Resource implications and health benefits of primary prevention strategies for cardiovascular disease in people aged 30 to 74: mathematical modelling study

Tom Marshall, Andrew Rouse

Abstract

Objective To develop a model to determine resource costs and health benefits of implementing guidelines for the prevention of cardiovascular disease in primary care.

Design Modelling of data from six strategies for prevention of cardiovascular disease. Strategies incorporated two ways of identifying patients for assessment: traditional (assessment of all adults) and novel (preselection of patients for assessment using a prior estimate of their risk of cardiovascular disease). Three treatment strategies were modelled in conjunction with each identification strategy.

Setting England.

Subjects Patients aged 30 to 74 eligible for primary prevention strategies for cardiovascular disease who were selected from a hypothetical population of 2000.

Main outcome measures Resource costs of assessing eligible adults, providing treatment and follow up to those eligible, and number of cardiovascular events this should prevent.

Results Novel strategies prevented more cardiovascular disease, at lower cost, than traditional strategies. Some treatment strategies prevent more cardiovascular disease with fewer resources than others. The findings were robust across a range of different assumptions about workload.

Conclusion Preselecting patients for assessment makes better use of staff time than assessing all adults. Treating many patients with low cost drugs is more efficient than prescribing a few patients intensive antihypertensives and statins. Authors of guidelines should model workload implications and health benefits of following their recommendations.

Introduction

The UK government policy framework for the prevention of coronary heart disease places specific obligations on primary care services.¹ The framework endorses joint British recommendations on preventing coronary heart disease: primary care teams must assess patients' risk of cardiovascular disease every five years and treat eligible patients (box 1).² The recommendations do not consider or evaluate alternative methods of identifying patients for treatment. They require the

commitment of many hours of clinical staff time and considerable cost. Part of this commitment will be devoted to assessing patients who ultimately do not require treatment. The joint British recommendations do not quantify either the resource implications or the health benefits of this policy for the prevention of cardiovascular disease.

We describe a model for estimating the efficiency (total health service resources invested versus cardiovascular events prevented) of strategies for primary care based prevention of cardiovascular disease. The data for our model came from several sources (fig 1). We used our model to evaluate six strategies. Three strategies are based on the joint British recommendations: they assume all patients undergo clinical risk assessment and that those at highest risk are treated.²

Public Health and Epidemiology, University of Birmingham, Birmingham B15 2TT

Tom Marshall
lecturer

Andrew Rouse
senior lecturer

Correspondence to:
T Marshall
TPMarshall@bham.ac.uk

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Box 1 Joint British recommendations for prevention of coronary heart disease in primary care

Assessment

- Assess cardiovascular risk of all patients five yearly

Criteria for antihypertensives

- Five year coronary heart disease risk > 7.5% (equivalent to 10 year coronary heart disease risk > 15%) and blood pressure > 140 mm Hg systolic or > 90 mm Hg diastolic
- Blood pressure > 160 mm Hg systolic or > 100 mm Hg diastolic (irrespective of coronary heart disease risk)

Criteria for cholesterol lowering treatment

- Five year coronary heart disease risk > 7.5% (equivalent to 10 year coronary heart disease risk > 15%) and total cholesterol concentration ≥ 5 mmol/l (equivalent to a total cholesterol to high density lipoprotein cholesterol ratio > 3.5)

Criteria for aspirin treatment

- Age over 50 and five year coronary heart disease risk > 7.5% (equivalent to 10 year coronary heart disease risk > 15%)

Long term management of patients receiving drug treatment

- Review at least twice a year

Three alternative strategies are described. These prioritise patients for clinical risk assessment on the basis of a prior estimate of their risk of cardiovascular disease—only patients most likely to benefit from treatment would be invited for assessment.

Methods

The joint British recommendations require patients to undergo five yearly assessments for risk of cardiovascular disease. Therefore our model analysed resource implications and health benefits over a five year period. Resource implications were considered from the perspective of the health service. Health benefits were limited to an estimate of cardiovascular events prevented.

