openheart

Patient-oriented risk score for predicting death 1 year after myocardial infarction: the SweDen risk score

Rebecca Tremain Rylance ,[1] Philippe Wagner,[2] Kevin K W Olesen,[3] Jonas Carlson,[1] Joakim Alfredsson,[4] Tomas Jernberg,[5] Margret Leosdottir ,[6,7] Pelle Johansson,[8] Peter Vasko,[4] Michael Maeng,[1] Moman Aladdin Mohammed,[1] David Erlinge[1]

► Additional supplemental material is published online only. To view, please visit the journal online (http://dx.doi.org/10.1136/openhrt-2022-002143).

To cite: Rylance RT, Wagner P, Olesen KKW, *et al*. Patient-oriented risk score for predicting death 1 year after myocardial infarction: the SweDen risk score. *Open Heart* 2022;**9**:e002143. doi:10.1136/openhrt-2022-002143

Received 17 September 2022
Accepted 28 October 2022

For numbered affiliations see end of article.

Correspondence to
Rebecca Tremain Rylance; rebecca.rylance@med.lu.se

ABSTRACT

Objectives Our aim was to derive, based on the SWEDEHEART registry, and validate, using the Western Denmark Heart registry, a patient-oriented risk score, the SweDen score, which could calculate the risk of 1-year mortality following a myocardial infarction (MI).

Methods The factors included in the SweDen score were age, sex, smoking, diabetes, heart failure and statin use. These were chosen a priori by the SWEDEHEART steering group based on the premise that the factors were information known by the patients themselves. The score was evaluated using various statistical methods such as time-dependent receiver operating characteristics curves of the linear predictor, area under the curve metrics, Kaplan-Meier survivor curves and the calibration slope.

Results The area under the curve values were 0.81 in the derivation data and 0.76 in the validation data. The Kaplan-Meier curves showed similar patient profiles across datasets. The calibration slope was 1.03 (95% CI 0.99 to 1.08) in the validation data using the linear predictor from the derivation data.

Conclusions The SweDen risk score is a novel tool created for patient use. The risk score calculator will be available online and presents mortality risk on a colour scale to simplify interpretation and to avoid exact life span expectancies. It provides a validated patient-oriented risk score predicting the risk of death within 1 year after suffering an MI, which visualises the benefit of statin use and smoking cessation in a simple way.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ There are available risk scores predicting death 1 year after myocardial infarction like the Global Registry of Acute Coronary Events and Thrombolysis in Myocardial Infarction (TIMI) scores. These require some medical knowledge in order to use. The importance of this study was to offer patients an alternative risk score that they can fill in by themselves.

WHAT THIS STUDY ADDS

⇒ As a result of this study, we created a patient-friendly, competitive risk score with less predictors than classic risk scores that was externally validated.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ The implications of this study are that it may be introduced to the patient at their first doctor's visit after suffering a myocardial infarction.

INTRODUCTION

Risk scores have been developed to aid in estimating the risk of new events or death after suffering a myocardial infarction (MI), motivate patients to adhere to treatment guidelines and lifestyle changes as well as optimise treatments for vulnerable patients.

The Global Registry of Acute Coronary Events (GRACE) score was based on 18 clusters in 14 countries gathering 10 000 patients with acute coronary syndrome yearly.[1] In its first version, the GRACE score incorporated age, heart rate, systolic blood pressure, serum creatinine, Killip class, cardiac arrest at admission, deviations of the ST segment and cardiac enzyme levels to predict in-hospital mortality.[2] The first Thrombolysis in Myocardial Infarction (TIMI) score was developed for unstable angina/non-ST MI to evaluate a composite endpoint of all-cause mortality, MI and urgent revascularisation.[3] It consisted of seven factors including age 65 years or older, having ≥3 coronary artery disease (CAD) risk factors such as hypertension, hypercholesterolaemia, diabetes, family history of CAD or current smoker, prior coronary stenosis of 50% or more, prior ST-segment deviation on ECG at presentation, at least two angina events in the prior 24 hours, the use of aspirin in the prior 7 days and elevated serum cardiac markers. However, these risk scores are not suitable for patients to use by themselves.

