (yes/no) | 1.63 | 1.32 | 2.02 | – | – | – |
| Family history of CHD: one family member | 1.26 | 0.96 | 1.65 | – | – | – |
| Family history of CHD: at least two family members | 2.42 | 1.36 | 4.31 | – | – | – |
| Region of birth (South Asia versus Norway) | 1.68 | 1.29 | 2.20 | 2.67 | 1.61 | 4.43 |
| Diabetes (yes/no) | 2.11 | 1.52 | 2.94 | 2.05 | 1.15 | 3.65 |
| Daily smoking X (Age-40) | 0.98 | 0.96 | 1.00 | – | – | – |
| $S_0(10)$ | 0.99275 | – | – | 0.99746 | – | – |
| $S_0(13)$ | 0.98902 | – | – | 0.99608 | – | – |

HR: Hazard ratio; CI: confidence interval; HDL: high-density lipoprotein; CHD: coronary heart disease
$S_0(10)$ and $S_0(13)$ are estimated baseline survivor functions at 10 and 13 years of follow-up.
10-year risk is calculated by $1\text{-}S_0(10)^{\exp(\mathbf{Z}^*\boldsymbol{\beta})} = 1\text{-}S_0(10)^{\exp(\mathbf{Z}^*\ln(\mathbf{HR}))}$.
13-year risk is calculated by $1\text{-}S_0(13)^{\exp(\mathbf{Z}^*\boldsymbol{\beta})} = 1\text{-}S_0(13)^{\exp(\mathbf{Z}^*\ln(\mathbf{HR}))}$.
The baseline survivor function is the survival at age = 40, systolic blood pressure = 120, serum total cholesterol = 4, daily smoking = 0, other covariates = 0.
**Z** is the vector of covariates after transformation: age-40, (systolic bp-120)/10, (total chol-4). **β** is the vector of regression coefficients.

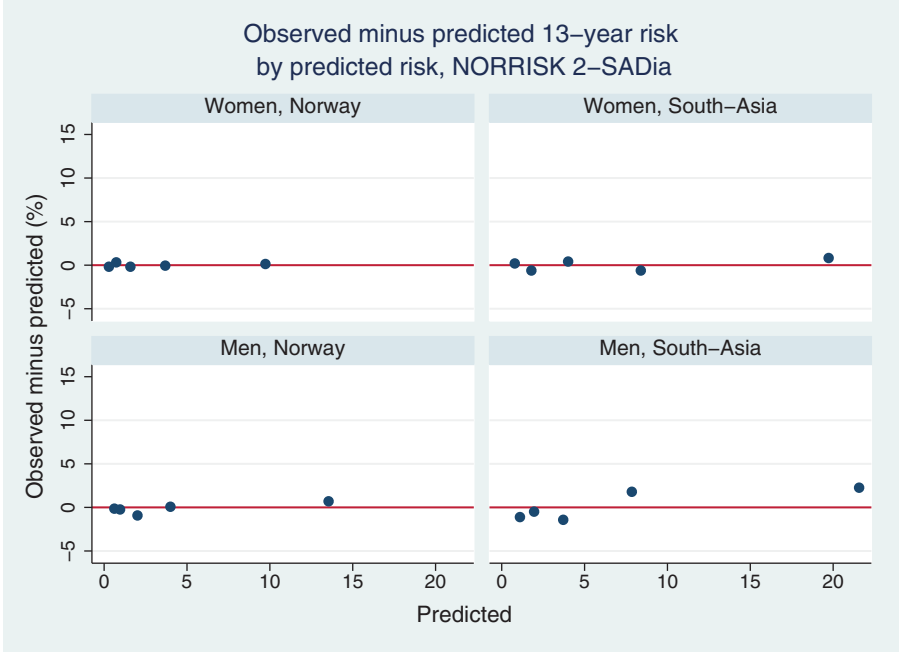


**Figure 2.** Calibration plots showing observed minus predicted 13-year risk for the updated NORRISK 2-SADia model.

group. To test if NORRISK 2-SADia is generalizable to other related populations, external validation is required [31].

