RESEARCH REPORT

Does consideration of either psychological or material disadvantage improve coronary risk prediction? Prospective observational study of Scottish men

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Objective: To assess the value of psychosocial risk factors in discriminating between individuals at higher and lower risk of coronary heart disease, using risk prediction equations.

Design: Prospective observational study.

Setting: Scotland.

Participants: 5191 employed men aged 35 to 64 years and free of coronary heart disease at study enrolment

Main outcome measures: Area under receiver operating characteristic (ROC) curves for risk prediction equations including different risk factors for coronary heart disease.

Results: During the first 10 years of follow up, 203 men died of coronary heart disease and a further 200 were admitted to hospital with this diagnosis. Area under the ROC curve for the standard Framingham coronary risk factors was 74.5%. Addition of "vital exhaustion" and psychological stress led to areas under the ROC curve of 74.5% and 74.6%, respectively. Addition of current social class and lifetime social class to the standard Framingham equation gave areas under the ROC curve of 74.6% and 74.9%, respectively. In no case was there strong evidence for improved discrimination of the model containing the novel risk factor over the standard model.

Conclusions: Consideration of psychosocial risk factors, including those that are strong independent predictors of heart disease, does not substantially influence the ability of risk prediction tools to discriminate between individuals at higher and lower risk of coronary heart disease.

The availability of effective preventive interventions has motivated a strategy of identifying people at higher risk for developing coronary events. In the UK, for example, it is recommended that lipid lowering treatment should be offered to people with a risk of 20% or more of experiencing a coronary event within 10 years.¹ Risk prediction is currently based on algorithms derived from large prospective observational studies, most notably the US Framingham study.^{2–3} These algorithms use information on standard physiological and behavioural coronary risk factors to predict individual risk, based on the predictive power of the same factors in the parent study. There are problems with this approach that may lead to inaccuracy.^{4–6} The first is that the relation between risk factors and events may be different in different populations, requiring recalibration to give accurate risk probabilities or even different risk factors to achieve the same discrimination between higher and lower risk individuals. Further, information may be missing for some risk factors in the algorithm, particularly those dependent on special tests. The substitution of "average" values is possible but is likely to lead to imprecision. Finally, it may be that standard risk factors do not explain a significant proportion of coronary risk. Additional consideration of the factors that explain this additional risk could improve prediction and consequently the targeting of prevention.

It is often suggested that psychological disadvantage in adulthood (for example increased psychological stress or feelings of "vital exhaustion") is an important determinant of coronary risk and that this influence is not necessarily mediated through standard risk factors.^{7–10} It has also been suggested that consideration of psychological factors (in particular "vital exhaustion"), which can be measured without special tests, would improve risk prediction.¹⁰ Material disadvantage across the life course, particularly in childhood, also appears to predict coronary risk independent of standard risk factors.¹¹

Consideration of this exposure, which can also be measured without special tests, may improve prediction.

We investigated whether consideration of simple measures of either psychological disadvantage in adulthood (higher psychological stress or vital exhaustion) or material disadvantage in either adulthood or over the life course (own occupation, father's occupation, or lifetime socioeconomic position) improved coronary risk prediction in a large cohort of Scottish men.

METHODS

The West of Scotland Collaborative Study

The study cohort has been described previously.^{11–14} Employees were recruited between 1970 and 1973 from 27 work places in the west of Scotland. Some 6022 men (about 70% of those invited) completed a questionnaire and attended a health examination. This study is based upon 5191 men who at enrolment were aged between 35 and 64 years, did not report symptoms of definite angina or claudication according to the Rose criteria,^{15–16} were without definite ECG evidence of ischaemia (codes 1.1 or 4.1 or 5.1; see below), and who provided full information on the variables considered in the present analysis.

The Framingham risk calculation

The Framingham risk calculation combines information on sex, age, systolic blood pressure, cigarette smoking (yes or no), total cholesterol, high density lipoprotein (HDL) cholesterol, diabetes (yes or no), and ECG determined definite left ventricular hypertrophy (ECG-LVH, yes or no). Measurement of these variables in the West of Scotland Collaborative Study is described elsewhere,^{11–14} with the exceptions of HDL cholesterol

Abbreviations: ECG-LVH, ECG determined definite left ventricular hypertrophy; ROC, receiver operating characteristic; RSI, Reeder stress inventory

Table 1 Coronary heart disease risk factor profile for 5191 men without evidence of coronary heart disease at enrolment