Hypothetical population

We studied a hypothetical population of 2000 patients: the number registered for each whole time equivalent general practitioner in England.³ Our model assumes patients aged 30 to 74 are eligible for primary prevention services.

We believe few practices consider clinical assessment in patients under 30, as modifiable high risk is uncommon and they are therefore unlikely to benefit.⁴ Patients with ischaemic vascular disease, those taking antihypertensives, and those over 75 are high priority groups. We have excluded them from our model as practices already assess and follow them up.

Cardiovascular risk estimation

The Framingham coronary heart disease risk equation predicts the occurrence of coronary events (myocardial infarction, new onset angina, or sudden cardiac death).⁵ It requires information on age, sex, blood pressure, ratio of total cholesterol to high density lipoprotein cholesterol, smoking history, history of diabetes, and whether there is electrocardiographic evidence of left ventricular hypertrophy. It has been validated in a range of populations.⁶ We used this risk equation to determine eligibility for treatment—reflecting the joint British recommendations—and to estimate the number of coronary events prevented.²

The Framingham cerebrovascular disease risk equation predicts the risk of stroke (cerebrovascular accident or transient ischaemic attack).⁷ We used it to estimate the number of strokes prevented.

The combined Framingham risk equation predicts the risk of all cardiovascular events (stroke, coronary

event, peripheral vascular disease, or heart failure). In some guidelines it is used to determine eligibility for treatment.⁸ A combined Framingham risk of 15% is about equivalent to a 10% risk of coronary heart disease. We used the combined Framingham risk equation to calculate prior risk estimates for the preselection strategies.

Distribution of cardiovascular risk factors and risk in eligible patients

Using data from the 1998 health survey of England, we estimated the distribution (in the English population) of systolic blood pressure and cholesterol concentration by age, sex, history of diabetes, and smoking history in individuals who neither had prior cardiovascular disease nor were receiving antihypertensives.⁹ Using these data and 1998 population estimates for England, we generated a hypothetical population whose distribution for age, sex, and risk factors reflected a typical general practitioner list.

Our typical general practitioner list had 939 patients, aged between 30 and 74, eligible for primary prevention services. We entered data on risk factors for cardiovascular disease in these patients into an Excel spreadsheet. For each we calculated the five year risk of all cardiovascular events, coronary heart disease events, and stroke using the Framingham risk equations. We thus modelled a list of patients eligible for inclusion in a programme for the prevention of cardiovascular disease.

Cardiovascular disease prevention strategies modelled

The joint British recommendations do not indicate how to prioritise assessed patients for treatment. In strategies JBR-1 (joint British recommendations-1), JBR-2, and JBR-3 all patients undergo five yearly assessments for clinical risk. Once assessed the general practitioner treats them in rank order of their risk of coronary heart disease: the total number of patients treated being determined by the total resources available.

In strategies RM-1 (Rouse Marshall-1), RM-2, and RM-3 (see box 2) a two stage assessment is proposed. Firstly, primary care teams make a prior estimate of each patient's total risk of cardiovascular disease, as follows. The teams have an electronic record of every patient's age and sex. They allocate each patient a default blood pressure and cholesterol concentration: the mean value for their age and sex (derived from the health survey of England). The teams determine each patient's diabetic status from electronic prescribing records. As non-smokers outnumber smokers in every age-sex group, they assume a default smoking status of non-smoking. The team then sets up an Excel spreadsheet incorporating the Framingham cardiovascular risk equation. Using the default values, it takes minutes on this spreadsheet to calculate a prior estimate of risk of cardiovascular disease for each patient in the entire practice. This is the best prior indication of their potential to benefit from treatment. It then takes seconds to rank patients by the prior estimate of their risk of cardiovascular disease. Secondly, the team identifies patients for full assessment of clinical risk in rank order. After clinical assessment most patients prioritised for assessment in this way will be found to be eli-

