**Supplemental Materials**

**Table of Contents**

[Appendix 1. The PACE model 4](#_Toc477795918)

[1.1 Cohort generation 4](#_Toc477795919)

[1.2 Selection of model parameters 4](#_Toc477795920)

[1.3 Risk factor progression 7](#_Toc477795921)

[1.4 Disease events 7](#_Toc477795922)

[1.5 Modelling health effects 9](#_Toc477795923)

[1.6 Mortality 10](#_Toc477795924)

[1.7 Health state utilities 11](#_Toc477795925)

[1.8 Costs 13](#_Toc477795926)

[1.9 Model calibration 15](#_Toc477795927)

[Appendix 2. Brief physical activity interventions 19](#_Toc477795928)

[Brief physical activity interventions 19](#_Toc477795929)

[Appendix 3. Input parameters and uncertainty 35](#_Toc477795930)

[Appendix 4. Sensitivity analyses 37](#_Toc477795931)

[References 39](#_Toc477795932)

**List of Tables**

[Table 1.1– Model input parameters and sources 5](#_Toc477804292)

[Table 1.2 – Studies used to generate exposure-response functions by condition 9](#_Toc477804293)

[Table 1.3 – Cause specific mortality rates used in the model 11](#_Toc477804294)

[Table 1.4 – Health state utilities related to comorbid disease condition 12](#_Toc477804295)

[Table 1.5 – Costs related to comorbid conditions 13](#_Toc477804296)

[Table 1.6 – Model calibration results by endpoints 17](#_Toc477804297)

[Table 2.1 – Unit costs of health care utilisation 20](#_Toc477804298)

[Table 2.2 – Estimates of resource use and cost per participant of a pedometer intervention (k= 8 RCTs) 25](#_Toc477804299)

[Table 2.3 – Estimates of resource use and cost per participant of an advice or counselling intervention (k=9 RCTs) 26](#_Toc477804300)

[Table 2.4 – Estimates of resource use and cost per participant of an action planning intervention (k=14 RCTs) 27](#_Toc477804301)

[Table 2.5 – Summary table of intervention and control groups of individual studies included in the meta-analyses of brief interventions 29](#_Toc477804302)

[Table 3.1 – Effective Health Check population 35](#_Toc477804303)

[Table 3.2 – Uncertainty around intervention effectiveness and costing parameters. 36](#_Toc477804304)

[Table 4.1– Cost-effectiveness of BIs when accounting for short-term direct health benefits of physical activity 37](#_Toc477804305)

**List of figures**

[Figure 1.1 – Comparison of aggregated endpoints by calibration method 18](#_Toc477804306)

[Figure 2.1 – Individual study and pooled effects of physical activity promotion on pedometer interventions vs control group (measured as changes in steps per day). 20](#_Toc477804307)

[Figure 2.2 – Individual study and pooled effects of physical activity promotion on self-reported physical activity at 12 months (MET-hours per day). 22](#_Toc477804308)

[Figure 2.3 – Effect of action planning on physical activity (MET-hours/day) at follow-up (k=14) 23](#_Toc477804309)

[Figure 4.1– CEAC showing probability of interventions being optimal by threshold value (intervention repeat year = 2) 37](#_Toc477804310)

[Figure 4.2– CEAC showing probability of interventions being optimal by threshold value (intervention repeat year = 5) 38](#_Toc477804311)

[Figure 4.3– CEACs showing the probability of BIs being cost-effective at different values of the societal willingness-to-pay when short-term benefits of physical activity on health (utility boost) were considered 38](#_Toc477804312)

## The PACE model

The Physical Activity Cost-Effectiveness (PACE) model is a discrete event simulation model. The model starts by generating a cohort of 10,000 representative individuals of the English population. It then follows each individual, updates the risk factor values and predicts the incidence of chronic disease and associated costs and outcomes over ten years. Physical activity enters as an exogenous variable into the model. Increased physical activity is assumed to influence risk factors to influence the following grisk factors: systolic blood pressure, cholesterol levels and HbA1c, and modification of these risk factors leads to changes in the risk of chronic disease and comorbidities. For example, reduced blood pressure is linked to reduced risk of cardiovascular disease. A decrease in chronic disease and comorbidities in turn leads to a decrease in costs and to the prevention of a decrease in quality of life. The model was run 10,000 times to calculate the expected costs and outcomes of the cohort, and the empirical distribution of the 10,000 mean costs and outcomes taken to represent uncertainty in the means.

### 1.1 Cohort generation

Data on demographic characteristics of individual participants (age, gender, ethnicity) were derived from the UK Office for National Statistics [[1](#_ENREF_1), [2](#_ENREF_2)]. The risk factor profile (systolic blood pressure, total cholesterol, high density lipoprotein (HDL) cholesterol, BMI, smoking status and HbA1c) and prevalence of type 2 diabetes and cardiovascular events (IHD, MI, stroke and heart failure) for individual participants in the cohort was generated using data from the 2011 Health Survey for England (HSE) [[3](#_ENREF_3)]. The severity of breast cancer was classified according to Nottingham Prognostic Index (NPI) prognostic groups – ductal carcinoma in situ (DCIS), excellent, good, moderate and poor [[4](#_ENREF_4)] – and age specific prevalence data for breast cancer was taken from the estimates for 2008 in the United Kingdom [[5](#_ENREF_5)]. The baseline parameter values for colorectal cancer were derived from Frazier et al [[6](#_ENREF_6)] and applied to the baseline population to generate prevalence data for colorectal cancer. The baseline prevalence data of lung and kidney cancers were based on estimates from Cancer Research UK [[7](#_ENREF_7), [8](#_ENREF_8)].

### 1.2 Selection of model parameters

The choice of parameters included in the model was informed by a two-stage process. First, published systematic reviews and meta-analyses examining the impact of physical activity and/or obesity on health and disease were reviewed to identify a series of comorbidities related to physical inactivity [[9-12](#_ENREF_9)]. Second, risk factors associated with those comorbidities were included as required by risk equations included in the model. For example, physically inactive individuals are at higher risk of type 2 diabetes [[13](#_ENREF_13)], and the risk of developing type 2 diabetes is a function of not only physical activity but also of age, gender and body mass index (BMI) [[14-16](#_ENREF_14)]. Therefore, for the presence or absence of type 2 diabetes, BMI, age and gender were all included as parameters in the model. The diseases included in the model are cardiovascular conditions (ischaemic heart disease, myocardial infarction, stroke, and congestive heart failure), type 2 diabetes and its microvascular complications, and several cancers known to be related to physical inactivity and/or obesity (breast, colorectal, lung and kidney). The full list of model parameters is reported in Table 1.1.

Table 1.1– Model input parameters and sources

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameter** | **Description** | **Source for initial cohort generation** | **Covariates & sources for annual progression / risk equation** |
| Age, gender and ethnicity | Patient age, gender and ethnicity | Office for National Statistics [[1](#_ENREF_1), [2](#_ENREF_2)] | n/a |
| SBP | Systolic blood pressure | HSE [[3](#_ENREF_3)] | Age, gender, BMI, smoking, T2DM, TC, SBP, MI history, physical activity [[17-19](#_ENREF_17)] |
| BMI | Body mass index | HSE [[3](#_ENREF_3)] | Age, gender, BMI [[3](#_ENREF_3)] |
| TC | Total cholesterol | HSE [[3](#_ENREF_3)] | Age, gender, TC, physical activity [[3](#_ENREF_3), [20](#_ENREF_20)] |
| HDL-C | High-density lipoprotein cholesterol | HSE [[3](#_ENREF_3)] | Age, gender, HDL-C, physical activity [[3](#_ENREF_3), [21](#_ENREF_21)] |
| TCHDL | TC/HDL ratio | HSE [[3](#_ENREF_3)] | TC, HDL,TCHDL, T2DM [[17](#_ENREF_17)] |
| HbA1c | Glycated haemoglobin A1c | HSE [[3](#_ENREF_3)] | Gender, HbA1c, T2DM, physical activity [[17](#_ENREF_17), [22](#_ENREF_22)] |
| Smoking | Smoking status | HSE [[3](#_ENREF_3)] | Age, gender, T2DM,Smoking, duration of T2DM [[17](#_ENREF_17)] |
| Antihypertensive | Antihypertensive drug treatment | HSE [[3](#_ENREF_3)] | Age, gender, SBP |
| AF | Atrial fibrillation | Majeed et al [[23](#_ENREF_23)] & NICE [[24](#_ENREF_24)] | Age, gender, BMI, SBP, Antihypertensive, HF [[25](#_ENREF_25)] |
| IHD | Ischemic heart disease | HSE [[3](#_ENREF_3)] | Age, gender, HbA1c, TCHDL, SBP, T2DM, duration of T2DM [[17](#_ENREF_17)] |
| MI | Myocardial infarction | HSE [[3](#_ENREF_3)] | Age, gender, ethnicity, SBP, TCHDL, HbA1c, smoking, IHD, T2DM, duration of T2DM [[17](#_ENREF_17), [26](#_ENREF_26)] |
| Stroke | Stroke | HSE [[3](#_ENREF_3)] | Age, gender, SBP, Antihypertensive, T2DM, smoking, AF, HF, MI, TCHDL, HbA1c, duration of T2DM [[17](#_ENREF_17), [27](#_ENREF_27)] |
| HF | Congestive heart failure | HSE [[3](#_ENREF_3)] | Age, gender, BMI, HbA1c, SBP, T2DM, duration of T2DM [[17](#_ENREF_17), [28](#_ENREF_28)] |
| T2DM | Type 2 diabetes | HSE [[3](#_ENREF_3)] | BMI, age, gender, physical activity [[13](#_ENREF_13), [16](#_ENREF_16), [29](#_ENREF_29), [30](#_ENREF_30)] |
| Retinopathy | Diabetic retinopathy | WESDR [[31](#_ENREF_31)] | T2DM, duration of diabetes [[31](#_ENREF_31)] |
| Neuropathy | Diabetic neuropathy | WESDR [[31](#_ENREF_31)] | T2DM, duration of diabetes [[31](#_ENREF_31)] |
| Nephropathy | Diabetic nephropathy | UKPDS | T2DM, duration of diabetes [[32](#_ENREF_32)] |
| Colorectal cancer | Colorectal cancer | CRUK [[8](#_ENREF_8)] | Age, polyp size, physical activity [[6](#_ENREF_6), [33](#_ENREF_33), [34](#_ENREF_34)] |
| Breast cancer | Female breast cancer | Maddams (2009) [[5](#_ENREF_5)] | Age, gender, prognostic groups, physical activity [[35](#_ENREF_35), [36](#_ENREF_36)] |
| Lung cancer | Lung cancer | CRUK [[8](#_ENREF_8)] | Age, gender, smoking, physical activity [[7](#_ENREF_7), [37](#_ENREF_37), [38](#_ENREF_38)] |
| Kidney cancer | Kidney cancer | CRUK [[8](#_ENREF_8)] | Age, gender, T2DM, physical activity [[8](#_ENREF_8), [13](#_ENREF_13), [39](#_ENREF_39)] |
| CRUK, Cancer Research UK; HbA1c, glycated haemoglobin A1c; HDL-C, high density lipoprotein cholesterol; HSE, Health Survey for England; IHD, ischaemic heart disease; MI, myocardial infarction; SBP, systolic blood pressure; T2DM, type 2 diabetes; TC, total cholesterol; UKPDS, the UK prospective diabetes study; WESDR, Wisconsin Epidemiologic Study of Diabetic Retinopathy. | | | |

