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Psychosocial factors may serve as additional eligibility criteria for cardiovascular risk screening in women and men in a multi-ethnic population: The HELIUS study

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ABSTRACT

Cardiovascular disease (CVD) prevention strategies include identifying and managing high risk individuals. Identification primarily occurs through screening or case finding. Guidelines indicate that psychosocial factors increase CVD risk, but their use for screening is not yet recommended. We studied whether psychosocial factors may serve as additional eligibility criteria in a multi-ethnic population without prior CVD. We performed a cross-sectional analysis using baseline data of 10,226 participants of Dutch, South-Asian Surinamese, African Surinamese, Ghanaian, Turkish and Moroccan origin aged 40–70 years, living in Amsterdam, the Netherlands. Using logistic regressions and Akaike Information Criteria, we analyzed whether psychosocial factors (educational level, employment status, occupational level, financial stress, primary earner status, mental health, stress, depression, and social isolation) improved prediction of high CVD risk (SCORE-estimated fatal and non-fatal CVD risk $\geq$5%) beyond eligibility criteria from history taking (smoking, obesity, family history of CVD). Next, we compared the additional predictive value of psychosocial eligibility criteria in women and men across ethnic groups, using the area under the curve (AUC). Of our sample, 32.7% had a high CVD risk. Only socioeconomic eligibility criteria (employment status and educational level) improved high CVD risk prediction ($p < .001$ for likelihood-ratio tests). These increased AUCs in women (from 0.563 to 0.682) and men (from 0.610 to 0.664), particularly in Dutch, South-Asian Surinamese, African Surinamese and Moroccan women, and Dutch and Moroccan men. Concluding, socioeconomic eligibility criteria may be considered as additional eligibility criteria for CVD risk screening, as they improve detection of women and men at high CVD risk.

1. Introduction

Cardiovascular disease (CVD) is a leading cause of death in women and men worldwide (Score working group and ESC Cardiovascular risk collaboration, 2021). To reduce CVD morbidity and mortality, timely detection and preventive treatment of those at high risk for CVD are essential. In clinical practice, high-risk individuals are identified by systematic or opportunistic CVD risk screening or case finding, e.g. using the Systematic Coronary Risk Evaluation (SCORE) algorithm (Score working group and ESC Cardiovascular risk collaboration, 2021; Conroy et al., 2003). Cardiovascular risk management (CVRM) guidelines state that eligibility for CVD risk screening is based on risk factors derived from history taking (e.g. smoking), and clinical risk factors (e.g. hypertension) (Piepoli et al., 2016; NHG, 2019). However, these eligibility criteria yield a substantial proportion of individuals who are missed for screening, in particular women and ethnic minority groups (Perini et al., 2018), who may be at high risk for future CVD, despite lower prevalence of these eligibility criteria (van Laer et al., 2018).

Additional screening eligibility criteria have been proposed to improve detection of high risk individuals, in particular in those who

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[1] All authors take responsibility for all aspects of the reliability and freedom from bias of the data presented and their discussed interpretation

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may be less likely to receive screening based on current CVRM guidelines (NHG, 2019; Perini et al., 2018; Perini et al., 2019; Visseren et al., 2021; Perini et al., 2020). The European Society of Cardiology (ESC) states that psychosocial factors (American Psychological Association, 2021) (e.g. low socioeconomic status (Schultz et al., 2018; de Mestral and Stringhini, 2017), stress (Fishta and Backe, 2015; Sonderlund et al., 2019), depression (Masters et al., 2020), and social isolation (Sonderlund et al., 2019; Leigh-Hunt et al., 2017; Yanguas et al., 2018; Xia and Li, 2018; Hodgson et al., 2020)) may be CVD risk modifiers. Whether these factors also help identify high risk individuals beyond current eligibility criteria from history taking, is to be determined (Powell-Wiley et al., 2022; Reilingh et al., 2022).

Because psychosocial risk factors, e.g. depression (Altemus et al., 2014; Stronks et al., 2020) and lower socioeconomic status (Johnson-Lawrence et al., 2017) are more prevalent among women and ethnic minority groups, they in particular may benefit from using psychosocial eligibility criteria (Perini et al., 2019; Perini et al., 2020). Hence, in this cross-sectional study, first, we assess whether considering psychosocial eligibility criteria, beyond current eligibility criteria from history taking, improves the prediction of prevalent high CVD risk in women and men ages 40–70 (Supplemental Fig. 1), and second, whether this improves prediction across ethnic groups.