Fig 1 Data sources for model

Box 2 Cardiovascular disease prevention strategies modelled

Identification and prioritisation

Strategies JBR-1, JBR-2, and JBR-3

- Assess cardiovascular risk factors in eligible patients
- Calculate cardiovascular risk in all eligible patients
- Prioritise patients by cardiovascular risk
- Treat highest priority patients who meet criteria in table 1

Strategies RM-1, RM-2, and RM-3

- Calculate a prior estimate of cardiovascular risk using age, sex, diabetes status, and default values for other risk factors
- Prioritise patients by prior cardiovascular risk estimate
- Assess cardiovascular risk factors in highest priority patients
- Treat assessed patients who meet criteria in table 1

Treatment

All strategies:

- Aspirin 150 mg as antiplatelet agent
- Hydrochlorothiazide 25 mg and atenolol 50 mg for initial blood pressure lowering
- In addition JBR-1, JBR-2, RM-1, and RM-2 require enalapril 20 mg for intensive blood pressure lowering and JBR-1 and RM-1 require simvastatin 10 mg

gible for treatment. Box 2 shows the six identification and treatment strategies.

Resource implications

We assumed that all clinical tasks are carried out by practice nurses. The total health service cost of providing an hour of practice nurse clinic time is £28.¹⁰ Costs of blood tests were derived from the Pathology Services costings.¹¹ Drug costs were obtained from the *British National Formulary*.¹² Dispensing costs were calculated at 87.4p for each prescribed item on the assumption that four prescriptions are issued each year.¹³ Where appropriate, costs have been discounted at 6% a year.

Assessing cardiovascular risk

To estimate the risk of cardiovascular disease with the Framingham risk equation, the clinician must measure each patient's blood pressure and cholesterol concentration and inquire about smoking, diabetes, and atherosclerotic disease. The clinician then calculates the risk of cardiovascular disease (using computer software or risk tables) and discusses the implications of this with the patient. The joint British recommendations give precise directions on measuring blood pressure. The clinician should measure blood pressure with the patient seated on at least three separate occasions, with the patient at rest for five minutes.² Each measurement therefore takes at least five minutes. Accurate cholesterol estimation requires blood specimens to be drawn on at least two separate occasions²; a process requiring at least two and a half minutes. Therefore, even ignoring the time taken to make inquiries, to calculate the risk of cardiovascular disease, and to discuss the implications of this with the patient, each risk

assessment takes a minimum of 20 minutes of clinical staff time.

Treatment and follow up

Ongoing management of patients receiving treatment requires at least two follow up clinic appointments a year, totalling 20 minutes of clinical staff time.² Patients receiving thiazide diuretics require an annual estimation of electrolyte and uric acid, and patients receiving statins require annual liver function tests.

Health benefits

Calculating benefits of treatment

We calculated the benefits of treatment as the number of cardiovascular events prevented. As patients may have two cardiovascular events, this differs from the number of patients having a cardiovascular event. To reflect the joint British recommendations, treatment decisions were determined by the risk of coronary heart disease. However, since treatments prevent both strokes and heart disease—both important health benefits—we included both in our model. Antihypertensives reduce the risk of stroke by more than they reduce the risk of coronary heart disease. In some individuals (patients with high cholesterol concentrations and low blood pressures) the risk of coronary heart disease is high and the risk of stroke low, whereas in others it is the reverse. An average estimate of the effect of treatment would therefore overestimate the number of events prevented in those at relatively high risk of coronary heart disease and underestimate the number of events prevented in those at relatively high risk of stroke. We therefore estimated the joint effects of treatment on reducing the risk of stroke and the risk of coronary heart disease: the sum of two separate effects.

For each patient, the absolute risk reduction is the product of the initial risk and the risk reduction with treatment. Table 1 summarises the assumed risk reductions afforded by treatment.

Eligibility for and benefits of treatment

The criteria for treatment eligibility followed the joint British recommendations as closely as possible and were the same in all six strategies (see box 1).

Aspirin reduces the risk of cardiovascular disease by about 20%, but increases major bleeding events by 0.1% annually (0.5% over five years).¹⁴⁻¹⁷ Our model offsets the absolute reduction in cardiovascular risk by 0.5% to take account of the increased risk of bleeding.

