Cost effectiveness of high risk and population approaches for preventing CHD: a comparative study in New Brunswick, Canada

By: Joyendu Bhadury, John A. Boyne, Jr. and Richard Ehrhardt

Boyne, J. J. A., Bhadury, J., & Ehrhardt, R. (July 01, 2008). Cost effectiveness of high risk and population approaches for preventing CHD: A comparative study in New Brunswick, Canada. International Journal of Business Research, 8, 4.)

Abstract:

This paper uses management science methodology to compare the cost-effectiveness of two different approaches to preventing coronary heart disease in the province of New Brunswick, Canada. The general model utilized included realistic assumptions about implementation costs, effectiveness levels, budget constraints and implementation strategies. Integer linear programming methods were then used to examine the cost-effectiveness of the two approaches, as well as to compare them with a third "integrated" approach which combined elements of both approaches. The study concludes that under ideal circumstances, a population approach has greater potential to prevent CHD, and when costs were considered from a societal perspective, it is also the more cost-effective option. However, under more realistic outcome conditions we found that a high risk approach may be more effective, and when costs were considered from the perspective of the publicly funded health care system we found that there are conditions under which the high risk approach is more cost-effective. Our final conclusion is that an integrated approach is more cost-effective than a straight high risk approach under all conditions, and more cost-effective than a straight population approach in all but a few circumstances.

Keywords: healthcare management science | cost-effectiveness analysis | integer programming applications | coronary heart disease | international business

Article:

1. INTRODUCTION

Cost pressures have contributed to the growing use of economic evaluation techniques to support health care planning and decision making. One health care area where economic evaluation is particularly important is the prevention of coronary heart disease (CHD), which is a leading cause of death and disability in much of the industrialized world. Since several of the major risk factors for heart disease are modifiable, it is generally accepted that CHD is largely preventable (Victoria Declaration on Heart Health, 1992). Recognition of the need for economic evaluation of CHD prevention strategies reflects both the large volume of health care resources at stake and the fact that a number of different approaches to reducing the health and economic burden of CHD have been advocated.

Strategies for the prevention of CHD tend to be distinguished by their focus on interventions which are applied either on an individual basis or on a mass basis. Individualized intervention activities are generally associated with the so called high risk approach to CHD prevention since they involve identifying and treating individuals who are at increased risk of developing CHD due to factors such as high blood pressure and elevated blood cholesterol. Mass intervention activities, on the other hand, are more commonly classed as population approaches because they focus on encouraging all individuals in a population to adopt lifestyle changes which will reduce their risk of developing heart disease.

Despite the general consensus that population-based approaches to CHD prevention are likely to be more cost-effective than high risk approaches (National Cholesterol Education Program, 1988; Canadian Consensus Conference on Cholesterol: Final Report, 1988; Toronto Working Group on Cholesterol Policy, 1990), very little is known about the actual costs or health impact of implementing either type of CHD prevention strategy on a long-term, province wide basis. Two studies, (Boyne et. al., 1996, 2000), have examined the potential health impact and probable costs associated with a population-based CHD prevention strategy in New Brunswick. The authors tested the utility of a multivariate risk prediction model for forecasting the potential impact of CHD prevention strategies on future heart disease rates in New Brunswick. The results suggested that even at very low efficacy levels (i.e., reducing CHD risk by only 9% of the amount possible) population-based CHD prevention programs may be capable of achieving a break-even level of effectiveness. There is a lack of information, however, comparing the expected costs and benefits of the population approach to alternative high risk intervention strategies.

Specifically, there are at least two aspects of research on the population-based and high risk approaches to CHD prevention which merit further investigation. First, the potential cost-effectiveness of the population approach has been examined only on the basis of seemingly optimistic assumptions about the compliance levels likely to result from the promotion of lifestyle changes in large, free living populations. Second, previous cost-effectiveness research has typically been based on an "all or none" type of scenario in which it is assumed that decision makers must choose between one intervention approach or the other. In reality, however, decision makers may implement combinations of high risk and population intervention strategies, and budget or operational constraints may preclude the extension of all intervention activities to all target groups.

1.1 CHD Prevention Strategies--The High Risk Approach

High risk approaches to CHD prevention consist of some form of screening activity to identify "at risk" individuals in the general population, followed by individualized treatment or counselling interventions designed to reduce risk factor levels in these individuals. Although this frequently involves the use of lipid and/or blood pressure lowering medications, the high risk approach may also include individualized behavioural modification activities such as counselling or treatment for smoking cessation, dietary change and/or increased physical activity. Many questions remain about the overall impact that population-wide pharmacological interventions are likely to have on CHD rates. Of particular concern is the problem of patient compliance with medication regimens. It appears that an optimistic estimate of long term compliance with either high blood pressure or lipid lowering medications is unlikely to be greater than 50%, while a realistic estimate is probably considerably lower (Health Services Utilization and Research Commission, 1995; McCombs et. al 1994; Jones, Gorkin and Lian, 1995).

