EDITOR'S CHOICE

Comparison of mass and targeted screening strategies for cardiovascular risk: simulation of the effectiveness, cost-effectiveness and coverage using a cross-sectional survey of 3921 people

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See Editorial, page 177

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ABSTRACT

Background Cardiovascular primary prevention should be targeted at those with the highest global risk. However, it is unclear how best to identify such individuals from the general population. The aim of this study was to compare mass and targeted screening strategies in terms of effectiveness, cost effectiveness and coverage.

Methods The Scottish Health Survey provided cross-sectional data on 3921 asymptomatic members of the general population aged 40–74 years. We undertook simulation models of five screening strategies: mass screening, targeted screening of deprived communities, targeted screening of family members and combinations of the latter two.

Results To identify one individual at high risk of premature cardiovascular disease using mass screening required 16.0 people to be screened at a cost of £370. Screening deprived communities targeted 17% of the general population but identified 45% of those at high risk, and identified one high-risk individual for every 6.1 people screened at a cost of £141. Screening family members targeted 28% of the general population but identified 61% of those at high risk, and identified one high-risk individual for every 7.4 people screened at a cost of £170. Combining both approaches enabled 84% of high risk individuals to be identified by screening only 41% of the population. Extending targeted to mass screening identified only one additional high-risk person for every 58.8 screened at a cost of £1358.

Conclusions Targeted screening strategies are less costly than mass screening, and can identify up to 84% of high-risk individuals. The additional resources required for mass screening may not be justified.

Primary prevention of cardiovascular disease is most effective if people are selected for intervention on the basis of their overall cardiovascular risk.[1] The Scottish Intercollegiate Guidelines Network (SIGN) recommends treatment of anyone with more than 20% risk of a cardiovascular event over the subsequent 10 years.[2] However, determining which members of the general population have a high cardiovascular risk is problematic. Mass screening of the whole population is one option. Alternatively, screening could be targeted at subgroups of the population known to have higher rates of cardiovascular disease, such as socioeconomically deprived communities and relatives of patients with premature cardiovascular disease. The aim of this study was to compare the relative strengths and weaknesses of these alternative approaches in terms of effectiveness, cost-effectiveness and coverage.

METHODS

Data sources and study population

The Scottish Health Survey is undertaken periodically to monitor the health and health-related risk factors of the Scottish population, and has cardiovascular disease as its principal focus. The survey uses multi-stage, stratified sampling to provide a representative sample of the Scottish population, and includes face-to-face interviews and physical measurements. Different participants are recruited to each survey. We combined data from the last two surveys, undertaken in 1998 and 2003, and included participants aged between 40 and 74 years inclusive. Participants were excluded if they had already been diagnosed with cardiovascular disease or had missing data required to compute their risk score.

Simulation models

The Scottish Health Survey data were used to simulate the impact of five screening strategies to identify those at high risk of cardiovascular events.

1. Mass screening of the whole population
2. Screening individuals living in deprived communities
3. Screening individuals with a family history of premature cardiovascular disease
4. Screening individuals who either lived in deprived communities or had a family history of premature cardiovascular disease
5. Screening individuals who both lived in deprived communities and had a family history of premature cardiovascular disease.

The simulation models were run separately for everyone at risk of cardiovascular disease (ages 40–74 years) and for those at risk of premature cardiovascular disease (men aged 40–54 years and women aged 40–64 years).

Definitions

High risk was defined as an ASSIGN risk score of ≥20. This corresponds to a ≥20% risk of a cardiovascular event over the subsequent 10 years and is the recommended cut-off for primary prevention in Scotland.[2] The ASSIGN score is derived from age, sex, systolic blood pressure, cigarette consumption, family history and

socio-economic status.[3] Deprived communities were defined as those in the bottom quintile of the Scottish Index of Multiple Deprivation (SIMD) (http://www.scotland.gov.uk/Topics/Statistics/SIMD/Overview) for the population as a whole (all ages). The SIMD score is an aggregated measure of material deprivation derived from 37 indicators in seven domains (income, employment, health, education, access to services, housing and crime) and is determined at the data zone level (geographical areas with a median population of 769). In the Scottish Health Survey, a family history of premature cardiovascular disease was defined as death of either natural parent as a result of cardiovascular disease before the age of 65 years.

Cost and cost-effectiveness

We assumed that the screening process would be identical in all of the models studied and therefore that the unit costs would be common to all. We included the costs of contacting people and arranging appointments, a screening appointment undertaken by a practice-based nurse, the laboratory costs of assaying cholesterol and glucose concentrations and the cost of a follow-up appointment at which the results would be fed back. Screening costs were based on the estimated 2008 prices published by the Department of Health for England and Wales and incorporated a sensitivity analysis.[3] We included only the costs associated with identifying people at high risk. Subsequent investigation and treatment costs were not included in the models, as this was not the focus of our research question.

