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University of Technology, Sydney
City campus, Haymarket
PO Box 123 Broadway NSW 2007
Tel: +61 2 9514 4720
Fax: + 61 2 9514 4730
Email: mail@chere.uts.edu.au
www.chere.uts.edu.au

When is an ounce of prevention worth a pound of cure: the case of cardiovascular disease?

Kees van Goo1[1], Marion Haas[1], Peter Sainsbury[2] and Richard Gilbert[3]

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1. Centre for Health Economics Research and Evaluation
Faculty of Business
University of Technology, Sydney

2. Population Health
Sydney South West Area Health Service
Level 9 South, King George V Building
Missenden Road
Camperdown NSW 2050

3. Health Services Planning
Sydney South West Area Health Service

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Abstract

Objective: To provide decision makers with a tool to inform resource allocation decisions at the local level, using cardiovascular disease prevention as an example.

Method: Evidence from the international literature was extrapolated to estimate the health and financial impacts in Central Sydney Area Health Service (CSAHS) of three different prevention programs; smoking cessation; blood pressure reduction and cholesterol lowering. The cost-effectiveness analysis framework was reconfigured to 1) estimate the risk of CVD in the community using local risk factor data, 2) estimate the number of CVD events prevented through investment in preventive programs and 3) estimate the local financial flow-on effects of prevention on acute care services. The model developed here estimates an upper bound of what local decision makers could spend on preventive programs whilst remaining consistent with their willingness to pay for one additional life-year gained.

Results: The model predicted that over a five-year period the cumulative impact of the three programs has the potential to save 1245 life-years in people aged 40-79 years living in CSAHS. If decision-makers are willing to invest in cost-saving preventive programs only, the model estimates that they can spend up $12 per person in the target group per year. However, if they are willing to spend $70,000 per life-year gained, this amount rises to $201.

Conclusions: Modelling the impact of preventive activities on the acute care health system enables us to estimate the amount that can be spent on preventive programs. The model is flexible in terms of its ability to examine these impacts in a variety of settings and therefore has the potential to be a useful resource planning tool.

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INTRODUCTION

Despite the increasing number of economic evaluations published every year, there is considerable evidence that this information remains under used by health care decision makers.[1] This seems to be especially true for decisions made at a local level – rather than a central level. One reason for this under use appears to be the difficulty decision-makers face in assessing whether the results of the published economic evaluation bear any relevance to their own circumstances.

The central aim of this paper is to present a model on cardiovascular disease (CVD) prevention that local decision makers can use to extrapolate information from the published literature and place it in the context of their local setting. The use of the model will enable decision makers to deal with the sources of variation between the local setting and the published study.

Decision makers have to deal with four possible sources of variation between local settings and the published literature[2]. These are the:

i. prevalence and incidence of the disease;
ii. resources used and their prices;
iii. local resource constraints and the values placed on health; and
iv. comparator used in the published study which may not be relevant to current local practice.

Each of these potential sources of variation may lead to marked differences between the local setting and the results of the published literature. The model presented in this paper can be used to deal with the first three sources of variation. Decision makers can then

assess whether the model has provided sufficient information to determine whether the fourth source of variation is likely to influence results.

The model will be particularly useful if there is a lack of local information about the incremental costs of preventive interventions. It provides decision-makers with an estimate of the upper limit that could feasibly be spent on an intervention whilst remaining cost-effective.

The data and results presented here are based on the characteristics of the Central Sydney Area Health Service (CSAHS) population but these are used for illustrative purposes only. The model is designed to be readily adaptable to suit other regional population characteristics and other conditions.

METHOD

The equation below provides the basis for calculating the point at which the cost of a preventive intervention is equal to the potential savings made elsewhere in the health care system. The intervention is deemed to be cost-effective if the Cost Effectiveness Threshold (the incremental amount that decision makers are willing to pay for a positive health effect - *e.g.* life-years gained) is equal to or greater than:

$$\frac{\{Intervention\ Costs - Direct\ Health\ Care\ Costs\ Avoided\}}{\{Life - Years\ Gained\}}$$

Rearranging gives:

$$\{Intervention\ Costs\} \leq \{(Cost\ Effectiveness\ Threshold \times LifeYears\ Gained) + Direct\ Health\ Care\ Costs\ Avoided\}$$

The model presented in this paper provides information on the maximum amount that can be spent on an intervention without breaking any predetermined expenditure limits for that condition.