2. Methods

We used data from the population-based HEalthy LIfe in an Urban Setting (HELIUS) study (Stronks et al., 2013; Snijder et al., 2017). Baseline data (2011–2015) were collected among 24,789 Dutch, South-Asian Surinamese, African Surinamese, Ghanaian, Moroccan, and Turkish women and men living in Amsterdam, the Netherlands. Potential participants were sampled with a simple random sampling method from the municipality registry, after stratification by country of birth. Data were obtained by questionnaire and physical examinations (including biological samples). The HELIUS study has been approved by the Academic Medical Centre/Amsterdam UMC Ethical Review Board. All participants provided written informed consent. We used Transparent Reporting of a multivariable prediction model for Individual Prognosis Or Diagnosis (TRIPOD) reporting guidelines.

Ethnicity was defined by country of birth (Stronks et al., 2009). Participants were considered to belong to an ethnic minority group if they, and at least one parent, were born outside the Netherlands, or if they were born in the Netherlands, but both parents were born outside the Netherlands. Based on self-reported ethnic origin, Surinamese participants were classified into "African", "South-Asian", "Javanese" or "other". Dutch participants were defined as those who themselves, and both of their parents, were born in the Netherlands. Because of the sampling strategy, there were no participants who were born outside the Netherlands, with both parents born in the Netherlands.

2.1. Study population

Questionnaire- and physical examination data were available for 22,614 participants. We included participants without diabetes mellitus (DM, based on self-report and/or medication use) between the ages 40–70, in line with CVRM guidelines. Additionally, we included participants with DM in the ages 25–55 based on the fact that the conversions in the Dutch SCORE (SCORE-NL) add 15 years to the calendar age of those with DM, given their increased risk of CVD. By including those with DM in the ages 25–55, their SCORE-adjusted age (+15 years) complied with the ranges specified for those without DM (NHG, 2019). Participants with prior CVD or missing data on either prior CVD, the SCORE, or current eligibility criteria from history taking (obesity, smoking status, a family history of CVD) were excluded. Due to low power, we excluded those with unknown Surinamese, Javanese Surname or unknown ethnicity. The final sample totaled 5836 women and 4390 men (Supplemental Fig. 2).

2.2. Psychosocial eligibility criteria

While the ESC considers socioeconomic factors closely related to psychosocial factors, we consider these part of psychosocial factors, in line with Dutch CVRM guidelines (NHG, 2019).

Educational level was based on the highest qualification attained in the Netherlands or the country of origin, based on the Dutch education system, defined as intermediate-high (intermediate, higher vocational, or university education) and lower (lower or no education).

Employment status was classified into paid employment and no paid employment (those looking for work, students, homemakers, retirees, social benefit recipients, and occupationally disabled) (Anujuo et al., 2014).

Occupational level was categorized based on job title and description, according to the Dutch Standard Occupational Classification system (Statistics Netherlands, 2010). We classified occupational level into higher (intermediate, higher, and academic) and lower (elementary and lower) occupational level.

Financial stress was assessed through perceived problems in managing the household income in the past year. Participants who reported some or many problems, were classified as experiencing financial stress.

Primary earner status distinguished between participants who were the primary earner, and those who were earned less than, or as much as, their partner (Bolijn et al., 2020).

Poor mental health was measured through the Mental Component Summary Score from the Medical Outcomes Study Short Form 12, which measures limitations in social and usual role activities due to emotional problems and psychological distress. Scoring was based on previously published scoring coefficients (Ware et al., 1998). Without standardized cut-off values, the cut-off was based on the lowest quintile at $\leq$41.95. Quintiles were chosen to balance the desired granularity against the numbers needed to allow for meaningful comparisons between those with poor and adequate mental health. Moreover, a quintile cut-off corresponds with the 10–20% prevalence of poor mental health reported by Statistics Netherlands (Statistics Netherlands, 2022).

Stress at home and at work was measured through the INTERHEART questionnaire (Sheps et al., 2004), asking whether participants felt stressed (i.e. irritable or anxious, or experienced trouble sleeping) due to a situation at work or at home, in the past year. Stress was defined as participants reporting several periods of stress or constant stress.

Depression was assessed through self-reported depressed mood (a Patient Health Questionnaire (PHQ-9) score $\geq$ 10 (Kroenke et al., 2010)), lifetime depression (a depressed mood and anhedonia for at least a two-week period, hindering one's everyday functioning, at any point in their life) and/or anti-depressants (including Anatomical Therapeutic Chemical (ATC) codes N03AF, N03AG, N03AX, N05AN, N06AA, N06AB and N06AX, or antidepressants without ATC codes). Either a depressed mood, lifetime depression, or anti-depressant use were coded as depression.

Social isolation, defined as a lack of social support, was measured using the Social Support Questionnaire for Transactions (SSQT) and Satisfaction (SSQS) (Leigh-Hunt et al., 2017; Yanguas et al., 2018; Xia and Li, 2018; Doeglas et al., 1996). SSQT-scores and SSQS-scores were calculated by adding scores on five questions on the frequency of social support (seldom or never (1), now and then (2), frequently (3) and often (4)), and satisfaction with the amount of social support (much less than (1), less than (2), as much as (3), and more than (4) desired). SSQT-scores and/or SSQS-scores $<$15, i.e. infrequent and/or insufficient social support, were considered social isolation.