We undertook three sets of analyses. First, we determined the absolute costs and effects associated with implementing each of the five screening strategies in isolation referent to no screening. The effectiveness of each strategy was defined as the number needed to screen (NNS) to detect one person at high risk of cardiovascular disease. The cost of detecting one person was calculated as the unit cost per patient screened multiplied by the NNS for that strategy. Second, we determined the additional costs and effects of each strategy referent to the other strategies, by assuming that more effective strategies were substituted in an incremental fashion, from the lowest population coverage (lowest overall cost) up to mass screening of the whole population (highest overall cost). We calculated the cost and NNS of detecting one additional person at high risk and thereby derived the incremental cost effectiveness ratios (ICER) of each strategy. Consistent with standard practice in health economics, any strategies that were both more costly and less effective (higher NNS) than the next incremental strategy were then excluded from the calculations as they were "dominated" by the more effective strategy. In addition, any strategies that were associated with a higher ICER than more effective (lower NNS) strategies were excluded from the calculations as they were "extended dominated" Where this occurred, the ICERs were then recalculated following the exclusion of the dominated or "extended dominated" strategy.

Sensitivity analyses

We tested the robustness of our results by applying sensitivity analyses to the costs, using an analysis of extremes, and to the differential uptake of screened populations, using a threshold analysis. For the sensitivity analysis of costs, the ICERs were recalculated using the lower and upper bounds for screening costs estimated by the Department of Health (table 1).[4] For the sensitivity analysis of uptake, we determined the lowest uptake level among the most deprived quintile at which the relative rankings based on ICER still held true.

RESULTS

Of the 9327 survey participants aged between 40 and 74 years, 2985 (32%) were excluded because they had cardiovascular disease and a further 2421 (26%) were excluded because data required to calculate their risk score were missing. The remaining 3921 (42%) were eligible for inclusion in the study. Of these, 804 (21%) had an ASSIGN risk score of ≥20.

Of the 5784 survey participants at risk of premature cardiovascular disease, 1597 (28%) were excluded because they had cardiovascular disease and a further 1701 (29%) were excluded because data required to calculate their risk score were missing. The remaining 2486 (43%) were eligible for inclusion in the study. Of these, 155 (6%) had an ASSIGN risk score of ≥20.

Screening everyone at risk of cardiovascular disease

Targeting deprived communities would result in 15% of the total population being screened but would identify 25% of the high-risk population (table 2). To identify one high-risk individual would require 3.0 people to be screened at a cost of £69. Targeting the offspring of people who die prematurely from cardiovascular disease would result in 28% of the total population being screened but would identify 43% of the high-risk population (table 2). To identify one high-risk individual would require 3.2 people to be screened at a cost of £75. Combining both strategies would enable 57% of the high-risk population to be identified by screening 39% of the general population. Moving directly from no screening to mass screening would identify all high-risk individuals and would require 4.9 people to be screened to identify one high-risk individual at a cost of £113.

In the incremental cost-effectiveness analysis, targeting deprived communities was dominated by targeting family members which was a more effective strategy, requiring fewer additional people to be screened to detect one additional high-risk person. Compared with the most effective targeted strategy (combining family members and deprived communities) the additional cost of expanding coverage to mass screening was £199 for every additional high-risk person identified because an additional 8.6 people needed to be screened.

Screening those at risk of premature cardiovascular disease

Targeting deprived communities would result in 17% of the total population being screened but would identify 45% of the high-risk population (table 3). To identify one high-risk individual would require 6.1 people to be screened at a cost of £141. Targeting the offspring of people who die prematurely from cardiovascular disease would result in 28% of the total population being screened but would identify 61% of the high-risk population (table 3). To identify one high-risk individual would require 7.4 people to be screened at a cost of £170. Combining both strategies would enable 84% of the high-risk

Table 1 Unit costs for cardiovascular screening

	Minimum (£)	Maximum (£)	Base case (£)
Administration	1.0	3.5	2.3
Screening and feedback appointments	9.3	23.3	16.3
Laboratory costs	3.0	6.0	4.5
Total	13.3	32.8	23.1

Table 2 Coverage, effectiveness and cost-effectiveness of alternative screening strategies applied to the population at risk of any cardiovascular disease (40—74 years of age)

