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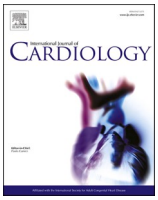

Adding ethnicity to cardiovascular risk prediction: External validation and model updating of SCORE2 using data from the HELIUS population cohort

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ABSTRACT

Background: Current prediction models for mainland Europe do not include ethnicity, despite ethnic disparities in cardiovascular disease (CVD) risk. SCORE2 performance was evaluated across the largest ethnic groups in the Netherlands and ethnic backgrounds were added to the model.

Methods: 11,614 participants, aged between 40 and 70 years without CVD, from the population-based multi-ethnic HELIUS study were included. Fine and Gray models were used to calculate sub-distribution hazard ratios (SHR) for South-Asian Surinamese, African Surinamese, Ghanaian, Turkish and Moroccan origin groups, representing their CVD risk relative to the Dutch group, on top of individual SCORE2 risk predictions. Model performance was evaluated by discrimination, calibration and net reclassification index (NRI).

Results: Overall, 274 fatal and non-fatal CVD events, and 146 non-cardiovascular deaths were observed during a median of 7.8 years follow-up (IQR 6.8–8.8). SHRs for CVD events were 1.86 (95 % CI 1.31–2.65) for the South-Asian Surinamese, 1.09 (95 % CI 0.76–1.56) for the African-Surinamese, 1.48 (95 % CI 0.94–2.31) for the Ghanaian, 1.63 (95 % CI 1.09–2.44) for the Turkish, and 0.67 (95 % CI 0.39–1.18) for the Moroccan origin groups. Adding ethnicity to SCORE2 yielded comparable calibration and discrimination [0.764 (95 % CI 0.735–0.792) vs. 0.769 (95 % CI 0.740–0.797)]. The NRI for adding ethnicity to SCORE2 was 0.24 (95 % CI 0.18–0.31) for events and − 0.12 (95 % CI -0.13–0.12) for non-events.

Conclusions: Adding ethnicity to the SCORE2 risk prediction model in a middle-aged, multi-ethnic Dutch population did not improve overall discrimination but improved risk classification, potentially helping to address CVD disparities through timely treatment.

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1. Introduction

In mainland Europe, the SCORE2-model [1] has been developed to predict 10-year CVD risk based on conventional cardiovascular risk factors for apparently healthy individuals without prior CVD or Type 2 diabetes (T2D) across different geographical risk regions. The SCORE2 model includes no coefficient to reflect differences in CVD risk for different ethnicities, despite Europe's increasingly diverse populations and the notion that most ethnic minority populations have an increased risk of CVD compared to European host populations. [2–4] Incorporating ethnicity into cardiovascular risk prediction models may improve risk prediction accuracy, [6] as other regions (such as the UK and USA) have shown. [7,8] The 2021 European Society of Cardiology (ESC) guideline recommends using the SCORE2-model but mentions ethnicity as a potential CVD risk modifying factor, independent from traditional risk factors in SCORE2. [6] It recommends multiplying factors for several ethnicities, i.e., multiplying the risk by 1.3 for Southern Asian Indians or 0.85 for Black Caribbeans. Nevertheless, country and risk-calculator-specific relative risks should be used where available, as the ethnic make-up and their overall impact on estimated risk may vary across regions and risk calculators. [6] Therefore, to gain a broader understanding of the impact of ethnicity in CVD risk prediction, research in diverse ethnic groups and contexts is needed. For instance, a recent study in the Netherlands found that SCORE2 underestimates CVD risk, especially in migrant groups with a Surinamese background. [5] Apart from that, little is known about the impact of ethnicity on the performance of the SCORE2 model. In this study, we aim to update the SCORE2 prediction model for the largest ethnic minority populations in the Netherlands.