1.2 CHD Prevention Strategies--The Population Approach

The population approach to CHD prevention is characterised by activities such as public education, social marketing campaigns and community mobilization initiatives which are targeted at large groups and designed to promote widespread adoption of "heart healthy" behaviour or lifestyle changes (for a review see Shea and Basch, 1990a). Findings on the impact of population-based approaches to CHD prevention have been mixed and somewhat difficult to interpret (Puska, Salonen, Nissinen, et al., 1983; Puska, Tuomilehto, Salonen, et al., 1989; Stern, Farquhar, Maccoby and Russell, 1976; Farquar, Fortman, Flora, et al., 1990; McCormick and

Skarabank, 1988; Oliver, 1983;.Shea and Basch, 1990b). These results have led reviewers to conclude that when implemented on a population-wide basis, heart health promotion programs are likely to have a more modest net effect on CHD risk than was suggested by some of the early community intervention trials, and that it may take periods of up to ten to fifteen years for the impact of healthy lifestyle changes to be reflected in reduced CHD rates (Mittlemark, Hunt, Heath, and Schnid, 1993).

1.3 CHD Prevention Strategies--Comparison Methods

In general, previous comparison methods have been unable to address two important questions concerning the relative cost-effectiveness of high risk and population intervention strategies. First, they ignore the fact that interventions do not have to be implemented in the entire population. Specific interventions could be targeted to those sub-segments of the population where they are expected to be most cost effective (Promoting Heart Health in Canada). The second, and perhaps more important question over looked by most previous research concerns the possibility that the most cost-effective strategy for preventing CHD may involve a combined approach in which high risk interventions are directed at some targeted groups, while population interventions are directed at others.

2. METHOD

In the present study a three stage calculation was used to compare the cost-effectiveness of high risk and population-based approaches. The first stage involved development of an outcome model designed to estimate the expected health impact of implementing a population and a high risk CHD prevention strategy in New Brunswick over a fifteen year period. The second stage of calculations was to estimate the expected costs of implementing the population and high risk approaches over the fifteen year intervention scenario. The final stage calculations utilized integer linear programming models to compare the cost-effectiveness of the population and high-risk approaches under various assumptions about costs, available resource levels and implementation strategies.

In all models, the population was segmented into six target groups comprised of males and females between the ages of 30-44, 45-59 and 60-74. In addition, for the cholesterol intervention activity, individuals in each age/sex group were further categorized into high and low risk segments based on their future risk of developing coronary heart disease.

2.1 Sample

The present study focused on CHD prevention in adult New Brunswickers between the ages of 30 and 74. A stratified random sample of 1,128 subjects was derived from the 1989 New Brunswick Heart Health Survey (NBHHS). Details of the demographic characteristics of the sample are presented in (Boyne, 1997).

2.2 Intervention Scenarios

As previously noted, the models used to estimate the expected costs and health impact of the high risk and population approaches were based on a fifteen year intervention scenario. The use of this relatively long time period is consistent with the view that the proper development and implementation of a comprehensive CHD prevention program requires at least a ten year time frame (Promoting Heart Health in Canada) and that the full impact of such a program may not become evident for several additional years (Mittlemark, et al., 1993). Exposition of the many details of the timing assumptions used in high risk and population approach scenarios can be found in (Boyne, 1997).

2.3 Calculation Stage 1: The Outcome Model

A model was developed for calculating outcome coefficients which represent the expected impact of each of the five intervention activities (promotion of smoking cessation, healthy eating and increased physical activity; detection and pharmacological treatment of high blood pressure and elevated blood cholesterol) on future CHD rates in each of the target groups. A 4-step procedure was followed:

1. Calculate expected CHD incidence in New Brunswick over a 15 year period without interventions. This involved using the Framingham risk prediction equations (Anderson et. al.,

1991; Kannel & Gordon, 1971). See (Boyne, 1997) and (Boyne, Bhadury and Balram, 1996) for details.

2. Transform population parameters to match 100% compliance with intervention strategies. For example, if the intervention was smoking cessation then all smokers were reclassified as nonsmokers.

3. Calculate expected CHD incidences for 100% compliance rates using the same method as in step 1. The difference between the first and second CHD incidence calculation provided an estimate of the expected number of CHD cases which could be avoided.

4. Calculate expected CHD incidence assuming partial compliance with intervention strategies. For example, if only 10% of smokers in a particular target group were expected to respond positively to a smoking cessation initiative, then the number of avoidable cases associated with 100% compliance in that target group was multiplied by 0.1.