	Targeted screening				
	Family members living in deprived communities	Deprived communities	Family members	Family members and deprived communities	Mass screening
Strategies implemented in isolation*					
Coverage of general population	5%	15%	28%	39%	100%
Coverage of high-risk population	10%	25%	43%	57%	100%
% of screened population at high risk	44%	34%	31%	30%	21%
Number needed to screen	2.3	3.0	3.2	3.3	4.9
Mean cost per high-risk case detected (£)	53	69	75	76	113
Strategies implemented incrementally†					
Additional coverage of general population	5%	—	23%	10%	61%
Additional coverage of high-risk population	10%	—	32%	15%	43%
% of additional screened population at high risk	44%	—	28%	26%	12%
Additional number needed to screen	2.3	3.8	3.5	3.9	8.6
Incremental cost-effectiveness ratio	53 (31 to 75)	89 (51 to 126)	81 (47 to 116)	91 (52 to 129)	199 (115 to 283)
Revised incremental cost-effectiveness ratio‡	53 (31 to 75)	Dominated	80 (46 to 114)	91 (52 to 129)	199 (115 to 283)

*Referent to no screening.
†Referent to screening strategy directly to the left (no screening for strategy 1).
‡Referent to the next non-dominated screening strategy to the left (no screening for strategy 1).

population to be identified by screening only 41% of the general population. Compared with no screening, mass screening would identify all high-risk individuals and would require 16.0 people to be screened to identify one high-risk individual at a cost of £370.

In the incremental cost-effectiveness analysis, a combined strategy of targeting both family members and deprived communities "extended dominated" either strategy in isolation, because this more effective strategy could be secured for a lower cost per additional high-risk person identified. Compared with combined screening of family members and deprived communities, expanding coverage to mass screening would require an additional 58.8 people to be screened to identify each additional high-risk person at a cost of £1358.

Sensitivity analyses

The cost sensitivity analysis changed the absolute values of the ICERs but the relative rankings of the screening strategies, in terms of cost-effectiveness, remained unchanged. When we reran the models applying lower uptake levels in the deprived quintile, we found that targeting only family members in the most deprived quintile, the narrowest screening strategy, remained a more cost-effective screening strategy than screening family members as long as uptake among the deprived remained at or above 11% for preventing any cardiovascular disease (or 7% for preventing premature cardiovascular disease). Furthermore, the combined strategy of screening both family members and the most deprived quintile remained more cost-effective than mass screening as long as uptake in the deprived quintile remained at or above 7% for preventing any cardiovascular disease (or 5% for preventing premature cardiovascular disease).

DISCUSSION

Principal findings

Targeted screening is more cost-effective than mass screening as a method of identifying asymptomatic people at high risk of cardiovascular disease in the general population. If the aim is to

Table 3 Coverage, effectiveness and cost-effectiveness of alternative screening strategies applied to the population at risk of premature cardiovascular disease (men 40—54 years of age; women 40—64 years of age)

	Targeted screening				
	Family members living in deprived communities	Deprived communities	Family members	Family members and deprived communities	Mass screening
Strategies implemented in isolation*					
Coverage of general population	5%	17%	28%	41%	100%
Coverage of high-risk population	23%	45%	61%	84%	100%
% of screened population at high risk	31%	16%	14%	13%	6%
Number needed to screen	3.3	6.1	7.4	7.8	16.0
Mean cost per high-risk case detected (£)	75	141	170	180	370
Strategies implemented incrementally†					
Additional coverage of general population	5%	—	—	36%	59%
Additional coverage of high-risk population	23%	—	—	61%	16%
% of additional screened population at high risk	31%	—	—	12%	2%
Additional number needed to screen	3.3	8.8	9.8	8.5	58.8
Incremental cost-effectiveness ratio	75 (43 to 107)	203 (117 to 289)	225 (130 to 321)	196 (113 to 278)	1358 (784 to 1931)
Revised incremental cost-effectiveness ratio‡	75 (43 to 107)	Extended dominated	Extended dominated	215 (124 to 306)	1358 (784 to 1931)

*Referent to no screening.
†Referent to screening strategy directly to the left (no screening for strategy 1).
‡Referent to the next non-dominated screening strategy to the left (no screening for strategy 1).

identify people of all ages who are at high risk, targeting screening at individuals with a family history of premature cardiovascular disease is more cost-effective than targeting deprived communities. If the aim is to identify those at high risk of premature cardiovascular disease, then a combined strategy that targets both family members and deprived communities is more cost-effective than either strategy in isolation. The cost-effectiveness of targeted screening is not achieved at the expense of coverage since this combined strategy identifies the vast majority of high-risk people in the general population.