2.3. Current eligibility criteria from history taking for CVD risk screening

The Dutch CVRM guideline includes eligibility criteria from history taking (obesity, smoking status, a family history of CVD), and clinical risk factors (hypertension, hypercholesterolemia). In line with earlier work (Reilingh et al., 2022), we focus on eligibility criteria from history

taking, as these are early indicators of future elevated CVD risk, can be measured non-invasively, and (generally) do not require drug treatment. Hypertension and hypercholesterolemia are late markers of CVD risk, but also diagnoses that require monitoring and treatment. Thus, we consider (testing for) these clinical factors part of the diagnostic process. Diagnostic testing is likely done when a general practitioner already suspects an individuals may have a high risk of future or prevalent CVD (NHG, 2019).

A family history of CVD was defined as a self-reported CVD diagnosis in a first-degree relative ≤60 years old. We classified smoking status into current smokers, i.e. those who answered yes to the question: "do you ever smoke", and those who do not (currently) smoke, including former smokers. Obesity was defined as a Body-Mass Index (BMI) ≥30 kg/m^2, measured during physical examinations.

2.4. SCORE-estimated CVD risk

CVD risk scores were calculated using the Dutch conversion of the SCORE-algorithm (SCORE-NL) (Conroy et al., 2003; van Dis et al., 2010). This algorithm estimates the 10-year risk of fatal and non-fatal CVD based on sex, age, smoking status, systolic blood pressure, and the total cholesterol/high-density lipoprotein-ratio (NHG, 2019; Perini et al., 2020). High CVD risk was defined as a SCORE-estimated CVD risk ≥5% (Reilingh et al., 2022). Systolic blood pressure was measured in duplicate on participants' left arm using an automated digital blood pressure device, after they had been sitting for five minutes. Total cholesterol and high-density lipoprotein were based on fasting blood samples using enzymatic colorimetric spectrophotometry. We used the SCORE-NL in line with clinical guidelines at the time of measurement. Additionally, the SCORE-NL includes conversions for people with DM (NHG, 2019; Perini et al., 2019); due to high prevalence of DM among certain subgroups, excluding those with DM would lead to large numbers of excluded participants.

2.5. Statistical analyses

Sample characteristics were presented as means [standard deviation (SD)] or frequencies [percentages], by sex and ethnicity. We imputed missing data (Supplemental Table 1) through multiple imputation via chained equations, using 20 imputations and five iterations (Seaman and Hughes, 2018; McNeish, 2017).

Using logistic regressions, we assessed which psychosocial eligibility criteria improved high CVD risk prediction, in women and men. The base model contained the eligibility criteria derived from history taking: a family history of CVD, smoking status, and obesity (NHG, 2019). We identified psychosocial eligibility criteria that improved models using Likelihood-ratio tests (LRTs) and Akaike Information Criteria (AIC) by separately adding psychosocial eligibility criteria to the base model. All psychosocial eligibility criteria that were positively associated with high CVD risk and significantly improved model prediction were added stepwise to the final model, until additional eligibility criteria no longer improved models.

To assess whether psychosocial eligibility criteria improved the predictive value across groups, we compared the Area Under the Curve (AUC) of the base- and final model across sex- and ethnic groups. To pool AUCs from our multiply imputed datasets, we bootstrapped the AUC-analyses, using 50 bootstraps, five iterations and five imputations. AUCs <0.7 were considered poor, 0.7- < 0.8 acceptable, and 0.8- < 0.9 good (Carter et al., 2016). Increases in AUCs were judged based on whether the 95%-Confidence Intervals (CIs) from the base- and final model overlapped.

We conducted three additional analyses. Additional eligibility criteria may help identify people at high risk of CVD, who are less likely to receive screening based on current CVRM guidelines (Perini et al., 2020). Hence, we first computed AUCs in participants ages 40–50, and second, in participants without self-reported hypertension and/or hypercholesterolemia. Third, we calculated the prevalence of high CVD risk among those eligible for screening based on the eligibility criteria from history taking and socioeconomic criteria, and compared this to the prevalence of high CVD risk among those eligible for CVD risk screening based on only the eligibility criteria from history taking.

Finally, we conducted several sensitivity analyses. First, we adjusted the LRTs for ethnicity, to determine whether the varying prevalence of the psychosocial eligibility criteria among ethnic groups affected our estimates. Second, we excluded participants with DM, in line with the regular SCORE-algorithm (NHG, 2019). Next, we excluded participants receiving treatment for hypertension and/or hypercholesterolemia, in line with CVRM guidelines (NHG, 2019), to determine to what extent our findings were influenced by case finding and management practices. Fourth, lifetime depression was excluded as an indicator of depression, to assess whether this affected results. Finally, we computed AUCs using the SCORE2, to see how the updated algorithm affected results (Score working group and ESC Cardiovascular risk collaboration, 2021).