2. Methods

2.1. Study population and outcome assessment

Our study included participants enrolled in the population-based multi-ethnic Healthy Life in an Urban Setting (HELIUS) study. Full details, including study rationale and design, are described elsewhere. [9] In short, HELIUS is a large-scale prospective cohort study on health and healthcare utilisation among the six largest ethnic groups living in Amsterdam, the Netherlands. Baseline data collection was conducted between January 2011 and December 2015, including participants aged 18–70 years of African Surinamese, South-Asian Surinamese, Turkish, Moroccan, Ghanaian, and Dutch origin. Participants were randomly selected through the municipal registry of Amsterdam, stratified for ethnic background to generate comparable group sizes. Of the 90,019 persons invited, we were able to contact and get a response from 55 % (49,952/90,019), either by written invitation or after a home visit by an interviewer. Of those, in total 50 % (24,789/49,952) agreed to participate, corresponding to a response rate of 28 %, with variation across ethnic groups. Data collection was done by a questionnaire/interview and physical examination at the research location, including the collection of biological samples. The Medical Ethics Committee of the Academic Medical Center approved the study protocols and this study was conducted in accordance with the ethical principles of the Declaration of Helsinki. All participants provided written informed consent. In total, 22,162 participants filled in the questionnaire and had a physical examination, of whom 19,932 gave permission for their data to be linked to data on hospital admission. Data were linked with Statistics Netherlands by citizen service number using pseudonymised identifiers for individuals. [10] Linkage was successful for 19,893 participants (99.8 %), of whom 19,875 (99.7 %) gave permission to request the official causes of death from Statistics Netherlands. We excluded those who had a self-reported history of CVD, defined as self-reported myocardial infarction, coronary or peripheral revascularisation or cerebrovascular event, or missing data on CVD in combination with self-reported usage of platelet aggregation inhibitors. Moreover, as SCORE2 applies to individuals aged between 40 and 70, we excluded those outside this age range. Finally, ethnic subgroups with less than ten events were excluded from all analyses. [11] This led to a study sample of $n = 11{,}614$ participants (Supplementary fig. 1). Participants with T2D, classified as having diabetes based on self-reported diabetes, using glucose-lowering medication or a fasting plasma glucose level ≥ 7.0 mmol/L, according to the WHO criteria, [12] were included in our initial analyses since they were also included in the SCORE2 risk prediction models' derivation. [1] Hospital admission data included all admissions between 2013 and 2021 of one or more days to general and academic hospitals in the Netherlands (coverage between 2013 and 2021, 97.3 to 99.7 %). Ambulatory contacts (such as emergency room visits without subsequent admission and outpatient visits) were not included. Death records included all causes of death registered in the cause of death registry at Statistics Netherlands between 2013 and 2021.

2.2. Outcomes

The primary outcome was similar to SCORE2, a composite of cardiovascular mortality, non-fatal myocardial infarction and non-fatal stroke. [1] Death from non-cardiovascular causes were considered competing events. Follow-up was until the first CVD event, non-cardiovascular death or end of the event registration period. Details of the different ICD-10 codes in the fatal and non-fatal components of the outcomes are provided in Supplementary table 1.

2.3. Predictors

A person was defined as of non-Dutch ethnic origin if he/she fulfilled one of two criteria: (1) he/she was born outside the Netherlands and has at least one parent born outside the Netherlands (first generation) or (2) he/she was born in the Netherlands but both parents were born outside the Netherlands (second generation). For the Dutch sample, we invited people who were born in the Netherlands and whose parents were born in the Netherlands. After data collection, participants of Surinamese ethnic origin were further classified according to self-reported ethnic origin (obtained by questionnaire) into 'African', 'South-Asian', 'Javanese', or 'other'. Age and sex were derived from the municipal registry at cohort entry. SCORE2 coefficients included sex, age, current smoking, systolic blood pressure, and non-HDL cholesterol. Current smoking was based on self-report. Blood pressure was measured on the left arm in a seated position after the subject had been seated for at least 5 min, using a validated automated digital BP device (Microlife WatchBP Home, Microlife AG, Heerbrugg, Switzerland) and performed in duplicate. The mean of the two measurements was used in the analyses. Total cholesterol and HDL-cholesterol were determined by enzymatic colorimetric spectrophotometry (Roche Diagnostics, Japan). Educational attainment was used as the indicator of socioeconomic status (SES) and defined as the highest level of education attained in the Netherlands or in the country of origin. Educational level was dichotomised as no or elementary schooling versus intermediate or higher schooling or university education. Few participants had missing data on predictors ($n = 62$; 0.56 %). We imputed these missing data by single regression imputation using predictive mean matching. Further details on handling of missing data are described in the Supplemental methods.