### 1.3 Risk factor progression

Each year, parameter values for each participant were recalculated; for continuous variables, the values in year were determined as a function of the values of other parameters in year () as detailed below. For binary variables such as whether or not the patient has type 2 diabetes or has an MI, risk equations determined the probability of the event. Whether or not the event occurred was determined by drawing a random number from a uniform distribution on the interval [0, 1]. The parameters are listed above in Table 1.1. The betas associated with those parameters in the risk equations are referred to as coefficients.

The progression of risk factor values in diabetic patients were updated using UKPDS risk factor equations [[17](#_ENREF_17)]. The UKPDS risk factor progression equation provide functional form, parameters and beta coefficients for HbA1c, SBP, total:HDL cholesterol and smoking. Systolic blood pressure values for individuals without diagnosis of type 2 diabetes was updated using a regression equation from the Baltimore Longitudinal Study of Ageing [[18](#_ENREF_18)]. The annual proportional change in the mean values of remaining risk factors is estimated using the HSE data from 2000 to 2011 [[3](#_ENREF_3)].

### 1.4 Disease events

#### Cardiovascular disease

For patients without pre-existing type 2 diabetes, risk equations from the Framingham Heart Study were used to estimate the probability of developing ischaemic heart disease, myocardial infarction, stroke and heart failure [[26-28](#_ENREF_26)]. Cardiovascular risk in individuals with type 2 diabetes was estimated using the UKPDS risk equations [[17](#_ENREF_17)].

#### Type 2 diabetes and microvascular complications

The probability of developing type 2 diabetes is dependent on age, gender and BMI [[16](#_ENREF_16), [29](#_ENREF_29), [30](#_ENREF_30)]. Microvascular complications comprised diabetic retinopathy, neuropathy and nephropathy. The natural history of retinopathy and neuropathy was modelled according to Eastman et al [[31](#_ENREF_31)], with transition probabilities for the stages of retinopathy (non-proliferative retinopathy, proliferative retinopathy, macular oedema and blindness) and neuropathy (symptomatic neuropathy, first lower-extremity amputation (LEA) and second LEA) depending on the duration of diabetes. The UKPDS data were used to model the progression of diabetic nephropathy [[32](#_ENREF_32)]. The health states modelled for diabetic nephropathy were microalbuminuria, macro-albuminuria, and elevated plasma creatinine or renal replacement therapy.

#### Cancers

We included four cancers known to be related to obesity and/or physical inactivity [[40](#_ENREF_40)], namely breast [[36](#_ENREF_36)], colorectal [[34](#_ENREF_34)], lung [[38](#_ENREF_38)] and kidney cancer [[41](#_ENREF_41)]. Breast cancer was divided into the following prognostic stages: ductal carcinoma in situ, excellent, good, moderate and poor [[4](#_ENREF_4)]. The annual transition probabilities by different prognostic groups, recurrences and death were taken from a previous modelling study [[35](#_ENREF_35)]. The colorectal cancer model simulates the evolution from normal epithelium to adenomatous polyp to malignancy. Individuals aged 50 years or above were placed into health states defined by the presence of polyp (low risk – less than 10mm or high risk – ≥10 mm) or cancer (localised, regional or distant).

Incidence rates of developing lung cancer in the general population were based on estimates from Cancer Research UK [[7](#_ENREF_7)] and a meta-analysis of observational studies that evaluated the association between tobacco smoking and each type of cancer, including lung cancer [[42](#_ENREF_42)]. The age and sex specific incidence rates for kidney cancer were obtained from Cancer Research UK statistics for 2010 [[8](#_ENREF_8)] and were adjusted for type 2 diabetes [[39](#_ENREF_39)] in order to estimate risk of kidney cancer. The effect of physical activity on cancers in the model was incorporated directly by adjusting risk estimates for developing cancers [[34](#_ENREF_34), [36](#_ENREF_36), [38](#_ENREF_38), [41](#_ENREF_41)].

### 1.5 Modelling health effects

We estimated the health effects of increased physical activity on health outcomes i.e. changes in risk factors and disease burden. The estimates of health effects of physical activity including exposure-response associations were obtained from systematic reviews and meta-analyses (Table 1.2). If the systematic reviews and meta-analyses provided an exposure-response function, we used that. In the absence of exposure-response function, we used the method presented by Woodcock and colleagues [[43](#_ENREF_43)] to derive the function. Given the curvilinear relationship in general, we used the square root of the exposure that is a power 0.5 transformation of the exposure.

Hence, the reduction in health outcome - as a result of the change in PA is equal to Where a = scenario MET-hours per week, and b = reference MET-hours per week.

Table 1.2 – Studies used to generate exposure-response functions by condition

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Study, year** | **Evidence (RCTs, cohort studies)** | **Population** | **Outcome** | **Net change/RR (95% CI) and corresponding exposure** |
| Systolic blood pressure (SBP) | Whelton (2002) [[19](#_ENREF_19)] | 53 RCTs (2,419 participants) | Med/women, mean age range 21-79 years. Included both hypertensive and normotensive participants | Change in SBP | -3.84 mmHg (-4.97 to -2.72); 18 MET-hours per week |
| HbA1c | Umpierre (2011) [[22](#_ENREF_22)] | 23 RCTs (933 patients) | Men/women, type 2 diabetes patients with or without comorbidities, aged ≥18 years | Change in HbA1c | -0.67% (-0.84 to -0.49); 6.4 MET-hours per week |
| Total cholesterol | Kelley (2005) [[20](#_ENREF_20)] | 21 RCTs, (1,427 participants) | Men/women, sedentary but healthy, mean age ≥50 years | Change in TC level | -3.3 mg/dl (-6.5 to -0.02); 23 MET-hours per week |
| HDL-cholesterol | Kodama (2007) [[21](#_ENREF_21)] | 25 RCTs (1,404 participants) | Men/Women, mean age range 23-75 years | Change in HDL-C level | 2.53 mg/dl (1.36 to 3.7); 15 MET-hours per week |
| Breast cancer | Wu (2013) [[36](#_ENREF_36)] | 7 cohort studies (19,882 cases) | Women, aged ≥20 years | Incidence breast cancer | 0.97 (0.95 to 0.99); 10 MET-hours per week |
| Colorectal cancer | Parkin (2011) [[34](#_ENREF_34)] | 4 cohort studies (3,386 cases) | Men/women aged ≥ 30 years | Incidence colon cancer | 0.994; 1 MET-hour per week |
| Lung cancer | Tardon (2005) [[38](#_ENREF_38)] | 11 prospective studies (5,685 cases) | Men/women, mean age ≥20 years | Incidence lung cancer | 0.87 (0.76 to 0.95); 14 MET-hours per week |
| Type 2 diabetes | Jeon (2007) [[13](#_ENREF_13)] | 10 cohort studies (9,367 cases) | Sedentary men/women aged ≥30 years | Incidence type 2 diabetes | 0.83 (0.76 to 0.90); 11 MET-hours per week |
| CI, Confidence Interval; RCTs, Randomised Controlled Trials; RR, Relative Risk; METs, Metabolic equivalent to task | | | | | |

### 1.6 Mortality

Background mortality was extracted from life tables for the English population [[44](#_ENREF_44)]. Death rates for the disease conditions included in the model, such as cardiovascular mortality (fatal MI and stroke) and cancer mortality, were excluded from the all-cause death rates to estimate other cause mortality rates. Annual transition probabilities for breast cancer recurrence to death were taken from Johnston (2001) [[35](#_ENREF_35)]. The rates were assumed to be the same across prognostic groups. Mortality estimates for colorectal cancer by stages were based on Frazier et al [[6](#_ENREF_6)]. Lung cancer mortality estimates were obtained from a comparative study of lung cancer survival in six high income countries and calculated as 1 minus the one-year net survival rate: 28.8% (95% CI: 28.3 – 29.4) in the UK [[45](#_ENREF_45)]. Survival rates for kidney cancer in the UK were used to estimate the mortality rates [[8](#_ENREF_8)]. To avoid double counting, we did not model deaths from type 2 diabetes as adults with diabetes are more likely to die from cardiovascular conditions.

