treatment but continue to be followed up, this makes no difference to the cost effectiveness rankings.

Conclusion

Incremental cost effectiveness analysis of treatments produces robust, practical cost effectiveness rankings. Authors of guidelines should take account of this when making treatment recommendations. If the aim of treatment is to maximise prevention of coronary disease, these results cast doubt on present policy, which emphasises achievement of target blood pressures and the use of statins for people at 15% five year risk of a coronary event.[14] A more efficient prevention strategy would be to offer aspirin and initial antihypertensive treatment to all people at over 7.5% five year coronary risk before offering statins to patients at 30% five year risk. According to national survey data, 87% of men and 56% of women aged over 65 are at over 7.5% five year risk.[15]

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Predictive accuracy of the Framingham coronary risk score in British men: prospective cohort study

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Editorial by Hense

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Abstract

Objective To establish the predictive accuracy of the Framingham risk score for coronary heart disease in a representative British population.
Design Prospective cohort study.
Setting 24 towns in the United Kingdom.
Participants 6643 British men aged 40-59 years and free from cardiovascular disease at entry into the British regional heart study.
Main outcome measures Comparison of observed 10 year coronary heart disease mortality and event rates with predicted rates for each individual, using the relevant Framingham risk equation.
Results Of 6643 men, 2.8% (95% confidence interval 2.4% to 3.2%) died from coronary heart disease compared with 4.1% predicted (relative overestimation 47%, $P<0.0001$). A fatal or non-fatal coronary heart disease event occurred in 10.2% (9.5% to 10.9%) of the men compared with 16.0% predicted (relative overestimation 57%, $P<0.0001$). These relative degrees of overestimation were similar at all levels of coronary heart disease risk, so that overestimation of absolute risk was greatest for those at highest risk. A simple adjustment provided an improved level of accuracy. In a "high risk score" approach, most cases occur in the low risk group. In this case, 84% of the deaths from coronary heart disease and non-fatal events occurred in the 93% of men classified at low risk (<30% in 10 years) by the Framingham score.
Conclusion Guidelines for the primary prevention of coronary heart disease advocate offering preventive measures to individuals at high risk. Currently recommended risk scoring methods derived from the Framingham study significantly overestimate the absolute coronary risk assigned to individuals in the United Kingdom.

Introduction

The national service framework for coronary heart disease in England and Wales states that people whose estimated risk of coronary heart disease based on a specified risk factor profile is ≥30% over 10 years should be identified and offered appropriate advice and treatment.[1] European, American, and Canadian guidelines also use predicted 10 year risk to identify people for risk factor modification.[2–5]

It is recommended that risk assessment be performed using one of several methods that combine values for different risk factors to produce a

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Baseline characteristics of men in Framingham studies and British regional heart study without pre-existing cardiovascular disease and with complete data on risk factors

Characteristic	Framingham (n=2590)*	British regional heart study (n=6643)
Period of baseline data collection	1968-75	1978-80
10 year coronary heart disease mortality (%)	NA	2.8
10 year coronary heart disease event rate (%)	12.4	10.2
Age range (years) at baseline	30-74	40-59
Smoking (%)	40.7	41.9
Diabetes (%)	7.1	1.1
Electrocardiographic evidence of left ventricular hypertrophy (%)	1.1	2.6
Median (95% CI) blood pressure (mm Hg):		
Systolic blood pressure	128 (109 to 168)	143 (115 to 182)
Diastolic blood pressure	82 (69 to 102)	81 (62 to 105)
Median ratio (95% CI) of total to high density lipoprotein cholesterol	4.8 (2.9 to 8.0)	5.5 (3.5 to 8.6)

NA=not available.
*From Anderson et al.[9]

quantitative risk estimate.[2 3 6–8] These methods use regression equations derived from a population sample of the Framingham heart study and the Framingham offspring study.[9] Despite evidence that Framingham risk equations systematically overestimate risk of coronary heart disease in populations with lower coronary heart disease mortality, risk scoring methods based on these equations have been introduced widely.[10–12]