TABLE 3A: EXPECTED TOTAL COST ($MILLIONS) & CE RATIOS OF HIGH RISK INTERVENTIONS

Activity	Sex	Age Group							
		30- 44		45 - 59		60 - 74		30 - 74	
		Total Cost	CE Ratio	Total Cost	CE Ratio	Total Cost	CE Ratio	Total Cost	CE Ratio
Blood Pressure	M	3	0.14	9.3	0.07	2.6	0.03	14.9	0.06
	F	1.7	0.24	2.9	0.10	2.6	0.04	7.2	0.07
Cholesterol	M	4.8	0.28	13.9	0.14	12.1	0.13	30.8	0.15
	F	4.6	0.66	10.4	0.16	14.6	0.16	29.6	0.18
Total Pharmaceutical	M	7.8	0.20	23.2	0.10	14.7	0.08	45.7	0.10
	F	6.3	0.45	13.3	0.14	17.2	0.11	36.8	0.14

2.4 Calculation Stage 2: The Cost Model

In the second stage of calculations, fixed and variable costs associated with implementation of the five intervention activities on a province wide basis were estimated and applied to the various target groups to arrive at a cost coefficient for each intervention activity in each target group. See (Boyne, 1997) for details.

2.5 Calculation Stage 3: The Integer Linear Programming Models

The outcome and cost coefficients were incorporated into a series of integer linear programming models. The decision variables represent all or none decisions, i.e., a target group could either be subjected to an intervention activity or not, but it could not be partially subjected to an intervention activity.

TABLE 3B: EXPECTED TOTAL COST ($MILLIONS) & CE RATIO OF POPULATION-BASED INTERVENTIONS

Activity	Sex	Age Group							
		30- 44		45 - 59		60 - 74		30 - 74	
		Total Cost	CE Ratio	Total Cost	CE Ratio	Total Cost	CE Ratio	Total Cost	CE Ratio
Smoking	M	2.9	0.08	1.6	0.02	0.9	0.01	5.4	0.03
	F	3	0.11	1.8	0.07	1.1	0.02	5.9	0.06
Diet	M	3	0.38	1.8	0.16	1	0.07	5.8	0.17
	F	3	1.50	1.9	0.27	1.2	0.17	6.1	0.38
Physical Activity	M	3	0.11	1.7	0.08	1.4	0.08	6.1	0.09
	F	3	0.18	1.8	0.05	0.9	0.03	5.7	0.07
Total Population-Based	M	8.9	0.12	5.1	0.05	3.3	0.03	17.3	0.06
	F	9	0.19	5.5	0.08	3.2	0.04	17.7	0.09

2.6 High Risk Approach Model

The objective function represents the expected number of new CHD cases which would be prevented over the 15 year intervention scenario when the BP and cholesterol intervention activities were implemented in the 18 different target groups. There are three sets of constraints: (1) total costs must not exceed the budget B , (2) no low risk segment of a target group can receive cholesterol intervention unless the high risk segment of that target group also receives it, (3) no target group can receive cholesterol intervention unless it also receives BP intervention. The value of B is varied to study how selected interventions depend on the total budget.

Decision Variables:

[X.sub.1] & [X.sub.2] = BP detection & treatment in 30-44 males & females

[X.sub.3] & [X.sub.4] = BP detection & treatment in 45-59 males & females

[X.sub.5] & [X.sub.6 = BP detection & treatment in 60-74 males & females

[X.sub.7] & [X.sub.8] = CH detection & treatment in 30-44 high risk males & females

[X.sub.9] & [X.sub.10] = CH detection & treatment in 45-59 high risk males & females

[X.sub.11] & [X.sub.12] = CH detection & treatment in 60-74 high risk males & females

[X.sub.13] through [X.sub.18] = Same as [X.sub.7] through [X.sub.12], but for low risk individuals

Objective Function (maximize): (22.3[X.sub.1] + 6.9[X.sub.2] + 141.83[X.sub.3] + 28.65[X.sub.4] + 78.96[X.sub.5] + 61.2[X.sub.6] + 3.96[X.sub.7] + 2.64[X.sub.8] + 55[X.sub.9] + 13.91[X.sub.10] + 85.53[X.sub.11] + 18.53[X.sub.12] + 13.09[X.sub.13] + 4.5[X.sub.14] + 44.34[X.sub.15] + 51.38[X.sub.16] + 9.73[X.sub.17] + 72.35[X.sub.18])

Cost constraint: (1.96[X.sub.1] + 1.21[X.sub.2] + 4.57[X.sub.3] + 1.56[X.sub.4] + 1.99[X.sub.5] + 2.28[X.sub.6] + .15[X.sub.7] + .31[X.sub.8] + 1.26[X.sub.9] + .67[X.sub.10] + 7[X.sub.11] + 3.23[X.sub.12] + 1.44[X.sub.13] + 1.35[X.sub.14] +1.51[X.sub.15] + 1.91[X.sub.16] + .98[X.sub.17] + 10.[X.sub.18]) <= B

Operational constraints

i) [X.sub.n+6]-[X.sub.n] <= 0 , n = 7, ... 12

ii) [X.sub.n+6]-[X.sub.n] <= 0 , n = 1, ... 6

iii) [X.sub.n+12]-[X.sub.n] <= 0 , n = 1, ... 6

Binary restrictions: [X.sub.1] through [X.sub.18] = 0 or 1

2.7 Population Approach Model

The basic population model has eighteen decision variables, each representing a different target group by intervention activity component. Each of 3 intervention activities was represented by six decision variables corresponding to the implementation of that activity in each of the age (30-44, 45-59 and 60-74) and gender combinations.