Table 1.3 – Cause specific mortality rates used in the model

|  |  |  |
| --- | --- | --- |
| **Mortality rates** | **Value** | **Source** |
| All-cause mortality | By age and gender | ONS life table [[44](#_ENREF_44)] |
| Fatal MI | By age and gender | Anderson et al [[26](#_ENREF_26)], ONS [[46](#_ENREF_46)] |
| Fatal Stroke | By age and gender | D’Agostino et al [[27](#_ENREF_27)], ONS [[46](#_ENREF_46)] |
| Colorectal cancer specific mortality rate | |  |
| Localised cancer | 0.002 | Frazier et al [[6](#_ENREF_6)] |
| Regional cancer | 0.032 | Frazier et al [[6](#_ENREF_6)] |
| Distal cancer | 0.566 | Frazier et al [[6](#_ENREF_6)] |
| Breast cancer specific rates |  |  |
| Local recurrence | 0.2152 | Johnston [[35](#_ENREF_35)] |
| Regional recurrence | 0.2438 | Johnston [[35](#_ENREF_35)] |
| Distal recurrence | 0.7450 | Johnston [[35](#_ENREF_35)] |
| Lung cancer | 0.712 | Walters et al [[45](#_ENREF_45)] |
| Kidney cancer | 0.2855 | CRUK [[8](#_ENREF_8)] |

### 1.7 Health state utilities

Utility weights for health states included in the model were derived from published sources [[47-52](#_ENREF_47)] and were sampled from the beta distribution. If an individual has more than one comorbidity, the lowest utility value was used.

Table 1.4 – Health state utilities related to comorbid disease condition

| **Data/parameter** | **Value** | **SE** | **Distribution** | **Source** |
| --- | --- | --- | --- | --- |
| Healthy | 1.00 |  |  |  |
| Hypertension | 0.72 | 0.0035 | Beta | [[47](#_ENREF_47)] |
| IHD | 0.65 | 0.0203 | Beta | [[47](#_ENREF_47)] |
| Acute MI | 0.60 | 0.0220 | Beta | [[47](#_ENREF_47)] |
| Stroke | 0.52 | 0.0192 | Beta | [[47](#_ENREF_47)] |
| Congestive heart failure | 0.49 | 0.0194 | Beta | [[47](#_ENREF_47)] |
| Left ventricular hypertrophy | 0.62 | 0.0087 | Beta | [[47](#_ENREF_47)] |
| Atrial fibrillation | 0.69 | 0.0095 | Beta | [[47](#_ENREF_47)] |
| Type 2 diabetes | 0.78 | 0.0530 | Beta | [[48](#_ENREF_48)] |
| Background diabetic retinopathy | 0.78 | 0.0050 | Beta | [[49](#_ENREF_49)] |
| Proliferative retinopathy | 0.76 | 0.0080 | Beta | [[49](#_ENREF_49)] |
| Blindness/vision loss | 0.71 | 0.0180 | Beta | [[49](#_ENREF_49)] |
| Foot ulcer | 0.60 | 0.0090 | Beta | [[50](#_ENREF_50)] |
| Amputation | 0.56 | 0.0560 | Beta | [[48](#_ENREF_48)] |
| Micro/macro albuminuria | 0.68 | 0.009 | Beta | [[50](#_ENREF_50)] |
| Renal failure | 0.61 | 0.0260 | Beta | [[50](#_ENREF_50)] |
| Lung cancer | 0.56 | 0.0433 | Beta | [[47](#_ENREF_47)] |
| Breast cancer | 0.76 | 0.0133 | Beta | [[47](#_ENREF_47)] |
| Breast cancer local/regional recurrence | 0.78 | 0.0373 | Beta | [[51](#_ENREF_51)] |
| Breast cancer distal recurrence | 0.69 | 0.0293 | Beta | [[51](#_ENREF_51)] |
| Localised colorectal cancer | 0.74 | 0.0230 | Beta | [[52](#_ENREF_52)] |
| Regional colorectal cancer | 0.67 | 0.0255 | Beta | [[52](#_ENREF_52)] |
| Distal colorectal cancer | 0.25 | 0.0281 | Beta | [[52](#_ENREF_52)] |
| Kidney cancer | 0.66 | 0.0729 | Beta | [[47](#_ENREF_47)] |

### 1.8 Costs

The costs associated with each health outcome simulated in the model were obtained from previously published studies [[16](#_ENREF_16), [35](#_ENREF_35), [37](#_ENREF_37), [53-59](#_ENREF_53)]. The overall cost for each individual in the model was estimated by multiplying the healthcare utilisation associated with the health state by the costs of each unit of healthcare.

Table 1.5 – Costs related to comorbid conditions

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Data/parameter** | **Value** | | **SE** | **Distribution** | **Source** |
| Antihypertensive treatment | Age and gender specific | | | Gamma | [[53](#_ENREF_53)] |
|  | men | women |  |  |  |
| 35-54 | £32.36 | £30.08 |  |  |  |
| 55-64 | £29.63 | £30.97 |  |  |  |
| 65-74 | £32.70 | £32.14 |  |  |  |
| 75+ | £33.54 | £34.65 |  |  |  |
| Ischaemic heart disease (IHD) | £3,997.01 | |  | Gamma | [[54](#_ENREF_54)] |
| IHD (history) | £203.68 | |  | Gamma | [[55](#_ENREF_55)] |
| Myocardial infarction (first) | £5,298.16 | |  | Gamma | [[55](#_ENREF_55)] |
| MI (subsequent) | £203.68 | |  | Gamma | [[55](#_ENREF_55)] |
| MI (fatal) | £1,891.16 | |  | Gamma | [[56](#_ENREF_56)] |
| Stroke (first) | £9,583.85 | |  | Gamma | [[55](#_ENREF_55)] |
| Stroke (subsequent) | £2,576.42 | |  | Gamma | [[55](#_ENREF_55)] |
| Stroke (fatal) | £8,386.76 | |  | Gamma | [[55](#_ENREF_55)] |
| Congestive heart failure (CHF) | £3,406.60 | |  | Gamma | [[56](#_ENREF_56)] |
| CHF (history) | £776.68 | |  | Gamma | [[56](#_ENREF_56)] |
| Left ventricular hypertrophy | £1,069.89 | |  | Gamma | [[16](#_ENREF_16)] |
| Atrial fibrillation | £453.08 | |  | Gamma | [[24](#_ENREF_24)] |
| Type 2 diabetes | £750.04 | |  | Gamma | [[60](#_ENREF_60)] |
| Diabetic eye examination | £24.98 | |  | Gamma | [[61](#_ENREF_61), [62](#_ENREF_62)] |
| Photoaugulation | £192.00 | |  | Gamma | [[63](#_ENREF_63)] |
| Blindness | £1,337.49 | |  | Gamma | [[56](#_ENREF_56)] |
| Blindness (history) | £431.00 | |  | Gamma | [[56](#_ENREF_56)] |
| Cataract extraction | £1,911.54 | |  | Gamma | [[56](#_ENREF_56)] |
| Cataract extraction (history) | £129.24 | |  | Gamma | [[56](#_ENREF_56)] |
| Micro- albuminuria | £139.35 | |  | Gamma | [[57](#_ENREF_57)] |
| Overt nephropathy (proteinuria) | £8,152.27 | |  | Gamma | [[57](#_ENREF_57)] |
| End Stage Renal Disease (ESRD) | £37,416.81 | |  | Gamma | [[57](#_ENREF_57)] |
| Amputation | £12,974.53 | |  | Gamma | [[56](#_ENREF_56)] |
| Amputation (history) | £460.14 | |  | Gamma | [[56](#_ENREF_56)] |
| Lung cancer initial treatment | £13,291.08 | |  | Gamma | [[37](#_ENREF_37)] |
| Lung cancer (annual) | £5,780.16 | |  | Gamma | [[37](#_ENREF_37)] |
| Colorectal cancer – localised | £12,352.43 | |  | Gamma | [[59](#_ENREF_59)] |
| Colorectal cancer – regional | £22,723.11 | |  | Gamma | [[59](#_ENREF_59)] |
| Colorectal cancer – metastatic | £14,229.00 | |  | Gamma | [[59](#_ENREF_59)] |
| Kidney cancer | £16,605.22 | |  | Gamma | [[58](#_ENREF_58), [63](#_ENREF_63)] |
| Breast cancer – DCIS | £4,139.76 | |  | Gamma | [[35](#_ENREF_35)] |
| Breast cancer – Excellent | £4,141.30 | |  | Gamma | [[35](#_ENREF_35)] |
| Breast cancer – Good | £4,501.74 | |  | Gamma | [[35](#_ENREF_35)] |
| Breast cancer – Moderate | £4,840.72 | |  | Gamma | [[35](#_ENREF_35)] |
| Breast cancer – Poor | £5,003.30 | |  | Gamma | [[35](#_ENREF_35)] |
| Follow-up after primary treatment | £108.90 | |  | Gamma | [[35](#_ENREF_35)] |
| Breast cancer – local recurrence | £3,837.60 | |  | Gamma | [[35](#_ENREF_35)] |
| Breast cancer – regional recurrence | £5,103.00 | |  | Gamma | [[35](#_ENREF_35)] |
| Breast cancer – distal recurrence | £8,050.99 | |  | Gamma | [[35](#_ENREF_35)] |
| Follow-up–local and regional recurrence | £250.01 | |  | Gamma | [[35](#_ENREF_35)] |
| Follow-up after distal recurrence | £6,650.62 | |  | Gamma | [[35](#_ENREF_35)] |
| Palliative care | £4,217.99 | |  | Gamma | [[35](#_ENREF_35)] |