Other studies

In the United Kingdom, the Department of Health has asked primary care trusts to commission an expansion of primary prevention services.[5] The existing evidence on the effectiveness of primary prevention delivered through primary care practitioners is largely based on a mass screening strategy.[6 7] From a population perspective, primary prevention is most effective if targeted at individuals with a high global risk of cardiovascular disease.[1] However, determining which asymptomatic members of the general population have a high global risk presents obvious logistical problems. Mass screening is the best method to ensure complete coverage but the absolute cost is prohibitive. In our model, the cost of screening all 1.4 million people aged 40–74 in Scotland would be £33 million. An alternative approach is to target screening at a subgroup of the population in which cardiovascular risk is over-represented. Deprived communities have a higher prevalence of cardiovascular risk factors and a higher incidence of cardiovascular events.[8] Similarly, people with a family history of premature cardiovascular disease have a twofold risk of developing the condition, owing to a combination of shared genetic predisposition and shared lifestyle.[9–11]

Strengths and weaknesses

Twenty-nine per cent of the Scottish Health Survey participants were excluded from our analysis because of missing data required to calculate their risk score. However, comparison of included and excluded participants demonstrated no significant differences in their breakdown by deprivation, smoking, family history or sex. Our findings were also robust in relation to the possibility of lower uptake of screening in deprived individuals. The uptake in the most deprived quintile had to be one-tenth of that in other groups before the relative rankings of screening strategies were altered.

The 1998 and 2003 surveys were combined to increase the statistical power of the models. We tested the robustness of our results by re-running the models using only the 2003 survey data. The results for 40–74 year olds were largely unchanged. Among those at risk of premature cardiovascular disease there was even stronger evidence against mass screening, with combined targeting of deprived communities and family members achieving 92% coverage of high-risk individuals. Therefore, extension of targeted screening to mass screening produced even less incremental benefit.

The Scottish Health Survey only provided information on parental death from cardiovascular disease. It did not provide information on parental premature, non-fatal disease or premature disease in siblings and second degree relatives, all of which are included in the ASSIGN definition of family history. Therefore, our model is likely to have underestimated the potential coverage of a strategy targeting family members. In the Utah family health tree study, families with a positive family history accounted for 48% of all cardiovascular events and 72% of premature events.[12] In our study the figures were only 43% and 61%, respectively. Use of more complete information on family history would have reduced still further the additional benefits of mass screening.

Our models assumed identical unit costs for screening. Therefore, the cost and cost-effectiveness rankings are not specific to the United Kingdom. However, in practice, the costs may be higher in deprived than affluent communities because of poorer uptake requiring more stringent efforts to attract participants into screening appointments. Our models were compared on the basis that the aim of primary prevention was to reduce cardiovascular events in the population as a whole. We did not consider their impact in relation to health inequalities. We demonstrated that a strategy targeted at family members would cover only 41% of those living in deprived communities (50% of those at risk of premature disease). Therefore, although such a strategy was the most cost-effective method of producing overall health gain, it is likely to be less effective at reducing health inequalities than a strategy targeting deprived communities.

Definitions box

Cost-effectiveness analysis
A systematic method of comparing two or more programmes by measuring the costs and consequences of each. The outcome of interest here is the number needed to screen to detect one person at high risk of cardiovascular disease.

ICER (incremental cost-effectiveness ratio)
This is the ratio of the difference in costs (incremental costs) divided by the difference in outcomes (incremental effect) between two programmes.

Dominance
A strategy (x) is said to be dominant when there exists an alternative (y) that is both less effective and more costly. The alternative strategy (y) is said to be dominated by strategy x, which is more effective and less costly.

Extended dominance
A strategy (y) is said to be extended dominated when there is an alternative (x) that is both more effective and more costly, but which involves a lower ICER than strategy y.

Meaning of study

Screening to identify individuals in need of primary prevention should focus on family members and deprived communities. Mass screening of the whole population may be difficult to justify as the incremental cost is much higher and incremental effectiveness lower.

Unanswered questions and future research

Engagement in health promotion is more difficult to achieve in deprived communities. Further studies are required to determine how best to tailor interventions to improve cardiovascular risk in this group. Guidelines already exist recommending screening of people with a family history,[2 13] but surveys suggest that only a minority are, in fact, screened.[14] Identifying people with a family history from the general population is difficult. Using hospitalisation of a patient for premature cardiovascular disease as the trigger to contact family members may be a more feasible mechanism and may improve the motivation of asymptomatic

relatives. To date, there has been only one published study of this type of intervention.[15] Further studies are required to devise effective methods of identifying family members and reducing their cardiovascular risk.

Contributors JPP and ACHP had the original concept; JPP, KL and EF agreed the methodology; KL accessed the data and undertook the analysis; EF supervised the analysis; all authors contributed to interpretation of the data; KL and JPP wrote the first draft; all authors redrafted the manuscript; all authors approved the final version.

Competing interests None.

Guarantor JPP had full access to all the data in the study and had final responsibility for the decision to submit for publication.

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