A review of the cost-effectiveness of face-to-face behavioural interventions for smoking, physical activity, diet and alcohol

L. Gordon, PhD[1,2], N. Graves, PhD[3], A. Hawkes, PhD[2], E. Eakin, PhD[4]

Affiliation and postal addresses of authors:

1. Queensland Institute of Medical Research, PO Royal Brisbane Hospital, Brisbane Q4029
2. Viertel Centre for Research in Cancer Control, The Cancer Council Queensland, PO Box 201, Spring Hill, Brisbane, Q4004, Australia
3. Institute of Biomedical and Health Innovation, Queensland University of Technology, Cnr Blamey St & Musk Ave, Kelvin Grove Q4059, Brisbane, Australia
4. School of Population Health, University of Queensland, Herston Rd, Herston Q4006, Brisbane, Australia

Corresponding author details:
Louisa Gordon
Queensland Institute of Medical Research
PO Royal Brisbane Hospital, Q4029, Australia
Email: Louisa.Gordon@qimr.edu.au

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Abstract

Objective: This review assesses the evidence for the cost-effectiveness of health behaviour interventions that address the major behavioural risk factors for chronic disease including; smoking, physical inactivity, poor diet and alcohol misuse. *Methods:* Medical and economic databases were searched for relevant economic evaluations. Studies were critically appraised using a published 35-point checklist, and the results are described using a narrative approach, noting methodological limitations. The review included 64 studies from 1995-2005, including 17 reports on multiple behaviour interventions. *Results:* There was considerable variation among the studies by target populations, intervention components, primary outcomes and economic methods, yet the reported incremental cost-effectiveness ratios were consistently low (e.g., <€14,000 per quality-adjusted life year gained for smoking-cessation programs in 2006 Euros) compared to certain preventive pharmaceutical and invasive interventions. Interventions targeting high-risk population sub-groups were relatively better value for money compared to those targeting general populations. *Discussion:* In general, results of this review demonstrate favourable cost-effectiveness for smoking interventions, physical activity interventions and multiple behaviour interventions in high-risk groups. For alcohol and dietary interventions, although appearing economically favourable, conclusions are difficult due to the variety in study outcomes. However, methodological limitations weaken the generalisability of findings, and suggest that the results of any given study be considered carefully when being used to inform resource allocation.

Keywords: cost-effectiveness, smoking cessation, physical activity, diet, alcohol intake

Introduction

In the Western world, the key behaviours contributing to the largest disease burden include: tobacco smoking, physical inactivity, poor diet, harmful alcohol intake, drug use, vaccination practices and sexual behaviours.[1-4] In the US, for example, the primary causes of death in 2000 were from tobacco smoking (18%), poor diet and physical inactivity (16%) and alcohol consumption (3.5%).[2] Unlike other factors that impact upon health outcomes, such as genetic predisposition, ageing or cultural background, these health behaviours are potentially avoidable and modifiable. Clearly, a more preventive approach to health is crucial if public health is to improve in any sizeable way.[2] Despite a substantial body of literature confirming the efficacy of health behaviour interventions in smoking, physical activity, dietary intake and alcohol,[5-10] translating these interventions into public health practice has been limited. Health behaviour interventions are the best way to both prevent and manage chronic disease. The current emphasis in the health behaviour intervention field is on converting this evidence into practice.[11] A key issue in this regard is the need for data on the cost-effectiveness of interventions to allow health care policy makers to make informed decisions about the value of such interventions.

Three reviews exist on the economic evaluation results of smoking-cessation strategies.[12-14] An early review by Warner *et al.* (1997) concluded that smoking-cessation interventions delivered by general practitioners were highly cost-effective and remained the 'gold-standard' in cost-effective health care. Similar conclusions were made by Woolacott *et al.* (2002) reviewing interventions with multiple strategies delivered by a range of health professionals, and targeting specific types of smokers and an emphasis on pharmacologic approaches and routine clinical care settings. In an attempt to improve the generalisability of cost-effectiveness findings from smoking-cessation programs, Ronckers *et al.* (2005) re-analysed findings to generate standardized cost-effectiveness ratios across settings, to help eliminate variation in program effects and costing methods. However, huge variation among cost-effective ratios remained (i.e., $US 490 - $15,280 life-years saved (LYS). [12] Compared to many pharmaceutical treatments, surgeries and hospital-based health care services, the general consensus is that smoking-cessation strategies represent excellent health care investment.[12, 13, 15]

Four other reviews on the cost-effectiveness of preventive interventions are aimed at specific diseases: diabetes, [16] coronary heart disease, [17, 18] and artherosclerosis.[19] Addressing behavioural modification interventions for diabetes, Vijgen *et al.* (2006) reviewed three older studies on diabetes management and concluded more research was needed although noted the findings supported their cost-effectiveness.[16] Similarly, Brown *et al.* (1998, 2002) reviewed seven pre-1995 studies on coronary heart disease prevention, focussing on primary prevention strategies for smoking-cessation and physical activity, and confirmed that GP-delivered smoking-cessation interventions were highly cost-effective, but that further evaluations were needed for physical activity interventions.

The aim of this review is to assess the evidence from economic evaluations of face-to-face behaviour interventions for smoking, physical inactivity, poor diet, and alcohol misuse from reports published during1995-2005. This review provides a unique addition to the literature by consolidating the economic evaluation literature for all four behaviours, something not done in any previous review. We have focused the review on interventions delivered through face-to-face methods because this provides a more homogenous group of interventions for comparison purposes, and because this was the most common intervention method during the period covered by the review.

Review Methods

Interventions were included if (1) they were an economic evaluation of a health behaviour change intervention for tobacco smoking or diet or physical activity or alcohol misuse behaviours or any combination of these behaviours; (2) interventions were delivered face-to-face; (3) interventions were aimed at individual-level behaviour change (rather than system-level or environmental changes e.g., mass media campaigns); and (4) studies were published in the English language from 1995 to 2005 inclusive. We have included studies involving behaviour change interventions if they were the either the focus of the study or one of the comparator interventions, because face-to-face behavioural interventions are often used in conjunction with other technologies (i.e., pharmacotherapies, surgeries). This time frame was chosen because standardized methods for the conduct and reporting of economic evaluations in health care were not available until 1987 and were not widely adopted until several years later.[20] We excluded non-English language studies because we did not have the resources to translate these reports. Both studies of healthy populations (i.e., primary prevention) and

those with or at risk of a disease (i.e., secondary prevention) were included. Furthermore, where studies involve persons with or at risk of disease, we have focussed on cardiovascular diseases, obesity, diabetes and cancer, because they incur the most costly health burdens in developed nations. For reports of interventions where two papers were published on the same study but report on different effectiveness measures , we have included only one report, and favoured outcomes in the generic outcome measure 'quality-adjusted life years gained' (QALYs). Studies were excluded if the report had insufficient data to assess the economic evaluation, that is, one or two brief paragraphs on the economic methods and outcomes. Partial economic evaluations do not provide efficiency information for resource allocation decisions therefore these studies were excluded. Specifically, this meant that studies describing only the costs of the intervention without health outcomes or studies that evaluated the costs and health benefits of one intervention with no mention of a comparator(s) were excluded. In addition, to preserve the quality of the studies chosen for the review, we also excluded studies that did not synthesize cost and health outcomes data into a summary measure for the economic evaluation, that is, no cost-effectiveness ratios were produced.