The Swedish Web-system for Enhancement and Development of Evidence-based care in Heart disease Evaluated According

to Recommended Therapies (SWEDEHEART) registry started in 2009, and encompasses 95% of all acute first time or repeated MI cases in Sweden of those under the age of 80 years. Background characteristics such as age, body mass index, smoking status, ECG findings as well as other examinations, interventions, complications, discharge medications and diagnoses are prospectively collected. The Western Denmark Heart registry contains similar information on patients.

In a world where patients seek knowledge and guidance online, we found the idea of a patient-oriented risk score both novel and intriguing. Therefore, the aim of this study was to develop a user-friendly risk score predicting death within 1 year after suffering an MI based on the Swedish and Danish populations.

METHODS

Data selection

For this study, data from 1 January 2008 to 27 May 2018 from the SWEDEHEART registry were selected, consisting of 247 904 MI cases. Patients who died during hospital stay or within 30 days after their MI were excluded. Patients with cancer or dementia, patients under the age of 55 years and patients who received cardiopulmonary resuscitation on their way to hospital were excluded. For patients with current events, the last hospital stay per patient was selected, assuming that this represents the most valid patient information, and the final database consisted of 125 806 patients.

Factors in model

The factors chosen for the SweDen score were chosen a priori by the SWEDEHEART steering group based on the premise that the factors should be clinically relevant information known by the patients themselves. These included age, sex, smoking (both current and previous), diabetes, heart failure and being prescribed statins.

Estimating the model

Age was treated as a continuous variable in the model. The categorical variables included in the model were categorised with a relevant reference group; if the patient had a condition that was associated with a higher risk, they were coded as '1' and if they did not, they were coded as '0'. As such, having heart failure, diabetes, being male, being a current or previous smoker, or not being treated with a statin were associated with higher risks. A Cox model was fitted with the preselected factors to generate log coefficients. Log-minus-log survival plots and the Schoenfeld residuals were checked visually to ascertain model fit.

Generating the risk score

The Framingham tutorial for clinical use was the basis for calculating the risk score.[4] This involved several steps (online supplemental appendix). For the calculation of the points, the age variable was categorised into 5-year age groups and the midpoint in each age category was used. The youngest age group included people between 55 and 60 years and therefore the midpoint for that age group was 57 years. The definition of a point was 5 years of ageing, which was calculated by taking the log hazard coefficient for age produced by the model and multiplying it by 5 and hereby referred to as *B*. The number of points was calculated for each factor. The number of points for each increase into a higher age group was found by taking the difference between the midpoints in each age group minus the midpoint in the lowest age group, 57, and multiplying it by the log hazard coefficient for age and dividing it by *B*. For example, if a person were 78 years old, they would be in the age group from 75 to 79 years and the midpoint in that group is 77. The number of points for being 78 years old was calculated to 4 (0.0780096×(77–57)/0.390048). The number of points for each categorical variable was produced similarly by taking the log hazard coefficient produced in the model for each particular variable and dividing by *B*. The diabetes variable produced a log hazard of 0.5153974, which constituted a 1-point increase if a person had diabetes (0.5153974×(1–0)/0.390048). The number was 1.32 and was rounded down to 1. Being male did not add an additional point; however, 0.0894894×(1–0)/0.390048 was equal to 0.23 and was rounded down to 0. Being a previous smoker did not add an additional point either. The total points were summed, and each point total was associated with a risk.

Validation

External validation involves a derivation dataset where the original analysis is performed and a validation dataset where the results are tested and verified.[5] The risk score was derived with the SWEDEHEART registry data, and was therefore the derivation data. The Western Denmark Heart registry, containing 45 003 patients with the same selection criteria as the SWEDEHEART registry, was used to evaluate the SweDen risk score and was the validation dataset.[6] HRs were produced for both populations.

Calibration and discrimination were two important concepts that were applied in the validation of the risk score model.[7] Discrimination can be defined as the model's ability to correctly separate low and high-risk patients.[8] Patients who were predicted to be at a higher risk should have experienced higher event rates.

Time-dependent receiver operating characteristics (ROC) curves of the linear predictor, which are the weighted sum of the factors in the derivation and validation models were produced as well as area under the curve (AUC) metrics to evaluate discrimination. The AUC calculates the probability that in a pair of patients selected at random, the patient with the shorter survival time has the higher risk.[9] The linear predictors were also plotted in histograms to visualise their spread.