We assessed the ability of the Framingham risk equations to predict death from coronary heart disease and the combination of fatal and non-fatal coronary heart disease events that is the outcome used in current scoring methods, in a representative population of British men over a 10 year period.[6–8]

Participants and methods

The risk assessment methods recommended for British and European use are adapted from published equations derived from 5573 men and women from the Framingham heart study and the Framingham offspring study. According to the equations, we used systolic blood pressure, smoking, ratio of total to high density lipoprotein cholesterol, electrocardiographic evidence of left ventricular hypertrophy, diabetes, and length of follow up to calculate the predicted probability of death or an all fatal and non-fatal coronary heart disease events (see box, bmj.com).[9 13]

The British regional heart study is a prospective study of 7735 men, aged 40-59 years at entry (1978-80), who were randomly selected from the age and sex registers of one general practice in each of 24 towns in the United Kingdom.[14]

Statistical methods

Using the appropriate Framingham equations, we calculated the risk of death from coronary heart disease and all coronary heart disease events over a 10 year period for each of the men in the British regional heart study who were initially free of cardiovascular disease and had complete information on risk factors. We compared the average predicted event rates within each quintile for both end points with the observed 10 year rates. The Hosmer Lemeshow test was used to assess goodness of fit.[15]

To assess the performance of the screening test at identifying individuals at "high risk," we calculated the sensitivity and specificity for risk score thresholds of ≥30% and ≥15% over 10 years.

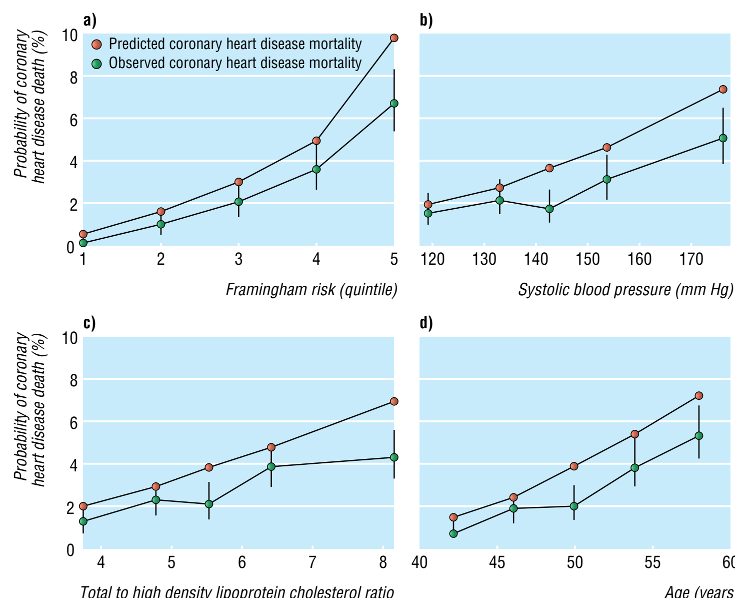

Fig 1 Ten year predicted versus observed coronary heart disease mortality with 95% confidence intervals by quintile of Framingham risk, systolic blood pressure, ratio of total to high density lipoprotein cholesterol, and age

Results

Of 7735 men recruited, 6643 were free of definite angina and had complete data on risk factors at baseline. The table compares the baseline characteristics of these men with those of the 2590 men from the Framingham cohorts used in the derivation of the risk equations.