2.4. Statistical analysis

To illustrate ethnic differences in CVD incidences we calculated crude and age-standardised CVD incidence rates per 1000 person-years stratified by ethnic group. We used the age structure of the Dutch origin HELIUS sample in 2014 (midpoint of baseline data collection) as the age reference group. We used Fine and Gray competing risk models to examine the risk-modifying effect of the ethnicities included in the HELIUS-study, on top of the SCORE2 predictions. [13] In these Fine and Gray competing risk models, the SCORE2 coefficients were included as a

linear predictor and included as an offset term. Using an offset term, or fixed predictor, ensures that the SCORE2 coefficients are the same as published. [14] Using this approach, sub-distribution hazard ratios (SHR) per ethnic group were obtained in reference to the Dutch origin group. In this way, the risk-modifying characteristic of ethnicity can afterwards be applied to individual predictions of the SCORE2 model using the naïve approach, [15] which adapts individual predicted risk based on the SHR and prevalence of the relevant factor (in this case, the distribution of ethnic groups in the Dutch general population). For this naïve approach, we obtained data on the nationwide distribution of relevant ethnic groups participating in HELIUS in the Netherlands using Statistics Netherlands (Supplementary table 2). [16,17] As the HELIUS cohort had less than the 10-year of follow-up that SCORE2 assumes, the calibration of the model was evaluated at 8 years. Visual assessment of event-free survival curves and corresponding proportions over the follow-up duration for each ethnic group indicated the 8th year was the last full year with a sufficient follow-up across all ethnic groups (Supplementary fig. 2, Supplementary table 3, Supplemental methods). The agreement between individual SCORE2 observed and predicted outcomes was assessed using observed/mean expected (OE) ratios for each ethnic group.

2.4.1. Model performance

As at least 200 events is considered suitable for external validation, model performance was assessed in the total population. [18] Though limited by fewer CVD events, we also assessed model performance in ethnic subgroups, as this constituted our research question. The performance of the SCORE2 algorithm with and without the addition of the factor ethnicity was evaluated in terms of calibration (goodness-of-fit), discrimination, and net categorical reclassification index (NRI). We used Harrell's C-index and corrected for competing risks to assess discrimination. [19] To assess calibration, we evaluated the impact of including ethnicity on the adapted SCORE2 goodness-of-fit by plotting sextiles of predicted risk against observed cumulative CVD incidences. Additionally, we calculated the Brier score (a measure of goodness of fit where lower values indicate better accuracy) and used a bootstrap estimation approach with 1000 samples to obtain 95 % confidence intervals. [20] The NRI was calculated based on the 2021 ESC prevention guideline cut-offs for individuals between 50 and 69 years old: 5 % and 10 % 10-year fatal and non-fatal CVD risk. [6] NRIs were calculated separately for events and non-events, and confidence intervals were obtained using bootstrapping (r-package *nricens*). [21] Additionally, we calculated the Integrated Discrimination Index as a reclassification measure that does not use categories but integrates the NRI over all levels of risks. [22] We used Sankey flow diagrams to visualize CVD risk recategorization in individuals with and without events when ethnicity was added to the model. In exploratory analyses, we used a Fine and Gray competing risk model, including ethnicity and educational attainment as covariates, to assess the contribution of variations in educational attainment, as a proxy for socioeconomic status, to observed ethnic differences in CVD risk. [5] As a sensitivity analysis, we evaluated whether the effect of including ethnicity in the SCORE2 algorithm was similar when participants with T2D were excluded. All analyses were performed using R (version 4.1.3*, R Foundation for Statistical Computing, Vienna, Austria*).