### 1.9 Model calibration

An essential – and often under-appreciated – part of model development is to check that the predictions of the model are consistent with other data sources describing the model outputs, i.e. the process of calibration [[64](#_ENREF_64), [65](#_ENREF_65)]. The accuracy of the model predictions depends on the structural assumptions of the model and the quality of key input parameters [[66](#_ENREF_66)]. The effect of increased physical activity in the model on disease events is mediated via the risk factors, and there exists direct evidence on the link between increased physical activity and risk of disease event. In addition, the risk equations used to predict cardiovascular outcomes in non-diabetic patients were from the Framingham Heart study. Thus, we calibrated the model using these targets, i.e. using the direct link between physical activity and risk of disease event (relative risks) and incidence/prevalence of diseases in the UK. The objective of the calibration exercise was to modify model input coefficients such that simulated values of parameters matched the observed parameters as closely as possible.

#### Calibration endpoints

Seven endpoints were selected as calibration targets due to their likely influence on the cost-effectiveness of interventions and on the basis of availability of evidence on the direct effect of physical activity on disease events (Table 1.6). The endpoints relate to relative risks (of all-cause mortality, stroke and CHD) with various levels of physical activity, disease incidence (MI and stroke) and prevalence (of CHD and type 2 diabetes). The evidence for these endpoints was derived from national statistics and meta-analyses of observational studies [[67-71](#_ENREF_67)].

#### Assessing the goodness-of-fit of calibration results

As the model has multiple endpoints, we combined the measure of goodness-of-fit across all calibration targets using the absolute weighted mean deviation (WMD). The WMD is calculated as the weighted sum across all the seven endpoints of the proportional difference between predicted and observed values of a given parameter (Equation 1).

|  |  |
| --- | --- |
|  | (1) |

Where = number of endpoints, = model-based estimates of the end point, = data-based target value of the end point, and = weight of the endpoint

Weights were assigned to each endpoint based on the relative importance of the estimates in the cost-effectiveness analysis (Table 1.6). In order of importance, from most important to least important, these were: relative risk (RR) of all-cause mortality, RR of stroke, RR of CHD, disease incidence (stroke and MI) and prevalence (CHD and diabetes). The weights were then assigned using Equation 2 [[72](#_ENREF_72)].

|  |  |
| --- | --- |
|  | (2) |

Where is the rank of the th end point, is the total number of end points.

#### Parameter search algorithm

We used the directed random search method [[73](#_ENREF_73)] to calibrate the model. This was done in two stages. First, 100,000 sets of all parameter coefficients were generated by sampling randomly from the mean +/- two standard errors with a uniform distribution. Second, the set yielding the lowest weighted mean deviation (WMD) was used as the starting point for a further 100,000 sets of sampled coefficients +/- one standard error. The set yielding the lowest WMD was chosen as the optimal set.

Table 1.6 – Model calibration results by endpoints

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Calibration endpoints** | **Values (Observed)** | **Model Predicted** | **Mean-deviation** | **Weighted deviation** |
| MI incidence per year per 100,000 [[71](#_ENREF_71)] | 13.58 | 16.67 | 0.23 | 0.021 |
| Prevalence of CHD [[71](#_ENREF_71)] | 5.3 % | 6.4% | 0.20 | 0.015 |
| Stroke incidence per year per 100,000 [[71](#_ENREF_71)] | 14.89 | 13.22 | 0.11 | 0.010 |
| Prevalence of Diabetes [[70](#_ENREF_70)] | 5.5 % | 6.1% | 0.12 | 0.008 |
| Relative risk of CHD (0 vs 11.3 METs) [[67](#_ENREF_67)] | 0.86 | 0.85 | 0.01 | 0.001 |
| Relative risk of stroke (0 vs 11.5 METs) [[69](#_ENREF_69)] | 0.89 | 0.91 | 0.02 | 0.004 |
| Relative risk of all-cause mortality (0 vs 11 METs) [[68](#_ENREF_68)] | 0.81 | 0.94 | 0.17 | 0.060 |
| Weighted average |  |  |  | 0.12 |

#### Calibration results

Prior to calibration, the WMD was 43%. The best-fitting parameter set from the random search method had a WMD of 12% (Table 1.6). Figure 1.1 shows the percentage deviation from the aggregated target for each calibration endpoint. Model predicted endpoints from the random search calibration deviated from the target endpoints by -11% to 23%.

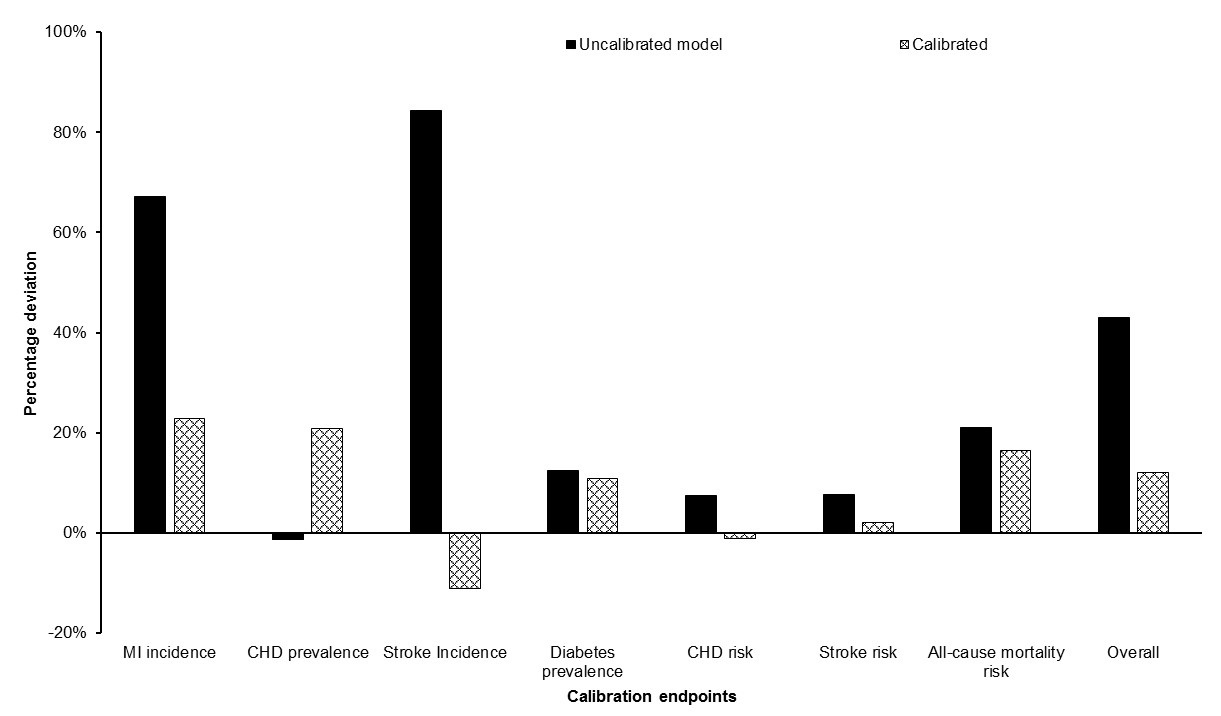


Figure 1.1 – Comparison of aggregated endpoints by calibration method

## Brief physical activity interventions

### Brief physical activity interventions

We identified four recent high quality reviews of brief interventions (BIs) in physical activity promotion, focusing on advice or counselling in primary care [[74](#_ENREF_74)], use of pedometers [[75](#_ENREF_75), [76](#_ENREF_76)] and action planning [[77](#_ENREF_77)]. These meta-analyses summarised intervention effects (as continuous outcomes) in either mean difference or standardised mean difference (SMD). Kang and colleague [[76](#_ENREF_76)] included more studies (k=32) in their meta-analysis of pedometer-based physical activity interventions than Bravata and colleagues (k=26) [[75](#_ENREF_75)] and reported a pooled intervention effect size (SMD) of 0.68, 95% CI: 0.55, 0.81. The pooled effect size was for all 32 studies and included all study designs. Bravata and colleagues [[75](#_ENREF_75)] estimated intervention effects for RCTs (k=8) and observational studies (k=18) separately and the effect size was measured in terms of increases in steps per day which facilitates clinical interpretation. Hence, we selected the Bravata review.