The number of endpoints was small among women. Thus, although anti-hypertensive medications, low HDL-cholesterol and family history of CHD did not prove to be significant predictors for CVD among women in our data, we still consider these variables to be important risk factors for both men and women.

Other risk factors not considered here could possibly also improve risk prediction for South Asians (in Norway). However, too many predictors in a model could result in a model more difficult to implement in clinical practice. We have included the classical CVD risk factors and few endpoints preclude inclusion of many risk factors, especially in women.

### *Strengths and limitations*

A strength of this study is the population-based study design and the inclusion of the major cardiovascular risk factors in the model.

Cardiovascular risk prediction scores have different definitions of endpoints, which makes it difficult to compare risk scores. A strength of the NORRISK 2 model compared to the European SCORE model and the previous Norwegian model (NORRISK) is the inclusion of both non-fatal and fatal events. Non-fatal events are especially important to address owing to the substantial decline in cardiovascular mortality in Norway since the 1970s. The acute endpoints of the NORRISK 2 model is also a strength as the ICD-coding of AMI and acute stroke in administrative databases has been found to be more reliable than less acute endpoints such as angina, heart failure and peripheral arterial disease [32–34]. We, therefore, believe coding of acute cardiovascular events to be of acceptable validity.

Diabetes information was self-reported. A previous study based on data from two Oslo health studies (one is included herein) showed that among South Asian diabetic men, about 50% had undiagnosed diabetes [14]. Undiagnosed diabetes may have contributed to the observed high risk in South Asians without known diabetes.

One limitation is the low participation rates (40–48%), which increases the possibility of selection bias. Usually, men and women who participate in health surveys are healthier than non-participating men and women. If the self-selection mechanisms were different for the different ethnic groups, it could influence the ethnic comparisons in this study. However, the ethnic differences in risk of CVD in this paper correspond to ethnic differences in risk of CVD that we found in a previous study where self-selection was not a problem [11].

Another limitation is that we studied South Asians from several countries combined despite within-group heterogeneity regarding CVD. We previously found that the standardized AMI event rate per 100,000 person-years in Pakistani men were 978 (95% CI 894–1061) versus 514 (95% CI 411–616) in Indian men [11]. Thus, it is possible that the new risk score does not improve risk prediction equally well for all South Asian subgroups. Also, excess risk may be influenced by environmental factors and change over time. Unfortunately, we did not have the information available to distinguish between South Asian subgroups. Based on the original health surveys, we have estimated that approximately 50% of the South Asian group are Sri Lankans and 35% are Pakistanis in our study [13].

Immigrants from Former Yugoslavia, the Middle East and Central Asia also have increased cardiovascular risk compared to Norwegian-born and may need more precise risk prediction tools [11]. We did not have sufficient data to study these ethnic groups, but it should be a future research objective to validate the NORRISK 2 model among other immigrant groups living in Norway.

In this article, we present an updated cardiovascular risk model to predict the risk of CVD in immigrants from South Asia living in Norway by including information about ethnicity and diabetes. It is of great importance to evaluate and improve the cardiovascular risk assessment tools in South Asian populations given their high risk of CVD.

## Acknowledgements

The authors would like to thank Tomislav Dimoski at the Norwegian Knowledge Centre for the Health Services (now Norwegian Institute of Public Health), Oslo, Norway for his contribution by developing software necessary for obtaining data from Norwegian hospitals, conducting the data collection and quality assurance of data in this project.

## Disclosure statement

The authors declare that there is no conflict of interest.

## Funding

This work was supported by Helse Vest [grant number F-12523].