In the first instance, the National Health Service-Economic Evaluation Database (NHS-EED) http://www.york.ac.uk/inst/crd/crddatabases.htm#NHSEED was used to identify relevant manuscripts. This has an international focus and includes studies of economic evaluations selected from a range of electronic databases (such as MEDLINE and EMBASE, Cochrane Library, PsychLit, Biomed Central) together with searching paper-based journals and other grey literature (e.g., working papers at centres of health economics research). The NHS-EED reviews provide a structured abstract that separately considers the quality of the evidence of clinical effectiveness in addition to the economic evidence while providing an independent critical assessment of the study's overall quality. Medical databases were also searched due to the delay between the production of NHS-EED review abstracts and when the original research was published. Reference lists of articles retrieved were hand-searched for additional relevant studies. Specific search terms, results, and reasons for exclusions are listed in Appendix 1.

It is beyond the scope of this paper to discuss in detail the standard 'best practice' methods for economic evaluations, and the reader is referred to other quality resources on this topic.[21, 22] Briefly, good practice economic evaluations are transparent with respect to the policy question and perspective taken, adequate description of all comparators, detailed costing and

health benefit methods, incremental cost-effectiveness ratios (see Appendix 2) and detailed sensitivity analyses. An incremental cost-effectiveness ratio provides information on the efficiency of one option compared to another by summarising its relative value for money. An average cost-effectiveness ratio is the same as an incremental cost-effectiveness ratio however it compares an intervention with baseline or zero ('do nothing') alternative. [23] Ratios of up to US $50,000 (€36,767) per QALY gained would generally be considered economically attractive, although this is a crude and arbitrary benchmark.[24] Sensitivity analyses test the stability of the incremental cost-effectiveness ratios by varying the point estimates used in the main analysis and are adequately justified (e.g. different effectiveness estimates from other epidemiological data, low and high confidence intervals, different possible costs or quantities of resources used). These analyses are performed to deal with the uncertainty within the data estimates and intervention protocols that commonly occur in economic evaluations. Relevant studies were critically appraised using the *British Medical Journal*'s 35-point checklist for reporting economic evaluations (http://bmj.bmjjournals.com/advice/checklists.shtml).[25] Studies were categorised by behaviour type, tabulated according to key features and outcomes and synthesized using a narrative approach. A narrative synthesis method was necessary because of the wide variability in economic study methods, outcomes and levels of quality, and because many economic evaluations include their own synthesis (meta-analyses) of epidemiological data for intervention efficacy and other data estimates. In addition to presenting the key findings in their original local currency and price year, incremental cost-effectiveness ratios were converted to 2006 Euros (using inflation deflators for individual countries and purchasing power parities),[26] where possible, to facilitate comparisons across studies. We also present the time horizon for the economic evaluation, any assumptions on intervention compliance or relapse behaviours and any assumptions on long-term efficacy.

Results

Of the 586 articles identified, most were excluded because they were not one of the four behaviours, were not economic evaluations or they were only partial economic evaluations (e.g cost studies) (see Appendix 1). Two studies were discarded because they had been amended and re-published when follow-up data became available[27, 28] and an additional two because later reports published outcomes in terms of QALYs gained.[29, 30] This left a total of 64 articles in the review. For each behaviour type, the number of studies included: smoking

cessation (15), physical activity (13), alcohol (12) and nutrition (7). An additional 17 interventions simultaneously addressed more than one of these four behaviours and were categorised as 'multiple behaviour interventions' (see Tables 1-5).

Smoking-cessation interventions

Smoking-cessation strategies were comprised of counselling by a range of health professionals and with or without nicotine replacement therapy or bupropion, printed materials or telephone quit lines and targeted certain types of smokers: highly addicted, new smokers, pregnant women, relapsers and potential relapsers (Table 1). The durations of the intervention ranged from 6-24 months while the economic analyses took a lifetime horizon. Despite the heterogeneity among the studies in terms of the target populations, intervention components, economic perspective and primary outcomes, the incremental cost-effectiveness ratios never exceeded €14,000 per QALY gained and €9,422 per LYS (2006 Euros), with the exception of one study that assessed Sudden Infant Death Syndrome deaths averted.[31] Studies reporting incremental cost per LYS ranged from €1,012 to €9,422[32-38] (2006 Euros). Cost per quality-adjusted life years (QALYs) gained ranged from €2,737 to €13,909, [32-35, 37] and cost per quitter up to €5,398 [33](2006 Euros) with ranges depending on age and gender. Cost-effectiveness ratios were higher for interventions combining nicotine replacement therapy with counselling compared to counselling alone. Unfortunately, in eight studies there was limited information reported on the quality, detail, justification or synthesis of estimates for the *effectiveness* of the interventions. [31-33, 35, 36, 39-41] Costs were of limited scope for two studies[32, 35] or costing methods were inadequately reported for two studies.[32, 40] Sensitivity analyses were incomplete in one study [42] and non-existent for two studies .[31, 32] In one study [43] costs were not discounted because of the short-time frame of the costing period (up to one year), however effects were discounted making the analysis inconsistent and against current recommendations.[22] Other limitations were a failure to state the economic perspective for three studies, [31, 43, 44] no price year provided for one study,[37] and inadequate descriptions of the interventions in one study.[31]

(Insert Table 1 here)