3. Results

Our study population involved 11,614 individuals, and their characteristics are presented in Table 1. The mean age at baseline was 52.2 ± 7.5 years, and 57.3 % were female. During a median of 7.8 years of follow-up (IQR 6.8–8.8), 274 fatal and non-fatal CVD events and 146 non-cardiovascular deaths were observed. Table 2 presents all CVD events and incidence rates stratified by ethnic group. Age-standardised CVD incidence per 1000 person-years in the Dutch participants was 3.5, ranging from 1.7 in the Moroccan participants to 5.8 in the South-Asian Surinamese participants. SCORE2 predictions generally overestimated CVD risk, except in the South-Asian Surinamese. OE-ratios for 8-year CVD risk were 0.66 in the Dutch participants, 1.24 in the South-Asian Surinamese, 0.95 in the Turkish, 0.88 in the Ghanaian, 0.72 in the African Surinamese, and 0.41 in the Moroccan participants. SHRs, representing the risk of developing CVD per ethnic group relative to the Dutch origin group, were significantly higher for the South-Asian Surinamese 1.86 (95 % CI 1.31–2.65) and Turkish 1.63 (95 % CI 1.09–2.44), and lower, though not statistically significant, for Moroccan 0.67 (95 % CI 0.39–1.18) participants.(Fig. 1).

As a clinical example, using SCORE2, the predicted 10-year risk was 5.8 % for a 59-year-old man with a South-Asian Surinamese ethnicity who does not smoke, has a systolic blood pressure of 150 mmHg, total cholesterol of 4.14 mmol/L and an HDL-cholesterol of 1.05 mmol/L. Using the SCORE2 updated for ethnicity would increase his risk to 10.5 %.

Adding ethnicity to the SCORE2 algorithm led to a comparable goodness-fit and discrimination, 0.764 (95 % CI 0.735–0.792) versus 0.769 (95 % CI 0.740–0.797) compared to the original SCORE2 and an improved NRI (Figs. 2 and 3). Brier scores were 0.022 (95 % CI 0.020–0.025) for both the original SCORE2 model and 0.022 (0.020–0.025) for the extended model. The IDI for adding ethnicity to SCORE2 was 0.010 (95 % CI: 0.008 to 0.013). In the total study population, the NRI for adding ethnicity compared to the original SCORE2 model was 0.244 (95 % CI 0.180–0.310) for events and − 0.125 (95 % CI

Table 1
Characteristics of the study sample, HELIUS study (2011–2015).

	Dutch	South-Asian Surinamese	African Surinamese	Ghanaian	Turkish	Moroccan	Missing
Total	2627	1663	2597	1468	1579	1680	
Women (n, %)	1404 (53.4 %)	983 (59.1 %)	1598 (61.5 %)	857 (58.4 %)	847 (53.6 %)	969 (57.7 %)	
Baseline:							
Age (years, ±SD)	54.4 (8.2)	52.5 (7.5)	53.5 (7.2)	50.2 (6.2)	49.3 (6.3)	50.9 (7.4)	
Systolic blood pressure (mmHg, ±SD)	128 (17.1)	133 (18.4)	135 (18.1)	139 (18.3)	128 (16.3)	127 (16.4)	24 (0.2 %)
Total cholesterol (mmol/l, ±SD)	5.48 (1.02)	5.15 (1.06)	5.04 (1.00)	5.10 (1.02)	5.15 (0.97)	4.86 (0.95)	62 (0.5 %)
HDL cholesterol (mmol/l, ±SD)	1.60 (0.46)	1.34 (0.38)	1.52 (0.44)	1.64 (0.45)	1.27 (0.36)	1.30 (0.34)	60 (0.5 %)
Smoking (n, %)	579 (22.0 %)	424 (25.5 %)	806 (31.0 %)	69 (4.7 %)	498 (31.6 %)	194 (11.5 %)	55 (0.5 %)
None or elementary education (n, %)	109 (4.1 %)	304 (18.3 %)	198 (6.1 %)	504 (34.3 %)	740 (46.9 %)	889 (52.9 %)	108 (0.9 %)
Diabetes (n, %)	124 (4.7 %)	397 (23.9 %)	392 (15.1 %)	210 (14.3 %)	245 (15.5 %)	337 (20.1 %)	50 (0.4 %)
Follow-up:							
Follow-up duration (person-years, IQR)	7.8 (6.7–9.0)	8.0 (7.0–9.0)	7.9 (6.8–9.2)	8.3 (7.7–9.2)	7.6 (6.8–8.4)	7.4 (6.7–8.1)	
Events							
- CVD (n, %)	57 (2.2 %)	68 (4.1 %)	64 (2.5 %)	29 (2.0 %)	40 (2.5 %)	16 (1.0 %)	
- Non CVD death (n, %)	43 (1.6 %)	19 (1.1 %)	50 (1.9 %)	19 (1.3 %)	(..)	(..)	