Evidence from randomised controlled trials suggests treatment with one to three antihypertensives (usually including thiazides and β blockers) reduces the risk of coronary heart disease and stroke.¹⁸ Our model assumes patients receive hydrochlorothiazide 25 mg and atenolol 50 mg. Table 1 shows the assumed effectiveness.

Under strategies JBR-1, JBR-2, RM-1, and RM-2, patients eligible for antihypertensives are also given more intensive treatment. Evidence suggests this may further reduce the risk of coronary heart disease and stroke.¹⁹ Our model assumes patients require enalapril 20 mg to achieve the additional effect shown in table 1.

Under strategies JBR-1 and RM-1, eligible patients are treated with statins—we assumed eligible patients receive simvastatin 10 mg. Statins reduce the risk of

Table 1 Treatment criteria for risk of cardiovascular or coronary heart disease and risk reductions with treatment

Treatment and criteria	Absolute reduction in 5 year risk of stroke	Absolute reduction in 5 year risk of coronary heart disease	Other major disease events*
Aspirin*			
Age >50 and 5 year coronary risk >7.5%	20%×initial risk	20%×initial risk	Increase by 0.5%
Thiazide and β blocker†			
Systolic blood pressure ≥ 160 mm Hg or systolic blood pressure ≥ 140 mm Hg and 5 year coronary risk >7.5%	36%×initial risk	17%×initial risk	No effect
Angiotensin converting enzyme inhibitor‡			
Systolic blood pressure ≥ 160 mm Hg or systolic blood pressure ≥ 140 mm Hg and 5 year coronary risk >7.5%	19%×initial risk	20%×initial risk	No effect
Cholesterol lowering treatment			
Total cholesterol to high density lipoprotein cholesterol ratio ≥ 3.5 and 5 year cardiovascular risk >7.5%	29%×initial risk	30%×initial risk	No effect

*Absolute benefits allow for increase in five year haemorrhage rate of 0.5%.

†Initial blood pressure lowering.

‡Intensive blood pressure lowering.

cardiovascular disease by 30% and the risk of stroke by 29%.^{20–22}

Results

Cost effectiveness

We illustrate cost effectiveness in two ways. Firstly, we show the number of cardiovascular events that can be prevented under each strategy by using increasing resources. This illustrates technical efficiency: the maximum health benefit achievable with these resources. However, it is more plausible that primary care teams first allocate staff time to devote to this activity and then try to maximise efficiency within the allocated staff time. We illustrate this by assuming the primary care team allocates one, two, or three clinics a month to the prevention of cardiovascular disease and by comparing the costs and health outcomes of the six strategies. This is equivalent to 180 hours of clinical time (180=3 hours×12 months×5 years).

Technical efficiency: maximising health benefits within total resources

For any given allocation of resources to the primary prevention of cardiovascular disease, more cardiovascular events can be prevented under RM strategies than under the equivalent JBR strategies. A primary care team can prevent 13.5 events for £49 960 under strategy RM-2 or 13.5 events for £15 110 under RM-3. The most efficient strategy for a primary care team with this budget is therefore RM-3. A primary care team can prevent 16.7 events for £119 806 under strategy RM-1 or 13.5 events for £73 716 under RM-2. The most efficient strategy for a primary care team with this budget is therefore RM-2. For a primary care team with over £119 806 the most efficient strategy is RM-1. Figure 2 shows the maximum number of events prevented with increasing amounts of resources under each strategy.

Maximising efficiency within available clinical staff time

For practices allocating one, two, or three clinics a month to the primary prevention of cardiovascular disease, RM strategies dominate JBR strategies (fig 3). At one clinic a month there is not sufficient clinical time to assess all eligible adults, JBR strategies therefore cannot be implemented. Strategy RM-3 prevented 9.1 cardiovascular events at a cost of £863 for

Fig 2 Total resource costs (assessment, follow up, drugs, and investigations) and health benefits of six strategies for primary prevention of cardiovascular disease

each event prevented. RM-2 prevented 1.9 more events at an incremental cost of £10 518 for each event prevented. RM-1 prevented 4.6 more events than RM-2 at an incremental cost of £17 808 for each event prevented.