## References

[1] Piepoli MF, Hoes AW, Agewall S, et al. 2016 European guidelines on cardiovascular disease prevention in clinical practice: the Sixth Joint Task Force of the European Society of Cardiology and Other Societies on Cardiovascular Disease Prevention in Clinical Practice (constituted by representatives of 10 societies and by invited experts) Developed with the special contribution of the European Association for Cardiovascular Prevention & Rehabilitation (EACPR)). Eur Heart J. 2016;37(29):2315–2381.

[2] World Health Organization. Prevention of cardiovascular disease. Pocket guidelines for assessment and management of cardiovascular risk. (WHO/ISH cardiovascular risk prediction charts for WHO epidemiological sub-regions AFR D and AFR E). Geneva, Switzerland: World Health Organization; 2007. ISBN 978 92 4 154726 0.

[3] Selmer R, Igland J, Ariansen I, et al. NORRISK 2: a Norwegian risk model for acute cerebral stroke and myocardial infarction. Eur J Prev Cardiol. 2017;24(7):773–782.

[4] Norwegian Directorate of Health. Nasjonal faglig retningslinje for forebygging av hjerte- og karsykdom (National guidelines for prevention of cardiovascular disease). Oslo, Norway: Norwegian Directorate of Health; 2017.

[5] Tillin T, Hughes AD, Mayet J, et al. The relationship between metabolic risk factors and incident cardiovascular disease in Europeans, South Asians, and African Caribbeans: SABRE (Southall and Brent Revisited)—A prospective population-based study. J Am Coll Cardiol. 2013;61(17):1777–1786.

[6] Hempler NF, Larsen FB, Nielsen SS, et al. A registry-based follow-up study, comparing the incidence of cardiovascular disease in native Danes and immigrants born in Turkey, Pakistan and the former Yugoslavia: do social inequalities play a role? BMC Public Health. 2011;11:662.

[7] Hedlund E, Lange A, Hammar N. Acute myocardial infarction incidence in immigrants to Sweden. Country of birth, time since immigration, and time trends over 20 years. Eur J Epidemiol. 2007;22(8):493–503.

[8] Fedeli U, Cestari L, Ferroni E, et al. Ethnic inequalities in acute myocardial infarction hospitalization rates among young and middle-aged adults in Northern Italy: high risk for South Asians. Intern Emerg Med. 2018;13(2):177–182.

[9] Volgman AS, Palaniappan LS, Aggarwal NT, et al. Atherosclerotic cardiovascular disease in South Asians in the United States: epidemiology, risk factors, and treatments: a scientific statement from the American heart association. Circulation. 2018;138(1):e1–e34.

[10] Ministry of Health. Asian health chart book 2006. Wellington, New Zealand: Ministry of Health; 2006.