VARIABLES AND DEFINITIONS

Life-years gained: $\sum_{i=1}^{n} r_{it} \times e_{it} \times PLYL_i$

Where n is the number of individuals in a target group with a modifiable risk factor and to whom a preventive intervention can be applied (*e.g.* the number of people in the population who smoke and can be targeted by an anti-smoking campaign); r_{it} is the absolute risk of cardiovascular death for individual i over time period t; e_{it} is the effectiveness of the preventive intervention for individual i over period t in reducing the risk of cardiovascular death; and PLYL is the number of potential life-years lost due to premature cardiovascular death for individual i.

Intervention costs: $(n \times Cp_i)$

Where Cp is the cost of the prevention intervention per individual, i.

Direct health care costs avoided : $\sum_{i=1}^{n} r_{it} \times e_{it} \times Ca_{it}$

Where Ca is the cost of acute care, for individual i, over time period t. For the purposes of this paper, acute care costs are defined as hospital costs, medical services and pharmaceutical expenditures.

DATA

Estimating the cost-effectiveness threshold: The most common decision rule for economic evaluation is to compare the incremental cost-effectiveness ratio with some benchmark value.[3] An intervention with an incremental cost-effectiveness ratio below this benchmark is considered to be good value for money.

In Australia, the National Health and Medical Research Council (NHMRC) suggest a threshold range depending on the strength of the evidence. If the evidence is strong then interventions with an incremental cost-effectiveness ratio of $70,000 or less per life-year gained should be recommended[4].

The model allows decision makers to enter their own cost-effectiveness threshold. For illustrative purposes, this paper shows the results for two threshold levels; $0 and $70,000. The former amount imposes a decision rule that the intervention must be cost-saving and the latter figure is consistent with the NHMRC guidelines.

Estimating the target population (n): The 1996 census was used to extrapolate population and age data for the CSAHS. The NSW Health Survey[5] provided estimates of the proportion of people in the CSAHS who smoke daily, have high blood pressure (defined as having a systolic blood pressure of over 140mmHg), have high blood cholesterol (defined as having total blood cholesterol to HDL cholesterol ratio of 6:1 or higher), or any combination of these risk factors[6].

The results from two other studies[7,8] were applied to the model to obtain an estimate of the distribution of severity of high cholesterol and systolic blood pressure levels within the population.

Estimating the absolute risk of cardiovascular disease (r): The Framingham Heart Study equations estimate the absolute risk of cardiovascular (CVD) events. One such equation estimates the total risk of suffering a CVD event that an individual faces over a given period of time. A CVD event is described as the following: stroke, myocardial infarction, angina pectoris, coronary insufficiency, death from coronary heart disease, congestive heart failure and peripheral vascular disease.[9]

The Framingham Heart Study equations used in this model calculate the overall risk of a CVD event and the risk of CVD related death - based on an individual's age, systolic blood pressure, smoking status, and cholesterol level. For the purposes of this paper, risks are estimated for a five-year period. Recent studies have validated the use of the Framingham equations for the population of interest in this paper.[10]

The cost of cardiovascular disease (Ca): Published results from Western Australia (WA) were used to estimate average hospital, pharmaceutical and medical service costs for patients who have suffered a CVD event.[11] The WA cost data were derived from longitudinal utilisation records. Individuals were identified if they were hospitalised, used subsidised medical services and/or pharmaceuticals related to CVD. Following identification, patient service use was tracked for one year.

Measuring the effectiveness (e_i): The results of three different types of interventions are presented in this paper. Each intervention targets one of three CVD risk factors: high blood pressure, high cholesterol and smoking. Evidence on the effectiveness of preventive interventions was derived from systematic reviews available from the

Cochrane Library and the Health Education Authority, London.[12,13,14] Each of these studies provides evidence of the impact that a preventive intervention has on at least one of the relevant CVD risk factors. Table 4 provides details of the effectiveness of the three preventive interventions.

Measuring potential life-years lost and gained: "Years of life lost (YLLs)" is the number of potential years of life lost due to premature death. The study calculated the years of life lost due to a death at a given age using the life expectancy at that age in standard life tables.[15,16] A 5% discount rate has been applied to years of life lost in the future to estimate the net present value of years of life lost.

RESULTS

ABSOLUTE RISK (r)

Table 1 illustrates the estimated probability of a cardiovascular disease event taking place over the next five-years for men aged between 40 and 79. For example, a male smoker aged 70-79 years, with systolic blood pressure of 180 mmHg and a total cholesterol to HDL cholesterol ratio of 6:1 has a 43% risk of suffering a CVD event in the next five-years. A similar exercise was undertaken to estimate the probabilities of CVD for women (not shown).

Table 1– Estimated five-year risk of a cardiovascular disease event for men aged 40–79 years , by smoking status, systolic blood pressure level and cholesterol level.