Compared with one clinic a month, allocating two clinics a month to RM-3 prevented 3.8 more events at a cost of £1445 for each event prevented. Allocating two clinics a month to RM-2 prevented a further 3.0 events at an incremental cost of £14 025 for each event prevented. Two clinics a month following strategy RM-1 prevented a further 6.3 cardiovascular events at an incremental cost of £19 843 for each event prevented (table 2).

Fig 3 Resource costs and effectiveness of six strategies for prevention of cardiovascular disease in practice allocating one, two, and three clinics a month (only non-dominated strategies shown)

Table 2 Incremental analysis of strategies for prevention of cardiovascular disease in primary care

Strategy	Cost (£)*
One clinic a month:	
RM-3 (1 clinic) v no programme	863
RM-2 (1 clinic) v RM-3 (1 clinic)	10 518
RM-1 (1 clinic) v RM-2 (1 clinic)	17 808
Two clinics a month:	
RM-3 (1 clinic) v no programme	863
RM-3 (2 clinics) v RM-3 (1 clinic)	1 445
RM-2 (2 clinics) v RM-3 (2 clinics)	14 025
RM-1 (2 clinics) v RM-2 (2 clinics)	19 843
Three clinics a month:	
RM-3 (3 clinics) v RM-3 (2 clinics)	3 073
RM-2 (2 clinics) v RM-3 (3 clinics)	16 619
RM-2 (3 clinics) v RM-2 (2 clinics)	19 178
RM-1 (2 clinics) v RM-2 (3 clinics)	19 945

*£1=£1.6; €1.6.

Sensitivity analysis

Prior prioritisation of patients by estimated cardiovascular risk

Our model suggests that more cardiovascular disease could be prevented with the same health service resources by assessing only patients preselected on the basis of a prior estimate of their risk of cardiovascular disease. Even if we assessed only patients over 50, taking only 15 minutes for each patient assessment but requiring one hour a year for follow up of each patient, our model suggests RM strategies prevent more cardiovascular disease than JBR strategies.

Prior knowledge of patients' blood pressures

Primary care teams with an electronic record of their patients' blood pressures could conceivably reduce the time for patient assessment to five minutes, favouring the JBR strategies. However, knowledge of patients' blood pressures also permits a more accurate prior estimate of the risk of cardiovascular disease. Our model shows that strategy RM-3 remains the most efficient for practices with records of their patients' blood pressures.

Effects of not prescribing statins or angiotensin converting enzyme inhibitors

The discounted costs of five years' treatment with simvastatin 10 mg and enalapril 20 mg were £1065 and £385, respectively. The discounted cost of assessing, treating (aspirin, atenolol, and hydrochlorothiazide), and following up the next patient identified according to the RM strategies was £231. The opportunity cost of treating a known patient with simvastatin was not identifying and treating five new patients with aspirin, hydrochlorothiazide, and atenolol. In the case of enalapril, it is two new patients. Only a statin or third line antihypertensive costing under £231 for five years' treatment was likely to alter this finding.

Discussion

Robustness of model

Our model estimated the maximum possible health benefits and minimum resource implications of six strategies for the prevention of cardiovascular and coronary heart disease in primary care. Nevertheless this

did not affect the relative efficiencies of different strategies. We assumed that all eligible patients accepted and complied fully with treatment. In reality some decline assessment; some judge small reductions in absolute risk insufficient to justify treatment, and some do not comply with prescribed treatment. Reducing the rest period before measurement of blood pressure to under four minutes risks significant overestimation.²³ Blood tests take longer than 2.5 minutes and, given the biological variability of cholesterol concentrations, accurate estimation takes more than two measurements.²⁴ Calculating the risks of cardiovascular disease and counselling patients takes time. Patient assessment therefore probably takes longer than 20 minutes. Follow up may also cost more than we estimated. Patients often visit their general practitioner more frequently than twice yearly, and further investigations may be needed. The cost of staff time may be underestimated, since medical time costs more than nursing time.

