matrix research and consultancy

NICE

Modelling the cost effectiveness of physical activity interventions

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Contents

1.0 Executive summary

Objective. The aim of this paper is to determine the cost effectiveness of four types of intervention aimed at increasing physical activity levels:

- brief interventions in primary care;
- pedometers;
- exercise referral; and
- walking and cycling programmes in the community.

Method. A review of effectiveness studies was undertaken to determine the impact of the interventions on physical activity levels. Studies were identified for only two of the interventions: brief intervention in primary care and exercise referral.

An economic model was constructed to estimate the health benefits of the changes in physical activity levels, and the consequent impact on participants' quality of life and NHS cost savings. The model draws the following estimates from the literature:

- the impact of interventions on participants physical activity levels;
- the impact of these activity levels on participants change of experiencing CHD, stroke, diabetes and colon cancer;
- the impact of experiencing these health states on participants quality of life; and
- the health costs of treating these health states.

Results. When costs are defined as only including the costs of the intervention, all the interventions have a cost per QALY gained significantly less than £30,000 when compared separately with 'usual care': the cost/QALY gained estimates for the interventions reviewed vary from c£20 to c£670.

When costs are defined to include the healthcare costs avoided through avoiding health states, all the interventions are dominant when compared separately with 'usual care'. That is, they result in an increase in quality of life for participants and net costs savings to the health services when compared with usual care: net costs saved per QALY gained vary from c£530 to c£3,150.

A number of assumptions are made in conducting the model. These work to both underestimate and overestimate the cost per QALY gained estimates. The cost-effectiveness estimates are shown not to be sensitive to these assumptions.

Little is known of the demographic characteristics of the participants in the studies on which the analysis is based. However, it is likely that they include few vulnerable groups most at risk of the health states that physical activity is designed to prevent. Furthermore, these vulnerable groups are likely to need more intensive interventions than the participants in the studies and are likely to have a higher rate of relapse. However, the model demonstrates that the interventions are likely to remain cost effective in these circumstances.

Interviews with exercise vouchers (Harland, 1999 B) is the most cost-effective of the interventions reviewed.

2.0 Introduction

2.1 Background

The National Institute of Health and Clinical Excellence (NICE) has been asked by the Department of Health to develop public health intervention guidance on physical activity as part of its 11th Wave.

Public health intervention guidance consists of recommendations on types of activity provided by local organisations to help to promote or maintain a healthy lifestyle or reduce the risk of developing chronic diseases or conditions. This guidance will provide recommendations for good practice, based on the best available evidence of effectiveness, including cost effectiveness.

NICE has been asked to develop public health intervention guidance on four commonly used methods to increase physical activity: brief interventions in primary care, pedometers, exercise referral schemes and community based exercise programmes for walking and cycling.

2.2 The need for guidance

There is a clear link between physical inactivity and ill health. The extent of this link is set out in publications such as the Chief Medical Officer's (CMO) report *At least five times a* week (DoH, 2004), which identifies the contribution of physical activity to the prevention and management of over twenty conditions and diseases including coronary heart disease, diabetes, cancer, positive mental health and weight management. Besides the human costs of inactivity in terms of mortality, morbidity and quality of life, the CMO's report estimates the cost of inactivity in England to be £8.2 billion annually. This excludes the contribution of physical inactivity to obesity, whose overall cost might run to £6.6–£7.4 billion per year according to recent estimates.

The current level of activity recommended for achieving the basic health benefits of physical activity are for adults to achieve at least 30 minutes of at least moderate activity on five or more days of the week or three 20 minute periods of vigorous activity per week (DoH, 1996). Approximately three-fifths of men and three-quarters of women in England are not active at recommended levels (DoH, 2000; Joint Health Surveys Unit, 2003).

Physical activity is an important component of many government policy statements and commitments, it is important in reaching many national targets, and is one of the six priorities outlined in the 2004 white paper, *Choosing Health* (Hillsdon et al, 2005). Most UK-based interventions aimed at increasing individual activity have been based in primary care (Hillsden and Thorogood, 1996; Hillsden et al, 1999), but there is little evidence that such interventions are effective (Fox et al, 1997; Riddoch et al, 1998).

2.3 Objectives

The aim of this paper is to determine the cost effectiveness of four types of intervention at increasing physical activity levels:

- **brief interventions in primary care**: any brief intervention involving verbal advice, encouragement, negotiation or discussion with the overall aim of increasing physical activity delivered in a primary care setting by a health or exercise professional, with or without written or other support or follow-up. A typical example might consist of discussions with the GP or other member of the healthcare team with the aim of enhancing self-efficacy regarding participation, promotion of social support for physical activity, influencing the decisional balance and applying the processes of change as mediators of change.

- **pedometers**: any intervention using pedometers to promote physical activity will be considered (where evidence is found), including purchase by individuals for personal use, provision of a pedometer with or without other advice by a member of the healthcare team, provision of a pedometer with or without advice by another professional/agency.

- **exercise referral**: projects whereby there is a 'referral' of an individual by an appropriate professional to a service where there is a formalised process of assessment of that person's need, development of a tailored physical activity programme to meet that need and monitoring of progress Exercise referral has been an increasingly popular intervention. The Department of Health *National Quality Assurance Framework* (2001) noted a significant and sustained growth in exercise referral schemes over the preceding ten years; and

- **walking and cycling programmes in the community**: projects and groups that aim to increase participation in walking and cycling through involvement in organised walks/rides.

This study reviews the incremental cost and effectiveness of these interventions. A review of the effectiveness of these interventions is used to determine the resources used in the interventions and their impact on physical activity levels. A model is then designed to estimate the impact of the intervention on participants' health and quality of life and savings to the health care system.

3.0 Method

3.1 The model

Figure one outlines the structure of the static decision-analytic model used to estimate the health impact, quality of life outcome and health care system costs and savings as a result of the physical activity interventions.

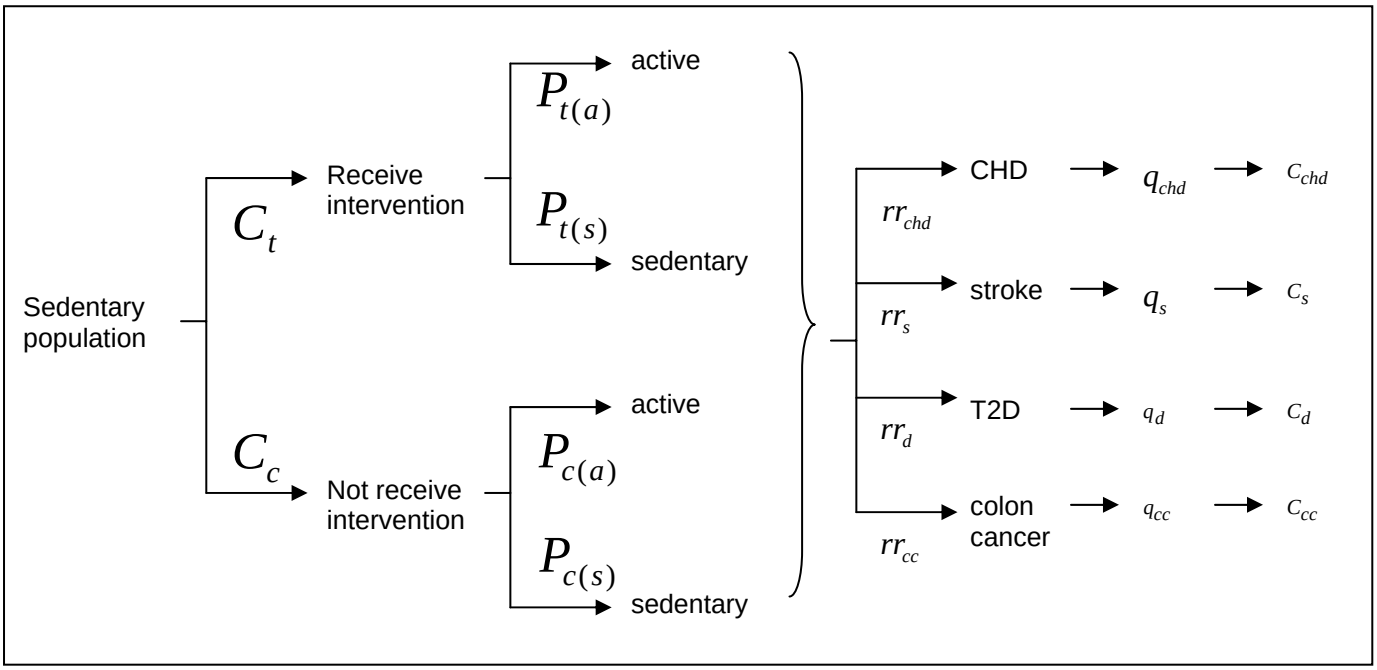

Figure 1: physical activity model structure

Where:

- C_t - C_c = the incremental cost per participant of the treatment per participant;
- $P_{t(a)}$ = the probability that the sedentary population will become and remain active if they receive the intervention;
- $P_{c(a)}$ = the probability that the sedentary population will become active if they do not receive the intervention;
- rr_{chd} , rr_s , rr_d and rr_{cc} = the probability that becoming active causes a person to avoid CHD, stroke, type II diabetes or colon cancer;
- q_{chd} , q_s , q_d and q_{cc} = the loss of QALY quality of life resulting from CHD, stroke, type II diabetes or colon cancer; and

- C_{chd} , C_s , C_d and C_{cc} = the cost of treating CHD, stroke, type II diabetes or colon cancer avoided.

3.2 Analysis

Two cost effectiveness calculations are performed. First, the cost-effectiveness of each intervention was estimated compared with usual care and including just the cost of the interventions:

$$CE = \frac{dC}{dE} = \frac{C_t - C_c}{\left(p_{t(a)} - p_{c(a)}\right)\left[\left(rr_{chd} \cdot q_{chd}\right) + \left(rr_s \cdot q_s\right) + \left(rr_{cc} \cdot q_{cc}\right) + \left(rr_d \cdot q_d\right)\right]}$$

Second, the incremental costs of the interventions were calculated, this time including both the cost of the intervention and the future treatment costs avoided:

$$CE = \frac{dC}{dE} = \frac{(C_t - C_c) - \left(\left(p_{t(a)} - p_{c(a)}\right)\left[\left(rr_{chd} \cdot C_{chd}\right) + \left(rr_s \cdot C_s\right) + \left(rr_{cc} \cdot C_{cc}\right) + \left(rr_d \cdot C_d\right)\right]\right.}{\left(p_{t(a)} - p_{c(a)}\right)\left[\left(rr_{chd} \cdot q_{chd}\right) + \left(rr_s \cdot q_s\right) + \left(rr_{cc} \cdot q_{cc}\right) + \left(rr_d \cdot q_d\right)\right]}$$

The model was run for the only population groups for which the effectiveness studies collected data. It was not thought appropriate to infer the impact of the interventions on physical activity outcomes beyond these groups.

The model was run for the means of the parameters, as well as 95 per cent confidence intervals. High and low cost/QALY results are reported for the combinations of these confidence intervals.

The sensitivity of the analysis to variations in the following variables were tested:

- relative risks of different health states;
- the staff used to deliver the interventions;
- the costs of exercise vouchers; and
- the drop-off in maintenance of exercise following the intervention.

The remainder of this section outlines the methods and datasets used to estimate each of these parameters of the model.

3.3 Review of effectiveness studies

A literature review was conducted to identify studies that used a controlled design to assess the effect of the interventions on physical activity levels in the adult population. Figure two summarises the search terms employed in the literature review. Each search was performed for English language papers published between 1990 and June 2005. For each of the interventions, the following databases were searched: Medline, Pubmed, Embase, Cinahl, PsychInfo and Sports Discuss. For the walking and cycling intervention, Transport Database TRIS was also searched.

Brief Interventions	Exercise referral	Cycling and Walking	Pedometers
Counselling	Exercise	Walk	Pedometers
Counselling	Physical activity	Walking	Step counters
Therapy	Physical fitness	Bicycling	
		Bike	
AND	AND	Cycling	
		Cycle	
Primary care	Referral	Bike riding	
General practice	Primary health care	Led walks	
Physical activity	Prescription	Health walks	
Exercise		Group walks	
Fitness	AND	Pedal back the years	
		Rides	
AND	Study	Riding	
	Intervention		
Controlled trial	Trial	AND	
	Control		
	Controlled	Community	
	Comparison	Project	
	Comparator	Programme	
		Program	
		Trial	

Figure 2: terms used in search of databases

Following the initial search, titles of all identified studies were screened by a lead researcher and irrelevant studies discarded. Abstracts and full papers, where relevant were then reviewed. Studies were included if they:

- assessed the effect of the intervention on physical activity in the adult population using a controlled research design; and
- measured physical activity outcomes (self-reported or objective measures) at baseline and from six week post intervention.

Figure three summarises the results of the review. The papers included in the review are listed in appendix one.