Alcohol interventions

Alcohol interventions were comprised of physician counselling techniques and aimed at either hospital patients, families or adolescents (Table 2). Using cost-benefit analyses where benefits were valued as reduced health care costs, averted motor vehicle accidents and criminal events/court case costs, results showed net benefits to society of €7,319 [45] per patient and €9,334 [46] (2006 Euros) per family. Similarly, when benefits were valued in terms of costs saved from hospitalizations averted, trauma and emergency room services avoided, net cost savings were found of €3.84 [47] and €10.67 [48] to every €1 invested in the interventions. Incremental cost per QALY was €23,865 (2006 Euros) for a motivational therapy program compared to a behavioural therapy program,[49] up to € 13,824 per QALYs for various intensities of alcohol therapies[50] and up to €51,674 per LYS for a screening and intensive advice intervention compared with an intervention with lower intensity.[51] Corry *et al.* (2004) found very high ICERs of €123,549 per year of life in disability averted for a current care option versus no treatment compared to €72,473 per year of life in disability averted for optimal care.[52] Strengths of the research by Fleming *et al.* (2002) and UKATT (2005) evaluating family physician counselling programs were the diverse and large samples (n≈750), 4-year follow-up rates, randomized designs and intention-to-treat procedures. Three studies reported average ratios, [45, 48, 53] two did not undertake sensitivity analyses, [48, 53] one study inadequately addressed issues of non-randomized samples or small samples, [48] and two others provided no price year[54-56] making price conversions difficult.

(Insert Table 2 here)

Physical activity interventions

Interventions included a range of targets (e.g., from moderate intensity of physical activity to vigorous exercise), delivery methods (e.g., health professional advice, group sessions and nurse-led home-based programs) and were aimed at a wide variety of target populations, including those with or without chronic illnesses (Table 3). Incremental cost per LYS were in the range €1,845 to €47,515,[57-59] and cost per QALY gained was €2,162 to €53,119 [60-64](2006 Euros). Cost savings per incremental unit of improved physical activity scores were found in one study[65] (2006 Euros). Very small between-group differences, of questionable clinical importance, were found for one study assessing two rehabilitation programs for breast cancer compared to usual care.[63] DeVries *et al.* (2002) found exercise training to be highly cost-effective when compared to two vascular surgeries for persons with coronary

artery disease. From the employers perspective, and using cost-benefit analysis where benefits were measured in cost savings from reductions in sick leave payments, physical activity counselling produced net savings of €305 per participant over 9 months. [66] The analytical perspective used (i.e., service provider, society or consumer, etc.) was unclear for three studies,[58, 67, 68] and often the quantity of resources used and costs were not reported separately.[58, 61, 63] Overall, sensitivity analyses were adequately reported as were the methods for the estimation of costs and measures of effectiveness.

(Insert Table 3 here)

Diet interventions

Counselling interventions with various health professionals were targeted at persons with diabetes or at high risk of developing diabetes,[69, 70] heart disease/obesity, [71] overweight children[72] or adults[73] (Table 4). *Average* costs per mg/dL change in fasting glucose levels were €5.04 for the dietitian program versus €6.64 for the basic care program (2006 Euros).[69] In another evaluation [72], a*verage* costs per '% decrease in energy from fat' over 12 months were €161 for a parent/child intervention versus €101 for counselling (2006 Euros). Tsai *et al.* (2005) found a low carbohydrate dietary intervention was dominant over a standard diet, but the differences in costs and in QALYs across the two options were not statistically significant.[74] For a dietitian counselling plus multidisciplinary care intervention, the incremental cost per patient achieving glycemic control was €3,705 (2006 Euros).[70] Counselling by a family practitioner was more cost-effective than a dietitian, with an incremental cost-effective ratio of €1,199 versus €8,757 per LYS respectively,[71] and involved very small gains in terms of LYS (i.e., 14-22 days). Better health outcomes were found if a family physician was the sole provider[71] or aided a dietitian with nutrition counselling however costs were also higher.[71, 73] Sensitivity analyses were not undertaken or were weak [69, 72, 73, 75], costs were inadequately reported[70, 73] and with one exception,[74] all studies had short time-frames (1 or 2 years) with no attempt to estimate longer-term costs and outcomes.

(insert Table 4)

Multiple behaviour interventions

Multiple behaviour or lifestyle interventions included different combinations of behaviour modification with or without health checks, pharmacotherapies, surgeries to improve health behaviours in general populations[76-80] or those with common chronic diseases (Table 5). Most multiple behaviour studies employed risk factor modelling techniques to estimate survival outcomes, and many used Markov or simulation modelling [79-84] to address uncertainty of evaluation estimates (Table 5). With one exception,[78] incremental cost per LYS ranged from €3,274 to €64,921[76-79, 85](2006 Euros). Incremental cost per QALYs ranged from cost savings to €24,523 (2006 Euros),[80-82, 84, 86] excluding two studies with extreme incremental cost per QALYs of €206,241[78] and €203,197[81] (2006 Euros). These very high ICERs were driven by very small differences in QALYs across the intervention options. Salkeld *et al.* (1997) reported that if their GP-delivered lifestyle intervention was targeted at high-risk men, the incremental cost-effective ratios were €53,569 per LYS and €40,094 per QALY gained (2006 Euros) compared to routine care. Four studies were found to have weak or no sensitivity analysis [78, 87-89] and two studies lacked sufficient detail on costing methods.[78, 90] Generally, authors presented little or no information on the quality, structure or validity of the economic models used. Interventions aimed at men were more cost-effective than those for women in two studies.[76, 78] One study performed a cost-benefit analysis of a school-based obesity program measuring benefits as reduced costs for medical and productivity costs avoided and found, with 80% probability, net savings to society.

(Insert Table 5 here)

Discussion

To our knowledge, this is the first review of the growing cost-effectiveness literature on face-to-face health behaviour interventions targeting smoking, physical inactivity, poor diet and alcohol misuse. Consistent with previous reports [12, 13, 15, 57] and subject to the limitations identified above, economic evaluations for smoking-cessation were found to be excellent public health investments and show economically attractive findings (i.e., € 14,000 per QALY gained, 2006 Euros). For the evaluations of alcohol interventions, net cost savings to society were found in four studies, favourable cost-effectiveness ratios (<€ 23,865 per QALY gained) in two others and one study demonstrated relatively high cost-effectiveness ratios (€ 72,473 per year of life in disability averted for optimal care versus no treatment. The findings for physical activity interventions generally indicated favourable cost-effectiveness

(<€ 53,119 per QALY gained) and two studies showed net cost savings. For the dietary interventions, incremental cost-effectiveness ratios (ICERs) were not produced for three of the seven studies and different outcome measures made any conclusions difficult. However, one study showed cost-effective findings of € 8,757 per LYS.