Kaplan-Meier curves of the risk groups were graphed as an informal assessment of discrimination.[8] The more widely separated the curves, the better the discrimination. The linear predictor was divided into quantiles at the 16th, 50th and 84th centiles. The percentages

Table 1 Baseline demographics SWEDEHEART registry (Derivation dataset) & Western Denmark registry (Validation dataset)

Baseline	Derivation n=125 806	Validation n=45 003
Male sex, n (%)	80 136 (63.7)	30 458 (67.7)
Age, mean (SD)	73.3±10.0	69.3±8.7
Diabetes, n (%)	27 874 (22.2)	7833 (17.4)
Body Mass Index (kg/m^2), mean (SD)	26.9±5.7	26.9±4.6
Non-smoker, n (%)	59 336 (47.2)	15 051 (33.4)
Previous smoker, n (%)	45 166 (35.9)	16 642 (37.0)
Current smoker, n (%)	21 304 (16.9)	13 310 (29.6)
Previous PCI	28 002 (21.6)	1003 (2.2)
Previous CABG	10 552 (8.1)	281 (0.6)
Heart failure, n (%)	16 514 (13.1)	10 930 (24.3)
Hypertension, n (%)	69 034 (54.9)	26 237 (58.3)
No statins, n (%)	16 323 (13.0)	6114 (13.6)
P-creatinine (umol/L), mean (SD)	94.4±57.2	101.9±684.4
Lipid-lowering treatment	111 669 (88.8)	20 887 (46.4)
Aspirin	116 549 (92.6)	39 329 (87.4)
Ace-inhibitor	75 935 (60.4)	20 516 (45.6)
Beta blocker	112 652 (89.5)	35 809 (79.6)

of patients in each of these risk groups, which can be thought of as good, fairly good, fairly poor and poor risk groups, were compared between the derivation and validation data. HRs of these risk groups and their CIs were also computed.

Calibration may be defined in terms of prediction accuracy, that is, how closely the survival in the validation data was captured by the model's predictions from the derivation data.[8] The calibration slope in the validation dataset was calculated by taking the coefficients produced from the derivation data and performing a Cox regression with them using the Danish data.

RESULTS

The results are presented for both derivation and validation datasets. Baseline demographics are presented in table 1. Time-dependent ROC curves are presented (figure 1) with AUC values of 0.81 in the derivation dataset and 0.76 in the validation dataset. Histograms visually demonstrate the spread of the centred linear predictor for the risk groups. No obvious outliers or irregularities were noted (online supplemental figure 3). HRs are presented in table 2. All covariates were significant in the models except for previous versus non-smoker, with an HR of 1.04 (95% CI 0.99 to 1.08) in the derivation data and an HR of 1.03 (95% CI 0.93 to 1.13) in the validation dataset. The Kaplan-Meier survival curves of the risk groups are depicted for both datasets (figure 2). The

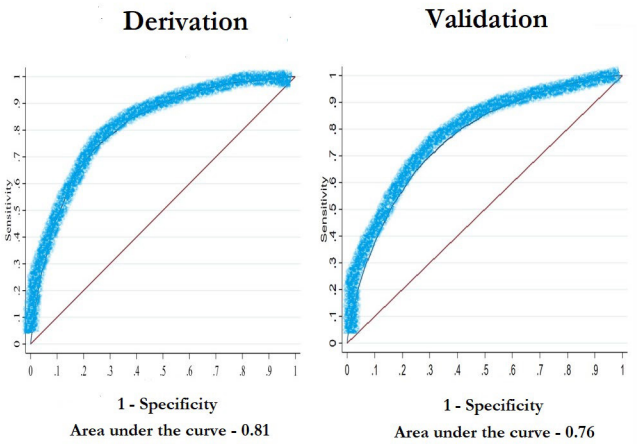

Figure 1 Time-dependent receiver operating characteristics curves predicting 1-year death adjusted for the linear predictor with the SWEDEHEART registry (derivation dataset) and the Western Denmark registry (validation dataset).

percentages of patients in the four groups, representing good, fairly good, fairly poor, and poor risk of survival were 15.5%, 32.6%, 33.4% and 18.6% in the derivation dataset, and 15.5%, 34.5%, 34.0% and 16.0% in the validation dataset, respectively, showing similar distributions of patient profiles in both datasets. The calibration slope was 1.03 (95% CI 0.99 to 1.08). The risk score resulted

Table 2 Hazard ratios from a model adjusted for age, gender, diabetes, smokers, statins and heart failure using Cox regression from the SWEDEHEART registry (Derivation dataset), and the Western Denmark registry (Validation dataset).