The objective function represents the expected number of new CHD cases which would be avoided when different intervention activities are implemented in different target groups.

The population approach model has only one constraint: total costs must not exceed the budget B . The value of B is varied to study how selected interventions depend on the total budget.

Decision Variables:

[X.sub.1] & [X.sub.2] = smoking cessation in 30-44 males & females

[X.sub.3] & [X.sub.4] = smoking cessation in 45-59 males & females

[X.sub.5] & [X.sub.6] = smoking cessation in 60-74 males & females

[X.sub.7] through [X.sub.12] = same as [X.sub.1] through [X.sub.6], but for increased physical activity

[X.sub.13] through [X.sub.18] = same as [X.sub.1] through [X.sub.6], but for dietary change

Objective Function (maximize): (37.45[X.sub.1] +28.17[X.sub.2] + 80[X.sub.3] + 26[X.sub.4] + 91.3[X.sub.5] + 51.3[X.sub.6] + 27.7[X.sub.7] + 16.7[X.sub.8] + 21.9[X.sub.9] + 33.9[X.sub.10] + 16.8[X.sub.11] + 29.16[X.sub.12] + 8.2[X.sub.13] + 2.2[X.sub.14] + 10.9[X.sub.15] + 6.8[X.sub.16] + 14.8[X.sub.17] + 6.5[X.sub.18])

Cost constraint (in $ millions at the $2 fixed cost level): (2.92[X.sub.1] + 2.99[X.sub.2] + 1.63[X.sub.3] + 1.75[X.sub.4] + 0.93[X.sub.5] + 1.13[X.sub.6] + 2.9[X.sub.7] + 2.91[X.sub.11] + .1.65[X.sub.9] + 1.77[X.sub.10] +1.02[X.sub.11] + 1.40[X.sub.12] + 3.02[X.sub.13] + 2.97[X.sub.14] +1.75[X.sub.15] + 1.89[X.sub.16] + 0.97[X.sub.17] + 1.22[X.sub.18]) < = B

Binary restrictions: [X.sub.1] through [X.sub.18] = 0 or 1

2.8 Integrated Model

In addition to the separate population and high risk models, an integrated model was also developed. The combined model includes 36 decision variables (18 from the high risk model and 18 from the population model) representing the implementation of each intervention activity in each of their respective target groups. The objective function for the integrated model is simply the sum of the objective functions for the high risk and population models. The left side of the cost constraint equation in the combined model is the sum of the left sides of the budget constraints of the high risk and population models. The combined model also incorporates the two sets of operational constraints from the high risk model, and the binary restrictions.

3. RESULTS AND DISCUSSION

3.1 Base CHD Incidence Estimate

Table 1 presents a breakdown of the number of new CHD cases predicted in the New Brunswick population over a fifteen year period, based on the risk factor profile of the 1989 sample. These assume the absence of any type of intervention program and therefore provide the base rates used to calculate outcome coefficients for the high risk and population-based intervention activities. The data in Table 1 are consistent with the existing fragmentary evidence of incidence rates in the New Brunswick population (Boyne, 1997).

3.2 Expected Impact Under Conservative Compliance Assumptions

Table 2, presents the expected actual impact of the various intervention activities on CHD incidence, after adjustment for the expected compliance rate of each intervention activity in each target group. The figures in the % P column are the estimated compliance rates for each intervention activity in each target group. The figures in the % T column the expected percentage reductions of CHD incident rates as presented in Table 1.

Notice in Table 2 that the low compliance rate of the population treatments cause the overall expected impact of the population approach to be less than the expected actual impact of the high risk approach for both men and women. However, in the youngest age group the population approach is still expected to be more effective in reducing CHD incidence than the high risk approach. Another important issue with respect to the results in Table 2 concerns the validity of the expected compliance rates used in the present simulation. For the high blood pressure and cholesterol interventions, the average compliance rates are in the range of 34% to 38%. These compliance levels are consistent with conservative estimates of medication compliance in the literature and appear to provide a solid basis for calculating the expected impact of the pharmacological based interventions on CHD incidence. The compliance rates for the population-based interventions were, to the extent possible, based on survey data which specifically addressed lifestyle change attempts. However, it is difficult to establish the validity of these estimates, since there has been very little research on long term compliance with population-based lifestyle change interventions. See (Boyne, 1997) for details.