Intervention	Total hits	After review of titles and abstracts	After review of paper
Brief interventions in primary care	1,749	50	12
Walking and cycling programmes	16,599	60	4
Exercise referral schemes	5,549	146	4
Pedometers	475	66	4
	24,372	**322**	**24**

Figure 3: summary of search results

Once the quality of the selected studies had been graded using the NICE internal validity criteria[1], the review concluded that:

- **brief interventions in primary care**: evidence from eleven primary studies (6 individual RCTs, 2 cluster RCTs, and 3 controlled non-randomised trials) suggests that brief interventions in primary care to increase physical activity can be effective in the short term (6 to 12 weeks), longer term (over 12 weeks) and over a very long timeframe (1 year or more);

- **pedometers**: The evidence from four randomised controlled trials for the effectiveness of pedometer-based interventions aimed at increasing physical activity levels in the adult population is equivocal in the short and longer term;

- **exercise referral**: the evidence from four randomised controlled trials suggests that exercise referral schemes can have positive effects on physical activity levels in the short term (6 to 12 weeks), but they are ineffective in increasing activity levels in the longer term (over 12 weeks) or over a very long timeframe (over 1 year).

- **walking and cycling programmes in the community**: the evidence from four primary studies (two individual RCTs, 1 cluster RCT, one delayed intervention study) for the effectiveness of community-based walking and cycling programmes in increasing physical activity is equivocal.

The model described above was applied to “good quality” studies and for the interventions that the above review demonstrated had an effect on physical

[1] NICE (2004), *Guideline Development Methods: Information for National Collaborating Centres and Guideline Developers*. London: Nation Institute for Clinical Excellence, www.nice.org.uk

activity levels (brief interventions in primary care and exercise referral). Appendix two provides a list of the studies included in the model.

Figure four summarises the interventions identified in the review and included in the modelling exercise.

Study	Intervention	Control
Lamb et al (2002)	Participants received: • 30 min advice seminar, advised to do 120 mins per week of moderate intensity physical activity; • this was supplemented by general written guidance; • they also received verbal and written information about health walks programme; and • they were referred to the local walk coordinator (Walks programme: led walks, walk packs and 3 telephone calls).	Participants received: • 30 min advice seminar, advised to do 120 mins per week of moderate intensity physical activity; and • this was supplemented by general written guidance Participants did no received information about the walking programme.
Harland 1999	Participants were split into four interventions groups: • all received brief advice (at baseline assessment from researcher); • all received motivational interviews from health visitor, but the intensity of the interviews varied (1 session or 6 sessions); and • some of the participants received leisure centre vouchers.	Participants received: • brief advice from the researcher at baseline assessment.
Swinburn 1998	Participants received: • brief verbal advice during a consultation with a GP; and • a written prescription.	Participants received: • brief verbal advice during a consultation with a GP.
Petrella 2003	Participants received: • a step test administered by family physician; • patient counselling; and • followed up at 3,6,12 month.	Participants received: • general advise.
Elley 2003	Participants received: • brief oral and written advice (based on motivational interviewing) prompted by the patient and delivered by a GP or a practice nurse; and • 3 phone calls from exercise specialist.	Participants received: • 'usual care'.
Smith 2000	Participants received one of two interventions: • written prescription (stage based advice) by a GP during consultation; and • randomised to either no further intervention or mailed stage based pamphlet after two weeks.	Participants received: • 'usual care'.

Hillsdon 2002	Participants received one of two interventions: • 30 minute session delivered by health promotion specialist delivering either brief negotiation based on motivational interviewing or direct advice; • 6 follow up phone calls up between 2 weeks and 34 weeks.	Participants received: • usual GP care as appropriate.

Figure 4: Interventions included in the modelling exercise

It is also important to note that the participants receiving the intervention varied between studies. Figure five shows the characteristics of the samples used in each study. While all studies measured the impact of the interventions on both genders, the age of the participants varied between studies.

Study	Sample	
	Gender	Age
Lamb 2002	Male and Female	40-60
Swinburn 1998	Male and Female	mean 49 (SD15)
Harland 1999	Male and Female	40-64
Petrella 2003	Male and Female	>65 (mean 73)
Elley 2003	Male and Female	40-79
Smith 2000	Male and Female	25-65
Hillsdon 2002	Male and Female	45-64

Figure 5: description of study samples

3.4 Cost of the intervention

The incremental cost of the intervention to the public sector[2] was estimated as the cost/participant of the intervention less the cost per participant for the alternative used in the studies identified. The extra resources used per participant in the intervention compared with the control were derived from the effectiveness studies. The cost of these resources was then calculated by applying appropriate tariffs[3]. Figure six summarises the estimated incremental cost per participant of the interventions.

[2] In addition to the conventional NHS and personal social services (PSS) perspective adopted by NICE, this analysis adopts a public sector perspective, defining relevant costs as any costs incurred by the public sector.

[3] Curtis, L. and Netten, A. (2004), Unit costs of health and social care. PSSRU: University of Kent. (The model uses the £ / hour of patient contact rates, including the "cost of qualifications": GP time is assumed to cost £123/hour)

A number of assumptions are made in deriving these cost figures:

- where the person undertaking the intervention is not specified, it is assumed to be delivered by a practice nurse (£28/hour);
- where the person undertaking follow-up telephone calls and investigations is not specified, it is assumed to be a heath assistant (£18/hour);
- the input of a exercise specialist and GP trainer is valued using the hour rate of a physiotherapist (£44);
- it is assumed that vouchers for one episode of exercise activities, such as swimming, are worth £5;
- phone calls are assumed to be 5 minutes, unless specified, and the actual telecom cost is assumed to be £6 per hour;
- the cost per participant of training a GP assumes 10 GPs attend training sessions, except in the Smith 2000 study where the training is provided at the surgery and the number of GPs per surgery is two; and
- mailers and brochures are assumed to cost £4 per participant, unless it is specified that the mailer/brochure is large or more elaborate, in which case it is assumed to cost £8.

It is important to note that the costs included in the model are only those specified in the effectiveness studies. This would suggest that the cost and cost/QALY estimates emerging from the model are underestimates.

Resource type	Elley 2003 (£)	Harland 1999 (£)				Hillsdon 2002 (£)		Lamb 2002 (£)	Petrella 2003 (£)	Smith 2000 (£)		Swinburn 1998 (£)
		Brief	Brief + vouchers	Intensive	Intensive + vouchers	Brief negotiation	Direct advice			Prescription	Prescription and booklet	
GP time - training	127.10								6.15	2.05	2.05	8.20
GP time - intervention	24.60								24.60	20.50	20.50	10.25
GP trainer's time	4.40								-	-	-	-
Nurse / researcher time		18.67	18.67	112.00	112.00							
Phone follow ups	4.50	0.50	0.50	0.50	0.50	4.20	4.20	1.50	2.80	1.50	1.50	0.50
Phone interviewer's (HA) time		1.50	1.50	1.50	1.50	12.60	12.60	7.00	8.40	4.50	4.50	1.50
Exercise specialist's time	33.00											
Cost of mailers and brochures	4.00	8.00	8.00	8.00	8.00			8.00			8.00	
Cost of vouchers			150.00		150.00							
Walk Co-ordinator - intervention								5.60				
Ind. investigator's (HA) time								3.00				
Total cost	**197.60**	**28.67**	**178.67**	**122.00**	**272.00**	**16.80**	**16.80**	**25.10**	**41.95**	**28.55**	**36.55**	**20.45**

Figure 6: incremental cost per participant

Figure seven compares the cost per participant calculated in figure four with the types of intervention delivered. It demonstrates that:

Study	Intervention	Incremental cost / participant
Hillsdon 2002	Motivational interviews vs. nothing	£16.80
Hillsdon 2002	Direct advice vs. nothing	£16.80
Swinburn 1998	Exercise prescription vs. advice	£20.45
Lamb 2002	Advice and exercise prescription vs. advice	£25.10
Smith 2000	Exercise prescription vs. advice	£28.55
Harland 1999	Interview vs. advice	£28.67
Smith 2000	Exercise prescription and further information vs. advice	£36.55
Petrella 2003	Exercise prescription vs. advice	£41.95
Harland 1999	Intensive interview vs. advice	£122.00
Harland 1999	Interview and exercise vouchers vs. advice	£178.67
Elley 2003	Exercise prescription vs. Advice (GP receives intensive training)	£197.60
Harland 1999	Intensive interview and exercise voucher vs. advice	£272.00

Figure 7: incremental cost per participant

The studies selected can be categorised into a range of types of interventions of varying resource intensity:

- advice and negotiation (advice regarding the benefits of physical activity, or some form of motivation interviewing) compared against no advice (Hillsdon, 2002);
- participant interviews compared against just advice (Harland, 1999 and Hillsdon, 2002);
- exercise prescription compared against advice (Swinburn 1998, Smith 2000, Lamb 2002, Patrella, 2003);
- intensive participant interviews compared with just advice (Harland, 1999)
- participant interview and vouchers to pay for exercise activities compared against just advice (Harland, 1999);
- exercise prescription where the GP has undergone intensive training compared against advice (Elley, 2003); and

- intensive participant interviews and vouchers to pay for exercise compared just advice (Harland, 1999).

Figure eight shows that the average cost per participant of these interventions is broadly what would be expected.

Intervention	Cost per person
Advice	£16.80
Interviews	£22.74
Exercise prescription	£30.52
Intensive interviews	£122.00
Interviews and exercise vouchers	£178.67
Exercise prescription with intensive GP training	£197.60
Intensive interviews and exercise vouchers	£272.00

Figure 8: average incremental cost per participant

3.5 Probability of increasing physical activity

Assumptions/caveats:

- the model assumes a 50% drop off in the physical activity outcomes identified. The sensitivity of the results of the model to this assumption is tested during the analysis; and
- it is assumed that physical activity outcomes identified are maintained over a period sufficient to ensure that the health benefits associated with that level of activity are attained.

The probability that the intervention increases physical activity are drawn from the effectiveness studies. There are a number of challenges modelling the health outcomes that result from this change in physical activity. First, the effectiveness studies all use different physical activity outcome measures, including measures of fitness (VO2 max), measures of energy consumption kcal/kg/week) and levels of activity (sedentary, moderate, vigorous).

This variety of physical activity outcome measures employed by the effectiveness studies is a challenge to the modelling of health and quality of life outcomes. This will be overcome by matching the units used to measure physical activity in the effectiveness study with the units used to create estimates of the change in relative risk (RR) of experiencing a health state that results from increased physical activity. That is, each physical activity outcome variable will be matched with a different RR score. Further detail on this matching of outcome variables is available in the next section.

Second, it is important for the health benefits of physical activity to be achieved that a regular pattern of physical activity is maintained to sustain the physical changes that are assumed responsible for the health benefits (Surgeon General, 1996).

The model adjusts the study outcomes to allow for a 50% drop off in the number of people increasing their physical activity levels as a result of the intervention, and then assumes that the resulting increase in physical activity is maintained long enough to obtain the health benefits of that physical activity level.

Third, in order to model the impact of changes in physical activity on health states and QALYs, physical activity outcomes need to be matched with RR scores from the literature. RR scores take the form of changes in the relative risk of suffering a particular health state if a particular physical activity threshold is achieved and maintained. Therefore, in order for effectiveness studies and RR studies to be matched, the effectiveness studies need to provide estimates of the change in the probability that participants will achieve these thresholds as a result of the intervention, or data from which such figures can be calculated. One effectiveness study provides estimates of the

change in the mean energy consumption as a result of the intervention (Hillsdon, 2002). Such data could not be converted into the format required for matching with the RR score literature, so these studies were removed from the modelling exercise.

Figure nine shows the effect sizes of the intervention, converted, where possible, into an estimate of the proportion of participants who achieved the physical activity threshold used in the studies as a result of the intervention.

Study	Type	Physical activity threshold	% achieve threshold as result of intervention
Hillsdon 2002	Interviews	Continuous variable (kcal / kg / week) could not calculate threshold	N/A
Hillsdon 2002	Advice	Continuous variable (kcal / kg / week) could not calculate threshold	N/A
Swinburn 1998	Prescription	Became 'active' as a result of the intervention	23.2%
Lamb 2002	Prescription	Became active (>= 120 min of moderate intensity activity per week) as a result of the intervention	5.7%
Smith 2000	Prescription	Achieved a increase in time spent physically active of 60 min	1.4%
Harland 1999	Interview	Achieved an increase in the number of vigorous activity session (>7.5 kcal / min)	6.0%
		Achieved an increase in the number of moderate activity sessions (5 - 7.5 kcal / min)	22.0%
Smith 2000	Prescription	Achieved a increase in time spent physically active of 60 min	4.8%
Petrella 2003	Prescription	Achieved a significant increase in VO2 max	14.0%
Harland 1999	Intensive interviews	Achieved an increase in the number of vigorous activity session (>7.5 kcal / min)	10.0%
		Achieved an increase in the number of moderate activity sessions (5 - 7.5 kcal / min)	8.0%
Harland 1999	Interviews and vouchers	Achieved an increase in the number of vigorous activity session (>7.5 kcal / min)	10.0%
		Achieved an increase in the number of moderate activity sessions (5 - 7.5 kcal / min)	23.0%
Elley 2003	Prescription	Achieve >2.5 hours of moderate or vigorous activity per week	9.7%
Harland 1999	Intensive interviews and vouchers	Achieved an increase in the number of vigorous activity session (>7.5 kcal / min)	6.0%
		Achieved an increase in the number of moderate activity sessions (5 - 7.5 kcal / min)	0.0%

Figure 9: changes in physical activity as a result of the intervention

These estimates of change in physical activity cannot be combined to provide an average for intervention types due to the different physical activity measures used in the studies. Figure ten shows the average proportion of participants achieving different physical activity thresholds as a result of the interventions.