To compare the cost-effectiveness of these BIs, intervention effectiveness was standardised in metabolic equivalents (METs) from observed changes in intensity, duration and/or frequency of activity. A previously reported formula [[78](#_ENREF_78)] was used to translate various physical activity outcomes into MET-hours. In addition, the compendium of physical activity [[79](#_ENREF_79)] was followed to code different types and intensity of physical activities into METs. Moderate intensity physical activity was assigned 3.0 METs, moderate-to-vigorous physical activity 4.5 METs and vigorous physical activity 6.0 METs. Once the physical activity outcomes of individual studies included in these meta-analyses were translated into MET-hours, the meta-analysis was updated using the translated values (MET-hours). As in the original meta-analyses, a random-effects model was used to estimate the pooled effect (expressed as a difference in means).

#### 2.1 Pedometer intervention

***Intervention effect***

The effect of pedometer BIs was calculated in MET-hours per day from the change in daily steps counted by the pedometer. A meta-analysis of eight RCTs found that pedometer users significantly increased their physical activity by a mean of 2,491 steps per day more than control participants (95% CI: 1,098 – 3,885 steps per day) [[75](#_ENREF_75)]. The effect size is then converted into MET-hours per day using a formula presented by Wu and colleagues [[78](#_ENREF_78)] which gives the effect size of 1.06 (95% CI: 0.47 to 1.65) in MET-hours per day.

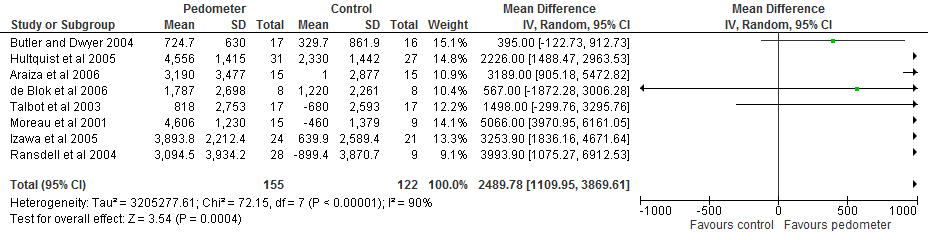


Figure 2.1 – Individual study and pooled effects of physical activity promotion on pedometer interventions vs control group (measured as changes in steps per day).

***Intervention costs***

The costs of a pedometer intervention include direct intervention costs and costs of intervention delivery. Resource use data were extracted based on the intervention description, and each RCT was costed for the quantities of resources used and the unit costs of each resource component. Unit costs for nurse and physiotherapist were taken from PSSRU unit costs [[61](#_ENREF_61)]. The cost of a pedometer was borrowed from a community based pedometer study (Walking for Wellbeing in the West) [[80](#_ENREF_80)]. Costs of production and delivery of exercise diary (A4 size black and white paper) and information booklet (A4 size colour paper) were estimated from the unit cost of printing and binding on A4 size paper (The UEA print service; [www.uea.ac.uk/print-services](http://www.uea.ac.uk/print-services)). The cost per participant was then evaluated as a weighted average of intervention costs for each RCT in the meta-analysis.

Table 2.1 – Unit costs of health care utilisation

|  |  |  |  |
| --- | --- | --- | --- |
| **Cost item** | **Unit cost** | **Distribution** | **Source** |
| Primary care consultation | £36 per consultation | Fixed | PSSRU 2011[[61](#_ENREF_61)] |
| Physiotherapist | £34 per hour | Fixed | PSSRU 2011[[61](#_ENREF_61)] |
| Exercise physiotherapist | £34 per hour | Fixed | Same as physiotherapist |
| Practice nurse (face-to-face) | £51 per hour | Fixed | PSSRU 2011[[61](#_ENREF_61)] |
| Nurse | £39 per hour | Fixed | PSSRU 2011[[61](#_ENREF_61)] |
| Pedometer | £14 per unit | Fixed | Shaw et al. [[80](#_ENREF_80)] |
| Physical activity diary | £0.96 per unit | Fixed | UEA print service |
| Physical activity information pack | £1.21 per unit | Fixed | UEA Print service |
| Trained facilitator\* | £10.89 per hour | Fixed | NHS Staff Earnings 2011(http://goo.gl/WDpmv) |
| Telephone call | £0.13 per min | Fixed | BT Tariff Guide (<http://goo.gl/QjVvG>) |
| Text messaging | £0.11 per SMS text | Fixed | BT Tariff Guide (<http://goo.gl/QjVvG>) |
| Postal cost | £0.75 per letter | Fixed | The Royal Mail Price Finder |

\* Median FTE total earnings for broad non-medical occupational groups

#### 2.2 Advice or counselling in primary care

***Intervention effect***

A meta-analysis of nine RCTs [[74](#_ENREF_74)] of physical activity promotion in sedentary adults recruited in primary care, with minimum follow-up at 12 months, found a small effects for continuous data (SMD of 0.25; 95% CI: 0.11 to 0.38). The pooled effect in terms of MET-hours per day gained was 0.33; 95% CI: 0.16 – 0.49 (Figure 2.2).

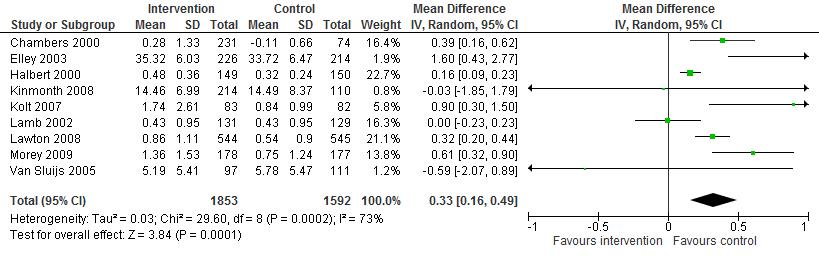


Figure 2.2 – Individual study and pooled effects of physical activity promotion on self-reported physical activity at 12 months (MET-hours per day).

***Intervention cost***

The costs associated with advice or counselling intervention include cost of advice or counselling sessions given face-to-face or by phone (or both) and written materials. A counselling session with primary care clinician was assumed as a standard primary care consultation with a general practitioner lasting around 12 minutes. Unit costs for primary care consultation, general practitioner, physiotherapist and practice nurse were taken from the PSSRU unit costs [[61](#_ENREF_61)]. Costs of production and delivery of a written material (information booklet) were estimated from the unit cost of printing (front page colour, four pages black and white print) and binding on A4 size paper.

#### 2.3 Action planning

***Intervention effect***

A meta-analysis of 19 RCTs of implementation intention interventions on physical activity at follow-up found a pooled effect (standardised mean difference) of 0.24 (95% CI: 0.13 to 0.35) [[77](#_ENREF_77)]. The pooled effect in MET-hours gained was estimated from 14/19 RCTs included in the original meta-analysis. Five RCTs were excluded because (i) they reported the physical activity outcome in terms of a scale such as the relative autonomy index or a score expressing frequency which was not possible to translate into MET-hours; or (ii) they did not report changes in intensity, duration and/or frequency of activity required for MET-hour translation. The overall pooled effect of action planning (k = 14) on physical activity (MET-hours) was 0.05; 95% CI: 0.02 to 0.08 (Figure 2.3).

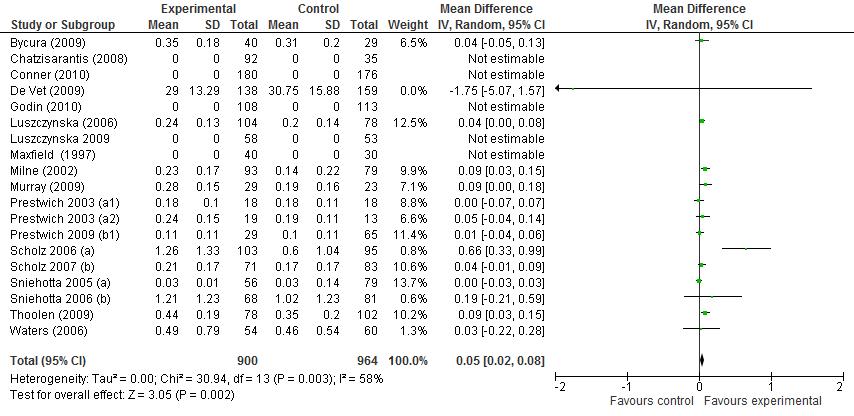


Figure 2.3 – Effect of action planning on physical activity (MET-hours/day) at follow-up (k=14)

***Intervention cost***

Costs associated with an action planning intervention included the cost of printing and developing materials (e.g. logbook, calendar, health education leaflet, pamphlet), adoption of intervention material (e.g. visual education material) tailored to local context, designing and operating the web-portal for SMS texting service, staff (nurse, health worker or fitness instructor’s time) for induction/training of participants; and other costs such as fitness club membership [[77](#_ENREF_77)]. In a typical action planning BI, the questionnaire prompted participants to formulate an action plan. Unit costs of administering the questionnaire (nurse admin time) was taken from the NHS staff earnings Jul-Sept 2010 (<http://goo.gl/WDpmv>), and health and social care costs were derived from the PSSRU unit costs for nurse, health worker, physician or other health professional time [[61](#_ENREF_61)]. Costs of production and delivery of the physical activity questionnaire and toolkit were estimated from the unit cost of printing and binding on A4 size paper (The UEA print service; [www.uea.ac.uk/print-services](http://www.uea.ac.uk/print-services)) and standard UK post rates (The Royal Mail Price Finder, <http://www.royalmail.com/price-finder>). Costs of phone calls and text messages were taken from standard BT prices (BT Tariff Guide, <http://goo.gl/QjVvG>). The cost of fitness club membership was estimated at £33 per month (Sportspark, <http://www.sportspark.co.uk>).