3. Results

The mean age was 51.1 (SD 7.4) years for women and 51.6 (7.5) years for men (Table 1). The history taking eligibility criteria varied by sex and ethnicity: for instance, 2.4–25.3% of women and 7.3–44.4% of men reported smoking, and 12.3–55.2% of women had obesity, compared to 11.7–33.9% of men. Approximately 3.7–46.4% of women, and 3.8–38.3% of men reported a family history of CVD. There was large variation across sex- and ethnic groups in the prevalence of socioeconomic eligibility criteria: for instance, 22.6–81.4% of women and 19.6–65.6% of men were lower educated, and 28.9–74.3% of women and 21.9–33.8% of men were not in paid employment. Of women, 17.7–93.4%, and 15.5–87.3% of men had a lower occupational level. Across ethnic groups, 31.2–76.8% of women and 71.1–86.3% of men were the primary earner, and 16.5–60.3% of men, and 20.3–61.7% of women reported experiencing financial stress. We also saw large variation across groups in the prevalence of psychological eligibility criteria: for example, 9.8–29.1% of men, and 13.7–35.5% of women reported poor mental health, and rates of depression ranged from 18.5 to 46.9% in women and 12.0–34.1% in men. Across ethnic groups, 5.7–20.8% of men reported stress at work and 6.1–15.0% reported stress at home, compared to 8.6–17.5% and 11.3–19.7% of women, respectively. Social isolation was reported by 38.4–65.7% of men, and 36.0–57.8% of women. Finally, the prevalence of high CVD risk ranged from 7.5% in Ghanaian to 20.9% in South-Asian Surinamese women, and 45.7% in Moroccan to 63.7% in African Surinamese men.

3.1. Main analyses

Employment status and educational level improved high CVD risk prediction in women, and employment status, educational level, and occupational level improved prediction in men (Table 2). Other socioeconomic (financial stress, primary earner status), and all psychological eligibility criteria (poor mental health, stress, depression, and social isolation) did not contribute to model prediction.

The final model included employment status and educational level on top of the eligibility criteria from history taking, for women and men (Table 3, Supplemental Tables 2–3). While occupational level improved model prediction (for men only), this variable was excluded in the final model for men, as it did not improve model prediction after employment status and educational level were added (data not shown).

In women (except Turkish and Ghanaian) and in Dutch and Moroccan men, the final model had higher AUCs than the base model (Table 4). AUCs were highest in Moroccan women (AUC 0.809, 95%CI [0.773, 0.836]) and men (0.727 [0.702, 0.754]), and lowest in Ghanaian women (0.678 [0.631, 0.733]) and men (0.617 [0.580, 0.659]). The predictive value was good in Dutch and Moroccan women, acceptable in Turkish, African Surinamese, and South-Asian Surinamese women, and

Table 1
Distribution of sociodemographic factors, psychological factors and current eligibility criteria from history taking by sex, in total and by ethnicity.