Intervention type	Average cost	Became 'active' as a result of the intervention	Became active (>+120min moderate activity / week)	Achieved an increase in time spent physically active	Achieved an increase in the number of vigorous activity sessions (>7.5 kcal / min)	Achieved an increase in the number of moderate activity sessions (5-7 kcal / min)	Achieved a significant increase in VO_2 max	Achieved >2.5 hours mod/vig activity per week
Advice	£16.80							
Interviews	£22.74				6.00%	22.00%		
Exercise prescription	£30.52	23.20%	5.70%	3.10%			14.00%	
Intensive interviews	£122.00				10.00%	8.00%		
Interviews and exercise vouchers	£178.67				10.00%	23.00%		
Exercise prescription with intensive GP training	£197.60							9.70%
Intensive interviews and exercise vouchers	£272.00				6.00%	0.00%		

Figure 10: percent of participants achieving physical activity levels as a result of interventions

3.6 Relative risk of experiencing health states

Assumptions/caveats:

- the model will focus on CHD, stroke, type 2 diabetes and colon cancer health states;
- it is assumed that the changes in physical activity identified in the effectiveness studies are equivalent to those used to measure relative risks;
- it is assumed that participants in the effectiveness studies have the same baseline risk level and experience the same change in risk level as participants of the studies to calculate the relative risks of experiencing health states between those who undertake physical activity and those who don't;
- the model ignores the possibility that some people have more than one risk factor for a disease; and
- the model assumes that the risk of experiencing a health state is independent of the risk of experiencing other health states.

Physical activity has been linked with a wide range of health benefits, including reduced risk of CHD, numerous forms of cancer (colon, rectal, endometrial, ovarian, testicular, breast and prostate cancer), and non-insulin-dependent diabetes mellitus, depression and anxiety, osteoporosis, and reduced blood pressure in people with hypertension (Colditz, 1999; Katzmarzyk et al, 2000; Surgeon General, 1996). The modelling will focus on

CHD, stroke, type 2 diabetes and colon cancer health states, as it was thought that these are most likely to be influenced by physical activity levels.

There is already a vast number of epidemiological studies comparing the physical activity levels of cohorts who have or develop diseases with those who do not. These have been used by a number of authors to calculate the relative risk of experiencing a health state for somebody who is active compared with somebody who is sedentary. The Surgeon General's report examines the strength of the associations reported in the studies and the research designed employed, the consistency of the findings, the temporality of the effects identified, and the biological gradient and feasibility of the impact of physical activity, and conclude that:

> The inverse association between physical activity and several disease states is moderate in magnitude, consistent across studies that different substantially in methods and populations, and biologically plausible. […] it is reasonable to conclude that physical activity is causally related to the health outcomes reported (Surgeon General, 1996: 145).

A literature review was undertaken to identify the change in relative risk (RR) of experiencing CHD, stroke, type II diabetes or colon cancer between different levels of physical activity. Appendix three summarises the outcome of the literature review. The physical activity levels used to calculate these RRs were then matched with the physical activity outcome variables employed in the effectiveness review to determine the 'most appropriate' RR using the following decision rules:

- the physical activity measures employed in the RR and effectiveness studies should be as similar as possible;
- the population on which the RR and effectiveness studies are based should be as similar as possible; and
- where possible, an RR study that presents 95% confidence intervals is selected to provide an estimate of the variance in RR scores.

In the event that these rules still result in a number of alternative RR studies, the RR score used in the model is the average of the mean RR scores, and the lower and higher ends of the 95% confidence intervals are used to estimate the variance. In the event that the rules did not identify an appropriate RR study, the average of the RR studies identified for the same disease state other effectiveness studies was taken, and the measure of variance employed was the lower and higher of the 95% confidence intervals from those scores. Figure eleven summarises the outcome of this matching exercise.

Study	Outcome Variables	Study population	Matched RR studies (95% CI)			
			CHD	Stroke	Diabetes	Colon Cancer
Lamb 2002	% of participants achieving 120 mins of moderate intensity activity per week	M/F, 40-60 yrs	Shaper et al (1991), RR = 2.00 (1.25, 5.00), M/F, 40-59	Herman et al (1983), RR = 1.39 (0.70, 2.70), M/F, 40-74	Average RR= 1.97 (1.06, 5.44)	Average RR= 1.53 (1.0, 2.5)
Petrella 2003	% of participants with a significant increase in VO2 max	M/F, >65 yrs	Combine matches, RR = 1.83 (0.94, 4.70)	Average RR= 1.6 (0.79, 4.76)	Average RR= 1.97 (1.06, 5.44)	Average RR= 1.53 (1.0, 2.5)
Harland 1999	% of participants who increased their total number of sessions with vigorous physical activity (>7.5 kcal/min)	M/F, 40-64 yrs	Average RR= 2.20 (2.20, 2.20)	Herman et al (1983), RR = 2.44 (1.19, 4.76), M/F, 40-74	Average RR= 1.97 (1.06, 5.44)	Average RR= 1.53 (1.0, 2.5)
	% of participants who increased their total number of sessions with moderate physical activity (5-7.5 kcal/min)	M/F, 40-64 yrs	Shaper et al (1991), RR = 2.00 (1.25, 5.00), M/F, 40-59	Herman et al (1983), RR = 1.39 (0.70, 2.70), M/F, 40-74	Combine matches, RR = 1.3 (1.06, 1.85)	Longnecker et al (1995), RR = 1.67 (1.0, 2.5), M, >30
Swinburn 1998	% of participants who become active as a result of the intervention	M/F, average age 49 yrs	Salonen et al (1988), RR = 1.20 (1.0, 1.50), M/F, 30-59	Salonen et al (1982), RR = 1.5 (1.2, 2.0)	Haapanen et al (1997), RR = 2.64 (1.28, 5.44), F	Shepherd et al (1997), RR = 1.39 (1.27, 1,51)
Smith 2000	Probability that achieve 60 mins of activity per week as a result of the intervention	M/F, 25 - 65 yrs	Leon et al (1987), RR = 1.11 (0.94, 1.32), M, 35-57	Average RR= 1.68 (0.79, 4.76)	Average RR= 1.97 (1.06, 5.44)	Average RR= 1.53 (1.0, 2.5)
Elley, 2003	% achieve >2.5 hours of moderate or vigorous activity per week		Combine matches, RR = 1.70 (0.56, 5.00)	Herman et al (1983), RR = 1.91 (0.70, 4.76)	Average RR= 1.97 (1.06, 5.44)	Average RR= 1.53 (1.0, 2.5)

Figure 11: matching of outcome and RR studies

A number of assumptions are made in applying the above RRs to calculate the change in health states as a result of the intervention:

- it is unlikely that the four health states identified are experienced in separation from each other. However, for the sake of simplicity the model assumes that the risk of experiencing a health state is independent of the risk of experiencing other health states;
- the RRs employed are calculated in a range of locations. It is assumed that these RRs can be applied to a UK population;
- a number of other risk factors influence the chance of experiencing the health states included in the model. For the sake of simplicity, the model ignores the possibility that some people have more than one risk factor for a disease. For these people, the elimination of a particular risk factor (e.g. becoming physically active) may not reduce risk to the level attainable by people who have only one risk factor (Surgeon General, 1996); and
- no negative outcomes of physical activity, such as injuries, have been considered in the model. However, the physical activity levels and populations considered mean that this assumption is unlikely to significantly impact the result of the model.

3.7 QALYs associated with health states

The QALY gained from avoiding a particular health state is defined as:

$$Q = \left[Q_A\left(t_4 - t_2\right)\right] - \left[Q_H\left(t_3 - t_2\right)\right]$$

Where:

- Q = quality of life gained;
- Q_A = average quality of life;
- Q_H = quality of life of different health states;
- t_4 = average age of mortality;
- t_3 = average age of mortality in different health states; and
- t_2 = average age of onset of health state.

The discounted QALY gained is defined as:

$$Q_d = Q \cdot \left({}^{1}\!\Big/\!_{(1+r)^{\left(t_4 + t_2\right)/2 - t_1}} \right)$$

Where:

- Q_d = discounted quality of life gained;
- t_1 = average age of participants; and
- r = discount rate (3.5%)

Figure twelve represents this calculation diagrammatically.

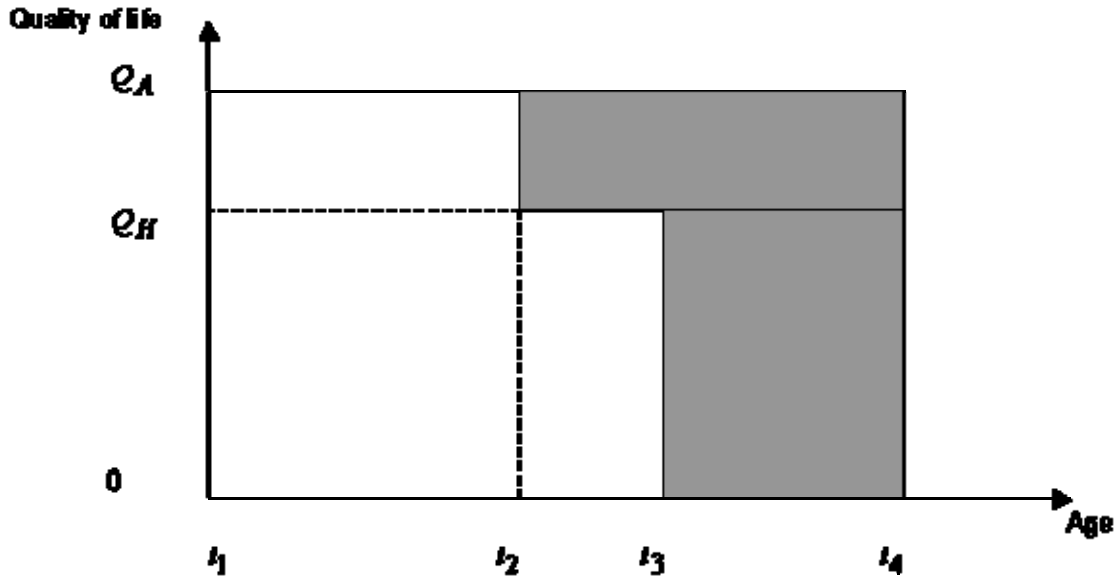

Figure 12: QALYs gained through avoiding a health state.

The discounted QALY gained estimates produced using the above formula are summarised in appendix four. The remainder of this section outlines the data sources used to calculate these figures.

Average Quality of Life Year (Q_A)

Figure thirteen shows the average QALYs taken from Kind et al (1999).

Age group	MEN				WOMEN				BOTH			
	Mean	SD	95 % CI		Mean	SD	95 % CI		Mean	SD	95 % CI	
			Low	High			Low	High			Low	High
All	0.86	0.24	0.85	0.87	0.85	0.22	0.84	0.86	0.86	0.23	0.85	0.87
01 to 25	0.94	0.12	0.92	0.96	0.94	0.12	0.92	0.96	0.94	0.12	0.93	0.95
26 to 34	0.93	0.16	0.91	0.95	0.93	0.15	0.92	0.94	0.93	0.15	0.92	0.94
35 to 44	0.91	0.17	0.89	0.93	0.91	0.15	0.89	0.93	0.91	0.16	0.90	0.92
45 to 54	0.84	0.27	0.80	0.88	0.85	0.23	0.82	0.88	0.85	0.25	0.83	0.87
55 to 64	0.78	0.28	0.74	0.82	0.81	0.26	0.78	0.84	0.80	0.26	0.78	0.82
65 to 74	0.78	0.28	0.74	0.82	0.78	0.25	0.75	0.81	0.78	0.26	0.76	0.80
>75	0.75	0.28	0.70	0.80	0.71	0.27	0.67	0.75	0.73	0.27	0.70	0.76

Figure 13: average QALYs for different age groups

Quality of life year in health states (Q_H)

Assumptions/caveats:

- EQ-5D estimates for colon cancer could not be obtained. It is assumed that the impact on quality of life of experiencing colon cancer is the same as the average for all cancers.

The Health Survey for England 1996 was used to calculate the EQ-$5D_{index}$ scores for CHD, stroke, type II diabetes and cancer for different age groups and genders. These are summarised in figure sixteen. The sample sizes meant that the EQ-$5D_{index}$ score could not be calculated for colon cancer. Instead, the EQ-$5D_{index}$ for cancer in general is used as a proxy. The EQ-$5D_{index}$ scores were compared with the averages for different age groups and genders in order to derive the loss in quality of life avoided by avoiding the different health states (Kind et al, 1999).

The Harvard Cost-effectiveness Analysis Registry preference weights[4] were used to validate the EQ-5D scores for colon cancer. These are reported for different stages of colon cancer, and not differential between age and gender groups. Figure fourteen summarises these preference weights.

Stage of disease	Source	Preference weight
Regional (chemo side effects)	Clinician judgement	0.63
Regional (no chemo side effects)	Clinician judgement	0.7
Local	Clinician judgement	0.74
Resectable stage III with treatment-induced toxicity	Author/clinician judgement	0.5
Resectable stage III relapse	Author/clinician judgement	0.5
Resectable stage III without symptoms and treatment toxicity	Author/clinician judgement	1
Average		0.68

Figure 14: preference weights for different stages of colon cancer

Figure fourteen shows that the average preference weight for the different stages of colon cancer is 0.68. Figure fifteen demonstrates that the mean EQ-5D score for cancer is 0.63. To some extent this validates the use of cancer QALYs as a proxy for colon cancer.