Incremental cost per QALY ratios for multiple behaviour interventions targeting high-risk populations ranged from cost saving to € 40,094 (2006 Euros). They were mostly cost-effective and higher than for smoking cessation interventions alone. No study explicitly addressed the possibility that multiple behaviour interventions may produce greater efficiencies compared to single behaviour interventions. While many individuals engage in a range of risk factor behaviours,[91] multiple behavioural interventions or 'lifestyle' interventions may be the logical way forward, since they are risk factors for most chronic diseases. They also interact with each other throughout the lifecycle [92] and increase overall absolute risk for chronic diseases. Behaviour management play a crucial role in primary and secondary prevention of chronic disease. Other treatment strategies that aim to modify single risk factors are found to have incremental cost-effectiveness ratios over € 85,000 per life-year saved, including some hyperglycemic drugs to lower blood glucose (pioglitazone and nateglinide),[16] antihypertensive drugs (calcium channel blockers, antiadrenergics),[17] and cholesterol-lowering drugs (colestipol, cholestyramine).[17]

Overall, the behavioural interventions aimed at populations with high-risk factors for disease were more cost-effective than those aimed at healthy individuals due to the larger health gains produced in these targeted cohorts. For example, middle-aged men often engage in multiple poor behaviours,[91] are set to gain more when they change to healthy lifestyles, which produces lower incremental cost-effectiveness ratios compared to other cohorts.[93] Due to the limited number of studies involving lower socioeconomic subgroups, known to have poorer health behaviours, further work is needed to determine the economic findings attributable to disadvantaged populations and the related issue of equity in resource distribution. This issue is especially important when translating an intervention into a different setting.

Generally, the costs of the behavioural interventions reviewed were low relative to those for other health care interventions such as pharmaceutical management. Interventions were primarily of a counselling nature, low-technological, community-based and did not require extensive capital outlays. Despite this, many studies in this review also showed that

behavioural interventions alone had lower effectiveness (e.g., counselling alone for smoking cessation had lower effectiveness than when combined with NRT), and it is the overall cost-effectiveness ratios that are important rather than simply assessing costs. With the exception of some interventions with longer follow-up contacts, the interventions were also short-term and, unlike other health interventions (e.g., pharmaceuticals) where resources are required for the remainder of an individual's life, total lifetime expenditure was small. However, costs of human resources in community-based health providers should not be trivialized, as these organizations may find that operational costs (in terms of staff training, adequate salaries to promote staff retention, time and space to implement interventions, etc.) are relatively high. Few studies in the review included indirect costs such as potential cost-savings due to better health and lower use of health services or future health care costs associated with living longer.

An important part of cost-effectiveness analyses of behavioural interventions is establishing the link between behaviour change and long-term mortality and quality of life outcomes. The studies here have drawn on both trial evidence and epidemiological data to support these links, however relatively weak evidence is available for the long-term health effects of physical activity, diet and drinking compared to smoking cessation.[94] Economic outcomes here for alcohol, diet and physical activity interventions are generated over the short term, aligning to the intervention follow-up times, and do not attempt to predict longer term effectiveness or maintenance of healthy behaviours. Despite being non-invasive and having minimal risk of adverse events, intervention effects are usually small across time and across treatment options (e.g., 5% smoking-cessation rates at 12 months is considered clinically meaningful although this small gain translates to relatively high numbers of life years saved). This is a reflection of the difficulty in modifying health behaviours in populations, including persons with confirmed risk factors for chronic disease and also by the 'natural' health gains occurring in the comparison groups (e.g., unaided smoking quit rate, physical activity improvements in 'usual care' groups). New epidemiological data is constantly emerging to challenge cost-effectiveness outcomes, despite the conservative health effect estimates often used and the use of sensitivity analyses. For example, Yudkin *et al.* (2003) reported a 7-year smoking relapse of 54%, with the studies in this review using estimates ranging from 0% to 40%, [29, 32, 37, 38, 40, 41, 95] because of this, underestimated cost-effectiveness ratios were produced.

When comparing these cost-effectiveness results across studies, particular care should be taken to acknowledge the different methods used, the different cost types, outcomes and baselines. Hence, a simple comparison of ICERs should be avoided. Generalizing the results of many or any one study from this review will require economic re-analysis to reflect local conditions, particularly as the evidence-base for the effectiveness of the interventions is constantly changing. Issues contributing to the generalisability and variation in cost-effectiveness ratios reported here include differences in: health care systems, incentives to health care professionals and institutions, clinical practice, population demographics, population values, target populations, risk factor profiles, disease prevalence, currency purchasing powers and the availability of and access to new technologies [96] (see Cornuz *et al.* [2006] for a recent multi-national comparison on pharmacotherapies for smoking cessation).[93] The decision to implement a program will also involve ethical and political considerations, and issues such as equity, reach, needs and priorities. Through this process, the program with the lower cost-effectiveness ratio may not always be the best one (see Bala & Zarkin 2002 for a further discussion).[97] The studies in this review typically omit cultural minorities and disadvantaged populations known to have increased levels of high-risk behaviours.[98] However, serving these disadvantaged populations may involve higher costs required to reach these sub-groups and more intensive interventions to maintain behavioural change.[99] Finally, the mix of strategies to control for many chronic diseases in practice may be more complex than those described in the studies here. They may use multiple methods (pharmacotherapy, behavioural therapy and surgery) and therefore additive effects and additional costs may need to be considered.

Study limitations and strengths

Retrieval of all possible papers was limited to those referenced in medical databases and excludes those located in the grey literature (outside that performed by NHS-EED) and those produced in monographs and books. All papers published after 1995 in English-language journals were included. A quality grading system was not employed because none are extensively used or widely validated,[100, 101] and there are limitations with using such a system, as important information may be missed in the reduction and categorisation process. [101] However, a comprehensive checklist was used to establish the methodological quality and/or reporting of methods in an explicit and standardized way and revealed a number of methodological limitations. The overall quality of the economic evaluations varied widely across and within each behaviour category.

This review targets clinicians, behavioural scientists, and public health researchers. The information will be most useful for decision-makers wanting to know which interventions are the 'best buys', when making investments in preventive public health. A study of interest may be identified as appropriate for a particular setting and, following some re-analysis to reflect local conditions, the intervention may be considered by policy makers for translation into practice. The review may also act as a reference guide for behavioural interventions tested elsewhere and the relative differences of the interventions compared using a common currency. In addition, the review has highlighted the gaps in economic evaluation methods and steers researchers and evaluators towards improving their practice and reporting high-quality economic findings, whilst building on existing knowledge.