	Total	Dutch	South-Asian Surinamese	African Surinamese	Ghanaian	Turkish	Moroccan
Men	4390	1140 [26.0]	548 [12.5]	900 [20.5]	550 [12.5]	652 [14.9]	600 [13.7]
Mean age in years [SD]	51.55 [7.52]	54.00 [8.36]	49.95 [7.07]	53.02 [7.19]	50.68 [6.46]	48.71 [6.04]	49.99 [7.20]
Psychosocial eligibility criteria							
Lower education level	2099 [48.2]	222 [19.6]	271 [49.6]	458 [51.5]	356 [65.6]	420 [65.1]	372 [62.7]
Not in paid employment	1212 [27.8]	275 [24.2]	119 [21.9]	302 [33.8]	138 [25.3]	193 [30.3]	185 [30.9]
Lower occupational level	2059 [50.4]	171 [15.5]	227 [44.1]	448 [53.4]	435 [87.3]	400 [68.8]	378 [69.0]
Financial stress	1594 [36.8]	188 [16.5]	154 [28.3]	364 [41.1]	219 [40.6]	386 [60.3]	283 [48.2]
Primary earner	3421 [78.8]	809 [71.1]	410 [75.1]	707 [79.8]	430 [80.4]	550 [86.3]	515 [86.3]
Poor mental health	723 [16.6]	111 [9.8]	98 [17.9]	109 [12.2]	81 [15.0]	187 [29.1]	137 [23.1]
Stress at work	527 [12.1]	139 [12.3]	72 [13.2]	76 [8.5]	31 [5.7]	133 [20.8]	76 [12.9]
Stress at home	418 [9.6]	69 [6.1]	62 [11.4]	72 [8.1]	42 [7.8]	96 [15.0]	77 [13.0]
Depression	1155 [26.7]	387 [34.1]	155 [28.4]	191 [21.5]	64 [12.0]	187 [29.6]	171 [28.9]
Current depressed mood	389 [8.9]	52 [4.6]	56 [10.2]	42 [4.7]	31 [5.7]	114 [17.9]	94 [15.8]
Anti-depressants	107 [2.4]	31 [2.7]	16 [2.9]	13 [1.4]	7 [1.3]	26 [4.0]	14 [2.3]
Lifetime depression	933 [21.6]	365 [32.1]	127 [23.3]	173 [19.4]	36 [6.8]	116 [18.5]	116 [19.6]
Social isolation	2065 [48.1]	505 [44.5]	237 [44.1]	387 [43.5]	206 [38.4]	411 [65.7]	319 [56.0]
SSQT<15	1664 [38.6]	319 [28.1]	210 [38.9]	325 [36.5]	157 [29.3]	378 [59.6]	275 [47.8]
SSQS<15	1450 [33.7]	381 [33.6]	164 [30.4]	247 [27.7]	126 [23.5]	312 [49.8]	220 [38.5]
Current eligibility criteria from history taking							
Smoking	1281 [29.2]	246 [21.6]	202 [36.9]	400 [44.4]	40 [7.3]	248 [38.0]	145 [24.2]
Obesity	808 [18.4]	140 [12.3]	64 [11.7]	153 [17.0]	105 [19.1]	221 [33.9]	125 [20.8]
Family history of CVD	947 [21.6]	292 [25.6]	210 [38.3]	162 [18.0]	21 [3.8]	188 [28.8]	74 [12.3]
High CVD risk	2402 [54.7]	661 [58.0]	304 [55.5]	573 [63.7]	276 [50.2]	314 [48.2]	274 [45.7]
Women	5836	1386 [23.7]	789 [13.5]	1360 [23.3]	750 [12.9]	719 [12.3]	832 [14.3]
Mean age in years [SD]	51.11 [7.36]	53.79 [8.06]	51.31 [7.38]	52.33 [7.06]	48.45 [5.56]	48.25 [6.20]	49.35 [6.85]
Psychosocial eligibility criteria							
Lower education level	3037 [52.4]	311 [22.6]	444 [56.6]	549 [40.6]	600 [81.4]	519 [72.9]	614 [74.2]
Not in paid employment	2476 [42.8]	399 [28.9]	275 [35.1]	410 [30.3]	333 [45.4]	446 [63.1]	613 [74.3]
Lower occupational level	2128 [44.3]	237 [17.7]	340 [47.9]	414 [32.6]	604 [93.4]	287 [67.4]	246 [60.4]
Financial stress	2298 [40.0]	281 [20.3]	316 [40.4]	547 [40.9]	300 [41.1]	437 [61.7]	417 [51.5]
Primary earner	3253 [56.4]	712 [51.5]	468 [59.8]	1032 [76.8]	550 [75.0]	219 [31.2]	272 [33.0]
Poor mental health	1307 [22.6]	189 [13.7]	193 [24.7]	235 [17.4]	157 [21.4]	252 [35.5]	281 [34.2]
Stress at work	804 [13.9]	241 [17.5]	122 [15.6]	191 [14.2]	63 [8.6]	110 [15.5]	77 [9.4]
Stress at home	905 [15.6]	203 [14.7]	154 [19.7]	170 [12.6]	83 [11.3]	139 [19.5]	156 [19.0]
Depression	2208 [38.5]	647 [46.9]	358 [46.3]	489 [36.7]	134 [18.5]	281 [39.9]	299 [36.7]
Current depressed mood	758 [13.1]	99 [7.1]	139 [17.8]	125 [9.2]	66 [9.0]	157 [22.1]	172 [20.9]
Anti-depressants	263 [4.5]	83 [6.0]	40 [5.1]	31 [2.3]	12 [1.6]	58 [8.1]	39 [4.7]
Lifetime depression	1812 [31.6]	603 [43.7]	301 [38.8]	446 [33.5]	77 [10.6]	188 [26.7]	197 [24.4]
Social isolation	2353 [41.1]	548 [39.7]	302 [39.0]	483 [36.0]	279 [38.7]	406 [57.8]	335 [41.6]
SSQT<15	1734 [30.2]	289 [20.9]	249 [31.9]	369 [27.4]	213 [29.5]	353 [50.1]	261 [32.2]
SSQS<15	1763 [30.8]	482 [34.9]	215 [27.8]	336 [25.0]	184 [25.5]	304 [43.3]	242 [30.0]
Current eligibility criteria from history taking							
Smoking	943 [16.2]	289 [20.9]	139 [17.6]	297 [21.8]	18 [2.4]	182 [25.3]	18 [2.2]
Obesity	2064 [35.4]	171 [12.3]	179 [22.7]	511 [37.6]	384 [51.2]	397 [55.2]	422 [50.7]
Family history of CVD	1548 [26.5]	395 [28.5]	366 [46.4]	323 [23.8]	28 [3.7]	295 [41.0]	141 [16.9]
High CVD risk	939 [16.1]	256 [18.5]	165 [20.9]	268 [19.7]	56 [7.5]	83 [11.5]	111 [13.3]