Observed and predicted coronary heart disease mortality and recalibration

When the coronary heart disease mortality equation was applied to each of the men in the British regional heart study, the predicted number of deaths from coronary heart disease within 10 years was 270 (4.1%). This compared with an observed 183 deaths from coronary heart disease, giving a rate of 2.8% (95% confidence interval 2.4% to 3.2%) over the first 10 years of follow up. Figure 1 displays predicted and observed mortality from coronary heart disease across

a range of risk levels (according to the quintiles of Framingham risk, systolic blood pressure, ratio of total to high density lipoprotein cholesterol, and age). This relative over-prediction of mortality risk by 47% (P value for goodness of fit <0.0001) was similar at all risk levels (fig 1a), so that over-prediction of absolute risk was greatest for people at highest risk. Similarly, figures 1b-d show that significant overestimation of risk occurs at all levels of the risk factors concerned, apart from the lowest level of systolic blood pressure. For the combined outcome of fatal coronary heart disease and any diagnosis of myocardial infarction or angina, the observed number of events over 10 years was 677 (event rate 10.2%, 9.5% to 10.9%) compared with a predicted 1062 (16.0%)—a relative over-prediction of 57% (P value for goodness of fit <0.0001).

We adjusted the Framingham scores by dividing the calculated score for each individual by the amount of over-prediction (see bmj.com). After making this correction, the predicted risk became close to the observed rate at all levels of risk (fig 2), as indicated by a substantial decrease in the χ^2 statistic for goodness of fit from 30.2 to 3.4. Similarly, the risk equation for coronary heart disease events was corrected to take into account the 57% relative over-prediction (fig 2). Again a large decrease was observed in the goodness of fit statistic from 155.3 to 24.6.

Discrimination

When we applied the coronary event equation to the baseline data in the British regional heart study, 444 men (6.7%) had a predicted 10 year coronary heart disease event risk of ≥30% (average predicted risk 36.2%), of whom only 106 (out of the 677 men with a coronary heart disease event) actually had a coronary heart disease event within the following 10 years—a sensitivity of 16% (106/677). The sensitivity increased to 75% (509/677) when a 15% risk threshold was used, but this was at the expense of a large drop in specificity from 94% (5628/5966) to 55% (3258/5966) and a large increase in the proportion of men classified as high risk (from 6.7% to 48.4%). Similar estimates of sensitivity and specificity were obtained when using these thresholds to identify individuals at high risk of coronary heart disease death within 10 years.

When the recalibrated equation was used, those in the high risk group identified by using the ≥30% threshold would now constitute only 0.5% of the population and identify only 1.8% (12/677) of the coronary heart disease events occurring within 10 years, so that preventive interventions restricted to this group would have a limited population impact. If a ≥15% threshold was used with the recalibrated equation, 17% of the population would be classified as high risk, and 37% (249/677) of coronary heart disease events would be identified. The specificities at the ≥30% and ≥15% thresholds using the recalibrated equation would be 99.6% (5944/5966) and 85% (5055/5966), respectively.

Discussion

The Framingham equations used in current risk scoring methods over-predict the risk of mortality from coronary heart disease and all fatal and non-fatal coronary heart disease events by 47% and 57%, respectively,

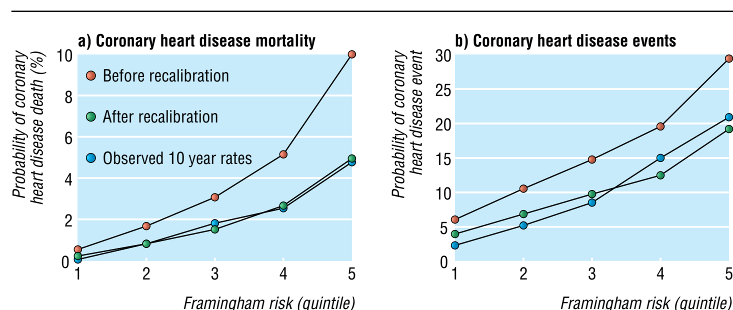

Fig 2 Predicted coronary heart disease death and coronary heart disease event risks before and after recalibration

compared with observed events in a representative sample of British men. The relative degree of over-prediction was similar at all levels of individual risk.

Overestimation of an individual's true risk and the poor sensitivity of the recommended tool to identify and target individuals for treatment have important implications for a national screening test.[1] An overestimated assessment of coronary heart disease risk will undermine a patient's ability to make an informed choice about starting preventive treatment, may cause unnecessary anxiety, and may affect life insurance premiums.[16] If the patient's absolute risk is lower than predicted, the absolute benefits of intervention will be smaller and the balance of risks and benefits less favourable. Additionally, overestimation of risk prediction will adversely affect direct prescribing costs as well as the costs of drug monitoring and dealing with side effects.