Systolic Blood Pressure (mmHg)	Non-smoker						Smoker						Systolic Blood Pressure (mmHg)
180	0.22	0.25	0.28	0.31	0.33	Age 70-79	0.34	0.37	0.41	0.43	0.46	180	
160	0.18	0.21	0.23	0.26	0.28		0.28	0.32	0.35	0.38	0.40	160	
140	0.14	0.16	0.19	0.21	0.23		0.23	0.26	0.29	0.32	0.34	140	
120	0.10	0.12	0.14	0.15	0.17		0.17	0.20	0.23	0.25	0.27	120	
180	0.16	0.18	0.21	0.23	0.25	Age 60-69	0.25	0.29	0.32	0.35	0.37	180	
160	0.12	0.15	0.17	0.19	0.21		0.21	0.24	0.27	0.30	0.32	160	
140	0.09	0.11	0.13	0.14	0.16		0.16	0.19	0.22	0.24	0.26	140	
120	0.06	0.08	0.09	0.10	0.12		0.12	0.14	0.16	0.18	0.20	120	
180	0.10	0.12	0.14	0.15	0.17	Age 50-59	0.17	0.20	0.23	0.25	0.27	180	
160	0.07	0.09	0.11	0.12	0.13		0.14	0.16	0.19	0.21	0.23	160	
140	0.05	0.06	0.08	0.09	0.10		0.10	0.12	0.14	0.16	0.18	140	
120	0.03	0.04	0.05	0.06	0.07		0.07	0.09	0.10	0.12	0.13	120	
180	0.05	0.06	0.07	0.09	0.10	Age 40-49	0.10	0.12	0.14	0.16	0.17	180	
160	0.03	0.04	0.05	0.06	0.07		0.07	0.09	0.11	0.12	0.14	160	
140	0.02	0.03	0.04	0.04	0.05		0.05	0.07	0.08	0.09	0.10	140	
120	0.01	0.02	0.02	0.03	0.03		0.03	0.04	0.05	0.06	0.07	120	
	4:1	5:1	6:1	7:1	8:1		4:1	5:1	6:1	7:1	8:1		

Total cholesterol:HDL cholesterol ratio

Source: 9

TARGET POPULATION (n)

The total number of CSAHS residents aged between 40 and 79 in 1998 was estimated to be 157,232, of which 77,515 were male[17]. On the basis of the NSW Health Survey results, we estimated the number of men and women in each of the relevant risk factor categories. For example, as shown in Table 2, the model predicts that there are 20 men aged between 70 and 79 who smoke, have systolic blood pressure of 180mmHg and a total cholesterol to HDL cholesterol ratio of level 6:1

Table 2– Estimated number of men living in the CSAHS aged 40-79 years by smoking status, systolic blood pressure and cholesterol level - 1998

Systolic Blood Pressure (mmHg)	Non-smoker						Smoker						Systolic Blood Pressure (mmHg)
180	88	340	233	123	39	**Age 70-79**	8	31	20	11	3	180	
160	409	1586	1089	575	181		37	144	93	49	16	160	
140	307	1189	558	294	93		32	124	60	32	10	140	
120	468	1813	850	449	142		49	189	91	48	15	120	
180	98	378	294	155	49	**Age 60-69**	13	48	30	16	5	180	
160	456	1766	1370	723	228		58	226	141	74	23	160	
140	428	1657	794	419	132		75	291	133	70	22	140	
120	652	2527	1211	639	202		114	444	203	107	34	120	
180	88	340	222	117	37	**Age 50-59**	25	99	56	29	9	180	
160	410	1589	1036	547	173		119	461	259	137	43	160	
140	612	2373	926	488	154		167	647	216	114	36	140	
120	934	3619	1411	745	235		255	987	329	174	55	120	
180	67	258	144	76	24	**Age 40-49**	17	67	44	23	7	180	
160	311	1204	673	355	112		81	313	203	107	34	160	
140	1146	4440	1061	560	177		366	1418	416	220	69	140	
120	1748	6772	1618	854	270		558	2162	634	335	106	120	
	4:1	5:1	6:1	7:1	8:1		4:1	5:1	6:1	7:1	8:1		

Total cholesterol:HDL cholesterol ratio

Source: 5,7,8

With the information contained in Tables 1 and 2, we estimated the number of expected CVD events and deaths over a five-year period by multiplying the absolute risk (r) by the estimated number of people in each risk factor category. Continuing the previous example, just under nine (0.43*20) CVD events are expected to take place over the next five-years amongst the group of 70-79 year old men who smoke, have a systolic blood pressure of 180 mmHg and a total cholesterol to HDL cholesterol ratio of 6:1. This calculation assumes that there is no change in the prevalence or severity of the risk factors during this period.