Conclusion

Wide-scale implementation of health behaviour interventions to curb the growing chronic disease burden in developed nations is an important population health objective. This review provides the current state of evidence for economic evaluations in 64 studies across the four key behaviours of smoking, alcohol, diet and physical activity. There was wide variation in terms of sample populations, interventions, settings, and intervention outcomes, in addition to the use of varying economic methods. Similarly, the quality of the studies in the review was wide-ranging, with many studies having major limitations when evaluated against a comprehensive economic evaluation checklist. Nevertheless, overall most health behaviour interventions were very good value on economic grounds, especially smoking-cessation counselling with pharmacotherapies and interventions targeting high-risk populations. Further economic evaluations of stronger quality are necessary to establish the cost-effectiveness of interventions for diet, alcohol and physical activity. Care is needed when generalising these findings in local settings, and economic re-analysis is recommended to account for different disease prevalence, health care systems (prices and access to health care) and currency purchasing powers. Further evaluations should target multiple behaviour interventions due to the potential synergy to be gained. Markov modelling and Monte Carlo simulation approaches (and their quality assessment) will be inevitable in future investigations of behaviour change interventions, because of the complexity of treatment effects, multiple behaviour interactions and the lifelong time-frame advocated for both lifestyle improvements and cost-effectiveness analysis.

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Appendix 1. Summary of search results

Limits: 1995-2005, terms in title or abstract, original research

Search terms – combination of:	Hits	Not behaviour change or not 4 behaviours	Not CVD, obesity, diabetes, cancer	Not face-to-face intvns	Not econ evaluations or partial evaluation	Not person level behaviour intvns	Non-English	No C/E ratios	Insufficient data to assess econ evaluation	Already included	Final[1]
Cost, cost-effectiveness, cost-benefit, cost-utility and smok*	64	1	0	3	16	16	1	0	1	11	15
Cost, cost-effectiveness, cost-benefit, cost-utility and physical activity, exercise, fitness	146	59	3	1	17	7	0	1	17	27	14
Cost, cost-effectiveness, cost-benefit, cost-utility and diet*, nutrition, obesity, weight loss	165	107	4	3	15	6	1	4	0	12	13
Cost, cost-effectiveness, cost-benefit, cost-utility and alcohol, drink*	85	29	1	1	28	7	0	7	0	5	7
Cost, cost-effectiveness, cost-benefit, cost-utility and behavio(u)r, lifestyle, risk factor	126	51	9	8	16	0	1	1	2	19	19

1. A further two studies were discarded because they had been amended and re-published when follow-up data became available[27, 28] and an additional two because later reports published outcomes in terms of QALYs gained [29, 30]

Appendix 2 Definition of an incremental cost-effectiveness ratio (ICER)

An incremental cost-effectiveness ratio is defined by:

$$ICER = \frac{C_I - C_C}{E_I - E_C} = \frac{\Delta C}{\Delta E}$$

where: C_I represents a measure of economic costs after the intervention has been implemented; C_C represents a measure of economic costs with the comparator (i.e. usual care or some other intervention); E_I represents the level of health benefits after the intervention has been implemented; and, E_C represents the level of health benefits with the comparator. Therefore, ΔC represents the change in cost due to the intervention compared with the comparator and ΔE represents the change in health benefits due to the intervention compared with the comparator. The ratio of ΔC and ΔE is interpreted as the amount by which cost changes in order to obtain a unit of health effect and this is the incremental cost-effectiveness ratio (ICER). An average cost-effectiveness ratio is calculated by dividing program costs by the change in outcomes generated by the program. This is defined as the additional outcome achieved by a program compared to a baseline of doing 'nothing'[23]

Table 1 Summary of key features of cost-effective evaluations for smoking-cessation interventions

First Author & Year	Interventions	Assumptions regarding compliance	Viewpoint	Price Year	Key findings	Converted ICERs to 2006 Euros
Fiscella 1996[35]	Counselling + nicotine patch vs counselling	Quit rate 4-7.9%, natural quit rate 2.5%, relapse rate 10-50%, future quit rate 1-4%	Consumer	1995	US$4,390 -$10,943 per QALY (women) US$4,955 -$6,983 per QALY (men) variation depends on age, sensitive to quit rates & discount rate	Up to €12,449 per QALY gained
Lowin 1996[44]	Counselling + patch vs counselling vs no intervention	Not stated	Not stated ? provider	1995	£1,742-4,258 per LYS (patch + counselling vs no intvn) variation depends on men/women and age, £1,846 per quitter vs counselling, lowest ICER for men aged 45-55 years	Up to €5,996 per LYS
Mudde 1996[42]	Self-help vs group based intvn	Quit rate 12-23%	Provider, consumer, society	1990	[1]US$648 - $1,297 per quitter, variation depends on number of quitters	No ICER provided
Wasley 1997[43]	Counselling + nicotine patch vs counselling	Quit rate 4.5-17.6%, natural quit rate 1%, relapse rate after 1 year 35%	Not stated ? Consumer, provider	1995	US$1,796-$2,949 per LYS (men) US$3,040-$4,391 per LYS (women) variation depends on age	Up to €4,996 per LYS
Meenan 1998[39]	Counselling + education + follow up vs usual care	Incremental quit rate 0.6-0.8%	Hospital	1994	US$1,691-$7,444 per LYS, variation depends on discount and quit rates For 500 smokers $175-$770 per LYS	Up to €8,708 per LYS
Crealey 1998[38]	Pharmacy-based program vs no intervention	Quit rate 5-25%, relapse rate 0-15%, natural quit rate 0-2%	Service provider	1997	£197 - £351 per LYS (men) £181 - £772 per LYS (women), sensitive to success rates, lowest ICER for men aged 50-65 years	Up to €1,029 per LYS
Stapleton 1999[41]	GP counselling +booklet + NRT vs counselling	Quit rate 2.8-11.3%, relapse rate after 1 year 30-50%, natural quite rate 1.2-1.8%	Health system	1998	£345 - £785 per LYS, variation depends on age group, lowest ICER for 35-44 years	Up to €1,012 per LYS
Cromwell 2001[33]	15 smoking cessation strategies recommended by US guidelines	Quit rate 5.6-21.6%, relapse rate 35-55%, natural quit rate 5%	Society	1995	US$1,171 - $2,406 per QALY, Lowest ICER for counseling + nicotine patch US$2,310-$4,745 per quitter	Up to €2,737 per QALY gained Up to €5,398 per quitter
Pollack 2001[31]	Smoking cessation for pregnant women vs control	Quit rate 15%	Not stated ?health	1998	US$210,500 per SIDS death averted	€223,899 per SIDS death averted