Variable		
Age in years (mean (SD))	48	(6.5)
Systolic blood pressure (mm Hg) (mean (SD))	133.68	(17.50)
Total cholesterol (mmol/l) (mean (SD))	5.87	(1.03)
Current cigarette smoker (%)	2962	(57)
Diabetic (%)	27	(0.5)
Left ventricular hypertrophy (%)	6	(0.1)
Lifetime socioeconomic position		
No manual occupations (%)	891	(17)
One manual occupation (%)	1083	(21)
Two manual occupations (%)	1102	(21)
Three manual occupations (%)	2115	(41)
Father's social class		
I or II (%)	740	(14)
IIIm (%)	538	(10)
IIIm (%)	2248	(43)
IV+V (%)	1665	(32)
Own social class		
I or II (%)	1723	(33)
IIIm (%)	929	(18)
IIIm (%)	1476	(28)
IV+V (%)	1063	(20)
Exhaustion item describes man		
Not at all (%)	2187	(42)
Not very accurately (%)	1511	(29)
To some extent (%)	1403	(27)
Exactly (%)	90	(2)
Daily stress category		
Low stress (scores 1, 2, 3) (%)	1717	(33)
Mid to low stress (score 4) (%)	1495	(29)
Mid to high stress (score 5) (%)	1316	(25)
High stress (scores 6, 7, 8) (%)	663	(13)

and ECG-LVH. HDL cholesterol was not measured in the West of Scotland Collaborative Study and so was not considered in the present analysis. ECG-LVH was ascertained using six lead ECG readings (leads I, II, III, aVR, aVL, and aVF) coded according to the Minnesota system.¹⁵ Increased R wave amplitude in leads reflecting potentials from the left ventricle with either a depressed S-T segment or flattened or inverted T waves in any leads (code 3.1 with 4.1 or 4.2 or 5.1 or 5.2) was taken to indicate definite ECG-LVH.¹⁷ Three men without ECG measurements were assumed not to have ECG-LVH.

The current Framingham risk calculation is based on associations between the above variables and subsequent cardiovascular disease, with those associations being quantified in an accelerated failure time model with Weibull distributed failure times.^{3 18 19} This model achieves a better fit than a previous version of the Framingham risk calculation which was based on logistic regression.^{18 19} However, the calculation is complex and it is difficult to get a clear picture of the independent contribution of individual covariates to the prediction of future cardiovascular disease. Hence, for present purposes, where the contribution of additional covariates was to be investigated, the logistic regression model was adopted.

Psychological disadvantage

A measure of vital exhaustion was derived from a man's response to a single statement included in the questionnaire completed at enrolment: "At the end of the day I am completely exhausted mentally and physically". Men were asked to respond to say whether the statement described them "exactly", "to some extent", "not very accurately", or "not at all". This statement was included in the questionnaire as part of the Reeder stress inventory (RSI),²⁰ and has been used as a measure of exhaustion in a previous study.²¹ In addition, a

global daily stress score, as measured by the RSI and derived as previously described,^{20 22} was categorised as high stress (scores of 6, 7, 8), mid to high stress (score of 5), mid to low stress (score of 4), or low stress (scores of 1, 2, 3).

Material disadvantage

Participants reported their own current occupation, their first occupation, and their father's main occupation. These were used to derive socioeconomic class using the contemporaneous classification scheme.²³ Socioeconomic class at all three times was categorised as professional plus managerial (I+II), other non-manual (IIIm), skilled manual (IIIm), or semiskilled plus unskilled manual (IV+V). Lifetime socioeconomic position was derived as the number of manual occupations (classes IIIm, IV, or V) held across the three time points considered.¹³ These variables were used as measures of socioeconomic environment in adulthood and over the life course. An area based measure of deprivation was derived from the post code of participant's normal place of residence according to the system of Carstairs and Morris.²⁴ Scores were divided into four categories (6 and 7; 5; 3 and 4; 1 and 2) from most deprived to least deprived.

Outcome measures

Participants were flagged with the NHS Central Registry, which provides death certificates. Data on hospital admissions for the same period were provided through linkage to the Scottish Morbidity Register.²⁵ This has data on all admissions to Scottish hospitals. Admissions to general hospitals (SMR1) were considered. Codes appearing in any diagnostic position (up to six are allowed) from the final consultant episode were used, as these were presumed to represent the most definitive diagnoses for that admission. Deaths and admissions were coded according to the ninth revision of the *International Classification of Diseases* (ICD-9). Death with coronary heart disease as the underlying cause (ICD-9 410–414) and hospital admissions including a discharge diagnosis of coronary heart disease in any diagnostic position were recorded if occurring within 10 years of screening.