COST OF ACUTE CARE (C_a)

Table 3 shows the estimated average cost per person for acute care and follow-up management of a CVD event based on results from the WA Linked Data Project.[11] It details the estimated first year and annual follow-up costs for individuals who have been hospitalised for a CVD event. It is assumed that a hospitalisation for the CVD event occurred in the first year and that follow-up treatment is conducted outside the hospital

system. Follow-up costs, after hospitalisation, were extrapolated for a five-year period. Costs incurred in years 2 to 5 have been discounted at a rate of 5% per annum and were indexed to reflect 2000/01 health prices.[18]

Table 3 – Per person health system cost in the first year and annual follow-up after a CVD event

	Cost of first year ($)	Annual follow-up costs ($)	Total cost for 5 years ($) (discounted at 5%)
Female	6,018	1,290	10,564
Male	7,860	1,275	12,352

Source: 11

EFFECTIVENESS OF PREVENTION *(e_i)*

Table 4 lists the three interventions used to extrapolate effectiveness data. The relative effectiveness of each intervention is measured in terms of its success compared to the control group (as defined by the Cochrane publication). The three interventions illustrate the model's ability to analyse the impact of interventions that counter any one of three CVD risk factors. It should be noted that the model is able to easily estimate the local impact of other types of interventions aimed at reducing smoking rates, lowering cholesterol or blood pressure, or any combination of the three.

Table 4 – CVD prevention interventions modelled and the evidence on effectiveness

Broad area of intervention	**Source**	**Intervention**	**Result**
Smoking cessation	[12]	Nicotine Replacement Therapy (NRT)	7 % of people quit smoking over and above control group
Reduce blood	[13]	Counselling or education	Reduced average systolic

pressure		interventions with or without pharmacological treatments	blood pressure by 3.9mmHg in people with hypertension
Reduce cholesterol	[14]	Counselling (nutritionist and trained counsellor)	Mean absolute reduction of 0.2 to 0.3 mmol/l reduction in total cholesterol.

BASELINE SCENARIO

Having identified the at-risk population along with the associated absolute risk of a CVD event occurring, we estimated the total number of expected CVD events in persons aged 40 to 79 over the next five-years in CSAHS and the health system costs associated with these events (Table 5).

Table 5 Expected number of CVD events, deaths, life-years lost and associated costs over five-years in Central Sydney

	Females	**Males**	**Total**
CVD events	4,558	7,145	11,703
CVD-related deaths	498	1,090	1,588
Potential life-years lost	5,615	11,069	16,684
Expected acute care costs (million)	$55.1	$88.2	$143.3

Overall, 11,703 CVD events are estimated to cost the health system $143.3 million over five-years, with over 16,000 potential life-years lost. The figures presented in Table 5 are the baseline health impact and health system costs from which potential health and economic gains are estimated.

POST INTERVENTION SCENARIO

Table 6 models the health and financial results following the introduction of the three preventive interventions for all CSAHS residents aged between 40 and 79 years. The model predicts that over a five-year period, the smoking-cessation program can save 111 life-years, the blood pressure reduction program 580 and the cholesterol lowering program 554 life-years. Table 6 also shows the potential acute care costs that can be avoided through intervention. These estimates have been discounted over a five-year period, reflecting the timeframe over which the savings are calculated.

Table 6 also presents the financial results of the three preventive interventions. If a $0 threshold is applied to the model (implying that the preventive intervention must be cost-saving) the total amount that can be spent on the interventions per year ranges between $182,000 for the quit smoking campaign to $507,332 for the blood pressure program. This would translate to an expenditure of $6 and $12 respectively for each person in the target population per year.

If a $70,000 threshold is applied (implying that the decision maker is willing to pay $70,000 per life-year gained), the total amount that can be spent on the programs ranges between $1.7 million for the quit smoking program and $8.6 million for the blood pressure program. This translates to a possible annual expenditure of up to $59 and $201 per person in the target group.

Table 6: Five-year health and financial results after introduction of interventions

	Intervention		
	Smoking cessation	Blood pressure reduction	Cholesterol reduction

a	Target population: number of people in CSAHS with risk factor		29,582	42,887	56,430
b	Health impact - number of potential life-years saved (discounted)		111	580	554
c	Financial impact –potential health system savings over 5 years (discounted).		$910,144	$2,536,659	$2,392,324
d	Maximum total cost-effective annual expenditure {(e*b+c)/t)} Where t = time = 5 years	When CE threshold (e) = $0	$182,029	$507,332	$478,465
		When CE threshold (e) = $70,000	$1,735,423	$8,624,673	$8,228,968
f	Cost-effective intervention expenditure per targeted person per year {d/a}	Threshold = $0	$6	$12	$8
		Threshold = $70,000	$59	$201	$146

DISCUSSION

Many health care decisions are taken at a regional level, including resource allocation choices in the field of population health. However, decision makers often face uncertainty about the likely impact that such decisions may have on health and resources within their local community. To address this issue, results from the international literature, the population characteristics of CSAHS, and Australian health service cost data were entered into a model to identify the amount that could be cost effectively spent on three CVD prevention interventions in CSAHS with no increase in total health service expenditure on CVD management.