Cox regression derivation dataset	HR	P value	95% CI
Age	1.08	≤ 0.001	1.07,1.08
Males vs Females	1.09	≤ 0.001	1.05,1.14
Diabetes	1.67	≤ 0.001	1.61,1.74
Previous vs non-smokers	1.04	0.079	0.99,1.08
Current vs non-smokers	1.46	≤ 0.001	1.37,1.56
No Statins	1.93	≤ 0.001	1.85,2.01
Heart failure	2.64	≤ 0.001	2.54,2.74
N	125 806		
Cox Regression Validation dataset	HR	P-value	95% CI
Age	1.08	≤ 0.001	1.08,1.09
Males vs Females	1.11	0.023	1.01,1.21
Diabetes	1.61	≤ 0.001	1.46,1.77
Previous vs non-smokers	1.03	0.573	0.93,1.13
Current vs non-smokers	1.43	≤ 0.001	1.28,1.59
No Statins	1.74	≤ 0.001	1.58,1.91
Heart failure	2.51	≤ 0.001	2.32,2.73
N	45 003		

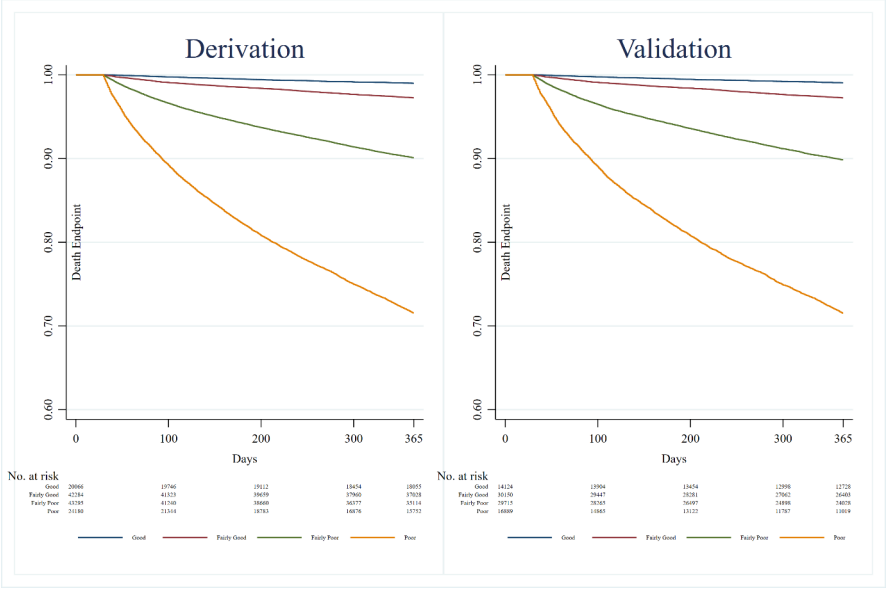

Figure 2 Kaplan-Meier curves of the categorised linear predictor (weighted sum of regression coefficients produced from the adjusted Cox model divided into groups) from SWEDEHEART registry (derivation dataset) and Western Denmark registry (validation dataset).

in a patient-based online calculator where an increasing number of points signifies an increasing risk of death (figure 3). A total of 0 points means a very low risk of death, whereas a total of 14 points conveys a very high risk of death. The risk of dying with 0 points was 1.8%, 1 point 2.6%, 2 points 3.8%, 3 points 5.6%, 4 points 8.1%, 5 points 11.8%, 6 points 16.9%, 7 points 23.9%, 8 points 33.2%, 9 points 44.9%, 10 points 58.5%, 11 points 72.7%, 12 points 85.3%, 13 points 94.1% and 14 points 98.5%. The score can be accessed here: www.sweden-score.info/english.

DISCUSSION

The SweDen score is a patient-oriented risk score with an AUC of 0.81 in the derivation cohort and 0.76 in the validation cohort. Despite the simplicity of the SweDen score, the AUC was high, the estimates were reproducible in a different cohort, and the results suggested both good discrimination and calibration.