Data are presented as frequencies [percentages], unless stated otherwise. SD, Standard Deviation; CVD, Cardiovascular Disease; SSQT, Social Support Questionnaire for Transactions; SSQS, Social Support Questionnaire for Satisfaction. High CVD risk was defined as a ten-year risk of fatal and non-fatal CVD ≥5%. Social isolation was defined as either a SSQT-score < 15 and/or SSQS-score < 15.

Dutch and Moroccan men, and poor in all other groups.

3.2. Additional analyses

In participants aged 40–50, the final model's results were comparable for women and men (Table 4). Analyses in participants without self-reported hypertension and/or hypercholesterolemia were also similar to the main analyses. Third, the prevalence of high CVD risk in women and men was similar for those identified for screening based on both the history taking and socioeconomic eligibility criteria, compared to those identified for screening based on only the history taking eligibility criteria (Supplemental Table 4).

3.3. Sensitivity analyses

The analyses adjusting for ethnicity (Supplemental Table 5), excluding participants with DM or receiving hypertension and/or hypercholesterolemia medication (Table 4), and excluding lifetime depression (Table 2) did not alter our interpretation of the results. The SCORE2 yielded higher AUCs in women and men of all ethnic groups, yet patterns across groups were relatively similar to the main analyses (Supplemental Table 6). With the SCORE2, the final model's AUCs were considered good for Dutch, South-Asian Surinamese, Ghanaian and Moroccan women, and Turkish men, and acceptable for all other groups except Ghanaian men, for whom AUCs were still considered poor.

4. Discussion

Employment status and educational level improved high CVD risk prediction beyond the eligibility criteria from history taking, in women and men. Findings were consistent across most ethnic groups in women, while these criteria only improved prediction in Dutch and Moroccan men. Psychological eligibility criteria did not improve prediction in women or men.

We note several limitations to our study. First, some proxies differed from CVRM guidelines, e.g. we defined a family history of CVD as CVD in a first-degree relative ≤60 years old, instead of CVD in a first degree male relative ≤55 and female relative ≤65 years old (Allport et al.,

Table 2
Binary logistic regression analyses, AICs and LRTs of the additional predictive value of psychosocial factors on top off the current eligibility criteria from history taking on the odds of having a high CVD risk, in women and men.

	Women (n = 5385)				Men (n = 4100)			
	OR	95%CI	AIC	p-value LRT	OR	95%CI	AIC	p-value LRT
Base model*			5113				5871	
+ lower educational level	1.70	[1.46, 1.97]	5066	0.002	1.30	[1.15, 1.47]	5855	0.014
+ no paid employment	3.44	[2.95, 4.01]	4839	<0.001	2.53	[2.19, 2.92]	5706	<0.001
+ lower occupational level	1.19	[1.03, 1.38]	5110	0.081	1.27	[1.12, 1.43]	5857	0.020
+ financial stress	0.85	[0.73, 0.99]	5110	0.097	0.93	[0.82, 1.06]	5871	0.347
+ primary earner	1.13	[0.98, 1.31]	5111	0.167	1.14	[0.98, 1.32]	5870	0.162
+ poor mental health	0.89	[0.75, 1.06]	5114	0.258	0.85	[0.72, 1.00]	5868	0.122
+ stress at work	0.42	[0.32, 0.54]	5063	0.003	0.78	[0.64, 0.94]	5866	0.059
+ stress at home	0.88	[0.72, 1.07]	5114	0.276	0.86	[0.70, 1.06]	5871	0.241
+ depression	0.90	[0.78, 1.05]	5114	0.248	0.86	[0.75, 0.99]	5869	0.100
+ depression (excl. Lifetime depression)	0.89	[0.73, 1.08]	5114	0.299	0.94	[0.77, 1.14]	5872	0.554
+ social isolation	0.85	[0.73, 0.98]	5111	0.088	0.90	[0.80, 1.02]	5869	0.176
Final model**			4835	<0.001			5701	<0.001

* The base model comprises of the history taking eligibility criteria: A family history of CVD, obesity, and smoking status.
** The final model for both women and men comprises of the history taking eligibility criteria, employment status and educational level. Occupational level was not included in the final model for men, as adding occupational level after employment status and occupational level were added to the base model, decreased the model's predictive power. Stress at work was not included in the final model, as the relationship with high CVD risk was inverse. AIC, Akaike information criterion; LTR, likelihood ratio test; CVD, cardiovascular disease; OR, odds ratio; CI, confidence interval.