3.3 Costs and Cost-Effectiveness

Tables 3a and 3b present the estimated fifteen year costs and cost-effectiveness ratios for the high risk and population-based intervention activities when all costs are considered. These cost estimates are adjusted for anticipated compliance and therefore represent the expected cost of achieving the impact levels described in Table 2. The cost-effectiveness ratio equals the total cost (in millions of dollars) of each intervention component divided by the number of cases expected to be prevented by implementation of each intervention component. Therefore, lower cost-effectiveness ratios indicated more cost-effective intervention components. In the next section we describe an optimization model that directs intervention towards the most cost-effective components.

Comparisons of the cost-effectiveness ratios for the high risk and population-based approaches show that from a total cost perspective the population approach (the last two rows of each table) is clearly more cost effective in each target group. However, there are intervention components of the high-risk approach that have better cost-effectiveness ratios than some of the population-based components. For example, the data suggest that detection and treatment of high blood pressure in 60-74 year olds is a more cost-effective means of preventing CHD than any lifestyle intervention in 30-44 year olds or dietary intervention in any age group.

3.4 Integer Linear Programming Model Comparisons

The comparisons associated with Tables 3a and 3b indicated that given full implementation the population approach is likely to be more cost- effective than the high risk approach. The objective of the linear programming stage of the calculations was to identify the combination of intervention components in each scenario (i.e., high risk and population-based intervention scenarios) which would prevent the greatest number of cases at specified spending levels. That is, the integer linear programs were used to identify the "optimum" combination of intervention components at each spending level. The calculations show that an intervention approach which combines both high risk and population-based intervention components will be more cost effective than a straight high risk approach at all spending levels, and superior to a straight population approach at all but very low annual spending levels. The relatively low annual funding levels at which the integrated approach is expected to become more cost-effective than the straight population approach indicates that some high risk intervention components become part of the optimal integrated approach well before all population-based intervention components have been incorporated.

To examine the order in which intervention components are likely to become part of an optimal integrated approach, Table 4 lists the intervention components in the integrated approach according to the annual spending level at which they first enter the optimal solution for the integrated model. Table 4 also provides the CE ratio for each intervention activity. As shown in Table 4, the order in which the intervention components entered the optimal solution for the integrated approach was not determined purely by the cost-effectiveness ratio of the individual intervention components. For example, although increasing physical activity in 60-74 year old males has a CE ratio of .08 it entered the optimal solution for the integrated approach prior to intervention components such as HBP detection and treatment in 45 59 year old males which has a significantly better CE ratio (.03). The reason for this is that for some high risk intervention components the entry order is also influenced by the operational constraints which were built into the integer linear programming model.

The results in Table 4 show that at the lower annual spending levels (i.e., under $.5 million/year) the optimal integrated approach consists primarily of lifestyle change interventions in the two older age groups. The one exception to this pattern is HBP deception and treatment in 60-74 year old males. The next distinctive grouping of intervention components to enter the optimal solution for the integrated approach consists of high risk plus physical activity and smoking interventions in 45-59 year olds, as well as HBP detection and treatment in 60-74 year old females. However, high blood pressure detection and treatment and smoking cessation in 30-44 year old females do not enter the optimal solution until the budget is about of $2.8 million.

Interventions which focus on reducing smoking and increasing physical activity in the older segments of the target population may be highly cost-effective methods reducing CHD incidence. This finding is of interest, because lifestyle change interventions are often targeted primarily at younger segments of the population. However, the present findings clearly suggest that the promotion of smoking cessation and increased physical activity in older target groups, and in particular older women, is likely to be more cost-effective than promoting these types of lifestyle changes in younger target groups. The favorable cost-effectiveness ratios associated with these lifestyle changes in the 60-74 year age group may to some extent be attributable to the fact that individuals in this age group are likely to have a higher overall risk of developing CHD, so that even a small reduction in their relatively high risk level may have a greater impact on CHD incidence than a similar reduction in the lower overall risk levels of younger individuals.

A second interesting point highlighted in Table 4 is that detection and treatment of both high blood pressure and high blood cholesterol in the 45-59 year age category, as well as detection and treatment of high blood pressure in 60-74 year olds are likely to be more cost-effective CHD prevention strategies than any population-based intervention in 30-44 year olds. This observation helps to explain why the integrated approach is considerably more cost-effective than the straight population approach at total spending levels greater than $.5 million per year, and reinforces the notion that an effective CHD prevention strategy must incorporate both high risk and population based intervention strategies.

A third point worth noting, with respect to Table 4, is that up to an annual spending level of approximately $1.8 million (or approximately $4.5 per capita/year) all of the intervention activities in the optimal integrated approach are restricted to the two older age groups, and that even when intervention activities in the youngest age group begin to enter the optimal solution (beginning at an annual spending level of $1.89 million for males and $2.81 million for females), the first intervention components to enter are the high risk interventions rather than population-based interventions.

While the present results certainly are not intended to provide a definitive ranking of the order in which different intervention components should be implemented in CHD prevention programs, they do provide a general framework for understanding how assumptions about spending levels, costs and the expected impact of different intervention strategies may influence planners' choices. Furthermore, the present results explicitly demonstrate the importance of appropriately matching intervention activities with target groups in order to achieve the most cost-effective CHD prevention programs.