The TIMI and GRACE scores are two other, in this context, meaningful scores that had the same aim as the SweDen score. The C-statistic from the GRACE score for

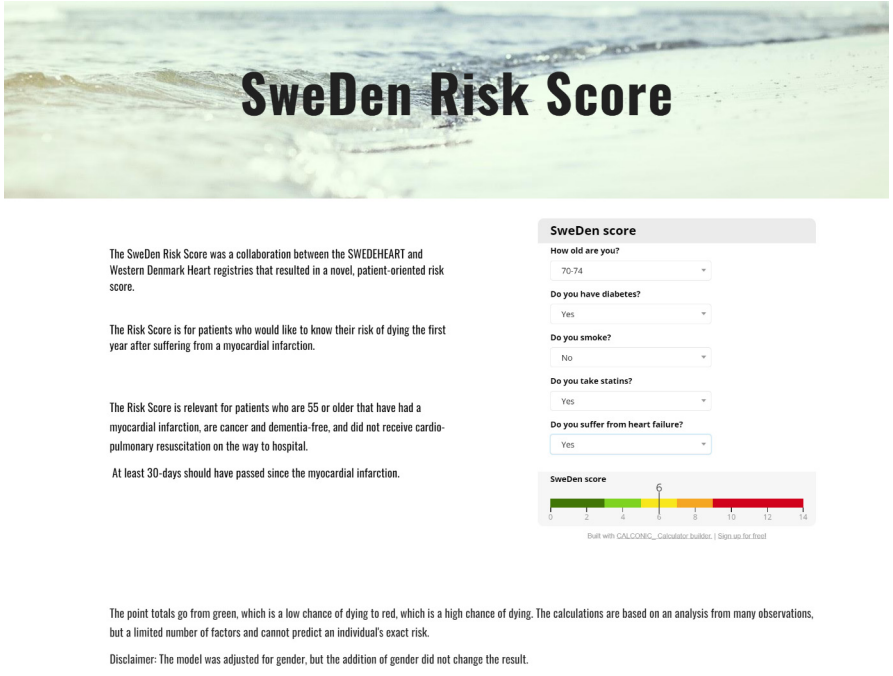

Figure 3 SweDen risk score calculator.

1-year mortality was 0.82 (95% CI 0.79 to 0.84)[10] and TIMI score was 0.65 (95% CI 0.63 to 0.66),[3] making the SweDen risk score a viable alternative for patients themselves to use. The chosen factors in these different scores are debatable. The SweDen risk score incorporated diabetes and previous and current smokers as separate factors, while the TIMI score only includes diabetes and current smokers if these are part of a combination of at least three factors.[11 12]

While systolic blood pressure was a factor in the GRACE score, we chose not to include it in the SweDen score because daily fluctuations in blood pressure would need to be accounted for rather than selecting one random daily measurement.[13] Killip class was used in the GRACE score as well, which may have increased the prediction accuracy in the SweDen score[14] if included, but it is a value unknown to most patients. Furthermore, if more predictors would have been included from the SWEDEHEART registry to predict death 1 year following an MI, prediction accuracy may have increased. Other SWEDEHEART studies have demonstrated this applying machine learning algorithms.[15] However, the calibration slope in the validation dataset was 1.03 indicating sufficiently high prediction accuracy.

Prediction accuracy via the calibration slope as well as the harmonious estimates show that the external validation was successful. Unfortunately, not enough studies engage in the transportability of a risk equation to a new population in cardiovascular disease.[16] External validation is crucial to evaluate a model's reproducibility and that is why the SweDen risk score was validated externally with the Western Denmark Heart registry.[5]

In summary, we wanted to create a patient-oriented risk score that predicts the risk of death within 1 year after suffering an MI. This was developed in collaboration between Sweden and Denmark resulting in the validated patient-oriented SweDen risk score. The SweDen risk score includes less factors than other similar risk scores, but has a predictability that we found to be at as good as other risk scores recommended in current guidelines. A further advantage is that patients themselves can fill in their information and visualise the potential benefit of smoking cessation and statin use, making it a feasible tool for patients who have suffered an MI.