Table 3
Binary logistic regression analyses of the model including the current eligibility criteria from history taking, employment status, and educational level on the odds of having a high CVD risk, in women and men.*

	Women (n = 5385)			Men (n = 4100)		
	OR	95%CI	p-value	OR	95%CI	p-value
Current eligibility criteria from history taking:						
Smoking	1.42	[1.18, 1.71]	<0.001	2.19	[1.90, 2.53]	<0.001
Obesity	1.19	[1.02, 1.38]	0.025	1.59	[1.35, 1.87]	<0.001
Family history of CVD	1.21	[1.03, 1.42]	0.021	1.12	[0.96, 1.30]	0.152
Psychosocial factors:						
No paid employment	3.25	[2.78, 3.81]	<0.001	2.47	[2.14, 2.86]	<0.001
Lower educational level	1.23	[1.05, 1.44]	0.011	1.19	[1.05, 1.35]	0.007

* CVD, cardiovascular disease; OR, odds ratio; CI, confidence interval.

2016). Second, some proxies may be defined differently across ethnic groups, e.g. a lower BMI cut-off for obesity is proposed in people of South-Asian ethnicity (Caleyachetty et al., 2021). Third, standardized cut-off values were not available for some variables, such as poor mental health. Fourth, possibly due to our use of cross-sectional data, we found a reversed association between work stress and high CVD risk, which may reflect a healthy worker effect. This may have led to an incorrect estimation of the predictive value of these criteria. Finally, excluding participants with missing values on the SCORE-algorithm and the eligibility criteria from history taking, instead of imputing their missing values, may have affected the results.

Further, we classified high CVD risk using the SCORE-NL for fatal and non-fatal CVD risk (van Dis et al., 2010). The current Dutch primary care guideline, however, recommends the algorithm based exclusively on CVD mortality (Score working group and ESC Cardiovascular risk collaboration, 2021), and the Action in Diabetes and Vascular Disease-PreterAx and DiamicroN Controlled Evaluation (ADVANCE)-algorithm is recommended for those with DM. We are uncertain whether these algorithms would yield similar results. Our analyses using the SCORE2 show relatively similar patterns across sex- and ethnic groups, despite slightly higher AUCs. This is important, as new Dutch CVRM guidelines are pending, which may recommend using the updated SCORE2. Additionally, we did not calibrate our findings, as we used the validated SCORE-NL which is recommended in Dutch general practice, including in our study population. Finally, in line with prior studies in this cohort (Perini et al., 2020; Reilingh et al., 2022), we defined high CVD risk using a 5%-threshold, while in practice, treatment decisions may be based on different thresholds.

Building on known associations between employment, education, and CVD (Schultz et al., 2018; de Mestral and Stringhini, 2017), we found these socioeconomic eligibility criteria improved high CVD risk prediction. Thus, these factors may help identify those at high CVD risk, which is further supported by the prevalence of high CVD risk identified for CVD risk screening based on the socioeconomic eligibility criteria, regardless of the history taking eligibility criteria. The additional predictive value of these criteria appeared larger in women than men. Earlier studies have also reported stronger associations between education, employment and CVD in women than men (Jenkins and Ofstedal, 2014), which may be explained by lower educated women's greater vulnerability to unfavorable social situations (e.g. single parenting), that contribute to CVD risk.

In our study, psychological eligibility criteria did not improve high CVD risk prediction beyond the current eligibility criteria from history taking, while these have previously been associated with CVD (Fishta and Backe, 2015; Masters et al., 2020; Leigh-Hunt et al., 2017; Hodgson et al., 2020). While the associations between psychological factors and incident CVD and CVD risk have been studied previously (Schultz et al., 2018; de Mestral and Stringhini, 2017; Fishta and Backe, 2015; Sonderlund et al., 2019; Masters et al., 2020; Leigh-Hunt et al., 2017; Yanguas et al., 2018; Xia and Li, 2018; Hodgson et al., 2020), the contribution of these factors for the prediction or etiology of incident CVD was not the aim of this study. Instead, these findings concern the added value of using psychological factors for determining eligibility for CVD risk screening by identifying women and men at high risk of CVD (Reilingh et al., 2022). One explanation for why psychological criteria did not improve prediction, is that these may not be associated with CVD risk independent of the eligibility criteria from history taking. Alternatively, mechanisms between psychological eligibility criteria and CVD may not be entirely captured by the SCORE-algorithm. Alternative pathways between stress and CVD may, for instance, be through endothelial dysfunction (Dar et al., 2019). Finally, the SCORE-algorithm may underestimate CVD risk in those with psychological risk-increasing comorbidities (Score working group and ESC Cardiovascular risk collaboration, 2021; Cunningham et al., 2019).