[4] http://www.hsph.harvard.edu/cearegistry/data.html

Age	MEN			WOMEN			TOTAL		
	Mean	SD	95 % CI	Mean	SD	95 % CI	Mean	SD	95 % CI
Cancer									
All	0.63	0.31	0.57-0.70	0.69	0.33	0.63-0.75	0.67	0.32	0.62-0.71
<45 yrs	0.8	0.32	0.56-1.0	0.84	0.25	0.74-0.95	0.83	0.27	0.74-0.93
45-59 yrs	0.64	0.36	0.48-0.81	0.72	0.33	0.61-0.83	0.69	0.34	0.60-0.78
60-74 yrs	0.59	0.31	0.49-0.68	0.68	0.33	0.58-0.77	0.63	0.32	0.57-0.70
>74 yrs	0.67	0.17	0.57-0.77	0.51	0.34	0.35-0.66	0.57	0.3	0.47-0.67
Diabetes									
All	0.73	0.3	0.68-0.77	0.64	0.34	0.68-0.77	0.69	0.32	0.65-0.72
<45 yrs	0.84	0.3	0.71-0.97	0.62	0.41	0.41-0.84	0.75	0.37	0.63-0.87
45-59 yrs	0.74	0.33	0.65-0.83	0.66	0.34	0.54-0.77	0.7	0.34	0.63-0.78
60-74 yrs	0.73	0.28	0.67-0.79	0.63	0.34	0.55-0.72	0.69	0.31	0.63-0.74
>74 yrs	0.64	0.27	0.55-0.73	0.63	0.32	0.52-0.74	0.64	0.29	0.57-0.70
Stroke / cerebral haemorrhage									
All	0.53	0.31	0.45-0.61	0.56	0.31	0.47-0.65	0.54	0.31	0.49-0.60
<45 yrs	0.85	0.1	0.69-1.0	0.59	--	--	0.77	0.3	0.45-1.0
45-59 yrs	0.47	0.28	0.20-0.73	0.55	0.36	0.33-0.77	0.52	0.33	0.36-0.67
60-74 yrs	0.53	0.34	0.42-0.65	0.54	0.34	0.37-0.70	0.54	0.34	0.45-0.63
>74 yrs	0.47	0.19	0.35-0.58	0.59	0.23	0.47-0.71	0.53	0.22	0.45-0.61
Heart attack / angina									
All	0.65	0.32	0.60-0.69	0.59	0.31	0.55-0.63	0.62	0.32	0.59-0.65
<45 yrs	0.56	0.39	0.33-0.80	0.69	--	--	0.57	0.38	0.35-0.79
45-59 yrs	0.61	0.38	0.50-0.72	0.44	0.36	0.30-0.59	0.55	0.38	0.47-0.64
60-74 yrs	0.65	0.32	0.59-0.71	0.6	0.32	0.54-0.66	0.63	0.31	0.59-0.67
>74 yrs	0.69	0.24	0.62-0.76	0.65	0.26	0.56-0.69	0.65	0.26	0.60-0.79

Figure 15: mean EQ-5D$_{index}$ scores for mean and women by age group

Average age of mortality (t_4)

Figure sixteen shows the average age of mortality for different age groups. In order to arrive at these figures, ONS life expectancy figures[5] were converted to the age bands used in the table by taking an average of any of the ONS age bands that they overlapped with. These life-expectancy figures were then added to the average age in each band to get the average age of mortality.

	0-34	35-44	45-54	55-64	65-74	75+
Male	73.8	75.0	77.7	77.7	80.7	89.7
Female	78.2	79.1	81.6	81.0	82.9	91.2

Figure 16: average age of mortality for different age groups

Average age of mortality with disease (t_3)

Figure seventeen shows the average age of mortality for people who first experience different health states at different ages. These figures were derived by calculating a mortality rate for different health states from prevalence and death data. The following sources were used for this data:

[5] http://www.statistics.gov.uk/

- Forman et al (2003)[6]: prevalence of colon cancer;
- Yorkshire and Humberside PHO[7]: diabetes prevalence;
- Office for National Statistics[8]: prevalence of CHD, stroke, and deaths from diabetes; and
- British Heart Foundation[9]: deaths from CHD, stroke and colon cancer.

These mortality rates were then combined with average mortality rates to calculate the life expectancy of those in these health states using the equation:

$$LE = \frac{1}{M_A + M_H}$$

Where:

- LE = life expectancy;
- M_A = average mortality rate; and
- M_H = mortality rate associated with each health state.

The life expectancy is then added to the average of the age groups reported to calculate the average age of mortality.

In applying this equation, it is assumed that mortality rates for each of the health states and average mortality rates are independent of each other.

		0-34	35-44	45-54	55-64	65-74	75+
CHD	Male	25.7	53.2	65.0	71.6	77.3	86.8
	Female	36.9	59.3	71.4	75.6	79.3	87.4
Stroke	Male	34.5	46.3	54.9	64.4	72.4	83.7
	Female	37.0	45.6	54.4	63.8	72.4	83.5
Colon cancer	Male	34.2	41.1	57.2	62.5	72.6	85.6
	Female	37.0	41.6	60.2	64.5	74.7	86.0
Diabetes	Male	52.4	70.6	76.7	77.4	80.4	89.4
	Female	66.5	75.1	80.5	80.7	82.7	91.0

Figure 17: average age of mortality for people first experiencing different disease states at different ages

[6] Forman, D. et al (2003), Cancer prevalence in the UK: results from the EUROPREVAL study. Annals of Oncology, 14:648-654

[7] Yorkshire and Humberside Public Health Authority diabetes prevalence model (http://www.yhpho.org.uk/viewResource.aspx?id=7

[8] http://www.statistics.gov.uk/

[9] British Heart Foundation (2004), Statistics Database, www.heartstats.org (reports data from ONS, 2003)

Average age of onset (t_2)

An assumption was made regarding the average age of onset of the different health states:

- the average age of onset for a 25 year old was assumed to be 45 years old;
- the average age of onset for a 45 year old was assumed to be 55 years old; and
- the average age of onset for a 90 year old was assumed to be 93 years old.

It was assumed that the age until onset for the age groups in between the above varied linearly between the age until onset assumed above.

Average life expectancy from point of onset of health state ($t_3 - t_2$)

Figure eighteen shows the life years remaining at the points of onset of CHD, stroke, colon cancer or diabetes at different points in life.

Age of onset	CHD	Stroke	Diabetes	Colon cancer
45-59 yrs	18.41	5.12	28.13	8.09
60-74 yrs	11.17	3.49	14.24	4.25
>74 yrs	2.38	0.80	2.80	1.88

Figure 18: summary of life years remaining at point of onset of health state at different points in life.

3.8 Public sector costs of health states

Assumptions/caveats:

- the estimate of cost-saving will ignore any increased health costs in the longer-term as a result of increased life-expectancy.

The estimate of the cost-saving due to the health states avoided as a result of increased physical activity focuses on the costs to the public sector. No attempt will be made to estimate the productivity gain resulting from improved health. All costs are reported at 2005 prices[10]. Figure nineteen summarises

[10] In line with Treasury Green Book guidance, costs are adjusted using an inflation rate of 2.5%.

estimates of annual costs per patient of treating CHD, stroke, and diabetes[11]. No reliable annual cost for the treatment colon cancer could be identified. Thus, the estimate of the annual cost saving as a result of the interventions is based on just the costs of treating CHD, diabetes and stroke.

	Incidence UK	Total NHS Costs (2005 estimates)	Cost / person / year
Type 2 diabetes	1,531,000[12]	£5,314,946,850[13]	£3,006
Colon cancer	21,610[14]		
CHD	2,600,000[15]	£3,677,187,500[7]	£1,414
Stroke	1,398,827[16]	£2,872,384,831[17]	£2,053

Figure 19: calculation of annual costs of treating health states

The total healthcare costs avoided from avoiding a particular health state is defined as:

$$C = C_A(t_3 - t_2)$$

Where:

- C = total treatment costs avoided;
- C_A = annual treatment cost;
- t_3 = average age of mortality in different health states; and
- t_2 = average age of onset of health state.

The discounted QALY gained is defined as:

$$C_d = C \cdot \left(1 \Big/ (1+r)^{[(t_3 + t_2)/2] - t_1} \right)$$

[11] Previous NICE technical reviews (http://www.nice.org.uk/page.aspx?o=cat.diseaseareas) and national tariff data were reviewed for cost of treatment data. However, the model required annual cost of treatment data, which was not available from these sources.

[12] Diabetes UK (2004), Diabetes in the UK 2004.

[13] Diabetes UK (http://www.diabetes.org.uk/infocentre/fact/fact3.htm). Based on Currie C.J. et al. (1997), NHS acute sector expenditure for diabetes: the present, future, and excess in-patient cost of care. Diabetic Medicine, 14: 686-692

[14] Cancer Research UK (2005), CancerStats Incidence – UK.

[15] CHD Statistics 2005 Edition. British Heart Foundation Health Promotion Research Group & Department of Public Health, University of Oxford

[16] Hearstarts.org, and Joint Health Surveys Unit (2004) Health Survey for England 2003. The Stationery Office London, and ONS (Population).

[17] "Burdens of Disease 1996" (Department of Health).

Where:

- C_d = discounted quality of life gained;
- t_1 = average age of participants; and
- r = discount rate (3.5%)

It is generally acknowledged that reducing the risk of experiencing a particular health state and extending a person life will reduce health costs in the shorter term at the expense of increased health costs in the longer term. The estimate of cost-saving will ignore these longer-term impact on costs due to increased life expectancy. Thus, the estimates of costs avoided are likely to be overestimates.

4.0 Results

4.1 Model results: cost of intervention

This section reports the results of the cost-effectiveness analysis conducted when costs are defined as those involved in the implementation of the intervention (that is, ignoring and costs saved through health treatment avoided).

Figure twenty shows the cost per person who increased their physical activity levels for each intervention. (It is important to note that the threshold physical activity level varied between each study.) It demonstrates that the cost of getting somebody active varied between c£90 and c£4500.

Study	Intervention	Age	Cost/person
Swinburn 1998	Exercise prescriptions vs. advice	48 - 50	£88.15
Harland 1999 A	Interview vs. advice	40 - 64	£102.39
Petrella 2003	Exercise prescription vs. advice	65 - 85	£299.64
Lamb 2002	Exercise prescriptions vs. advice	40 - 60	£440.35
Harland 1999 B	Interviews with exercise voucher vs. advice	40 - 64	£541.42
Harland 1999 C	Intensive interviews vs. advice	40 - 64	£677.78
Smith 2000 B	Exercise prescriptions vs. advice	25 - 65	£761.46
Elley 2003	Exercise prescription with intensive GP training vs. advice	40 - 79	£2,037.11
Smith 2000 A	Exercise prescription and exercise information vs. advice	25 - 65	£2,039.29
Harland 1999 D	Intensive interviews with exercise voucher vs. advice	40 - 64	£4,533.33

Figure 20: cost of getting one person to increase their physical activity level

Figure twenty-one summarises the estimates of the cost per QALY gained for each of the interventions selected as a result of CHD, stroke, diabetes and colon cancer episodes avoided. As noted above, the model was run for only the populations for which the effectiveness study provided change in physical activity estimates.

The cost/QALY gained estimates vary from c£20 to c£670. Again, the interventions with the least cost per QALY gained are exercise prescription or

interviews. Adding addition elements to the intervention, such as information about local facilities, more intensive interviews or providing GPs with more intensive training does not have the physical activity impact to justify the extra cost.

Study	Intervention	Age	Cost / person	QALY gained	Cost/QALY gained
Harland 1999 A	Interview vs. advice	40 - 64	£28.67	0.34	£18.78
Swinburn 1998	Exercise prescriptions vs. advice	48 - 50	£20.45	1.01	£20.19
Petrella 2003	Exercise prescription vs. advice	65 - 85	£41.95	0.57	£73.52
Lamb 2002	Exercise prescriptions vs. advice	40 - 60	£25.10	0.31	£80.96
Harland 1999 B	Interviews with exercise voucher vs. advice	40 - 64	£178.67	0.79	£96.68
Harland 1999 C	Intensive interviews vs. advice	40 - 64	£122.00	1.15	£112.56
Smith 2000 B	Exercise prescriptions vs. advice	25 - 65	£36.55	0.23	£158.83
Smith 2000 A	Exercise prescription and exercise information vs. advice	25 - 65	£28.55	0.07	£425.36
Elley 2003	Exercise prescription with intensive GP training vs. advice	40 - 79	£197.60	0.45	£437.11
Harland 1999 D	Intensive interviews with exercise voucher vs. advice	40 - 64	£272.00	0.63	£670.33

Figure 21: cost of intervention / QALY gained estimates for selected interventions

4.1.1 Sensitivity to relative risks of experiencing health states

A key parameter in the model is the impact on the likelihood of experiencing health states of undertaking physical activity (the relative risk score). The model was put through a series of iterations to examine the effects of different levels of relative risks on cost per QALY gained. The relative risk factor for each of the four health states was assumed to be identical and then varied between 1.0 and 2.0, and other assumptions in the model were kept constant.