The accuracy of risk estimates derived from cohort studies or from randomised controlled trials are always open to the criticism of being out of date compared with current morbidity rates, owing to the delay between the collection of baseline data and the reporting of incident events.[17] If coronary heart disease rates

What is already known on this topic

Primary prevention of coronary heart disease involves identifying patients at high risk and offering them lifelong preventive treatment

Most risk assessment methods rely on equations derived from the Framingham study

Evidence is conflicting as to the suitability of these equations for British and other European populations

What this study adds

Recommended risk scoring methods overestimated coronary risk in a representative British male population

This was similar at all levels of coronary heart disease risk and could be reduced by a simple adjustment

Use of a predicted ≥30% coronary heart disease 10 year event rate threshold to identify patients at high risk can fail to identify most who go on to have a coronary heart disease event over the following 10 years

continue to fall, the discrepancy between predicted and actual risk is likely to increase, as the decline is not entirely attributable to falls in the risk factors included in the Framingham equation.[18] Furthermore, fewer people will fall into the high risk group, causing the proportion of coronary heart disease events prevented by targeting only these individuals to be reduced.

We have shown that current risk scoring methods seem to overestimate coronary heart disease risk, and that a simple adjustment can improve their predictive accuracy in the British population. Nevertheless, further refinements are necessary before the substantial variations in coronary heart disease risk found between different regions and different ethnic groups, socioeconomic status, and family history of coronary heart disease can be accommodated into an accurate and effective treatment decision aid.

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Gallstones in custard

Most recipes are not inventions. The Delia Smiths of this world don't invent new recipes in the scientific sense of the word. They take a known mix and add a bit more garnish here, a few herbs there, and, if successful, promulgate the new recipe under their name, t be passed on from friend to friend and generation to generation. The stimulus for the activity may be an important dinner party, a new boss to impress, or, in the case of professional chefs, a new book or television programme to fill. The stimulus for our recipe was an invitation from a retired professor of bacteriology, the chairman of a local medical and scientific society, to contribute to a Saturday exhibition for the general public in the Corn Hall of nearby Cirencester by showing how we use ultrasonography to visualise the gall bladder.

We made a few posters, arranged to borrow a portable ultrasound machine, and set about making an ultrasound "phantom." Making an artificial gall bladder was straightforward. A few pebbles from my drive in a party balloon partially inflated with water served the purpose. To my wife's annoyance, I then spent several evenings messing up the kitchen stove with gelatine trying to perfect the surrounding medium. The best medium was children's jelly (orange flavoured) with half the normal quantity of water; orange flavoured is a little more transparent than blackcurrant. I allowed a few cupfuls to set in a transparent container, placed the "gall bladder" on top, added further liquid jelly, and let it all set in the fridge. The jelly was transparent enough for the gall bladder to be seen within, and ultrasonography could reveal the pebbles as echogenic structures in the echo-free "bile" with acoustic shadowing. I embellished the phantom with plums, olives, and bits of metal from the garage, but the next step, even if I say so myself, was a stroke of genius.

I made two more phantom gall bladders and immersed one in custard and another in Angel Delight (a commercial form of mousse). The gall bladder in custard was shown less well by ultrasound than the one in jelly because of fat globules in the milk, and, because of the air bubbles caught up in the mix, the gall bladder in Angel Delight could not be detected at all. The three phantoms graphically demonstrated how ultrasound can show things the eye cannot see but that fat and air interfere with the transmission of sound.

The exhibition contained exhibits from eminent haematologists and immunologists, professors from Cranfield, and academics from Oxford. Several hundred members of the public attended. It is with pride that I tell you, even though things got pretty sticky by the end of the afternoon, the most popular exhibit was gall stones in custard. If you want, feel free to pass the recipe on to your friends.

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