			system			
Tran 2002[95]	Pharmacy advice ± cold turkey, patches, gum, bupropion vs no intvn	Quit rate 15-40%	Consumer	Not stated	Cost per quitter vs no intvn: US$236 cold turkey, $936 patch, $1,232 gum $1,150 bupropion, US$720-1,418 per LYS, US$450-578 per QALY	Conversion not possible
Song 2002[40]	NRT vs bupropion vs GP advice	Quit rate 3-12%, natural quit rate 0.5-2%, relapse rate 30-40%	Health service	2001	US$1,441-$3,455 per LYS NRT vs advice, $920-$2,150 bupropion + advice per LYS, $1,282-$2,836 per LYS NRT + bupropion + advice	Up to €3,374 per LYS
Chirikos 2004[32]	Different combinations of high/low contact with high/low content to prevent relapse vs NRT± intensive counselling	Relapse rate 0%, relapse rate at 2 yrs 34-42%	Consumers	2000	Relapse intvn US$2,400 - $4,300 per QALY, US$5,000-$9,100 per QALY excludes natural quitters, $488 mean cost to patient to quit	Up to €9,162 per QALY gained
Javitz 2004[37]	Different combinations of bupropion doses and counselling	Quit rate 7.9-14%, relapse rate 0-37%, natural quit rate 0-2.5%	Not stated ?Service provider	Not stated	$US528-$2,194 per LYS, $US512-$1,796 per QALY, lowest ICERs for men aged 30-65 years, sensitive to discount and quit rates	Conversion not possible
Gilbert 2004[36]	Pharmacotherapies + counselling vs counselling only	Quit rate counselling OR 1.73, natural quit rate 2.5%, relapse rate 35% after 1 year	Health service	2002	$US 1,311-$6,032 LYS (men) $2,052-$9,777 (women), lowest ICERs for men aged 35-49 years	Up to € 9,422 per LYS
Feenstra 2005[34]	5 intvns – minimal contact, counselling + NRT, intensive counselling ± bupropion, telephone counselling vs current practice (mix of above)	Quit rate 3.4-17.2%	Societal	2000	€1,600 - €10,500 per QALY, counseling with bupropion more C/E than intensive counseling with NRT	€13,909 per QALY gained

Abbreviations: C/E – cost-effectiveness, GP – general practitioner, ICER – incremental cost-effectiveness ratio, LYS – life years saved, intvn – intervention, NRT – nicotine replacement therapy, QALY – quality-adjusted life-year, SIDS – Sudden Infant Death Syndrome.

1. Average cost-effectiveness ratios reported only

Table 2 Summary of key features of cost-effective evaluations for alcohol abuse interventions

First Author & Year	Interventions	Time horizon	Viewpoint	Price Year	Key findings	Converted ICERs to 2006 Euros
Downs 1995[56]	Screening +counselling high-risk taking adolescents vs no program	5 years	Society	Not stated	US$10,000-12,000 per LYS @ 5% efficacy, marginal costs of adverse events prevented $4,580	No conversion possible
O'Farrell 1996[48]	Behavioural marital therapy ± alcohol counselling vs individual counselling	2 years	Society	1992	[1]Benefit to cost ratios: counselling+marital vs individual counselling $8.64 for every $1 invested Average cost per continuously abstinent rate: US$2,143 counselling + marital, $3,580 interaction couples counselling	€10.67 saved for every €1 invested
Lindholm 1998[51]	Screening and advice to people with alcohol problems – two different program intensities	Lifetime	Not stated ?Health provider	1997	<€44,000 per LYS in more intensive intervention, lower ICER for nurse-led rather than GP	€ 51,674 per LYS
Pettinati 1999[53]	Inpatient vs outpatient treatment based on multimodal 12-step program	3 months	Not stated ?Consumer	Not stated	[1] US$9,014 for 3 month inpatient vs outpatient US$1,420 per probability of return to drinking	No ICER provided
Weisner 2000[55]	Day hospital vs outpatient program for alcohol and drug dependence	8 months after program	Provider	Not stated	US$9,576 per drug and alcohol abstinence (self-selected group), US$5,464 per alcohol abstinence for day hospital vs outpatient program	No conversion possible
Fleming 2002[46]	Long-term GP advice vs booklet	4 years	Health system & society	1993	Health system net benefit US$546 per pt (95%CI $71, $1164) Societal net benefit US$7,780 per pt (95%CI $894, $14,668)	€9,334 net benefit per patient to society
Spoth 2002[45]	Two youth alcohol-prevention in young adults – 7 session vs 5-session family programs	4 years	Society	1992	[1]US $12,459 per prevented case (7 session intvn) and $20,439 per prevented case with 5 session intvn, Net benefit $5,923 and $2,697 per family, $9.60 saved for every $1 invested or $5.85 – both programs cost-beneficial.	€7,319 net benefit per family to society
Corry 2004[52]	Current care vs optimal care vs no treatment	1 year	Government	1997	Compared to no treatment, current care AU$98,095 and optimal care AU$57,542 per years of life in disability averted.	€ 123,549 per years of life in disability averted € 72,473 per years of life in

						disability averted
UKATT 2005[49]	Social behaviour vs motivational enhancement therapies	1 year	Provider + public sector	2001	£18,230 / QALY for motivational relative to social behaviour therapies, social therapy dominates If WTP £30,000 motivation therapy 58% probability of being C/E vs social therapy	€ 23,865 per QALY gained
Fals-Stewart 2005[54]	Brief cognitive behavioural therapy vs standard CBT vs individual-based therapy vs psychoeducational therapy for couples	1 year	Society	Not stated	Average C/E for every $100 spent on brief CBT. Brief CBT as efficacious as standard CBT 4.61 vs 3.30	No conversion possible
Genitello 2005[47]	Alcohol screening and intervention vs none in trauma patients attending an emergency department	1 year	Health provider	2000	US $43.81 saved for every $ 1 spent on intervention, cost saving $89 per injured adult, 91.5% probability findings are C/E	€ 3.84 saved for every € 1 invested. €77 saved per injured adult.
Mortimer 2005[102]	Brief intvn vs psychotherapy vs drug therapy for problem and dependent drinkers vs usual care	Lifetime	Society	2003	AUD $490-$12,966 per QALY, higher for more intensive intvn and very dependent drinkers	€ 13,824 per QALY