Table 2.2 – Estimates of resource use and cost per participant of a pedometer intervention (k= 8 RCTs)

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Study, year** | **Intervention participants** | **Resource use** | | | | | **Costs** | | | | | |
| Pedometers | Physical activity counselling | Information pack | Telephone  calls | Diary | Pedometers | Counselling | Information pack | Telephone calls | Diary | Total |
| Araiza 2006 | 15 | 1 | - | - | - | 1 | £ 14.00 | – | – | – | £0.96 | £14.96 |
| Butler and Dwyer 2004 | 17 | 1 | - | - | - | - | £ 14.00 | – | – | – | – | £14.00 |
| de Blok 2006 | 8 | 1 | 4x30 mins physiotherapist | - | - | 1 | £ 14.00 | £ 68.00 | – | – | £0.96 | £82.96 |
| Hultquist 2005 | 31 | 1 | - | - | - | 1 | £ 14.00 | – | – | – | £0.96 | £14.96 |
| Izawa 2005 | 24 | 1 | - | - | - | 1 | £ 14.00 | – | – | – | £0.96 | £14.96 |
| Moreau 2001 | 15 | 1 | - | - | - | 1 | £ 14.00 | – | – | – | £0.96 | £14.96 |
| Ransdell 2004 and Ornes 2005 | 28 | 1 | 2x120 mins exercise physiologist | 1 | 6x3 mins exercise physiologist | - | £ 14.00 | £ 136.00 | £ 1.21 | £ 32.34 | – | £183.55 |
| Talbot 2003 | 17 | 1 | 12x5 mins practice nurse | 1 | - | - | £ 14.00 | £ 50.00 | £ 1.21 | – | – | £65.21 |
| Total | 155 |  |  |  |  |  |  | Weighted average cost per participant | | | | £54.33 |

Table 2.3 – Estimates of resource use and cost per participant of an advice or counselling intervention (k=9 RCTs)

| **Study, year** | **Intervention participants** | **Resource use** | | | | **Costs** | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Counselling | Telephone calls | Postal contact | Written material | Counselling | written material | Telephone calls | Postal contact | Total |
| Chambers 2000 | 77 | 1x key messages reinforced in GP letter |  |  | 1 | £ 16.13 | £ 1.21 | - | - | £ 17.34 |
| 76 | 1x individualised advice on exercise |  |  | 1 | £ 25.50 | £ 1.21 | - | - | £ 26.71 |
| 78 | 1x exercise assessment, 4x small-group exercise sessions physiotherapist |  |  | 1 | £ 39.10 | £ 1.21 | - | - | £ 40.31 |
| Halbert 2000 | 149 | 3x exercise advice sessions exercise specialist |  |  |  | £ 25.50 | - | - | - | £ 25.50 |
| Lamb 2002 | 131 | 1x group advice session | 3x telephone calls physiotherapist |  | 1 | £ 2.83 | £ 1.21 | £ 20.90 | - | £ 24.94 |
| Elley 2003 | 226 | 1x 7 mins GP | 3x 5 min calls by exercise specialist; 3x5 min calls by nurse |  | 1 | £ 21.54 | £ 1.21 | £ 22.15 | - | £ 44.90 |
| Van Sluijs 2005 | 97 | 2x counselling session with primary care clinician | 2 telephone support call (practice nurse) x 5 mins |  | 1 | £ 72.00 | £ 1.21 | £ 7.80 | - | £ 81.01 |
| Kolt 2007 | 83 |  | 8x13 min (avg) phone call from exercise counsellor |  | 1 | - | £ 1.21 | £ 72.45 | - | £ 73.66 |
| Kinmonth 2008 | 105 | 4x sessions | 9 telephone support calls |  |  | £ 41.92 | - | £ 73.12 | - | £ 115.04 |
| 109 | 1 session | 6 telephone support calls | 7 | 1 | - | £ 1.21 | £ 63.98 | £.75 | £ 73.94 |
| Lawton 2008 | 544 | 2x 10 min practice nurse | 5x 15 min practice nurse |  | 1 | £ 17.00 | £ 1.21 | £ 58.50 | - | £ 76.71 |
| Morey 2009 | 178 | 1x session health counsellor | 12x 18 min phone call |  | 1 | £ 12.75 | £ 1.21 | £168.48 | - | £ 182.44 |
| Total | 1,853 |  |  | Weighted average cost per participant | | | | | | £ 71.26 |

Table 2.4 – Estimates of resource use and cost per participant of an action planning intervention (k=14 RCTs)

| **Study, year** | **Intervention participants** | **Resource use** | | | | **Costs** | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Material development / instrument | Implementation intention | Diary, log book etc. | Fitness membership | Material development / instrument | Implementation intention | Diary, logbook, brochures etc. | Total |
| Bycura 2009 | 40 | – | 10 min health worker, 6 min nurse | 1 | – | – | £ 6.88 | £ 0.18 | £ 7.06 |
| de Vet 2009 | 138 | – | 5 min nurse | 1 | – | – | £ 0.87 | £ 2.32 | £ 3.19 |
| Luszczynska 2006 | 104 | – | 15 min interviewer + 15 mins psychologist | 1 | – | – | £ 22.45 | £ 0.26 | £ 22.70 |
| Milne 2002 | 93 | 1 | 10+5 min nurse admin | 1 | – | £ 1.34 | £ 2.62 | £ 0.34 | £ 4.30 |
| Murray 2009 | 29 | – | 15 min nurse, 30x6 min fitness supervisor, 9 wk gym membership | 1 | 1 | – | £ 127.00 | £ 0.32 | £127.32 |
| Prestwich 2003 (a1) | 18 | – | 15 min nurse, 5 min fitness advisor | 1 | – | – | £ 3.87 | £ 2.08 | £ 5.95 |
| Prestwich 2003 (a2) | 19 | – | 20 min nurse, 5 min fitness advisor | 1 | – | – | £ 6.07 | £ 2.16 | £ 8.3 |
| Prestwich 2009 (b1) | 29 | – | 15 min health worker | 1 | – | – | £ 7.75 | £ 0.40 | £ 8.15 |
| Scholz 2006 (a) | 103 | – | 15x2 min nurse, 9 min GP | 1 | – | – | £ 129.62 | £ 11.32 | £140.94 |
| Scholz 2007 (b) | 71 | – | 15 min nurse, 20 min interviewer | 1 | – | – | £ 10.68 | £ 1.05 | £ 11.73 |
| Sniehotta 2005 (a) | 56 | – | 25 min nurse, 15 min interviewer | 1 | – | – | £ 15.11 | £ 11.26 | £ 26.37 |
| Sniehotta 2006 (b) | 68 | – | 25 min nurse +15 min interviewer | 1 | – | – | £ 15.11 | £ 15.06 | £ 30.17 |
| Thoolen 2009 | 78 | 1 | 2+5 min nurse | 1 | – | £ 1.60 | £ 23.18 | £ 1.06 | £ 25.84 |
| Waters 2006 | 54 | 1 digital timer | 10 min nurse | 1 | – | £ 20 | £ 1.75 | £ 2.69 | £ 24.43 |
| Total | 900 |  |  | Weighted average cost per participant | | | | | £ 33.21 |

#### 2.4 Summary of intervention and control groups included in the meta-analyses of brief interventions

Table 2.5 – Summary table of intervention and control groups of individual studies included in the meta-analyses of brief interventions