[11] Rabanal KS, Selmer RM, Igland J, et al. Ethnic inequalities in acute myocardial infarction and stroke rates in Norway 1994-2009: a nationwide cohort study (CVDNOR). BMC Public Health. 2015;15:1073.
[12] Statistics Norway. Immigrants and Norwegian-born to immigrant parents. 2019. [accessed 2019 Oct 04]. Available from: https://www.ssb.no/en/befolkning/statistikker/innvbef
[13] Rabanal KS, Meyer HE, Tell GS, et al. Can traditional risk factors explain the higher risk of cardiovascular disease in South Asians compared to Europeans in Norway and New Zealand? Two cohort studies. BMJ Open. 2017;7(12):e016819.
[14] Jenum A, Diep L, Holmboe-Ottesen G, et al. Diabetes susceptibility in ethnic minority groups from Turkey, Vietnam, Sri Lanka and Pakistan compared with Norwegians - the association with adiposity is strongest for ethnic minority women. BMC Public Health. 2012;12(1):150.
[15] Sattar N, Gill JM. Type 2 diabetes in migrant south Asians: mechanisms, mitigation, and management. Lancet Diabetes Endocrinol. 2015;3(12):1004–1016.
[16] Naess O, Søgaard AJ, Arnesen E, et al. Cohort profile: cohort of Norway (CONOR). Int J Epidemiol. 2008;37(3):481–485.
[17] Sulo G, Igland J, Vollset SE, et al. Cardiovascular disease and diabetes mellitus in Norway during 1994–2009 CVDNOR - a nationwide research project. Nor Epidemiol. 2013;23(1):101–107.
[18] Sulo G, Igland J, Nygård O, et al. Favourable trends in incidence of AMI in Norway during 2001–2009 do not include younger adults: a CVDNOR project. Eur J Prev Cardiolog. 2014;21(11):1358–1364.
[19] Fine JP, Gray RJ. A proportional hazards model for the subdistribution of a competing risk. J Am Statist Assoc. 1999;94(446):496–509.
[20] Cosentino F, Grant PJ, Aboyans V, et al. 2019 ESC Guidelines on diabetes, pre-diabetes, and cardiovascular diseases developed in collaboration with the EASD: the task force for diabetes, pre-diabetes, and cardiovascular diseases of the European Society of Cardiology (ESC) and the European Association for the Study of Diabetes (EASD). Eur Heart J. 2019;41:255–323.
[21] McKeigue PM, Miller G, Marmot M. Coronary heart disease in south Asians overseas: a review. J Clin Epidemiol. 1989;42(7):597–609.
[22] Gopal DP, Usher-Smith JA. Cardiovascular risk models for South Asian populations: a systematic review. Int J Public Health. 2016;61(5):525–534.
[23] Tillin T, Hughes AD, Whincup P, et al. Ethnicity and prediction of cardiovascular disease: performance of QRISK2 and Framingham scores in a U.K. tri-ethnic prospective cohort study (SABRE-Southall And Brent REvisited). Heart. 2014;100(1):60–67.
[24] Rabanal KS, Meyer HE, Pylypchuk R, et al. Performance of a Framingham cardiovascular risk model among Indians and Europeans in New Zealand and the role of body mass index and social deprivation. Open Heart. 2018;5(2):e000821.
[25] Aarabi M, Jackson PR. Predicting coronary risk in UK South Asians: an adjustment method for Framingham-based tools. Eur J Cardiovasc Prev Rehabil. 2005;12(1):46–51.
[26] New Zealand Guideline Group. The assessment and management of cardiovascular risk. Wellington, New Zealand: New Zealand Guideline Group; 2003.
[27] Cooper A, O'Flynn N, Guideline Development Group. Risk assessment and lipid modification for primary and secondary prevention of cardiovascular disease: summary of NICE guidance. BMJ. 2008;336(7655):1246–1248.
[28] Hippisley-Cox J, Coupland C, Brindle P. Development and validation of QRISK3 risk prediction algorithms to estimate future risk of cardiovascular disease: prospective cohort study. BMJ. 2017;23(357):j2099.
[29] Tillin T, Chaturvedi N. Stemming the tide of type 2 diabetes and its consequences in south Asian individuals. Lancet Diabetes Endocrinol. 2014;2(3):186–188.
[30] Cook NR. Use and misuse of the receiver operating characteristic curve in risk prediction. Circulation. 2007;115(7):928–935.
[31] Steyerberg EW, Vickers AJ, Cook NR, et al. Assessing the performance of prediction models: a framework for traditional and novel measures. Epidemiology. 2010;21(1):128–138.
[32] McCormick N, Bhole V, Lacaille D, et al. Validity of diagnostic codes for acute stroke in administrative databases: a systematic review. PLoS One. 2015;10(8):e0135834.
[33] McCormick N, Lacaille D, Bhole V, et al. Validity of myocardial infarction diagnoses in administrative databases: a systematic review. PLoS One. 2014;9(3):e92286.
[34] Lasota AN, Overvad K, Eriksen HH, et al. Validity of peripheral arterial disease diagnoses in the Danish National patient registry. Eur J Vasc Endovasc Surg. 2017;53(5):679–685.