4. CONCLUSIONS AND LIMITATIONS

The most interesting findings from the present research emerged not from comparisons of the high risk and population approaches, but rather from the development and assessment of an "integrated" approach scenario which incorporated elements of both of the basic approaches.

Comparisons of the integrated approach with the population and high risk approaches showed that the integrated approach was always expected to be more cost-effective than the high risk approach and was expected to become more cost-effective than the population approach at surprisingly low total funding levels. The relatively early stage at which the integrated approach was expected to become more cost-effective than the population approach indicated that certain high risk intervention strategies may become part of an optimal CHD prevention strategy well before all potential population-based intervention strategies have been fully implemented.

Like all cost-effectiveness studies, the present research has a number of significant limitations. First, the cost estimates employed and in particular those associated with the population approach are imprecise and subject to future changes. Further research will be necessary to better define the nature and timing of input resource flows associated with the high risk and population approaches as well as to determine of whether these differences are likely to have a substantial impact on the relative cost-effectiveness of the two approaches. A second limitation of the present study concerns the compliance levels used to estimate the expected impact of the different intervention strategies. In the present research the use of conservative compliance levels resulted in expected health impacts which (at least in the case of the population approach) are considerably lower than would be expected on the basis of previous research. However, it is important to point out that there has been extremely little research on long term compliance with voluntary lifestyle changes in free living populations. Further research is needed to better define both the level of compliance that may be expected in population-based health promotion initiatives as well as the factors that may contribute to compliance.

Despite its limitations, the present research has a number of practical implications for health care planners and decision makers. The present research shows that a simple dichotomy between high risk and population-based approaches is not likely to provide an adequate basis for planning and implementing a successful CHD prevention initiative. In addition to providing useful information for program planning purposes, the present study has also demonstrated the utility of employing integer linear programming techniques to enhance cost-effectiveness evaluation. As a result it was possible to conduct analyses which reveal the potential cost-effectiveness of an integrated approach to CHD prevention. In addition, the integer linear programs were very useful in identifying the order in which different intervention components should be implemented in order to achieve optimal program effectiveness, given a specific set of budget and operational constraints. The integer linear programming techniques used in the present research greatly expand the range and complexity of information that can be considered in cost-effectiveness evaluations. Although the present research focused on a single disease, it is clear that these techniques could be applied to cost-effectiveness research in a wide range of public health applications.

REFERENCES:

Anderson, K.M., Wilson, P.W.F., Odell, P.M., and Kannel, W.B., "An updated coronary risk profile: A statement for health professionals", Circulation, Vol. 83 (1), 1991, 356-362.

Boyne, J., Bhadury, J. and Balram, B.C., "Using Self Report Measures to Lower The Cost of Population Heart Health Assessment", Canadian Journal of Program Evaluation, Vol. 12 (1), 1997, 31-46.

Boyne, J., Bhadury, J and Page, J.G., "Break Even Efficacy of Heart Health Promotion Campaigns In New Brunswick", OPTIMUM: Journal of Public Sector Management, Vol. 30 (1), 2000, 1-13.

Boyne, J., Comparing the Cost-Effectiveness of High Risk and Population Approaches for Preventing Coronary Heart Disease in New Brunswick, Master's Thesis, University of New Brunswick, 1997.

Farqhar, J., Fortman, S., Flora, J., et al. "Effects of community wide education on cardiovascular disease risk factors", Journal of the American Medical Association, Vol. 264 (3), 1990, 359-365.

Health and Welfare Canada, Promoting Heart Health in Canada: A Focus on Cholesterol, Ottawa, ON, 1991.

Health and Welfare Canada, Victoria Declaration on Heart Health, Victoria, BC, 1992.

Health Services Utilization and Research Commission, Cholesterol Testing and Treatment in Adults, Saskatoon, SK, 1995.

Jones, J.K., Gorkin, L. and Lain, J.F., "Discontinuation of and changes in treatment after start of new courses of antihypertensive drugs", British Medical Journal, Vol. 311, 1995, 293-295.

Kannel, W.B. , Wolf, P.A. and Garrsion, R.J. (Eds.), The Framingham Study: An Epidemiological Investigation of Cardiovascular Disease, Section 37, National Technical Information Service No. PB 87-221644/A5, Springfield, VA, 1987.

McCombs, J.S., Nichol, M.B., Newman, C.M. and Sclar, D.A., "The costs of interrupting antihypertensive drug therapy in a Medicaid population", Medical Care, Vol. 32 (3), 1994, 214-226.

McCormick, J. and Skrabanek, P., "Coronary Heart Disease in not Preventable by Population Interventions", Lancet I (8615), 1988, 839-841.

Mittlemark, M.B., Hunt, M.K., Heath, G. W. and Schnid, T.L., "Realistic Outcomes: Lessons from Community-Based Research and Demonstration Programs for the Prevention of Cardiovascular Diseases", Journal of Public Health Policy, 1993, 437-493.