(..) is smaller than 10 and is therefore undisclosed from Statistics Netherlands.
CVD, cardiovascular disease.

Table 2
CVD incidence 2013–2021 (fatal and non-fatal) in total and by ethnicity.

	Total	Dutch	South-Asian Surinamese	African Surinamese	Ghanaian	Turkish	Moroccan
Total	11,614	2627	1663	2597	1468	1579	1680
CVD cases (n)	274	57	68	64	29	40	16
Follow-up duration sum (years)	90,826	20,425	13,294	20,484	12,166	11,999	12,458
Crude incidence rate*	3.1	2.8	5.1	3.1	2.4	3.3	1.3
Age-standardised incidence rate*	3.5	2.8	5.8	3.2	4.0	5.0	1.7

* per 1000 person-years. CVD, cardiovascular disease.

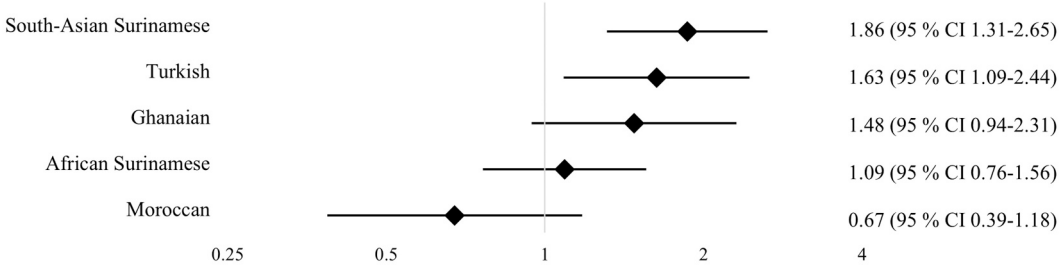

Fig. 1. Subdistribution hazard ratio's (95 % CI) per ethnic group in reference to the Dutch participants.

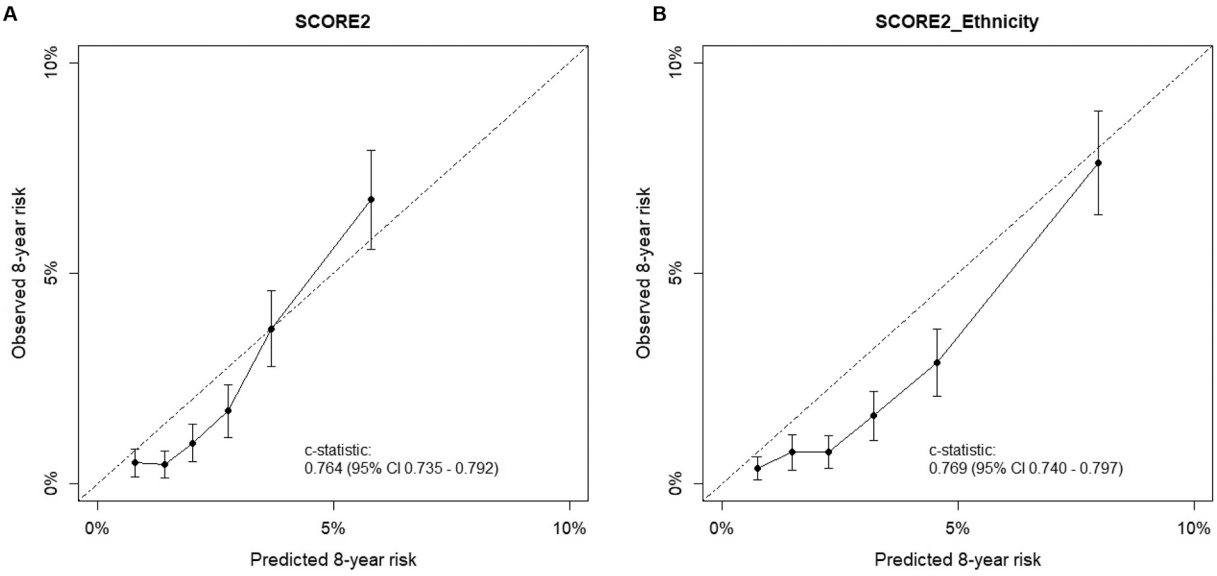

Fig. 2. Calibration plots of original SCORE2 model (A) and SCORE2 updated for ethnicity (B).