Our model assumed no patients leave or join the practice over five years. An annual turnover of 10% in the practice population increases the number of five yearly assessments by 41%. In contrast, periodically recalculating prior risk estimates and re-ranking patients takes only minutes, and the primary care team could fill clinic time left by patient departures by inviting the next highest ranked patients for assessment. The turnover of practice populations therefore strongly favours the RM strategies.

Our model assumed that primary care teams following the joint British recommendations do prioritise patients for treatment on the basis of their risk of coronary heart disease. This means that they must first assess all patients' risk and only then select patients at highest risk for treatment. In fact, patients whose risks are above a threshold are likely to be treated as they are identified. A practice list may have 29 eligible patients whose five year risk of coronary heart disease exceeds 15% but only time to follow up 20. The first 20 identified are unlikely to be the 20 patients at highest risk. Our model therefore exaggerates the effectiveness of the joint British recommendations. The RM strategies make no such assumption.

Our model used the lowest cost drug for each category of treatment. Non-generic enalapril costs twice as much as generic enalapril. Simvastatin was costed at 10 mg a day, whereas higher doses are usual.²⁵ Compared with clinical practice, our model therefore exaggerated the cost effectiveness of strategies using simvastatin and enalapril.

Our model assumed treatment effects were multiplicative and that additional benefits accrued from more intensive blood pressure lowering. In general these assumptions are in line with current guidelines for the prevention of cardiovascular disease. However our estimate of the additional benefits of intensive blood pressure lowering comes from studies comparing less intensive treatment with more intensive treatment.¹⁹ Our estimate of the benefits of initial blood pressure lowering comes from studies of all blood pressure lowering.¹⁸ We have probably exaggerated the benefits of intensive blood pressure lowering.

What is already known on this topic

It is possible to estimate patients' risk of cardiovascular disease and their probability of benefiting from treatment

There are data on the distribution of cardiovascular risk factors in the population

What this study adds

A model estimated the efficiency of six strategies for primary prevention of cardiovascular disease: three strategies followed guidelines and three prioritised patients for assessment on the basis of a prior estimate of cardiovascular risk

Strategies that prioritise patients for risk assessment may reduce staff time to the extent that more patients can be treated and more disease prevented within available resources

Statins and angiotensin converting enzyme inhibitors cost more than identifying and treating new patients, so strategies avoiding these may allow more disease to be prevented within available resources

Implications of model for treatment recommendations

Our model raises questions about current treatment recommendations in the context of a population based programme for the prevention of cardiovascular disease. Recent research confirms statins are effective irrespective of initial cholesterol concentrations, across a wide range of risks.²⁶ Our model showed that they are not cost effective even for patients meeting current criteria. More intensive blood pressure lowering may reduce risk but does not justify the additional cost. This casts doubt on the importance of achieving blood pressure targets in a publicly financed, population based programme for the prevention of cardiovascular disease. Aspirin is currently recommended only for patients whose risk of coronary heart disease over five years exceeds 15%.² Our model suggests it may be cost effective for patients at much lower risk levels.

Conclusions

It is possible to calculate both the resource implications and the potential health benefits resulting from implementing guidelines for the prevention of cardiovascular disease. This obliges the authors of guidelines to be explicit about the assumptions they make about resource implications and effectiveness. We recommend that authors of future guidelines should make explicit statements about the resource implications, health benefits, and efficiency of implementation strategies. Our model suggests that the population benefits of following the joint British recommendations for the prevention of cardiovascular disease are modest and that the resource implications are substantial. Furthermore, the efficiency of prevention of cardiovascular disease in primary care could be greatly enhanced by two innovations: prioritising patients for assessment on the basis of a prior estimate of their

cardiovascular risk and avoiding costly drugs such as simvastatin and enalapril.

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