Statistical analysis

The independent associations of risk factors with the occurrence of coronary heart disease (death, and death or hospital admission) over a 10 year period were quantified using multivariable logistic regression. Areas under receiver operating characteristic (ROC) curves (sensitivity plotted against 1–specificity) were compared, with a greater area indicating that an improvement in discrimination between higher and lower risk individuals had been achieved by adding a novel risk factor (exhaustion, stress, own social class, father's social class, lifetime socioeconomic position) to the standard risk factors included in the Framingham risk equation.

Prediction of coronary heart disease mortality over 10 years was compared with observed mortality within occupational classes. Predictions were based on the standard Framingham risk equation,^{3 18} the Framingham risk equation but with the coefficients recalibrated to the current cohort, and the Framingham risk equation with a novel risk factor added and then recalibrated to the current cohort. Recalibration used the same statistical model as the standard Framingham risk equation,¹⁹ with the unmeasured high density lipoprotein assumed to be 1.3 mmol/l for all men.²⁶ To allow use of standard software, recalibrated coefficients were based upon 20 iterations, the dispersion parameter of the Weibull distribution estimated using the linear combination of covariates with coefficients taken from the previous iteration.

Stata 9 statistical software was used for all analyses (StataCorp, College Station, Texas USA).

Table 2 Multivariable logistic regression equations, quantifying the independent associations of risk factors with death from coronary heart disease within 10 years of screening

	Framingham predictors OR (95% CI)	+ Exhaustion OR (95% CI)	+ Daily stress OR (95% CI)	+ Own social class OR (95% CI)	+ Father's social class OR (95% CI)	+ Lifetime SE position OR (95% CI)
5 year older age	1.43 (1.26 to 1.61)	1.43 (1.26 to 1.61)	1.43 (1.26 to 1.61)	1.42 (1.26 to 1.61)	1.43 (1.27 to 1.62)	1.42 (1.26 to 1.61)
15 mm Hg greater SBP	1.32 (1.19 to 1.46)	1.32 (1.19 to 1.46)	1.31 (1.19 to 1.46)	1.30 (1.17 to 1.45)	1.31 (1.18 to 1.45)	1.30 (1.17 to 1.44)
Total cholesterol (mmol/l)	1.40 (1.23 to 1.60)	1.40 (1.23 to 1.60)	1.41 (1.23 to 1.60)	1.44 (1.25 to 1.64)	1.44 (1.26 to 1.64)	1.46 (1.28 to 1.67)
Smoker (yes/no)	3.08 (2.21 to 4.30)	3.08 (2.21 to 4.30)	3.06 (2.19 to 4.28)	3.00 (2.15 to 4.20)	3.03 (2.17 to 4.23)	2.96 (2.12 to 4.14)
Diabetes (yes/no)	1.87 (0.42 to 8.23)	1.82 (0.41 to 8.04)	1.90 (0.43 to 8.40)	1.91 (0.43 to 8.44)	1.89 (0.43 to 8.31)	1.89 (0.43 to 8.29)
LVH (yes/no)	2.56 (0.27 to 24.16)	2.57 (0.27 to 24.15)	2.54 (0.27 to 24.09)	2.65 (0.28 to 24.78)	2.45 (0.26 to 23.43)	2.67 (0.29 to 24.71)
Exhaustion*		1.05 (0.89 to 1.24)				
Daily stress*			0.96 (0.83 to 1.10)			
Own social class*				1.09 (0.95 to 1.24)		
Father's social class*					1.19 (1.01 to 1.39)	
Lifetime SE position*						1.17 (1.02 to 1.34)
Area under the ROC curve (95% CI)	0.745 (0.713 to 0.777)	0.745 (0.713 to 0.777)	0.746 (0.714 to 0.777)	0.746 (0.714 to 0.778)	0.749 (0.717 to 0.781)	0.749 (0.718 to 0.781)
Comparison with Framingham predictors (p value)		0.79	0.57	0.52	0.25	0.17

Novel risk factors are added in turn to the standard Framingham predictors.

*Coefficient describes the linear trend in odds across the four categories of this covariate, as exhaustion, stress and reliance on manual work increase.
CI, confidence interval; LVH, left ventricular hypertrophy; OR, odds ratio; ROC, receiver operating characteristic; SBP, systolic blood pressure; SE, socioeconomic.

RESULTS

Table 1 describes the 5191 men included in the present analysis in terms of the measures included in the Framingham risk prediction and the additional measures considered in the present investigation. Few men had diabetes or ECG-LVH. During the first 10 years of follow up, 203 men had died of coronary heart disease and a further 200 men had been admitted to hospital with a diagnosis of coronary heart disease.