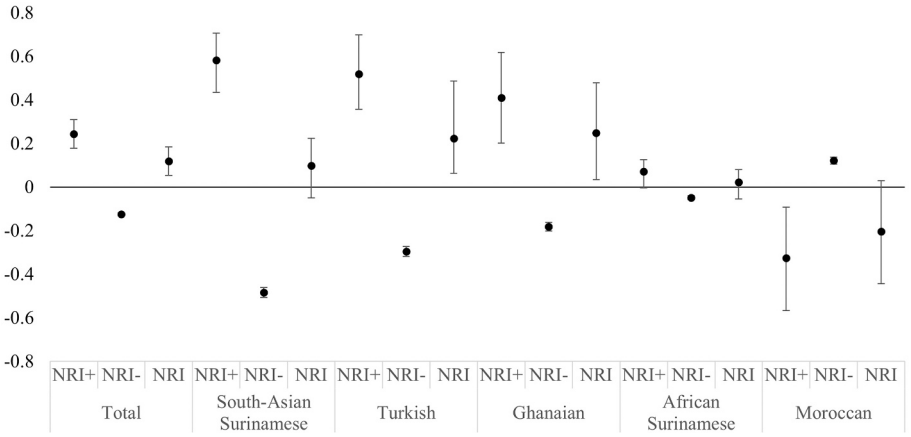

Fig. 3. Net reclassification for events, non-events and combined per ethnic group.

-0.131-0.118) for non-events. In the Ghanaian and Turkish participants, adding ethnicity to SCORE2 significantly improved NRIs (Fig. 3). Goodness-of-fit per ethnic group improved when adding ethnicity to SCORE2, especially reducing underestimation in the South-Asian Surinamese and Turkish groups and overestimation in the Moroccan group (Supplementary fig. 3). The Sankey flow diagrams visualizing recategorization when adding ethnicity to SCORE2 show that relatively many participants in the event group were appropriately reclassified in to higher risk categories, while a relatively smaller group was inappropriately reclassified in the non-event group (Supplementary fig. 4). The SHRs of ethnic groups included in the study were generally slightly attenuated but consistent with the main models when the educational attainment was included in the analyses. (Supplementary table 4). In a sensitivity analyses excluding participants with T2D, the SHRs, calibration, and discrimination were consistent with the findings in the total study population (Supplementary table 5 and supplementary figs. 5–6).

4. Discussion

4.1. Summary of key findings

This study aimed to evaluate the performance of the SCORE2 CVD risk prediction model in ethnic groups in the multi-ethnic HELIUS study cohort and update the model to include ethnicity. Overall performance showed overestimation in most subgroups. Compared to the Dutch participants, markedly higher CVD risks were observed in the South-Asian Surinamese and Turkish participants, while differences with other groups were smaller and non-significant. Adding ethnic backgrounds to SCORE2 led to comparable calibration and discrimination in the total population, but improved overall risk classification according to the NRI and calibration within the ethnic groups.

Our findings corroborate the need for accounting for ethnicity in CVD risk prediction. [6,7] The OE-ratio for South-Asian Surinamese for SCORE2 was about 1.87 as high as that of the Dutch participants, slightly larger than an observation in a recent Dutch external validation study that found SCORE2 underestimated risks in Surinamese individuals. [5] However, due to the absence of self-identified ethnicity data, this recent study could not distinguish between South-Asian Surinamese and African Surinamese groups, who have distinct risk factor profiles. [4] The divergent risk between these groups in our findings illustrates the value of adding self-reported ethnicity rather than solely country of birth in risk prediction modelling considering ethnicity. Additionally, our results substantiate the ESC guideline recommendation that ideally, country specific risk calculators should be used. [6]