National Cholesterol Education Program, Report of the Expert Panel on Detection, Evaluation and Treatment of High Blood Cholesterol in Adults, U.S. Department of Health and Human Services, Public Health Service, National Institutes of Health, National Heart Lung and Blood Institute, NIH Pub. No. 882925, Bethesda, MD, 1988.

New Brunswick Department of Health and Community Services, New Brunswick Heart Health Survey Report, Fredericton, NB, 1989.

Oliver, M., "Coronary risk factors: should we not forget about mass control?", World Health Forum, Vol. 5, 1983, 5- 8.

Puska, P., Tuomilehto, A. N., Salonen, J.T., Vartiainen, E., Pietinen, P., Koskela, K. and Korhonin, J. H., "The North Karelia Project: 15 Years of Community-Based Prevention of Coronary Heart Disease", Annals of Medicine, Vol. 21, 1989, 169-173.

Puska, P., Salonen, J., Nissinen, A., et al., "Change in risk factors for coronary heart disease during 10 years of a community intervention programme (North Karelia project)", British Medical Journal, Vol. 287, 1983, 1840-44.

Shea, S., and Basch, C.E., "A review of five major community based cardiovascular disease prevention programs. Part 1: Rationale, design and theoretical framework", American Journal of Health Promotion, Vol. 4 (3), 1990a, 203-213.

Shea, S., and Basch, C.E., "A review of five major community based cardiovascular disease prevention programs. Part II: Intervention Strategies, evaluation methods, and results" American Journal of Health Promotion, Vol. 4 (4), 1990b, 223-237.

Stern, M.P., Farquhar, J.W., Maccoby, N. and Russell, S.H., "Results of a two-year health education campaign on dietary behavior. The Stanford three community study", Circulation, Vol. 54 (5), 1976, 826-833.

The Canadian Consensus Conference on Cholesterol, "Final Report", Canadian Medical Association Journal; Vol. 139 (suppl), 1988a, 1-8.

Toronto Working Group on Cholesterol Policy, "Asymptomatic hypercholesteroolemia: A clinical policy review", Journal of Clinical Epidemiology, Vol. 43, 1990, 1021-1121.

John A. Boyne Jr., New Brunswick Department of Health, New Brunswick, Canada

Joyendu Bhadury, The University of North Carolina at Greensboro, North Carolina, USA

Richard Ehrhardt, The University of North Carolina at Greensboro, North Carolina, USA

AUTHOR PROFILES:

John A. Boyne, Jr. earned his MBA from University of New Brunswick in 1997. He is currently Director of Accountability and Health Information Management at the Department of Health in New Brunswick, Canada.

Dr. Joyendu Bhadury earned his Ph.D. at The University of Texas at Dallas in 1991. He is currently Professor of Information Systems and Operations Management and Associate Dean for Research and Graduate Programsin the Joseph M. Bryan School of Business and Economics at The University of North Carolina at Greensboro, Greensboro, NC.

Dr. Richard Ehrhardt earned his Ph.D. at Yale University in 1976. He is currently Professor of Information Systems and Operations Management at The University of North Carolina at Greensboro, Greensboro, NC.

TABLE 1: PREDICTED 15-YEAR CHD INCIDENCE IN THE NEW BRUNSWICK POPULATION

	Age Group			
	30-44	45-59	60-74	30-74
Males	5409	9060	8866	23335
Females	1621	5290	6038	12949
Total	7030	14350	14904	36284

TABLE 2: EXPECTED COMPLIANCE RATES AND EXPECTED % REDUCTION IN CHD INCIDENCE

Age Group

Activity	Sex	30-44		45-59	
		% P	% T	% P	% T
Blood Pressure	M	15	0.41	47	1.57
	F	16	0.43	21	0.55
Cholesterol	M	13	0.31	33	1.09
	F	29	0.43	43	1.23
Total High Risk	M	14	0.72	40	2.66
	F	21	0.86	33	1.49
Smoking	M	6	0.70	10	0.88
	F	9	1.73	5	0.49
Diet	M	7	0.15	8	0.12
	F	10	0.12	8	0.13
Physical Activity	M	9	0.52	5	0.24
	F	13	1.05	10	0.64
Total Population	M	7	1.37	8	1.25
	F	10	2.90	7	1.27

Age Group

Activity	Sex	60-74		Total	
		% P	% T	% P	% T
Blood Pressure	M	41	0.89	38	1.04
	F	63	1.01	35	0.75
Cholesterol	M	35	1.07	30	0.90

	F	41	1.51	41	1.26
Total High Risk	M	37	1.96	34	1.95
	F	48	2.52	38	2.01
Smoking	M	19	1.03	11	0.90
	F	17	0.84	9	0.81
Diet	M	12	0.17	10	0.15
	F	13	0.12	10	0.12
Physical Activity	M	5	0.19	6	0.29
	F	8	0.48	10	0.62
Total Population	M	13	1.39	9	1.33
	F	12	1.44	9	1.55