Table 2 shows associations between the available Framingham predictors and coronary heart disease mortality during the first 10 years of follow up. There was strong evidence of independent associations for age, systolic blood pressure, total cholesterol, and smoking. There was also very weak evidence for increased risk associated with diabetes and ECG-LVH, these effects being imprecisely estimated owing to the small number of cases of each. The area under the ROC curve for this first multivariable model is 74.5%.

Further multivariable models additionally include, in turn, vital exhaustion, daily stress, own current social class, father's social class, and lifetime socioeconomic position (table 2). With the standard Framingham predictors included in the multivariable equation there was no convincing evidence of independent associations between mortality from coronary heart disease over 10 years and vital exhaustion ($p = 0.53$), daily stress ($p = 0.52$), or the man's own social class ($p = 0.22$). There was evidence of independent associations between coronary heart disease mortality and both father's social class ($p = 0.032$) and lifetime socioeconomic position ($p = 0.030$). However, in no case was there a strong indication of an improvement in the prediction of coronary heart disease mortality: area under the ROC curve was 74.5% for the model including vital exhaustion, 74.9% for the model including father's social class, and 74.9% in the model including lifetime socioeconomic position.

With mortality or hospital admission for coronary heart disease within 10 years of screening as the outcome, the results of the analysis were very similar to those described above (data not shown). There was modest evidence of independent associations with own current ($p = 0.099$), father's ($p = 0.046$), and lifetime ($p = 0.015$) socioeconomic position, but with little improvement in the prediction of coronary heart disease (less than 1% increase in area under the ROC curve).

Increasing the follow up period of the present analysis to 15 years increased the number of coronary heart disease deaths observed to 378, but the evidence of improvements in prediction with the addition of new measures remained modest. The area under the ROC curve for the model including lifetime socioeconomic position was 0.734 (95% confidence interval (CI), 0.710 to 0.759) whereas for the model with only standard Framingham predictors the area was 0.727 (0.702 to 0.752) with a comparison of the two giving evidence of an improvement ($p = 0.038$).

Area based measures of deprivation also showed associations with coronary heart disease mortality independent of the standard Framingham predictors (odds ratio for one category increase in area deprivation = 1.16 (95% CI, 1.01 to 1.33), $p = 0.030$). Adding area deprivation to the recalibrated Framingham equation, however, made only a small contribution to prediction (area under ROC curve = 0.748 (0.716 to 0.780), p value for comparison with standard Framingham equation = 0.38).

DISCUSSION

In this population with a high incidence of coronary heart disease the basic Framingham-derived risk prediction algorithm allowed reasonable discrimination between men at higher and lower risk of death from coronary heart disease over the subsequent 10 years with area under the ROC curve of around 75%. Performance of the algorithm did not appear to be

Table 3 Observed and predicted coronary heart disease mortality over ten years, by man's occupational class at enrolment

Occupational class	Observed mortality		Standard Framingham equation		Recalibrated Framingham equation		Recalibrated equation + lifetime socioeconomic position	
	%	(95% CI)	%	(risk ratio)	%	(risk ratio)	%	(risk ratio)
I/II	2.96	(2.21 to 3.87)	1.85	(0.63)	3.73	(1.26)	3.25	(1.10)
III _{nm}	4.20	(3.00 to 5.69)	1.95	(0.46)	3.97	(0.95)	3.62	(0.86)
III _m	4.54	(3.53 to 5.73)	2.06	(0.45)	4.20	(0.92)	4.65	(1.03)
IV/V	4.33	(3.19 to 5.73)	2.35	(0.54)	4.65	(1.07)	5.11	(1.18)
Non-manual	3.39	(2.74 to 4.16)	1.88	(0.56)	3.82	(1.12)	3.38	(1.00)
Manual	4.45	(3.68 to 5.33)	2.18	(0.49)	4.38	(0.98)	4.84	(1.09)
Sensitivity/specificity			4.43%/99.1%		27.6%/92.2%		27.6%/92.0%	

Predicted mortality risk is based upon the standard Framingham equation, the Framingham equation recalibrated to the present cohort, and the Framingham equation with lifetime socioeconomic position as an extra covariate calibrated to the present cohort. Risk ratios compare predictions against the observed mortality rate. Sensitivity and specificity are for observed coronary heart disease mortality in men at predicted 10%+ risk of such death. CI, confidence interval.

critically dependent on information from special tests as HDL cholesterol was not available and ECG-LVH in this cohort from which men with definite ECG evidence of ischaemia were excluded was rare. Consideration of additional information on psychological disadvantage (vital exhaustion or daily stress) did nothing to improve discrimination and consideration of lifetime material disadvantage did little more. In the case of the former, while vital exhaustion has been proposed as a refined measure of psychological disadvantage, it appeared to be no more important a determinant of heart disease than other measures of psychological disadvantage we have previously investigated with this cohort.²⁷