As expected, the analysis demonstrated a clear inverse relationship between costs per QALY gained and average relative risk factors. Figure twenty-two illustrates the drop in cost per QALY gained by different types of interventions at increasing levels of relative risk.

All interventions have a cost/QALY less than £30,000 for even very low risk factors. For instance, at a relative risk of 1.05, the highest cost per QALY gained among all the interventions is c£6,000.

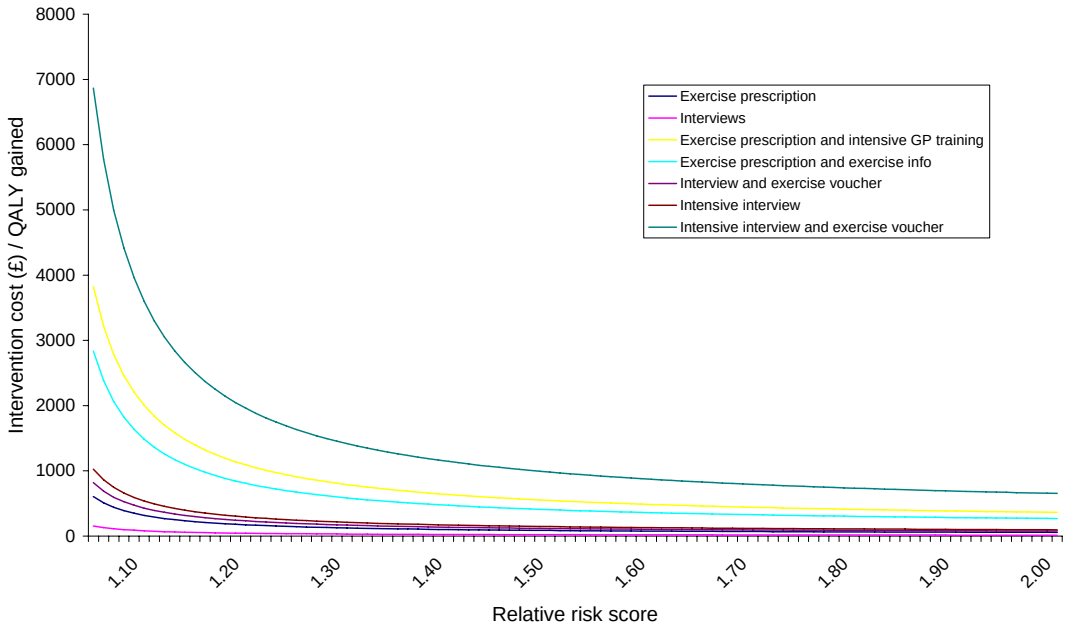

Figure 22: sensitivity of cost per QALY estimates to relative risks

4.1.2 Sensitivity to drop off rates in physical activity

The model assumes that fifty percent of participants maintain any improved levels of physical activity after the intervention for a long enough period to derive the health benefits of that new activity level. In order to measure the impact of this key assumption on the outcome of the model, the model was put through a series of iterations to examine the effects of different levels of exercise drop-off on cost per QALY gained. The entire range of drop off rates from 0 to 100% was considered in the iterations while no changes were made to any of the other assumptions in the model.

Figure twenty-three illustrates the drop in cost per QALY gained by different types of interventions at lower drop-off rates. It demonstrates that all the interventions have a cost/QALY less than £30,000 for even very high drop off rates. Even if only three percent of participants maintained their new exercise levels, all the interventions have a cost per QALY gained of less than c£11,000, and most of the intervention types had cost per QALY gained estimates of less than £2,000.

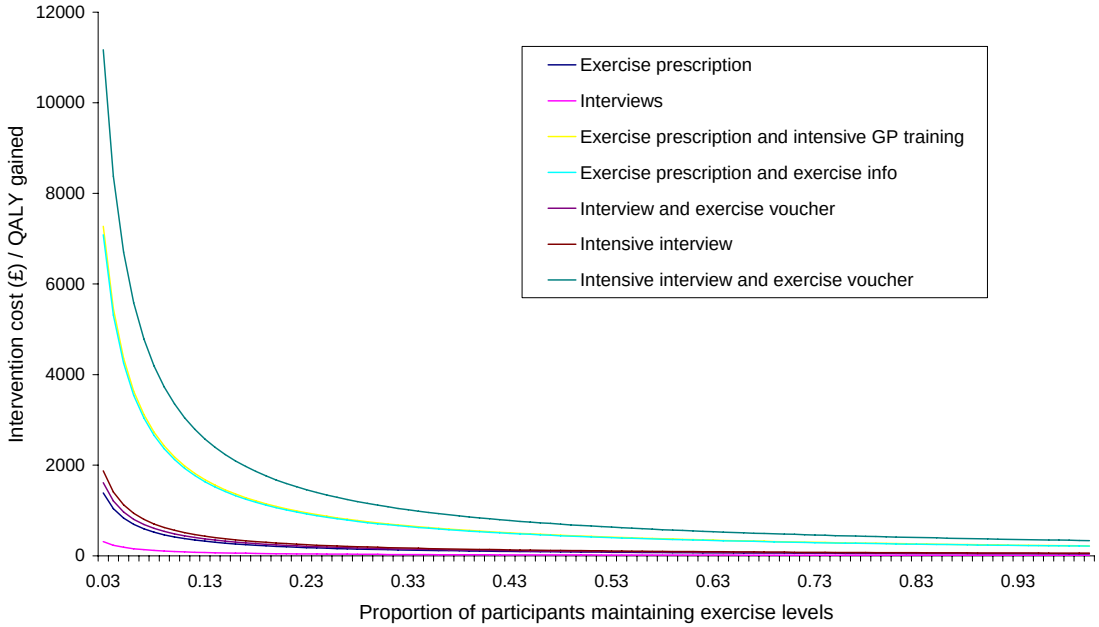

Figure 23: sensitivity of cost per QALY estimates to rate of activity maintenance

4.1.3 Sensitivity to cost assumptions – NHS staff used

The model was repeated with different resource costs to examine the effects of using different types of staff to deliver the interventions on the cost per QALY gained:

- GP time was replaced by staff nurse time; and
- GP and nurse time was replaced by healthcare assistant time.

In each case it was assumed that there were no changes in the effectiveness of the interventions as a consequence of changing the NHS resource used.

Figure twenty-four below summarises the effects of changing the NHS staff members used in the intervention:

- each type of intervention becomes more cost-effective if healthcare assistants are used; and
- exercise prescription becomes more cost-effective if GP time is replaced by nurse time.

It demonstrates that only one type of intervention – exercise prescription – is more cost-effective when nurses replace GPs. This is because none of the interventions other than exercise prescription use GP time. That is, most interventions are delivered by a mixture of nurses and healthcare assistants.

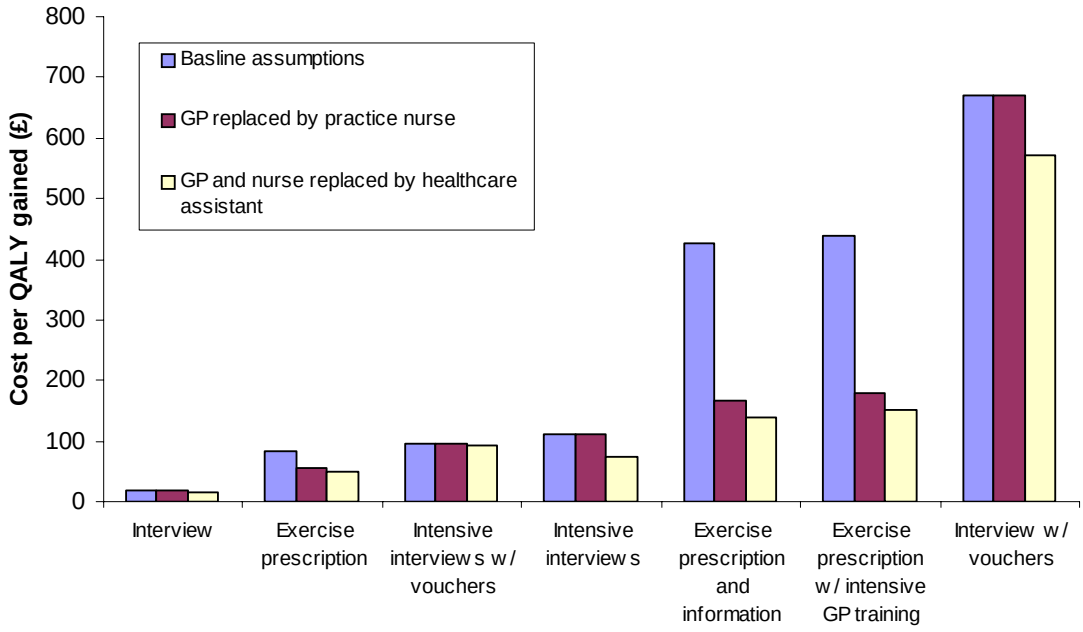

Figure 24: sensitivity of cost per QALY estimates to NHS staff used

Whilst the samples drawn by the studies included in the model are broadly representative, certain groups in society may need more contact with health staff in order to motive them to increase their physical activity levels. In order to determine the amount of extra time that could be dedicate to participants within the same cost profile, figure twenty-five shows the amount of time different grades of staff can spend with participants for the same cost. For instance, it shows that exercise prescription takes seven minutes of GP time. If the same cost is spent on nursing time, it would allow a nurse to spend 34 minutes with participants. If the same cost is spent on healthcare assistant time, it would allow 53 minutes of contact with the participant.

Another way to measure the time available to spend with participants is to ask how much time could be spent with individual participants before the intervention exceeds the £30,000 per QALY gained threshold. Figure twenty-five shows the amount of time a nurse could spend with individual participants before the £30,000 per QALY gained threshold is passed. It assumes that the same physical activity effect is achieved. This is a conservative assumption. It would reasonably be expected that the more time spent with individual participants would result in a better physical activity effect.

Figure twenty-five demonstrates that a lot of time could be spent delivering the intervention before the cost per QALY gained reached £30,000. For instance, nurses could spend 203 hours per person delivering exercise prescription before the cost per QALY gained reached £30,000.

	Interview	Exercise prescription	Intensive interviews w/ vouchers	Intensive interviews	Exercise prescription and information	Exercise prescription w/ intensive GP training	Interview w/ vouchers
GP time delivering intervention	0	7	0	0	10	12	0
Nurse time delivering intervention	40	4	40	40	0	0	40
Time available if GP cost paid for nurse time	40	34	40	40	44	53	40
Time available if GP and nurse cost paid for healthcare assistant time	62	53	62	62	68	82	62

Figure 24: NHS staff time per participant affordable with intervention cost profile

	Interview	Exercise prescription	Intensive interviews w/ vouchers	Intensive interviews	Exercise prescription and information	Exercise prescription w/ intensive GP training	Interview w/ vouchers
Nurse hours available @ £30,000/ QALY gained	1065	203	207	178	52	60	30

Figure 25: nurse hours available at cost per QALY gained of £30,000

4.1.4 Sensitivity to cost assumptions – incentive based interventions

The estimates of the costs per QALY gained for the two interventions that used exercise vouchers are high. The model assumed a cost per exercise voucher of £5. For the interventions that used exercise vouchers, the sensitivity of the cost per QALY gained estimates to this assumption was tested. Figure twenty-six demonstrates the cost per QALY gained at different levels of cost per voucher used. It demonstrates that the interventions that significant amount can be spent on exercise vouchers before the interventions become cost-ineffective. For instance, interventions that involved interviews and exercise vouchers would have a cost per QALY gained of approximately £400 even if the vouchers cost £25 per exercise session.

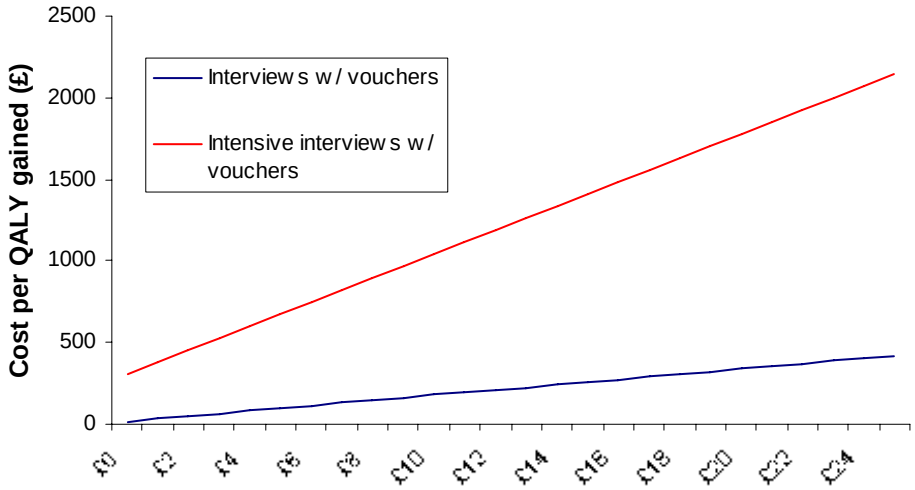

Figure 26: sensitivity of cost per QALY estimates to cost per voucher used

4.2 Model results: total costs saved

This section reports the results of the cost-effectiveness analysis conducted when costs are defined as those involved in the implementation of the intervention as well as costs saved through health treatment avoided (the previous section only considered the costs of the intervention).