The multiplication factor recommended for Black Africans (i.e. 0.7), based on findings from the UK, [6] may not be suitable in a Dutch context for those of Ghanaian or African Surinamese ancestry as our findings suggest that for Dutch Ghanaians a multiplication factor of 1.5 may yield better risk prediction, and CVD risk was comparable for those of African Surinamese and European Dutch origin. Our findings may have relevance for migrant populations in low-risk regions with prevalence rates similar to those in the Netherlands, such as Turkish migrants in Denmark, Austria or Moroccans in Belgium. [23] Nonetheless, it is important to consider socioeconomic factors and potential variations in contextual factors, such as the provision of and accessibility to preventive healthcare, across different regions. Therefore, country-specific or locoregional CVD risk prediction models may be preferable, as the relative CVD risks in ethnic groups compared to host populations can vary. [6] It is worth noting that multiplication factors among ethnic groups compared to European host populations may change over time and across generations. [24]

Compared to previous SCORE2 external validation studies, our results indicate a relatively high C-index and good calibration of the original model. [1,5,25] The moderate sample size in our study may have led to greater variability, potentially leading to higher performance of the model, especially in subgroups. [18] Updating SCORE2 with ethnicity, henceforth SCORE2_Ethnicity, yielded comparable calibration and discrimination across the whole population, possibly due to varying risk profiles observed in the studied ethnic groups, including both higher and lower risk categories relative to the Dutch population. In ethnic subgroup analyses, SCORE2_Ethnicity improved calibration, reducing underestimation in South-Asian Surinamese and Turkish participants. Therefore, its potential impact may be more individual-focused, rather than improving population-level model performance. The improvements in NRI suggest that the model is more likely to accurately classify both high and low risk patients compared to the original SCORE2 model, underscoring the potential individual-level benefits. The difference in results for the NRI compared to the C-index, Brier score, and IDI, may be explained by a relatively large proportion of individuals correctly reclassified in the event group, compared to the relatively small proportion of individuals correctly reclassified in the non-event group, as illustrated by the Sankey plots. The NRI weighs these groups equally. The identical c-statistics for the old and new score may indicate that for the overall population, there may be a gain in sensitivity that is balanced by a loss in specificity, with the area under the curve remaining identical. In practice, SCORE2_Ethnicity may enhance proactive care by estimating higher risk levels for many patients with a migration background, potentially prompting appropriate drug treatment. [6] External validation of SCORE2_Ethnicity is warranted before such applications are considered.

In a recent Dutch study, SCORE2 underwent external validation using a comprehensive General Practitioner Research Network database, incorporating linked national data on outcomes and ethnic background. [5] External validation for SCORE2_Ethnicity may be assessed in the largest migrant populations in these clinical care data. However, interpretation should take place with caution as patients registered in primary care may be at higher overall risk than participants taking part in a population-based cohort study. [26] For other European countries, country specific or locoregional CVD risk prediction models may be preferable as the relative CVD risks in ethnic groups compared to host populations may vary. [6]

In our study, adjusting for educational level as a proxy for SES slightly attenuated relative risks. Ethnicity is multifaceted and many mechanisms may underlie its impact on non-communicable diseases, such as CVD. [27] Limited by few incident CVD cases, our study did not allow for extensive adjusting of other relevant factors, including social deprivation, or racism. [28] Future studies may shed further light on the factors that link ethnicity to a higher CVD risk. Notably, these factors are absent in SCORE2. The incorporation of ethnicity could offer a practicable method to improve SCORE2 risk prediction for the ethnicities included in this study.