Author affiliations
[1]Department of Cardiology, Clinical Sciences, Lund University and Skåne University Hospital, Lund, Sweden
[2]Center for Clinical Research, Uppsala University, Uppsala, Sweden
[3]Department of Cardiology, Aarhus University Hospital, Aarhus, Denmark
[4]Department of Cardiology, Karolinska University Hospital, Linkoping, Sweden
[5]The Swedish Heart and Lung Association, Stockholm, Sweden
[6]Department of Clinical Sciences, Skåne University Hospital Lund, Malmö, Sweden
[7]Department of Clinical Sciences, Lund University, Malmo, Sweden
[8]The Swedish Heart Failure Registry, Stockholm, Sweden

Contributors All authors contributed to the manuscript. RR is the guarantor.

Funding The funding comes from the Swedish Research Council and the Swedish Heart and Lung Foundation.

Competing interests None declared.

Patient consent for publication Not required.

Ethics approval This study involves human participants and was approved by the ethics committee, Lund, 2015 (approval code: 297).

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available upon reasonable request. Interested parties may contact the corresponding author about gaining access to the data.

ORCID iDs
Rebecca Tremain Rylance http://orcid.org/0000-0002-5921-3786
Margret Leosdottir http://orcid.org/0000-0003-1677-1566

REFERENCES

1 GRACE Investigators. Rationale and design of the grace (global registry of acute coronary events) project: a multinational registry of patients hospitalized with acute coronary syndromes. *Am Heart J* 2001;141:190–9.
2 Granger CB, Goldberg RJ, Dabbous O, *et al*. Predictors of hospital mortality in the global registry of acute coronary events. *Arch Intern Med* 2003;163:2345–53.
3 Antman EM, Cohen M, Bernink PJ, *et al*. The TIMI risk score for unstable angina/non-ST elevation MI: a method for prognostication and therapeutic decision making. *JAMA* 2000;284:835–42.
4 Sullivan LM, Massaro JM, D'Agostino RB. Presentation of multivariate data for clinical use: the Framingham study risk score functions. *Stat Med* 2004;23:1631–60.
5 Altman DG, Royston P. What do we mean by validating a prognostic model? *Stat Med* 2000;19:453–73.
6 Schmidt M, Maeng M, Madsen M, *et al*. The Western Denmark heart registry: its influence on cardiovascular patient care. *J Am Coll Cardiol* 2018;71:1259–72.
7 Collins GS, de Groot JA, Dutton S, *et al*. External validation of multivariable prediction models: a systematic review of methodological conduct and reporting. *BMC Med Res Methodol* 2014;14:40.
8 Royston P, Altman DG. External validation of a Cox prognostic model: principles and methods. *BMC Med Res Methodol* 2013;13:33.
9 van Klaveren D, Gönen M, Steyerberg EW, *et al*. A new concordance measure for risk prediction models in external validation settings. *Stat Med* 2016;35:4136–52.
10 van der Sangen NMR, Azzahhafi J, Chan Pin Yin DRPP, *et al*. External validation of the GRACE risk score and the risk-treatment paradox in patients with acute coronary syndrome. *Open Heart* 2022;9:e001984.
11 Ek A, Ekblom Örjan, Hambraeus K, *et al*. Physical inactivity and smoking after myocardial infarction as predictors for readmission and survival: results from the SWEDEHEART-registry. *Clin Res Cardiol* 2019;108:324–32.
12 Walker AM, Cubbon RM. Sudden cardiac death in patients with diabetes mellitus and chronic heart failure. *Diab Vasc Dis Res* 2015;12:228–33.
13 Chadachan VM, Ye MT, Tay JC, *et al*. Understanding short-term blood-pressure-variability phenotypes: from concept to clinical practice. *Int J Gen Med* 2018;11:241–54.
14 Khot UN, Jia G, Moliterno DJ, *et al*. Prognostic importance of physical examination for heart failure in non-ST-elevation acute

coronary syndromes: the enduring value of Killip classification. *JAMA* 2003;290:2174–81.
15 Mohammad MA, Olesen KKW, Koul S, *et al*. Development and validation of an artificial neural network algorithm to predict mortality and admission to hospital for heart failure after myocardial infarction: a nationwide population-based study. *Lancet Digit Health* 2022;4:e37–45.
16 Wallisch C, Heinze G, Rinner C, *et al*. Re-estimation improved the performance of two Framingham cardiovascular risk equations and the pooled cohort equations: a nationwide registry analysis. *Sci Rep* 2020;10:8140.