| **Study (year)** | **Study group** | **Summary of intervention and control** |
| --- | --- | --- |
| **Pedometers [**[**75**](#_ENREF_75)**]** | | |
| Araiza 2006 | Control | given a pedometer, but instructed to maintain normal activity  during intervention |
| Intervention | given a pedometer; instructed to walk 10 000 steps per day, 5  times/week |
| Butler 2004 | Control | wore a pedometer with an obscured monitor and asked to walk 30 min/day for the first 2 week, 40 min/d for the following 2 week |
| Intervention | modified version of Just Walk It Program; given pedometers and a daily goal (first 2 week: 3000 steps/day or 30 min/day, following 2 week: 4000 steps/day or 40 min/day) |
| De Blok 2006 | Control | received COPD rehabilitation only |
| Intervention | COPD rehabilitation (including exercise training and dietary intervention), given a pedometer and 4 lifestyle physical activity counselling and goal-setting sessions to increase steps/day |
| Hultquist 2005 | Control | wore a sealed pedometer and asked to walk 30 min/d on most days |
| Intervention | directed to walk 10 000 steps/day, wearing pedometer for feedback |
| Izawa 2005 | Control | received supervised cardiac rehabilitation |
| Intervention | received supervised cardiac rehabilitation and performed pedometer self-monitoring |
| Moreau 2001 | Control | wore pedometer 1 week/month and asked to not make any changes to daily physical activity |
| Intervention | given pedometer and step goal that would be equal to 3 km/day above baseline by end of intervention; week 1, 1.4 km/day increase, then increased by 0.5 km/day per week for 3 weeks until the 3 km target was reached |
| Ransdell 2004; Ornes 2005 | Control | asked not to increase physical activities; attended a 2-h info session about using pedometer; recorded baseline and 6-month steps over 3 day |
| Intervention | home-based physical activity intervention with 2 classroom sessions of 2 hr; given home-based physical activity packet and monthly reminder telephone calls; asked to exercise 3 times/week with the triad and increase walking time and intensity in a step-wise fashion. |
| Talbot 2003 | Control | attended a 12-hr arthritis self-management course |
| Intervention | received pedometer walking program (30% increase in baseline over 12 weeks) and 12-hr arthritis self-management program |
| **Advice/counselling in primary care [**[**74**](#_ENREF_74)**]** | | |
| Chambers 2000 | Control | no intervention |
| Intervention | 1 mailed booklet promoting benefits of exercise, 1 exercise assessment, and 4 exercise sessions in small groups |
| Halbert 2000 | Control | 1 written information leaflet on good nutrition for older adults, with subsequent discussion |
| Intervention | 1 session comprising individualised advice (about benefits of exercise, discussion about the barriers to exercise, written physical activity goal), and 2 follow-up sessions to discuss progress |
| Lamb 2002 | Control | 1 group advice session (including health benefits of exercise and recommended activity levels) and written guidance |
| Intervention | referral to health walks programme, ≤3 telephone calls encouraging participation, written information on self-led walks, and control intervention |
| Elley 2003 | Control | no intervention |
| Intervention | 1 advice session with primary care clinician using motivational interview techniques, written exercise prescription, ≥3 support phone calls, quarterly newsletters, and other mailed motivational materials |
| van Sluijs 2005 | Control | 1 brief advice session with clinician recommending increased physical activity |
| Intervention | 1 stage specific counselling session on physical activity with primary care clinician written exercise prescription, 1 follow-up counselling session with primary care clinician and 2 telephone support calls |
| Kolt 2007 | Control | no intervention |
| Intervention | 8 counselling sessions by telephone, generic written information on physical activity, and self-monitoring tools |
| Kinmonth 2008 | Control | mailed leaflet with brief motivational advice on benefits of increased physical activity |
| Intervention | mailed leaflet with brief motivational advice, 5 counselling sessions (designed to alter behavioural determinants and teach behavioural change strategies to increase physical support, and 9 support telephone calls and postal contacts |
| Lawton 2008 | Control | no intervention |
| Intervention | 2 counselling sessions with primary care nurse (including motivational interview techniques to promote physical activity), written exercise prescription, and average of 5 telephone support calls |
| Morey 2009 | Control | no intervention |
| Intervention | 1 counselling session, about 12 counselling telephone calls, about 12 automatic telephone messages, 1 endorsement of physical activity by primary care provider, self-monitoring tools, and 4 written progress reports |
| **Action planning [**[**77**](#_ENREF_77)**]** | | |
| Bycura 2009 | Control | asked to commit predetermined goal (moderate-vigorous PA, 3 times a week for 20-60 min in duration) |
| Intervention | asked to commit the same goal as control and also made a plan towards the goal – when (day and time of the day) and where |
| de Vet 2009 | Control | no intervention |
| Intervention | assigned activity (walking) and told to increase physical activity by walking an extra two hrs, asked to form intentions – what day(s), when, where and how long to walk |
| Luszczynska 2006 | Control | no intervention |
| Intervention | individual session lasting 10-15 min, received instructions to form a plan regarding their physical activity – plan what, when (day and time of day), where and how to exercise, received supportive feedback regarding participant’s implementation intention |
| Milne 2002 | Control | motivational intervention – received health education leaflet containing information about the prevalence and nature of CHD and the effects of exercise on reducing the risk of CHD – addressing perceived severity (painful and debilitating effects of CHD), perceived vulnerability (vulnerability of developing CHD if not engaged in regular exercise), response efficacy (effectiveness of exercise in preventing CHD), self-efficacy (suggestion to engage in exercise) and response-costs (regular exercise have its costs but benefits far overweight the costs) on subsequent changes in exercise cognitions, intention and behaviour |
| Intervention | received motivational intervention and asked to form an implementation intention specifying where and where to engage in exercise |
| Murray 2009 | Control | received supervised instructional resistance-training (6 sessions) but not asked to form intentions |
| Intervention | received 6 supervised instructional resistance-training sessions, asked to form implementation intentions specifying when (day and time of day) and how often to exercise |
| Prestwich 2003 | Control | no intervention |
| Intervention 1 | asked to think of and record the anticipated gains and losses which may arise from their exercising 2 more sessions/week, and received feedback on their responses |
| Intervention 2 | asked to specify the time, place and type of extra exercise that participant would engage in over the following 4 weeks |
| Intervention 3 | Combined intervention – intervention 1 and intervention 2 |
| Scholz 2006 | Control | standard-care, guided exercise session 3-4 times/week with individualized intensity level |
| Intervention | received brief self-regulatory skills training (action planning and coping planning), took part in 15-min individual interviewer-assisted specified 3 action plans, 3 coping plans or possible barriers and how to overcome them; sent brief diary each week with patients personal action plans and coping plans, asked to complete and return diary shortly after receiving them, |
| Scholz 2007 | Control | no intervention |
| Intervention | received planning sheet from the interviewer and invited to read instructions written on the planning sheet, asked to formulate personal plans i.e. when, where, how and how often to exercise |
| Sniehotta 2005 | Control | no intervention |
| Intervention | received a planning booklet with two planning sheets for action plans and for coping plans, instructed to produce detailed action plans – when, where and how to be physically active |
| Sniehotta 2006 | Control | no intervention |
| Intervention | individual planning session, received planning sheet and instructed to produce action plans, participant formed up to 3 action plans about when, where and how they intended to exercise and/or intended to implement extra everyday physical activities |
| Thoolen 2009 | Control | no intervention – received a brochure on diabetes self-management |
| Intervention | 2 individual (personal experience) and 4 group sessions (personally relevant goals in the domains of physical exercise, diet and medication), assigned course depending on their medical treatment, simulated to formulate a personally relevant goal and work based on pro-active 5 step plan (action and coping plans), record daily register of goal-attainment over 2 weeks |
| Waters 2006 | Control | no intervention |
| Intervention | asked to identify at least 5 obstacles to exercising regularly and ways to overcome each obstacle |

## Input parameters and uncertainty

Table 3.1 – Effective Health Check population

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Total resident population aged 40 to 74 [**[**81**](#_ENREF_81)**]** | **Estimated on the disease register [**[**82**](#_ENREF_82)**]** | **Estimated eligible population aged 40-74** | **Total discounted\* population aged 40-74** |
| A | B | C = (A-B) | D |
| Prevalent population | 21,88,7396 | 6,566,219 | 15,321,177 | 15,321,177 |
| Incident population (year 1) | 764,005 | 229,202 | 534,803 | 516,718 |
| Incident population (year 2) | 731,914 | 219,574 | 512,340 | 478,275 |
| Incident population (year 3) | 699,168 | 209,750 | 489,418 | 441,427 |
| Incident population (year 4) | 685,626 | 205,688 | 479,938 | 418,238 |
| Incident population (year 5) | 668,403 | 200,521 | 467,882 | 393,944 |
| Incident population (year 6) | 662,338 | 198,701 | 463,637 | 377,169 |
| Incident population (year 7) | 660,465 | 198,140 | 462,325 | 363,383 |
| Incident population (year 8) | 700,813 | 210,244 | 490,569 | 372,544 |
| Incident population (year 9) | 738,069 | 221,421 | 516,648 | 379,081 |
| **Total** | **7,198,218** | **8,459,460** | **19,738,737** | **19,061,956** |

\* Future population discounted at 3.5% per annum

Table 3.2 – Uncertainty around intervention effectiveness and costing parameters.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Parameter** | **Value**  **Mean (SE)** | **Distribution** | **Sources and assumptions** | **Interventions** |
| Pedometers | £54.33 (£5.43) | Gamma | Per patient cost for pedometers [[75](#_ENREF_75)]. Standard error assumed to be 10% of point-estimate. | Pedometers |
| Advice from primary care doctor or nurse | £71.26 (£7.13) | Gamma | Cost of two primary care consultations and written materials [[74](#_ENREF_74)]. Standard error assumed to be 10% of point-estimate. | Advice/counselling in primary care |
| Action planning | £33.21 (£3.32) | Gamma | Per patient cost for action planning intervention [[77](#_ENREF_77)]. Standard error assumed to be 10% of point-estimate. | Action planning |
| Change in activity due to intervention | 7.41 (2.12) MET-hour per week | Normal | Meta-analysis of 8 RCTs [[75](#_ENREF_75)] | Pedometers |
| Change in activity due to intervention | 2.31 (0.59) MET-hour per week | Normal | Meta-analysis of 9 RCTs [[74](#_ENREF_74)] | Advice/counselling in primary care |
| Change in activity due to intervention | 0.33 (0.11) MET-hour per week | Normal | Meta-analysis of 14 RCTs [[77](#_ENREF_77)] | Action planning |

## Sensitivity analyses

Table 4.1– Cost-effectiveness of BIs when accounting for short-term direct health benefits of physical activity

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Brief intervention** | **Mean cost (SE)** | | **Mean QALY (SE)** | | **Mean NB\* (SE)** | |
| Advice/counselling in primary care | £ 1,758 | (580) | 7.8869 | (0.230) | £ 155,980 | (5,105) |
| Action planning | £ 1,736 | (582) | 7.8818 | (0.229) | £ 155,900 | (5,093) |
| Pedometers | £ 1,721 | (580) | 7.8936 | (0.230) | £ 156,152 | (5,115) |
| Current practice | £ 1,713 | (584) | 7.8484 | (0.228) | £ 155,255 | (5,078) |
| \*NB calculated at a WTP of £20,000 per QALY. | | | | | | |



Figure 4.1– CEAC showing probability of interventions being optimal by threshold value (intervention repeat year = 2)



Figure 4.2– CEAC showing probability of interventions being optimal by threshold value (intervention repeat year = 5)

Figure 4.3– CEACs showing the probability of BIs being cost-effective at different values of the societal willingness-to-pay when short-term benefits of physical activity on health (utility boost) were considered

# References

[1] Office for National Statistics. Vital Statistics: Population and Health Reference Tables - Spring 2011 Update. Available from: <http://www.ons.gov.uk/ons/publications/re-reference-tables.html?edition=tcm%3A77-213289> [Accessed 1 December 2011].