Figure twenty-seven shows the total costs saved per QALY gained as a result of the interventions. It demonstrates that the future costs saved per participant (discounted at 3.5%) always exceed the cost of the interventions per person. That is, considered separately, each of the interventions are dominant over usual care, both improving QALYs and reducing healthcare costs.

The total costs saved per QALY gained vary from c£530 to c£3,150. There is no obvious relationship between the type of intervention and the total costs saved per QALY gained.

Study	Intervention	Age	Cost / person	Total cost saving	QALY gained	Saving /QALY gained
Swinburn 1998	Exercise prescriptions vs. advice	48 - 50	£20.45	£3,204.10	1.01	£3,142.95
Lamb 2002	Exercise prescriptions vs. advice	40 - 60	£25.10	£765.54	0.31	£2,388.41
Harland 1999 A	Interview vs. advice	40 - 64	£28.67	£3,088.41	1.52	£2,004.28
Smith 2000 B	Exercise prescriptions vs. advice	25 - 65	£36.55	£468.60	0.23	£1,877.46
Harland 1999 B	Interviews with exercise voucher vs. advice	40 - 64	£178.67	£3,528.41	1.85	£1,812.50
Elley 2003	Exercise prescription with intensive GP training vs. advice	40 - 79	£197.60	£928.87	0.45	£1,617.65
Smith 2000 A	Exercise prescription and exercise information vs. advice	25 - 65	£28.55	£136.68	0.07	£1,610.93
Harland 1999 C	Intensive interviews vs. advice	40 - 64	£122.00	£1,751.25	1.08	£1,503.19
Petrella 2003	Exercise prescription vs. advice	65 - 85	£41.95	£468.15	0.57	£746.93
Harland 1999 D	Intensive interviews with exercise voucher vs. advice	40 - 64	£272.00	£487.33	0.41	£530.68

Figure 27: Total cost saved per QALY gained per person

4.2.1 Sensitivity to relative risks of experiencing health states

A key parameter in the model is the impact on the likelihood of experiencing health states of undertaking physical activity (the relative risk score). The model was put through a series of iterations to examine the effects of different levels of relative risks on costs saved per QALY gained. The relative risk factor for each of the four health states was assumed to be identical and then varied between 1.0 and 2.0, and other assumptions in the model were kept constant.

Figure twenty-eight shows how the net saving per QALY gained changes with different levels of relative risk. It demonstrates that:

- interviews, intensive interviews, exercise prescription and interviews with exercise vouchers result in net savings to the health service even at very low relative risk levels;
- exercise prescription with additional exercise information and exercise prescription with intensive GP training result in a net cost to the health service at relative risk scores less than c1.10; and
- intensive interviews with exercise vouchers result in a net cost to the health service at relative risk scores less than c1.20.

However, whilst very low relative risk scores cause some of the interventions to result in a net cost to the health service, the cost per QALY gained for these interventions is still significantly less than £30,000 for even very low risk

factors. For instance, at a relative risk of 1.05, the highest cost per QALY gained among all the interventions is c£3,500.

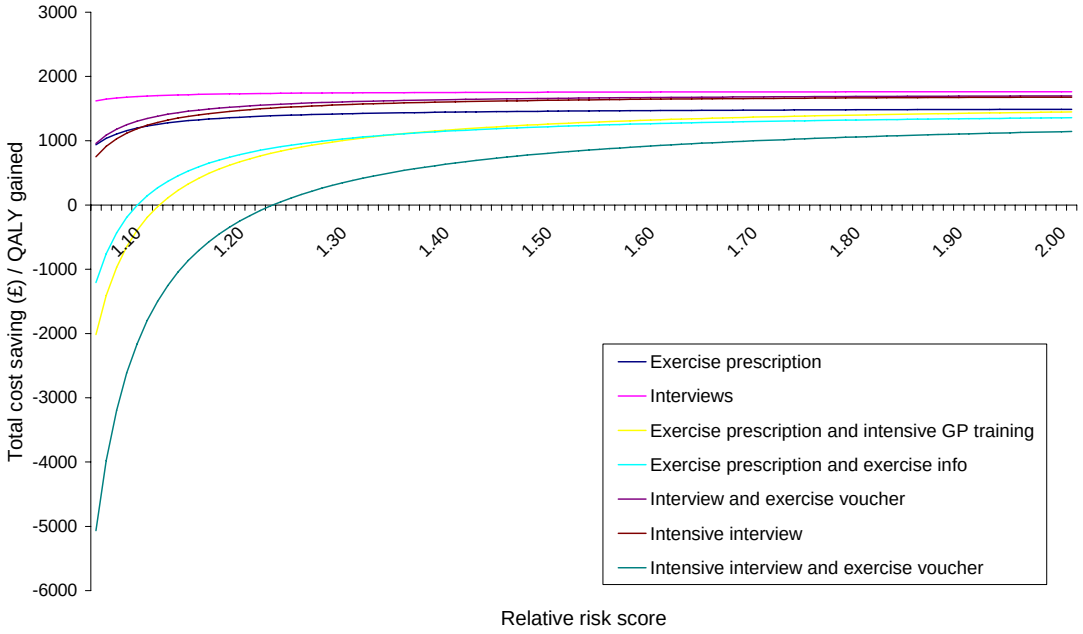

Figure 28: Sensitivity of net saving per QALY estimates to relative risks

4.2.2 Sensitivity to drop off rates in physical activity

The model assumes that fifty percent of participants maintain any improved levels of physical activity after the intervention for a long enough period to derive the health benefits of that new activity level. In order to measure the impact of this key assumption on the outcome of the model, the model was put through a series of iterations to examine the effects of different levels of exercise drop-off on net savings per QALY gained. The entire range of drop off rates from 0 to 100% was considered in the iterations while no changes were made to any of the other assumptions in the model.

Figure twenty-nine shows how the estimate of net saving per QALY gained varies with the proportion of participants maintaining physical activity levels. It demonstrates that:

- interviews, intensive interviews, exercise prescription and interviews with exercise vouchers result in net savings to the health service even at very low levels or participants maintaining physical activity levels;
- exercise prescription with intensive GP training and exercise prescription with exercise information result in a net cost to the health service only if less than ten percent of participants maintain their physical activity levels; and

- intensive interviews with exercise vouchers result in a net cost to the health service only if less than c30 percent of participants maintain their physical activity levels

However, whilst very low levels of physical activity maintenance cause some of the interventions to result in a net cost to the health service, the cost per QALY gained for these interventions is still significantly less than £30,000. For instance, if only ten percent of participants maintain their physical activity levels, the highest cost per QALY gained among all the interventions is c£2,000.

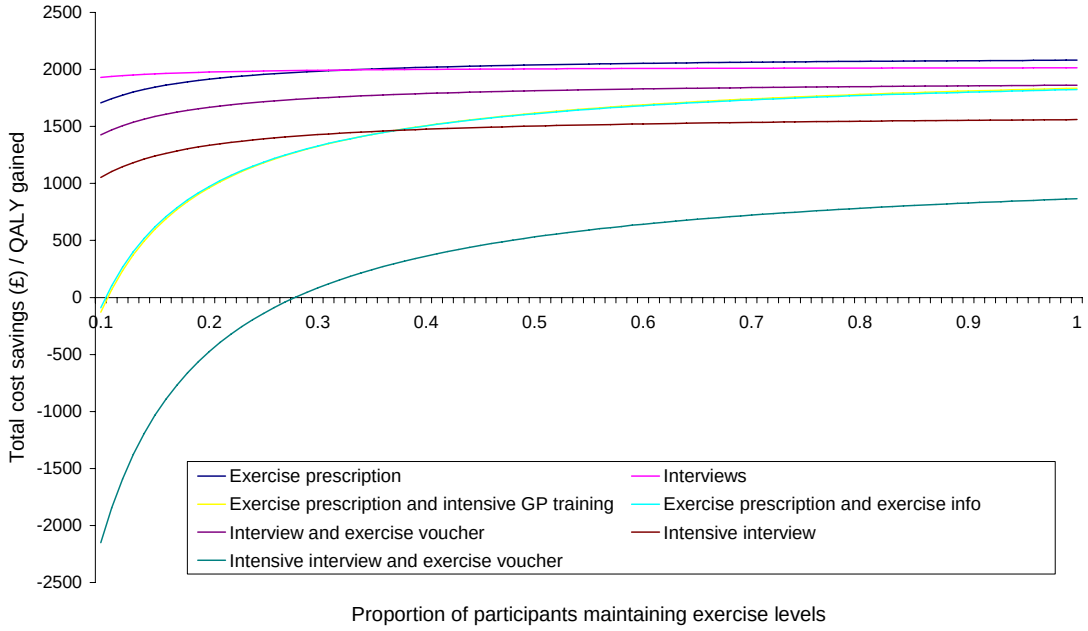

Figure 29: Sensitivity of net saving per QALY estimates to drop-off rates

4.2.3 Sensitivity to treatment costs

A key parameter in the model employed is the annual treatment costs of the health states avoided due to improved physical activity levels. In order to measure the impact of this key assumption on the outcome of the model, the model was put through a series of iterations to examine the effects of different levels of treatment cost on net savings per QALY gained. A range of annual treatment costs from £50 to £5,000 was considered in the iterations while no changes were made to any of the other assumptions in the model.

Figure thirty show how the estimate of net saving per QALY gained varies with annual treatment costs. It demonstrates that only at annual CHD, stroke and diabetes treatment costs less than c£1,000 per person do any of the interventions result in a net cost to the health service. And that, even at annual treatment costs as low as £50 per person, the highest cost per QALY

gained for these interventions is less than c£700, still significantly less than £30,000.

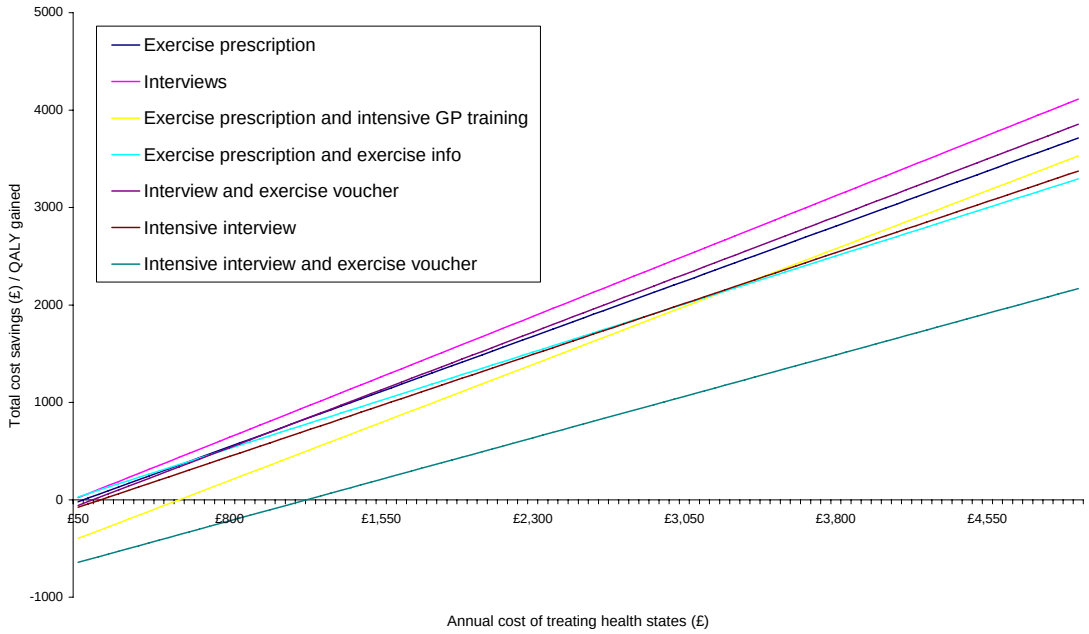

Figure 30: Sensitivity of net saving per QALY estimates to annual treatment costs

4.3 Incremental cost-effectiveness analysis

Previous sections have demonstrated that, when considered separately against usual care, each of the interventions proves cost-effective. This section asks which of the physical activity interventions is the most cost-effective. In doing so, it is assumed that interventions are mutually exclusive. This may seem a strange assumption, especially considering the fact that there are a number of interventions included in the modelling exercise that are defined as 'exercise referral'. However, treating the interventions as mutually exclusive is justified due to variations in the staff delivering the interventions and variations in the participants receiving the interventions. Furthermore, compared with technical appraisals there is significant scope for variation in the implementation of the interventions. For instance, exercise advice could be given in a variety of ways. One model of implementation could employ elements of motivational interviewing.

Figure thirty-one demonstrates that one of the interventions dominates – resulting in both a higher cost saving and a greater increase in QALYs than the other interventions: interviews with exercise vouchers (Harland, 1999 B).