Abbreviations: C/E – cost-effectiveness, GP – general practitioner, ICER – incremental cost-effectiveness ratio, LYS – life years saved, intvn – intervention, QALY – quality-adjusted life year, CBT – cognitive behavioural therapy.
1. Average cost-effectiveness ratios reported only

Table 3 Summary of key features of cost-effective evaluations for physical activity interventions

First Author & Year	Interventions	Time horizon & assumptions	Viewpoint	Price Year	Key findings	Converted ICERs to 2006 Euros
Ades 1997[57]	Cardiac rehabilitation exercise vs no intervention	Lifetime modelling, assumed no difference in benefit after 3 yrs	Consumer	1995	US $2,130 per LYS (1985) US $4,950 per LYS (1995)	€ 5,631 per LYS
Stevens 1998[68]	Exercise intvn for 45-74 yr olds vs minimal written materials	8 months	Not stated ?Service provider	Not stated ?1997	[1]£623 per % decrease in sedentary persons, £2,498 per inc persons active, £327 per change of person to higher exercise level	No ICER provided
Sevick 2000[67]	Compares exercise lifestyle intvn vs structured behavioural skills in sedentary adults Project ACTIVE	2 years	Service provider and consumer	Not stated ?1994	[1]$US 343 per mth per additional kg lost at 2 years, Total costs were $49,805 for lifestyle intvn vs $134,411 structured intvn	No conversion possible
Lowensteyn 2000[59]	Supervised vs unsupervised exercise program for cardiovascular disease (CVD)	Lifetime modelling, compliance 20-50%	Service provider	1996	<US$12,000 / LYS all pts, <$15,000 per LYS men (CVD), $12,000-$43,000 women (CVD) and men (no CVD), basic unsupervised intvn highly C/E all groups	Up to € 47,515 per LYS
Georgiou 2001[58]	Exercise training for chronic heart failure vs no intervention	14 months, after follow-up survival identical across groups	Not stated ?Society	1999	US$1,773 per LYS, included medically stable heart failure male pts only 55-64 yrs, omitted some societal costs	€ 1,845 per LYS
deVries 2002[62]	Combinations of walking exercise ± vascular surgery	Lifetime modelling	Society	1995	US$38,000 per QALY gained PTA/EX (vs EX only) US$311,000 per QALY gained EX±PTA/bypass (vs PTA/EX) Surgeries high risk and expensive.	€ 43,230 per QALY gained PTA/EX vs EX
Treesak 2004[65]	Supervised exercise vs lower extremity PTA vs no intervention	1 year Weekly compliance rate 0.89 for 3 months	Society	2001	Exercise therapy at 6 months cost-saving compared to PTA. Cost per increase in walking ability. Exercise therapy clinically efficacious and cost-effective	€ cost-saving
Munro 2004[64]	Exercise intvn for 65+yrs vs control	Low adherence, similar survival	Service provider	1994	€17,174 per QALY (95%CI €8,300-87,120), 2 year time frame	€ 29,310 per QALY gained

		across groups				
Yu 2004[90]	Cardiac rehabilitation with exercise vs no intervention	Life expectancy same in 2 groups	Health system	2003	US-$650 (saving) per QALY per patient, n=181 in cardiac rehabilitation, cost-saving, 2 year follow-up	-€612 (saving) per QALY gained
Proper 2004[103]	Physical activity counselling at a work site vs no intvn	9 months	Employers	Not stated	€ 305 net costs gained from intvn, benefits in terms of costs of reduced sick leave payments	Conversion not possible
Briffa 2005[50]	Exercise-based cardiac rehabilitation vs usual care	1 year	Health system	1998	AUD $42,535 per QALY – sensitive to utility scores	€ 53,119 per QALY
Gordon 2005[63]	Physical therapy + support at home vs group exercise + psychosocial support vs no intervention for women with breast cancer	1 year	Society	2004	A$1,344 per QALY physical therapy intvn vs A$14,478 per QALY group exercise + support, modest difference in effects At WTP $14,400 50% probability that both interventions are C/E	Up to € 13,235 per QALY gained
Dalziel 2006[61]	GP intervention vs usual care	1 year Survival rates 0.59-0.71 relative risk, active vs inactive	Health system	2001	NZ$2,053 per QALY ($827 - $37,516) 90% of ICERs < $7,500, behaviour maintenance questionable but estimates conservative	€ 2,162 per QALY gained

Abbreviations: C/E – cost-effectiveness, CI – confidence interval, CVD – cardiovascular disease, EX – exercise, GP – general practitioner, intvn – intervention, ICER – incremental cost-effectiveness ratio, LYS – life years saved, PTA – percutaneous transluminal angioplasty, QALY – quality-adjusted life year, WTP – willingness to pay.

1. Average cost-effectiveness ratios reported only

Table 4 Summary of key features of cost-effective evaluations for dietary interventions

First Author & Year	Interventions	Time horizon	Viewpoint	Price Year	Key findings	Converted ICERs to 2006 Euros
Franz 1995[69]	Dietitian best practice advice vs basic care for diabetics	6 months	Health system	1993	[1]US$5.32 /mg/dL change in fasting glucose level vs $4.20 best practice, no stat. sign.	No ICER provided
Brannon 1997[72]	Parent/child diet program vs dietitian for children	1 year	Patient/ family	1992	[1]Parent/child US$130 per % decrease fat vs counselling $82 – 12 months, Parent/child $36/mg/dL plasma low density lipoprotein vs counselling $30	No ICER provided
Glasgow 1997[75]	Brief GP intervention vs usual care	1 year	Health provider	Not stated	$62 vs $105 per 1% reduction in diet and saturated fat intake, respectively. Increase cost per unit decrease in cholesterol (mg/dL) $8.	No conversion possible
Pritchard 1999[73]	GP + dietitian counselling vs GP vs no intervention	1 year	Health system	1994	AUD$9.76 per extra kg lost for GP/dietitian group, $7.30 per extra kg lost dietitian only, better outcomes if GP involved	€14 per extra kg lost GP+ dietitian
Yokoyama 2002[70]	Dietitian counselling + education + multidisciplinary care vs usual care	2 years	Health insurer	2000	US$3,680 per patient achieving glycaemic control	€3,705 per patient achieving glycaemic control
Olsen 2005[71]	GP + dietitian counselling vs no intvn for pts with ischemic heart disease	Lifetime 1 year LYS assumed for lifetime maintenance	Health system	2001	GP DKK8,213 per LYS, dietitian DKK59,987 per LYS, gains modest i.e. 14-44 days gained, If WTP 25,000 DKK per LYS, GP intervention acceptable only	GP € 1,199 per LYS Dietitian € 8,757 per LYS
Tsai 2005[74]	Low carbohydrate vs standard diet	1 year, no differences in effects after 1 year	Society	2001	US -$1,225 per QALY (low carb diet dominant) but costs and QALYs not statistically different, wide 95%CIs and ICER spans 1 (weak result).	Cost saving per QALY gained (low carb diet dominant)

Abbreviations: AUD – Australian dollar, C/E – cost-effectiveness, DKK – Danish krone, intvn – intervention, GP – general practitioner, ICER – incremental cost-effectiveness ratio. LYS – life years saved, QALY – quality-adjusted life year.