Life course material disadvantage, in contrast, is strongly associated with risk of heart disease in this cohort, an influence that does not appear to be fully mediated by established behavioural and physiological risk factors.^{11 13} Another general population based study in the West of Scotland found underprediction of coronary risk by the Framingham equation associated with increasing social disadvantage.²⁶ In the Scottish Heart Health extended cohort the Framingham equation overestimated risk overall but underestimated the variation in risk associated with deprivation. Together, these findings have led to suggestions that disadvantage be considered in risk prediction to avoid exacerbation of social gradients in heart disease through the inappropriate allocation of treatment.²⁸

In this cohort of working men we also found evidence for underprediction of coronary risk and thus confirmed the potential for undertreatment of individuals who might benefit. Underprediction was apparent across the occupational spectrum but was less marked among men in professional and managerial occupations compared with other social groups.

Recalibration of the Framingham equation to the risk experience of the present cohort improved the sensitivity of prediction but additional consideration of lifetime socioeconomic position within this recalibrated equation made little difference. Ecological measures of social position may be easier to obtain than individually based indices where the former can be derived from routinely available information such as address. However, whether social position was indexed by individual or ecological measures made little difference to prediction. It may seem counterintuitive that consideration of factors with a strong and apparently independent association with risk should not considerably improve risk prediction. Nevertheless, others have found a similarly modest improvement in risk prediction associated with the addition of novel factors strongly and independently associated with increased risk in other cohorts.^{29 30}

Though addition of novel factors to the standard Framingham algorithm may not substantially improve prediction, consideration of these factors in some situations where certain standard Framingham risk factors are missing may allow similar predictive precision as achieved through consideration of the missing standard factors.³⁰ Further it should be emphasised that the contribution of a risk factor to the precision of risk prediction should not be used to infer its importance in terms of prevention. Cholesterol, for example, appears to make a relatively modest contribution to risk prediction, yet risk reduction interventions directed against cholesterol can make a large contribution to improved population health.³¹ The relatively small additional contribution to risk prediction associated with consideration of lifetime material circumstances in no way undermines the case for reducing material disadvantage to improve population health.

Potential limitations of the present analysis are that the full Framingham risk equation was not used; no measure of HDL cholesterol was available, and multivariable logistic regression was used to quantify independent associations between risk factors and outcomes. The use of a simpler statistical technique clarified the contributions of individual risk factors. Inability to consider HDL cholesterol will not have limited our study, as failure to combine information from the full set of risk factors in an optimal model provides greater scope for demonstrating a contribution of novel risk factors. Despite these favourable circumstances, there was no substantial improvement in the prediction of coronary heart disease with any of the novel risk factors considered. For additional variables to improve risk prediction, consideration of the relevant variable must allow detection of additional cases. Even in a relatively large dataset with large event numbers, numbers of additional cases identified are likely to be small. Increasing event numbers through increasing the follow up period to 15 years had little influence on prediction.

What is already known

- The use of risk prediction equations to identify individuals at higher risk of heart disease is widely advocated as a guide to treatment decisions.
- Equations derived from the Framingham study population are the most widely used, but their discriminatory power may be poor when they are applied in a population other than the one in which they were calibrated and when they fail to consider all, important independent risk factors for heart disease.
- Recalibration using local data and consideration of novel psychosocial factors independently associated with heart disease risk in prediction equations may overcome this problem.

What this study adds

- In a Scottish male working population the standard Framingham risk equation performed reasonably well in discriminating between individuals at higher and lower risk of heart disease.
- Recalibration to the risk associated with the standard Framingham risk factors, using local data, improved performance.
- Additional consideration of psychosocial factors, including those strongly and independently associated with heart disease risk in this population, had little additional influence on performance.

Policy implications

- Recalibration of risk prediction equations, based on established risk factors using local data, improves prediction but is dependent on the availability of appropriate local data.
- Additional consideration of novel risk factors, such as social disadvantage, may have little to add.
- Rather than focusing on improving currently available risk prediction tools, policy should concentrate on facilitating the active assessment of risk and delivery of treatment based on this, across all social groups.

The coverage of coronary preventive interventions among people with the potential to benefit from them is relatively low; however, it is unclear whether improving the precision of coronary risk prediction would substantially change this situation. Many factors, including the behaviour of patients and health workers and the structure of health services, influence access to effective health interventions. Improving tools that help practitioners identify patients at higher risk of heart disease is important. The influence of this improvement on the coverage of coronary prevention, however, is contingent on the active consideration of treatment within a framework informed by risk prediction.^{32 33}

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