Study	Intervention	Cost saving	QALY gained	Incremental cost saving (£)	Incremental QALY gained	Incremental saving / QALY (£)
	'usual care'	0	0			
Smith 2000 A	Exercise prescription and exercise information vs. advice	£108.13	0.07	simply dominated		
Smith 2000 B	Exercise prescriptions vs. advice	£432.05	0.23	simply dominated		
Lamb 2002	Exercise prescriptions vs. advice	£740.44	0.31	simply dominated		
Harland 1999 D	Intensive interviews with exercise voucher vs. advice	£217.33	0.41	simply dominated		
Elley 2003	Exercise prescription with intensive GP training vs. advice	£731.27	0.45	simply dominated		
Petrella 2003	Exercise prescription vs. advice	£426.20	0.57	simply dominated		
Swinburn 1998	Exercise prescriptions vs. advice	£3,183.65	1.01	simply dominated		
Harland 1999 C	Intensive interviews vs. advice	£1,629.25	1.08	simply dominated		
Harland 1999 A	Interview vs. advice	£3,037.74	1.52	simply dominated		
Harland 1999 B	Interviews with exercise voucher vs. advice	£3,349.74	1.85	£3,349.74	1.85	£1,810.67

Figure 31: Incremental cost effectiveness analysis

5.0 Discussion

The model reported in this paper measured two forms of cost-effectiveness for physical activity interventions. First, defining cost as the cost of the intervention. Second, defining costs as including the cost savings to the health service from avoided health states.

When costs are defined as only including the costs of the intervention, all the interventions have a cost per QALY gained significantly less than £30,000 when compared separately with 'usual care': the cost/QALY gained estimates for the interventions reviewed vary from c£20 to c£670.

When costs are defined to include the healthcare costs avoided through avoiding health states, all the interventions are dominant when compared separately with 'usual care'. That is, they result in an increase in quality of life for participants and net costs savings to the health service: net costs saved per QALY gained vary from c£530 to c£3,150.

A number of assumptions are made in conducting the model. These work to both underestimate and overestimate the cost per QALY gained estimates. Figure thirty-two summarises the assumptions made and their likely impact on the cost per QALY gained estimates.

Assumptions that cause the model to **underestimate** the cost per QALY gained	Assumptions that cause the model to **overestimate** the cost per QALY gained
It is assumed that 50% of participants maintain their physical activity levels long enough to benefit from the health states associated with those physical activity levels.	The model focused on four health outcomes: CHD, stroke, diabetes and colon cancer. This ignores the positive impact of physical activity on other health outcomes, such as mental health
It is assumed that physical activity is the only risk factor in determining whether health states are experienced. Thus health benefits estimates may not be experienced if other risk factors increase – for instance, smoking.	No annual costs for treating colon cancer could be identified for inclusion in the model, reducing the estimated cost saving as a result of the interventions.
It is assumed that the chances of experiencing the four health states included in the model are independent. This is unlikely to be the case.	
The model does not consider the costs to the health service of increased longevity as a result of the intervention.	
Negative effects of physical activity, such as injuries, are not considered in the model. However, it is thought that these are unlikely for the levels of physical activity and the population included in the model	

Figure 32: Assumptions employed in the economic model

A number of other assumptions are made in the model. The direction of impact of these assumptions on the cost-effectiveness estimates is more difficult to predict:

- the model uses the average annual cost of treating health states. This assumes that, had the participants suffered health states in the absence of the intervention, they would have had the same cost distribution as those suffering form the health state in the nation as a whole;
- it is assumed that participants' baseline risk of suffering health states and the change in risk accompanying improvements in physical activity are the same as the participants in the relative risk studies used to estimate the impact of physical activity on health;
- it is assumed that the QALY for colon cancer is the same as that for cancer;
- assumptions are made regarding the age of onset of the four health states modeled.

Whilst the direction of the impact of these assumption on the cost-effectiveness estimates is uncertain, sensitivity analysis suggests that the conclusion that the interventions are cost-effective is not sensitive to the values of relative risk, cost of treatment or proportion of participants maintaining physical activity levels used in the model.

With regard to health inequalities, no data were found or modelled for the differential effectiveness amongst lower socio-economic, black and ethnic minority, or vulnerable groups. However, the model demonstrated that the interventions would still be cost-effective if staff spent significantly more time delivering the interventions, something that might be required with more vulnerable groups. Vulnerable groups may also be expected to have a higher rate of relapse. As discussed above, the sensitivity analysis demonstrated that the interventions are still cost-effective below a £30,000 per QALY gained threshold at very high rates of relapse.

Comparing the costs and effects of the interventions, and assuming that they are mutually exclusive, the analysis suggests that interviews with exercise vouchers (Harland, 1999 B) is the most cost-effective intervention.

6.0 Appendix one: studies included in effectiveness review

Pedometers

DuVall C, Dinger MK, Taylor EL, Bemben D. Minimal-contact physical activity interventions in women: a pilot study. *American Journal of Health* Behaviours 2004;**28**(3):280-286.

Talbot LA, Gaines JM, Huynh TU, Metter JE. A home-based pedometer-driven walking programme to increase physical activity in older adults with osteoarthritis of the knee: a preliminary study. *American Geriatrics Society,* 2003;**51**:387-392.

Moreau KL, Degarmo R., Langlet J, McMahon C, Howley ET, Bassett DR, Thompson DL. Increasing daily walking lowers blood pressure in postmenopausal women. *Medicine and Science in Sports and Exercise* 2001;**33**(11):1825-1831.

Tudor-Locke C, Bell RC, Myers AM., Harris SB, Ecclestone, NA, Lauzon N, Rodger NW. Controlled outcome evaluation of the First Step Programme: a daily physical activity intervention for individuals with type II diabetes. *International Journal of Obesity* 2004; **28**:113-119.

Exercise Referral

Taylor AH, Doust J, Webborn N. Randomised controlled trial to examine the effects of a GP exercise referral programme in Hailsham, East Sussex, on modifiable coronary heart disease risk factors. J Epidemiol Community Health 1998; 52(9):595-601.

Halbert JA, Silagy CA, Finucane PM, Withers RT, Hamdorf PA. Physical activity and cardiovascular risk factors: effect of advice from an exercise specialist in Australian general practice. Med J Aust 2000; 173(2):84-87.

Harrison RA, Roberts C, Elton PJ. Does primary care referral to an exercise programme increase physical activity one year later? A randomized controlled trial. J Public Health (Oxf) 2005; 27(1):25-32.

Lamb SE, Bartlett HP, Ashley A, Bird W. Can lay-led walking programmes increase physical activity in middle aged adults? A randomised controlled trial. 56, 246-252. 2002. Journal of Epidemiology and Community Health.

Brief Intervention

Bull FC, Kreuter MW, Scharff DP. Effects of tailored, personalized and general health messages on physical activity. *Patient.Educ.Couns.* 1999;**36**:181-92.

Elley CR, Kerse N, Arroll B, Robinson E. Effectiveness of counselling patients on physical activity in general practice: cluster randomised controlled trial. *BMJ* 2003;**326**:793.

Goldstein MG, Pinto B.M., Lynn H, Jette A.M, Rakowski W, McDermott S *et al*. Physician-based physical activity counseling for middle-aged and older adults: a randomized trial. *Ann.Behav.Med.* 1999;**21**:40-7

Halbert J, Silagy C, Finucane P, Withers R, Hamdorf P. Physical activity and cardiovascular risk factors: effect of advice from an exercise specialist in Australian general practice. *Medical Journal of Australia* 2000;**173**:84-7.

Halbert J, Crotty M, Weller D, Ahern M, Silagy C. Primary care-based physical activity programs: effectiveness in sedentary older patients with osteoarthritis symptoms. *Arthritis.Rheum.* 2001;**45**:228-34.

Harland J, White M, Drinkwater C, Chinn D, Farr L, Howel D. The Newcastle exercise project: a randomised controlled trial of methods to promote physical activity in primary care. *BMJ* 1999;**319**:828-32.

Hillsdon M, Thorogood M, White I, Foster C. Advising people to take more exercise is ineffective: a randomized controlled trial of physical activity promotion in primary care. *Int.J.Epidemiol.* 2002;**31**:808-15.

Naylor PJ, Simmonds G, Riddoch C, Velleman G, Turton P. Comparison of stage-matched and unmatched interventions to promote exercise behaviour in the primary care setting. *Health.Educ.Res.* 1999;**14**:653-66.

Petrella RJ, Koval JJ, Cunningham DA, Paterson DH. Can primary care doctors prescribe exercise to improve fitness? The Step Test Exercise Prescription (STEP) project. *Am.J.Prev.Med.* 2003;**24**:316-22.

Smith BJ, Bauman AE, Bull FC, Booth ML, Harris MF. Promoting physical activity in general practice: a controlled trial of written advice and information materials. *Br.J.Sports.Med.* 2000; **34**:262-7.

Swinburn BA, Walter LG, Arroll B Tilyard MW, Russell DG. The Green Prescription Study: A randomized controlled trial of written exercise advice provided by general practitioners. *Am J Pub Health* 1998; **88**:288-91.

Walking and cycling

Lamb SE, Bartlett HP, Ashley A, Bird W. Can lay-led walking programmes increase physical activity in middle aged adults? A randomised controlled trial. J.Epidemiol.Community Health 2002;56:246-52.

Hamdorf PA,.Penhall RK. Walking with its training effects on the fitness and activity patterns of 79-91 year old females. Aust.N.Z.J.Med. 1999;29:22-8.

Fisher KJ,.Li F. A community-based walking trial to improve neighborhood quality of life in older adults: a multilevel analysis. Ann.Behav.Med. 2004;28:186-94.
MacRae PG, Asplund LA, Schnelle JF, Ouslander JG, Abrahamse A, Morris C. A walking program for nursing home residents: effects on walk endurance, physical activity, mobility, and quality of life. J.Am.Geriatr.Soc. 1996;44:175-80.

7.0 Appendix two: studies included in modelling exercise

Brief Interventions

Elley CR, Kerse N, Arroll B, Robinson E. Effectiveness of counselling patients on physical activity in general practice: cluster randomised controlled trial. *BMJ* 2003;**326**:793.

Harland J, White M, Drinkwater C, Chinn D, Farr L, Howel D. The Newcastle exercise project: a randomised controlled trial of methods to promote physical activity in primary care. *BMJ* 1999;**319**:828-32.

Hillsdon M, Thorogood M, White I, Foster C. Advising people to take more exercise is ineffective: a randomized controlled trial of physical activity promotion in primary care. *Int.J.Epidemiol.* 2002;**31**:808-15.

Petrella RJ, Koval JJ, Cunningham DA, Paterson DH. Can primary care doctors prescribe exercise to improve fitness? The Step Test Exercise Prescription (STEP) project. *Am.J.Prev.Med.* 2003;**24**:316-22.

Smith BJ, Bauman AE, Bull FC, Booth ML, Harris MF. Promoting physical activity in general practice: a controlled trial of written advice and information materials. *Br.J.Sports.Med.* 2000; **34**:262-7.

Swinburn BA, Walter LG, Arroll B Tilyard MW, Russell DG. The Green Prescription Study: A randomized controlled trial of written exercise advice provided by general practitioners. *Am J Pub Health* 1998; **88**:288-91.

Exercise Referrral

Lamb SE, Bartlett HP, Ashley A, Bird W. Can lay-led walking programmes increase physical activity in middle aged adults? A randomised controlled trial. 56, 246-252. 2002. Journal of Epidemiology and Community Health.

8.0 Appendix three: review of relative risk literature

Figure 33: relative risk of CHD

Study	Population			Physical activity measure	CHD event	Impact
	Gender, no.	Location, health	Age			
Morris et al, 1973	Men - 232 cases and 428 controls	Britain; heart attack victims	40-60	Vigorous (7.5 kcal/min) vs. non-vigorous	First CHD attack	RR = 0.33
Rosenman et al, 1977	Men - 2,065	San Francisco Bay Area	35-59	Caloric expenditure	Fatal and non-fatal CHD	none
Chave et al, 1978	Men - 3,591	Britain	40-64	Non-vigorous vs. vigorous (7.5 kcal/min)	Fatal and non-fatal first CHD attack	RR = 2.2
Paffenbarger et al, 1978	Men - 16,936	US	35-74	Less than 2,000 kcal/week vs. greater	Fatal and non-fatal first CHD attack	RR = 1.64
Morris et al, 1980	Men - 17,944	Britain	40-64	Non-vigorous vs. vigorous (7.5 kcal/min)	Fatal and non-fatal first CHD attack	RR = 2.2
Salonen et al, 1982	Men - 4,110; Women - 3,829	Eastern Finland	30-59	Low / high PA	Fatal acute myocardial infarction	RR = 1.5 (1.2 - 2) for men, and 2.4 (1.5 - 3.7) for women
Peters et al, 1983	Men - 2,779	Los Angeles County	<55	Low vs. high fitness	Incident cases of fatal and non-fatal myocardial infarction	RR= 2.2 (1.1 - 4.7)
Paffenbarger et al, 1984	Men - 16,936	US		Highest category (+2000 kcal/week) vs. lower two categories	Death due toCHD	R = 1.28 and 1.84
Lapidus and Bengssson, 1986	Women - 1,462	Sweden	38-60	Low leisure time activity vs. other	Non-fatal myocardial infarction and and angina pectoris	R = 2.8 (1.2 - 6.5)
Leon et al, 1987	Men - 12,138	North American; at risk of CHD	35-57	More active and most active vs. low active	Fatal and non-fatal CHD	R = 0.9 (0.76 - 1.06) and 0.83 (0.7 - 0.99)
Pekkanen et al, 1987	Men - 636	Finland	45-64	Low vs. high physical activity	Death due CHD	R = 1.3 (p=0.17)
Sobolski et al, 1987	Men - 2,109	Belgium	40-55	4 categories of physical activity	Incident cases of fatal and non-fatal myocardial infarction and sudden death	none