The final model's predictive value varied somewhat between ethnic

Table 4
AUC analyses of the base- and final models, in women and men in total and across ethnic groups.

	Women (n = 5852)		Men (n = 4392)	
	AUC [95%CI] base model*	AUC [95% CI] final model**	AUC [95%CI] base model*	AUC [95% CI] final model**
Final sample	0.563 [0.539, 0.584]	0.682 [0.664, 0.699]	0.610 [0.595, 0.627]	0.664 [0.644, 0.681]
Dutch	0.604 [0.558, 0.640]	0.807 [0.772, 0.838]	0.609 [0.582, 0.638]	0.721 [0.691, 0.757]
South-Asian Surinamese	0.581 [0.541, 0.623]	0.756 [0.711, 0.793]	0.613 [0.568, 0.646]	0.667 [0.627, 0.708]
African Surinamese	0.591 [0.554, 0.633]	0.701 [0.669, 0.731]	0.642 [0.620, 0.665]	0.666 [0.633, 0.693]
Ghanaian	0.598 [0.528, 0.642]	0.678 [0.631, 0.733]	0.574 [0.539, 0.613]	0.617 [0.580, 0.659]
Turkish	0.678 [0.631, 0.733]	0.707 [0.650, 0.744]	0.617 [0.580, 0.659]	0.680 [0.644, 0.741]
Moroccan	0.609 [0.568, 0.661]	0.809 [0.773, 0.836]	0.631 [0.584, 0.672]	0.727 [0.702, 0.754]
Additional and sensitivity analyses				
40–50 years only	0.655 [0.603, 0.723]	0.721 [0.663, 0.753]	0.707 [0.679, 0.735]	0.719 [694, 0.749]
No hypertension or hypercholesterolemia (self-report)	0.562 [0.525, 0.599]	0.668 [0.639, 0.705]	0.618 [0.595, 0.643]	0.665 [0.645, 0.696]
No DM	0.549 [0.522, 0.573]	0.686 [0.671, 0.710]	0.611 [0.592, 0.630]	0.668 [0.649, 0.683]
No hypertension or hypercholesterolemia medication	0.558 [0.535, 0.578]	0.661 [0.634, 0.681]	0.615 [0.601, 0.628]	0.667 [0.651, 0.680]

* The AUC of the base model is based on a the history taking eligibility criteria: A family history of CVD, smoking status and obesity.

** For both women and men, the AUC of the final model is based on the history taking eligibility criteria, employment status and educational level. Increases in AUCs were judged based on whether the 95%CIs of the base- and final model overlapped. AUC, area under the curve; CI, confidence interval; DM, diabetes mellitus.

groups. The socioeconomic eligibility criteria might contribute less to prediction in some ethnic minority groups compared to the Dutch, such as the Ghanaian group. In contrast, the final model's predictive value appeared better in Moroccan participants. Differences may relate to the prevalence of current eligibility criteria from history taking, e.g. smoking and obesity (Reilingh et al., 2022) which is already higher in some groups. Moreover, differences may relate to differences in underlying predictors. The use of ethnic-specific risk factors for screening could be considered to improve detection of ethnic minority women and men at high risk of CVD. Finally, we should also consider that this may possibly be an artefact, as a result of the use of the SCORE. A recent study has validated the SCORE2-algorithm among ethnic minority and lower socioeconomic status groups, and found risk estimation was less accurate for individuals with a lower socioeconomic status and in those of South-Asian Surinamese background (Kist et al., 2023).

5. Conclusion

Our findings suggest that using employment status and educational level as additional eligibility criteria may improve high-risk CVD screening strategies, in particular in women. However, the feasibility, generalizability and acceptability of using these criteria should be evaluated, in both systematic screening- and case finding scenarios. A practical limitation is that employment status and educational level are not registered in Dutch general practice, and doing so may lead to some additional costs. Additionally, these factors may not always be easily explored due to fear of stigmatization. Moreover, where data are available, how modified pre-selection for screening affects prevention and treatment decisions should be studied, as such decisions are generally based on more factors (NHG, 2019; Visseren et al., 2021).

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CRediT authorship contribution statement

Bryn Hummel: Conceptualization, Methodology, Formal analysis, Writing – original draft, Writing – review & editing, Visualization. **Ralf E. Harskamp:** Methodology, Writing – original draft. **Renee Bolijn:** Writing – original draft. **Eric P. Moll van Charante:** Methodology, Writing – original draft. **Henrike Galenkamp:** Methodology, Writing – original draft, Writing – review & editing. **Paula M.C. Mommersteeg:** Writing – original draft, Writing – review & editing. **Irene G.M. van Valkengoed:** Conceptualization, Methodology, Writing – original draft, Writing – review & editing, Supervision, Funding acquisition.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The authors do not have permission to share data.

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