The overestimation SCORE2 risk in most subgroups is in contrast with recent findings of underestimation observed in a prospective, dynamic population-based study from routine health care databases, possibly due to generally more healthy individuals taking part in cohort studies. [5,26] Another explanation may be the median follow-up duration of 8 years in our study, necessitating interpolation of the 10-year SCORE2 algorithm assuming a linear association of CVD risk over time, while an exponential pattern is more likely. Nevertheless, while both mechanisms may lead to the observed underestimations, relative risks generally remain unaffected. [29]

4.2. Limitations and strengths

Our study has several limitations. First, due to limited number of CVD cases, we presented our main analyses without stratifying for sex which may limit our insight in how predictions differ by sex. Second, our findings may have been affected by response or attrition bias. Response rates were relatively low despite employing supportive measures to increase enrolment of ethnic groups, such as working with faith communities and endorsement from local key figures. Still, the HELIUS study was able to include large numbers of each ethnic groups and non-

response analyses indicated that differences in socio-economic indicators between participants and non-participants were relatively small, especially when compared to differences across ethnic groups. [9] The Salmon bias, which suggests that severely ill individuals may return to their country of origin, could be a plausible explanation for the relatively low CVD rate among Moroccans in the Netherlands, but evidence does not support this hypothesis. [30] Alternatively, cross-border healthcare use may contribute to lower CVD rates, but previous research suggests that this is primarily driven by developing symptoms or worsening conditions during visits to the country of origin rather than dissatisfaction with healthcare in the Netherlands. [31] Still, underregistration of events remains possible as migrants may spend relatively long periods of time in their countries of origin, where events may occur that are not captured in our data. This possible underregistration may lead to an underestimation of the elevated CVD risk in most ethnic groups within our sample, and an overestimation of the lower CVD risk in the Moroccan origin group.

Our study has several strengths too. First, a key strength of this study lies in the unique multi-ethnic prospective cohort of the HELIUS study, encompassing comprehensive baseline measurements for SCORE2 calculation within the largest ethnic minority groups in the Netherlands, allowing for detailed subdividing by self-reported ethnicity. Second, we adjusted our analyses for competing risks of non-CVD death, which reduces potential overestimation of cumulative incidence. [32] Third, we used a methodology for the flexible addition of risk-modifying characteristics on top of the SCORE2 algorithm. After further validation, implementation may be facilitated through incorporation of ethnicity as a separate variable of widely used online calculators such as http://www.u-prevent.com/ to accommodate risk stratification. [14]

4.3. Conclusion

Adding ethnicity improves risk classification of the SCORE2 risk prediction model in a middle-aged, multi-ethnic Dutch population but does not improve discrimination performance for the overall population. Compared to Dutch origin participants, markedly higher CVD risks were observed in the South-Asian Surinamese and Turkish origin participants. Improved risk classification may help to address CVD disparities through timely treatment in those in the highest risk categories.

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CRediT authorship contribution statement

Joshua A.N. van Apeldoorn: Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Conceptualization. **Steven H.J. Hageman:** Writing – review & editing, Visualization, Methodology, Investigation, Formal analysis, Conceptualization. **Ralf E. Harskamp:** Writing – review & editing. **Charles Agyemang:** Writing – review & editing. **Bert-Jan H. van den Born:** Writing – review & editing. **Jan Willem van Dalen:** Writing – review & editing. **Henrike Galenkamp:** Writing – review & editing, Data curation. **Marieke P. Hoevenaar-Blom:** Writing – review & editing. **Edo Richard:** Writing – review & editing. **Irene G.M. van Valkengoed:** Writing – review & editing. **Frank L.J. Visseren:** Writing – review & editing. **Jannick A.N. Dorresteijn:** Writing – review & editing, Conceptualization. **Eric P. Moll van Charante:** Writing – review & editing, Conceptualization.

Declaration of competing interest

All authors declare no conflicting interest.

Data availability

The data used for this study are part of the HELIUS study and are not publicly available. The HELIUS data are owned by the Amsterdam UMC in Amsterdam, the Netherlands. Researchers can request the data by submitting a proposal to the HELIUS Executive Board as outlined at http://www.heliusstudy.nl/en/researchers/collaboration. Requests for further information and proposals can be submitted to HELIUS's scientific coordinator (heliuscoordinator@amsterdamumc.nl). The HELIUS Executive Board will check proposals for compatibility with the general objectives, ethical approvals and informed consent forms of the HELIUS study and potential overlap with ongoing work affiliated with HELIUS. There are no other restrictions to obtaining the data; all data requests will be processed similarly. R-scripts used for the current analyses will be shared on reasonable request.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijcard.2024.132525.

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