1. Average cost-effectiveness ratios reported only

Table 5. Summary of key features of cost-effective evaluations for multiple behaviour interventions

First Author & Year	Interventions	Modelling approach	Viewpoint	Price Year	Key findings	Converted ICERs to 2006 Euros
Johannesson 1995[104]	Multiple behaviour intvn vs pharmacotherapy for hypertensive pts	Framingham coronary heart disease model	Society	1991	62,000 – 163,000 SEK per LYS depending on different estimates of risk factors, highly sensitive to assumptions about quality of life during treatment	Up to € 22,034 per LYS
Field 1995[76]	Health checks + counselling ± pharmacotherapy	Framingham coronary heart disease model	National Health Service	Not stated ?1993	?£1,240 - £2,180 per LYS depending on basic to comprehensive intvn, more cost-effective in men and those higher in age.	Conversion not possible
Oldenburg 1995[105]	Health risk assessment vs risk factor education vs behavioural counselling vs behavioural counselling+ incentives	-	Health system	Not stated	Behavioural counselling more C/E than risk factor education at maintenance phase (1 year)	Conversion not possible
Lindholm 1996[106]	Community health promotion activities to prevent CVD	-	Health system, societal	1992	[1] Societal £1200 per LYS (range £14,900 to net savings) Health system £1100 to £4050	No ICER provided
Johannesson 1996[85]	Usual vs intensive counselling with or w/o pharmacotherapy in high-risk CVD population	CVD risk factor modelling	Health system	1991	US $51,000 usual advice + drug vs intensive treatment. Intensive treatment is not C/E – dominated.	€ 64,921 per LYS
Salkeld 1997[78]	GP lifestyle intvn for cardiovascular disease vs routine care	Simulation model	Govt health provider	1994	AUD$191,689 per LYS, $152,128 per QALYs (men), sensitive to behaviour change through time, $29,574 per QALY high risk men, small benefits found	€259,874 per LYS, €206,241 per QALY gained (men) €53,469 per LYS, €40,094 per QALY gained (high risk men)
Segal 1998[79]	Six programs for diabetes – surgery, group behaviour, media campaign, GP advice, intensive diet and behaviour program vs no intvn	Markov modelling, Success rates 10-50%	Health system	1997	Behavioural/diet programs for high risk groups highly C/E relative to other programs AUD$1000-$2600 per LYS, surgery poorest option, exploratory analysis	Up to €3,274 per LYS
Wylie-Rosett 2001[88]	Weight loss intervention – minimal, intermediate and intensive levels	-	Health provider	Not stated ?1997	[1]US $ 6.32 , $8.57, $18.78 per pound of weight lost for minimal, intermediate, intensive levels	No ICER provided

Finkelstein 2002[87]	Cardiovascular disease screening with enhanced vs minimal lifestyle intvn (WISEWOMAN project for financially vulnerable)	Coronary heart disease risk factor model	Not stated ?Service provider	Not stated ?1996	US$637 for % point decrease in 10-year probability of coronary heart disease (enhanced over minimal program) , reductions in two programs not statistically significant.	Conversion not possible
Yosefy 2003[89]	Diet, exercise, smoking-cessation, pharmacotherapy for hypertension	-	Not stated ?Service provider	2002	[1]US$506 per LYS , program needs to run for 10 years for positive C/E results (savings), little synthesis of costs and effects.	No ICER provided
Lindgren 2003[77]	Combinations of exercise + diet advice + no intervention	Framingham coronary heart disease model	Society + Health system	2000	127,065 SEK per LYS dietary vs control, if declining effect of intvn assumed, diet most C/E option	€ 15,375 per LYS
Wang 2003[80]	School-based obesity program vs no intvn	25 year decisional model	Society	1996	$US 4,305 per QALY gained, 95% CI $1,615-9,010, cost savings $7,313, 80% probability	€ 4,757 per QALY gained € 8,801 net cost savings
Warren 2004[86]	Pharmacotherapy + diet + lifestyle advice vs advice only	Framingham coronary heart disease model	National Health Service	2000	£4,870 per QALY for Sibutramine + lifestyle vs lifestyle alone	€ 6,005 per QALY gained
Herman 2005[82]	Lifestyle modification vs pharmacotherapy vs placebo for adults at risk for diabetes	Markov modelling	Health system & societal	2000	US$1,124 per QALY lifestyle vs placebo $31,286 per QALY medication vs placebo Lifestyle dominant	€ 1,132 per QALY gained
Raftery 2005[84]	Nurse-led clinic lifestyle vs medical care	Monte Carlo simulation	Society	1999	£1,236 LYS, £1,097 per QALY, 70% probability intvn will be ≤ £5,000 per QALY	€ 1,569 per QALY gained
Eddy 2005[81]	Lifestyle modification vs pharmacotherapy vs placebo for adults at risk for diabetes (re-analysis of Herman 2005)	Archimedes modelling	Society, Health provider, High risk individual	2000	Lifestyle vs baseline US$24,523 per QALY Intensive lifestyle vs lifestyle $201,818 per QALY, sensitive to effectiveness estimates	€ 24,691per QALY gained €203,197 per QALY gained intensive vs lifestyle
Malone 2005[83]	LOSE weight program with and without pharmacotherapy	Bootstrapping ICERs, Monte Carlo simulations, 1 year timeframe post-intvn	Health provider	2004	US $ 194 per additional pound of weight lost (or $423 per Kg) when all health care costs included	€ 178 per additional pound of weight lost

Abbreviations: C/E – cost-effectiveness, QALY – quality-adjusted life year, CVD – cardiovascular disease, GP – general practitioner, ICER – incremental cost-effectiveness ratio, intvn – intervention, LYS – life years saved.

Average cost-effectiveness ratios reported only

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