TABLE 3A: EXPECTED TOTAL COST ($MILLIONS) & CE RATIOS OF HIGH RISK INTERVENTIONS

		Age Group			
Activity	Sex	30-44		45-59	
		Total Cost	CE Ratio	Total Cost	CE Ratio
Blood Pressure	M	3	0.14	9.3	0.07
	F	1.7	0.24	2.9	0.10
Cholesterol	M	4.8	0.28	13.9	0.14
	F	4.6	0.66	10.4	0.16

Total	M	7.8	0.20	23.2	0.10
Pharmaceutical	F	6.3	0.45	13.3	0.14

		Age Group			
Activity	Sex	60-74		30-74	
		Total Cost	CE Ratio	Total Cost	CE Ratio
Blood Pressure	M	2.6	0.03	14.9	0.06
	F	2.6	0.04	7.2	0.07
Cholesterol	M	12.1	0.13	30.8	0.15
	F	14.6	0.16	29.6	0.18
Total Pharmaceutical	M	14.7	0.08	45.7	0.10
	F	17.2	0.11	36.8	0.14

TABLE 3B: EXPECTED TOTAL COST ($MILLIONS) & CE RATIO OF POPULATION-BASED INTERVENTIONS

		Age Group	
Activity	Sex	30-44	45-59

		Total Cost	CE Ratio	Total Cost	CE Ratio
Smoking	M	2.9	0.08	1.6	0.02
	F	3	0.11	1.8	0.07
Diet	M	3	0.38	1.8	0.16
	F	3	1.50	1.9	0.27
Physical Activity	M	3	0.11	1.7	0.08
	F	3	0.18	1.8	0.05
Total Population-Based	M	8.9	0.12	5.1	0.05
	F	9	0.19	5.5	0.08

		Age Group			
Activity	Sex	60-74		30-74	
		Total Cost	CE Ratio	Total Cost	CE Ratio
Smoking	M	0.9	0.01	5.4	0.03
	F	1.1	0.02	5.9	0.06
Diet	M	1	0.07	5.8	0.17
	F	1.2	0.17	6.1	0.38
Physical Activity	M	1.4	0.08	6.1	0.09
	F	0.9	0.03	5.7	0.07
Total Population-Based	M	3.3	0.03	17.3	0.06
	F	3.2	0.04	17.7	0.09

TABLE 4: INTERVENTION COMPONENTS RANKED BY ORDER OF ENTRY INTO OPTIMAL SET

Intervention Component (CE Ratio)

Entry 30-44

Level

Male Female

.03

.13

.14

.17

.23

.30

.37

.53

.55

.74

1.2

1.69

1.8

1.89 HBP (.10)

[CH.sup.1] (.04)

1.93 Smoking .08)

2.18 [CH.sup.2] (.11)

2.19 Activity (.09)

2.25

2.33

2.8 HBP (.17)

Smoking (.11)

3.27

3.32 [CH.sup.1] (.11)

3.42 Activity (.18)

3.54

3.81

4.64

4.8 Diet (.38)

5.02 [CH.sup.2] (.30)

5.48 Diet (1.5)

Intervention Component (CE Ratio)

Entry 30-44

Level

Male Female

.03

.13

.14

.17 Smoking (.02)

.23

.30

.37 Activity (.05)

.53 [CH.sup.1] (.02) HBP (.06)

[CH.sup.1] (.05)

.55 HBP (.03)

.74 [CH.sup.2] (.03)

1.2 [CH.sup.2] (.03)

1.69 Smoking (.07)

1.8 Activity (.08)

1.89

1.93

2.18

2.19

2.25

2.33

2.8

3.27 Diet (.16)

3.32

3.42

3.54

3.81

4.64 Diet (.27)

4.8

5.02

5.48

Intervention Component (CE Ratio)

Entry Level	30-44 Male	30-44 Female
.03	Smoking (.01)	
.13	Activity (.08)	
.14		Smoking (.02)
.17		
.23		Activity (.03)
.30	HBP (.03)	
.37	Diet (.07)	
.53		HBP (.04)
.55		
.74		
1.2		
1.69		
1.8		
1.89		
1.93		
2.18		

2.19		
2.25	[CH.sup.1] (.09)	
2.33	[CH.sup.2] (.10)	
2.8		
3.27		
3.32		
3.42		Diet (.17)
3.54		[CH.sup.1] (.17)
3.81		[CH.sup.2] (.14)
4.64		
4.8		
5.02		
5.48		

[CH.sup.1] = Detection and treatment of elevated blood cholesterol levels in high risk individuals.

[CH.sup.2] = Detection and treatment of elevated blood cholesterol levels in low risk individuals.

The results in Table 4 highlight several interesting points. First, these results show that population-based

Boyne, John A., Jr.^Bhadury, Joyendu^Ehrhardt, Richard