Study	Population			Physical activity measure	CHD event	Impact
	Gender, no.	Location, health	Age			
Sobolski et al, 1987	Men - 2,109	Belgium	40-55	Low vs. high fitness	Incident cases of fatal and non-fatal myocardial infarction and sudden death	RR = 1.6
Donahue et al, 1988	Men - 7,644	Hawaiian men of Japanese ancestry; no history of heart disease	45-64	Active vs. sedentary	Incident cases of fatal and non-fatal CHD	RR = 0.69 (0.53 - 0.88) for 45-64 yr old, 0.43 (0.19 - 0.99) for 65- 74 yr olds
Salonen et al, 1988	Men and women - 15,088	Eastern Finland	30-59	Inactive vs. active	Death due to CHD	RR = 1.2 (1.0 - 1.5) for leisure time activity
Johansson et al, 1988	Men - 7,495	Göteburg (Sweden)	47-55	Physically active and incative at work and in leisure time	Incident cases of fatal and non-fatal CHD	none
Slattery et al, 1988	Men - 2,431	US		Highest vs. lowest heart rate	Death due to CHD	RR = 1.20 (1.1 - 1.26)
Slattery et al, 1989	Men - 3,043	US		Sedentary vs. not	Death due toCHD	none
Morris et al, 1990	Men - 9,376	Britain	45-64	3 episodes of vigorous activity per week vs. sedentary	Fatal and non-fatal CHD	R = 0.36
Berlin et al, 1990				Low vs. high activity	Cad (coronary artery disease)	R = 1.90 (1.6 - 2.20)
Linsted et al, 1991	Men - 9,484	US	>30	Increasing physical activity levels	Ischemic heart disease mortality	none
Shaper and Wannametheee, 1991	Men - 7,735	Britain	40-59	Active vs. sedentary	Fatal and non-fatal heart attack	RR = occassional 0.9 (0.5-1.3), light 0.9 (0.6-1.4), moderate 0.5 (0.2-0.8), moderately vigorous 0.5 (0.3 - 0.9), vigorous 0.9 (0.5 - 1.8)
Seccareccia and Menotti, 1992	Men - 1,712	Northern and Central Italy	40-59	Active vs. sedentary	Death due toCHD	RR = moderate activity 0.69, heavy 0.58
Hein et al, 1992	Men - 4,999	Copenhagen, Denmark	40-59	Least active vs. more active	Fatal myocardial infarction	RR = 1.59 (1.14 - 2.21)
Hein et al, 1992	Men - 4,999	Copenhagen, Denmark	40-59	Least fit vs. most fit	Fatal myocardial infarction	RR = 1.46 (0.94 - 2.26)
Nicholl et al, 1994			15-45	Those who exercise vs. those who don't	Heart disease and hypertension	RR = 0.6
			>45	Those who exercise vs. those who don't	Heart disease and hypertension	RR = 0.6

Study	Population			Physical activity measure	CHD event	Impact
	Gender, no.	Location, health	Age			
Rodriguez et al, 1994			45-68		Incident cases of fatal and non-fatal CHD	none when adjust for cholesterol, BP, BMI, diabetes

Figure 34: relative risk of stroke

Study	Population			Physical activity measure	Stroke event	Impact
	Gender, no.	Location, health	Age			
Salonen et al, 1982	Men - 4,110; Women - 3,829	Eastern Finland	30-59	Low v high levels of PA	Cerebral Stroke	RR = 1.5 (1.2 - 2.0) for men, 2.4 (1.5 - 3.7) for women
Herman et al, 1983	Men and women - 132 cases; 239 controls	The Netherlands; hospitalised stroke patients	40-74	PA levels v lowest	Signs of disturbance to cerebral function of vascular origin	RR = 0.72 (0.37 - 1.42) for moderate and 0.41 (0.21 - 0.84) for high
Paffenbarger et al, 1984	Men - 16,936	US		Lower category of activity v highest (>2,000 kcal/week)	Death due to stroke	RR = 1.25 and 2.71 for next lowest categories
Lapidus and Bengtsson, 1986	Women - 1,462	Sweden	38-60	Scale of work and leisure activity: low v high	Fatal Stroke	RR = 7.8 (2.1 - 23.0) for work, and 10.1 (3.8 - 27.1)
Harmsen et al, 1990	Men - 7,495	Sweden	47-55	PA in work and leisure	Fatal Stroke	None
Linsted, Tonstad, Kuzma, 1991	Men - 9,484	US	>30	Higher activity levels v low	Fatal Stroke	RR = 0.78 (0.61 - 1.0) for moderate, 1.08 (0.58 - 2.01) for high activity
Abbot et al, 1994	Men - 7,644	Hawaiian men of Japanese ancestry; no history of heart disease	45-64	Different level of PA	Fatal and non-fatal neurological deficit with sudden occurrence	None
Kiely et al, 1994	Men	Framingham, Massachussetts	35-69	low v medium/high levels of activity	Fatal and non-fatal occurrence of atherothrombotic brain infarction, cerebral embolism or other stroke	RR = 0.9 (0.62 - 1.31) for medium and 0.84 (0.59 - 1.18) for high
	Women		35-68	above	above	RR = 1.21 (0.89 - 1.63) for medium and 0.89 (0.60 - 1.31) for high
	Men		49-83	above	above	RR = 0.41 (0.24 - 0.69) for medium and 0.53 (0.34 - 0.84) for high
	Women		49-83	above	above	RR = 0.97 (0.64 - 1.47) for medium and 1.21 for high
Nicholl et al, 1994	Men and women		15-45	those who exercise v. those who don't	Cerebrovascular disease and other disorders of the circulation	RR = 0.67

Study	Population			Physical activity measure	Stroke event	Impact
	Gender, no.	Location, health	Age			
	Men and women		>45	those who exercise v. those who don't	Cerebrovascular disease and other disorders of the circulation	RR = 0.67
Wannamethee et al, 1992	Men - 7,735	Britain		None v. moderate		1.67 (0.67–5.00)
Gillum et al, 1996	Men - 2,368			Low v. moderate		1.24 (0.63–2.41)
Gillum et al, 1996	Women - 2,713			Low v. moderate		3.13 (0.95–10.32)
Abbott et al 1994	Men and women - 7,530	Honolulu, Hawaii		Low v. high tertile		3.70 (1.20–6.70)
Kiely et al, 1994	Men - 1,228	Framingham, Massachussetts		Tertile 1 v. tertile 2		2.44 (1.45–4.17)
Kiely et al, 1994	Women - 1,676	Framingham, Massachussetts		Tertile 1 v. tertile 2		1.03 (0.68–1.56)
Salonen et al, 1982	Men - 3,978	Finland		None v. some leisure		1.00 (0.65–1.62)*
Salonen et al, 1982	Women - 3,688	Finland		None v. some leisure		1.30 (0.73–2.16)*
Agnarsson et al, 1999	Men - 4,484	Iceland		None v. some after age 40		1.45 (0.99–2.13)
Evensonet al, 1999	Men and women - 14,575			Low v. high quartile		1.12 (0.73–1.75)
Lee et al, 1999	Men - 21,823			None v. vigorous exercise 2–4 times/wk		1.25 (1.01–1.54)
Lee et al, 1998	Men and women - 11,130			< 4184 kJ/wk v. 8368–12 548 kJ/wk		1.85 (1.32–2.63)

Figure 35: relative risk of diabetes

Study	Population			Physical activity measure	Diabetes event	Impact
	Gender, no.	Location, health	Age			
Manson et al, 1991	Women	US nurses		> 1 times vigorous activity per week vs. < 1 time/week	Self-reported physician diagnosed diabetes	RR = 0.84 (0.75 - 094)
Manson et al, 1992	Men	US physicians		> 1 times vigorous activity per week vs. < 1 time/week	Self-reported physician diagnosed diabetes	RR = 0.71 (0.54 - 0.94)

Study	Population			Physical activity measure	Diabetes event	Impact
	Gender, no.	Location, health	Age			
Nicholl et al, 1994			15-45	Those who exercise vs. those who don't	Diabetes mellitus	RR = 1.0
			> 45	Those who exercise vs. those who don't	Diabetes mellitus	RR = 0.71
Manson et al, 1991	Women - 87,253	US nurses		None vs. vigorous exercise once/wk	Type 2 DM	1.45 (1.00–2.08)
Manson et al, 1992	Men - 21,271	US physicians		None vs. vigorous exercise once/wk	Type 2 DM	1.41 (1.10–1.79)
Haapanen et al, 1997	Women - 2,840	Finland		Low vs. high tertile	Type 2 DM	2.64 (1.28–5.44)

Figure 36: relative risk of colon cancer

Study	Population			Physical activity measure	Colon cancer event	Impact
	Gender, no.	Location, health	Age			
Gerhardsson et al, 1988	Men and women - 16,477	Sweden	43-82	Least vs. most active	Colon cancer incidence	RR = 3.6 (1.3 - 9.8)
Slattery et al, 1988	Men and women	Utah	40-79	High active tertile relative to low active tertile	Colon cancer incidence	RR = 0.7 (90% CI 0.38 - 1.29) for men, and 0.48 (0.27 - 0.87)
Severson et al, 1989	Men - 7,925	Japan	46-86	High active tertile relative to low active tertile	Colon cancer incidence	RR = 0.71 (0.51 - 0.99)
Gerhardsson et al, 1990	Men and women - 864	Sweden		Low active vs. high active	Colon cancer incidence	RR = 1.8 (1.0 - 3.4)
Whittemore et al, 1990	Men - 877, Women - 608	North American Chinese	> 20	Sedentary vs. active	Colon cancer incidence	RR = 1.6 (1.1-2.4) for men, and 2.0 (1.2 - 3.3) for women
	Men - 773, Women - 696	Asian Chinese	20-79	Sedentary vs. active	Colon cancer incidence	RR = 0.85 (0.39 - 1.9) for men, 2.5 (1.0 - 6.3) for women
Marcus et al, 1994	Women - 2,851	Wisconsin	< 74	Strenuous vs. non-strenuous activity	Colon cancer incidence	RR - 1.0 (0.8 - 1.3)
Giovannucci et al, 1995	Men - 47,723	US health professionals	40 - 75	Most active quintile vs. least active quintile	Colon cancer incidence	RR = 0.53 (0.32 - 0.88)
Longnecker et al, 1995	Men - 866	US	> 30	Vigorous activity (> 2 hours/week) vs. none	Right-side colon cancer incidence	RR = 0.6 (0.4 - 1.0)
Shephard et al, 1997		Meta-analysis of 35 studies		Sedentary v. active	Colon cancer incidence	1.39 (1.27–1.51)

9.0 Appendix 4: Discounted QALY gained

AGE	Health state avoided			
	CHD	Stroke	Diabetes	Colon cancer
25	9.94	9.35	4.82	9.41
26	10.04	9.39	4.79	9.43
27	9.96	9.31	4.73	9.36
28	10.15	9.43	4.79	9.46
29	10.06	9.34	4.72	9.38
30	10.25	9.46	4.79	9.47
31	10.14	9.35	4.71	9.38
32	10.33	9.46	4.77	9.47
33	10.21	9.35	4.69	9.35
34	10.39	9.45	4.75	9.43
35	9.05	11.97	3.26	13.58
36	9.20	12.12	3.31	13.75
37	9.06	12.00	3.24	13.65
38	9.20	12.13	3.29	13.81
39	9.04	11.99	3.22	13.69
40	9.18	12.11	3.27	13.84
41	9.01	11.96	3.19	13.71
42	9.14	12.07	3.24	13.84
43	8.96	11.90	3.16	13.69
44	9.08	11.99	3.21	13.81
45	7.17	10.95	2.19	9.96
46	7.26	11.11	2.24	10.01
47	7.08	10.91	2.19	9.82
48	6.90	10.71	2.13	9.62
49	6.72	10.50	2.07	9.41
50	6.53	10.28	2.02	9.20
51	6.34	10.06	1.96	8.98
52	6.40	10.17	2.01	8.99
53	6.20	9.92	1.94	8.75
54	6.00	9.67	1.88	8.51
55	5.30	8.95	1.22	9.51
56	5.10	8.70	1.18	9.26
57	4.90	8.45	1.13	9.02
58	4.70	8.18	1.09	8.76
59	4.73	8.22	1.12	8.71
60	4.13	7.97	1.16	8.34
61	3.93	7.69	1.11	8.06
62	3.74	7.41	1.05	7.78
63	3.55	7.12	1.00	7.50
64	3.35	6.83	0.95	7.21
65	3.73	6.86	0.86	6.48
66	3.68	6.84	0.88	6.40
67	3.46	6.54	0.83	6.11
68	3.24	6.23	0.77	5.81
69	3.03	5.92	0.72	5.52
70	2.82	5.62	0.67	5.22
71	2.62	5.30	0.62	4.92
72	2.42	4.99	0.56	4.63
73	2.37	4.95	0.59	4.52
74	2.18	4.64	0.54	4.23
75	3.00	4.77	0.62	3.78
76	2.78	4.49	0.56	3.52
77	2.56	4.21	0.50	3.26
78	2.35	3.94	0.45	3.01
79	2.14	3.66	0.39	2.76
80	2.05	3.62	0.42	2.70
81	1.86	3.36	0.38	2.47
82	1.68	3.11	0.33	2.24
83	1.51	2.86	0.29	2.03
84	1.35	2.62	0.24	1.82
85	1.19	2.38	0.20	1.62

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