The model's flexibility gives it the capacity to be of value to decision-makers in a wide range of populations. The model can be easily modified to (1) produce results for any population size, (2) incorporate costs from a wider range of perspectives than those shown in this paper, (3) change the distribution of risk factors in line with the characteristics of certain population sub-groups, (4) analyse the results over varying time periods (between 4 and 12 years), (5) separate the general CVD results presented here into other CVD categories such as heart disease, myocardial infarction and stroke, and (6) examine the health and economic impact of programs that target multiple CVD risk-factors simultaneously.

However, whilst the model's methodology is firmly based on cost-effectiveness analysis, it is not a substitute for it. Its two main outputs are to estimate (1) the potential life-years saved in a local community following the introduction of CVD prevention programs and (2) to provide decision-makers with information on the maximum amount that could be spent on those programs within a given CE threshold. Decision-makers then have to make an assessment on whether the maximum amount allowable is realistic given their costs and resource constraints.

It should be noted that the three interventions presented in this paper were chosen to illustrate the wide range of possible programs that can be modelled. However, local decision-makers could essentially model any preventive program that targets smoking, high blood pressure or cholesterol or any combination of these three. Furthermore, the model is capable of estimating the incremental effects of programs that target the same risk factor (e.g. compare the impact of two or more alternative quit smoking programs).

The model contains a number of assumptions and limitations. First, the impact of each preventive intervention is modelled for the primary risk factor only. This may lead to an underestimate of the impact because, for example, dietary advice aimed at reducing cholesterol levels may also affect blood pressure. Second, only the costs and consequences of preventing CVD have been estimated and each intervention may have further, non-CVD, impacts. For example, reducing the number of smokers in society could impact on lung cancer incidence. Similarly, some patients whose CVD event is prevented may then go on to develop worse (or more expensive) illnesses. For example, for every CVD death prevented, a proportion of the population may go on to develop Alzheimer's disease.

At the outside, this paper aimed to assist decision-makers with three out of the four main sources of variation between published studies and the local context. The fourth source that deals with the issue of a locally relevant comparator intervention is not directly dealt with in the model. One way of dealing with this source of variation is that local decision makers have to choose the published study from which to extrapolate effectiveness information carefully. Ideally, a published study will provide comparisons between two (or more) programs that bear relevance to current local practice and to what is being considered for implementation. Often this ideal may not be realised. For example, the published study might be reporting on the effectiveness of having dieticians provide advice on how to reduce cholesterol, whereas the local decision maker might be considering implementing a dietary advice program delivered by local doctors.

If there are significant differences between the comparator used in the published study and local practice, the local decision maker will have to make an assessment of the likely impact on the study result. There are a number of techniques within the model to assist in this assessment. Firstly, if the published study result is likely to be less effective than a local program, the model's estimation could be considered an underestimate of the health and economic impact of the program (e.g. current local practice is known to be less effective than the comparator used in the published study). In this case, decision-makers may be satisfied knowing that the envisioned program is likely to deliver more health gains than have been estimated. Secondly, if there is uncertainty about the difference in effectiveness between the published result and the local program, a new (lower) CE threshold could be entered into the model. This sets a higher bar for the program by estimating a lower feasible expenditure on the intervention for it to remain cost-effective. This approach is in line with recommendations made by the NHMRC[4]. Thirdly, the model can estimate a range of effectiveness measures to provide a sensitivity analysis. The decision-maker will then be provided with a range of feasible expenditures for the prevention program.

The model presented can be modified as better evidence on effectiveness and costs become available. With better data, the model has the potential to become an increasingly useful tool for health care planning and priority setting.

Finally, the model's estimates are based on the potential savings to the health system following the implementation of preventive programs. However, there is no guarantee that such potential savings can be realised. Health services throughout the world face considerable demand pressures for their services and therefore any potential savings

made may go towards meeting some of that unmet demand. Furthermore, due to difficulties in shifting resources from one part to the health care sector to another, local decision makers may sometimes face financial disincentives to implement population health interventions - even if these are shown to be cost-effective.

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