[2] Office for National Statistics. 2011 Census: Key Statistics for local authorities in England and Wales. Available from: <http://www.ons.gov.uk/ons/rel/census/2011-census/key-statistics-for-local-authorities-in-england-and-wales/> [Accessed 12 December 2012].

[3] Craig R, Mindell J. Health Survey for England 2011. Leeds: The Health and Social Care Information Centre 2012.

[4] Blamey RW, Ellis IO, Pinder SE, et al. Survival of invasive breast cancer according to the Nottingham Prognostic Index in cases diagnosed in 1990-1999. Eur J Cancer 2007;43:1548-55.

[5] Maddams J, Brewster D, Gavin A, et al. Cancer prevalence in the United Kingdom: estimates for 2008. Br J Cancer 2009;101:541-7.

[6] Frazier AL, Colditz GA, Fuchs CS, et al. Cost-effectiveness of screening for colorectal cancer in the general population. JAMA 2000;284:1954-61.

[7] Cancer Research UK. Average Number of New Cases Per Year and Age-Specific Incidence Rates, UK, 2007-2009. Available from: <http://www.cancerresearchuk.org/cancer-info/cancerstats/types/lung/incidence> [Accessed Jan 2, 2013].

[8] Cancer Research UK. Cancer Research UK CancerStats. Available from: <http://info.cancerresearchuk.org/cancerstats/types/kidney> [Accessed 8 January 2013].

[9] Reiner M, Niermann C, Jekauc D, et al. Long-term health benefits of physical activity--a systematic review of longitudinal studies. BMC Public Health 2013;13:813.

[10] Warburton DE, Charlesworth S, Ivey A, et al. A systematic review of the evidence for Canada's Physical Activity Guidelines for Adults. Int J Behav Nutr Phys Act 2010;7:39.

[11] Lee IM, Shiroma EJ, Lobelo F, et al. Effect of physical inactivity on major non-communicable diseases worldwide: an analysis of burden of disease and life expectancy. Lancet 2012;380:219-29.

[12] Guh DP, Zhang W, Bansback N, et al. The incidence of co-morbidities related to obesity and overweight: a systematic review and meta-analysis. BMC Public Health 2009;9:88.

[13] Jeon CY, Lokken RP, Hu FB, et al. Physical activity of moderate intensity and risk of type 2 diabetes: a systematic review. Diabetes Care 2007;30:744-52.

[14] Lipton RB, Liao YL, Cao GC, et al. Determinants of Incident Non-Insulin-Dependent Diabetes-Mellitus among Blacks and Whites in a National Sample - the Nhanes-I Epidemiologic Follow-up-Study. Am J Epidemiol 1993;138:826-39.

[15] Colditz GA, Willett WC, Rotnitzky A, et al. Weight-Gain as a Risk Factor for Clinical Diabetes-Mellitus in Women. Ann Intern Med 1995;122:481-86.

[16] Wilson E, Fordham R. A model to estimate health impacts and costs of obesity in Norfolk over the next 10 years - Final Report. Norwich: NHS Health Economics Support Programme, Health Economics Group, University of East Anglia, 2005.

[17] Clarke PM, Gray AM, Briggs A, et al. A model to estimate the lifetime health outcomes of patients with type 2 diabetes: the United Kingdom Prospective Diabetes Study (UKPDS) Outcomes Model (UKPDS no. 68). Diabetologia 2004;47:1747-59.

[18] Bos AJ, Brant LJ, Morrell CH, et al. The relationship of obesity and the development of coronary heart disease to longitudinal changes in systolic blood pressure. Coll Antropol 1998;22:333-44.

[19] Whelton SP, Chin A, Xin X, et al. Effect of aerobic exercise on blood pressure: a meta-analysis of randomized, controlled trials. Ann Intern Med 2002;136:493-503.

[20] Kelley GA, Kelley KS, Tran ZV. Exercise, lipids, and lipoproteins in older adults: a meta-analysis. Prev Cardiol 2005;8:206-14.

[21] Kodama S, Tanaka S, Saito K, et al. Effect of aerobic exercise training on serum levels of high-density lipoprotein cholesterol: a meta-analysis. Arch Intern Med 2007;167:999-1008.

[22] Umpierre D, Ribeiro PA, Kramer CK, et al. Physical activity advice only or structured exercise training and association with HbA1c levels in type 2 diabetes: a systematic review and meta-analysis. JAMA 2011;305:1790-9.

[23] Majeed A, Moser K, Carroll K. Trends in the prevalence and management of atrial fibrillation in general practice in England and Wales, 1994-1998: analysis of data from the general practice research database. Heart 2001;86:284-8.

[24] National Institute for Health and Clinical Excellence. NICE clinical guideline 36 - Atrial fibrillation: the management of atrial fibrillation. London: National Institute for Health and Clinical Excellence, 2006.

[25] Schnabel RB, Sullivan LM, Levy D, et al. Development of a risk score for atrial fibrillation (Framingham Heart Study): a community-based cohort study. Lancet 2009;373:739-45.

[26] Anderson KM, Odell PM, Wilson PW, et al. Cardiovascular disease risk profiles. Am Heart J 1991;121:293-8.

[27] D'Agostino RB, Wolf PA, Belanger AJ, et al. Stroke risk profile: adjustment for antihypertensive medication. The Framingham Study. Stroke 1994;25:40-3.

[28] Kannel WB, D'Agostino RB, Silbershatz H, et al. Profile for estimating risk of heart failure. Arch Intern Med 1999;159:1197-204.

[29] Colditz GA, Willett WC, Rotnitzky A, et al. Weight gain as a risk factor for clinical diabetes mellitus in women. Ann Intern Med 1995;122:481-6.

[30] Brailsford S, Davies R. Screening for diabeteic retinopathy: the evaluation of screenign policies for diabetic retinopathy using computer simulation. 2004.

[31] Eastman RC, Javitt JC, Herman WH, et al. Model of complications of NIDDM. I. Model construction and assumptions. Diabetes Care 1997;20:725-34.

[32] Adler AI, Stevens RJ, Manley SE, et al. Development and progression of nephropathy in type 2 diabetes: the United Kingdom Prospective Diabetes Study (UKPDS 64). Kidney Int 2003;63:225-32.

[33] Frazier AL. Age Dependent Transition Probabilities From Health to Low Risk Adenoma Disease States Within a Markov Model. Massachusetts: Harvard Medical School, 2002.

[34] Parkin DM. 9. Cancers attributable to inadequate physical exercise in the UK in 2010. Br J Cancer 2011;105 Suppl 2:S38-41.

[35] Johnston K. Modelling the future costs of breast screening. Eur J Cancer 2001;37:1752-8.

[36] Wu Y, Zhang D, Kang S. Physical activity and risk of breast cancer: a meta-analysis of prospective studies. Breast Cancer Res Treat 2013;137:869-82.

[37] Godfrey C, Ali S, Parrott S, et al. Economic model of adult smoking related costs and consequences for England. York: Department of Health Sciences, University of York, April 2011.

[38] Tardon A, Lee WJ, Delgado-Rodriguez M, et al. Leisure-time physical activity and lung cancer: a meta-analysis. Cancer Causes Control 2005;16:389-97.

[39] Larsson SC, Wolk A. Diabetes mellitus and incidence of kidney cancer: a meta-analysis of cohort studies. Diabetologia 2011;54:1013-8.

[40] Clague J, Bernstein L. Physical activity and cancer. Curr Oncol Rep 2012;14:550-8.

[41] Behrens G, Leitzmann MF. The association between physical activity and renal cancer: systematic review and meta-analysis. Br J Cancer 2013;108:798-811.

[42] Gandini S, Botteri E, Iodice S, et al. Tobacco smoking and cancer: a meta-analysis. Int J Cancer 2008;122:155-64.

[43] Woodcock J, Edwards P, Tonne C, et al. Public health benefits of strategies to reduce greenhouse-gas emissions: urban land transport. Lancet 2009;374:1930-43.

[44] Office of National Statistics. UK Interim Life Tables, 1980-82 to 2009-2011. Available from: <http://www.ons.gov.uk/ons/rel/lifetables/interim-life-tables/2009-2011/rft-england.xls> [Accessed 17 April 2013].

[45] Walters S, Maringe C, Coleman MP, et al. Lung cancer survival and stage at diagnosis in Australia, Canada, Denmark, Norway, Sweden and the UK: a population-based study, 2004-2007. Thorax 2013;68:551-64.

[46] Office for National Statistics. Mortality statistics by cause: review of the registrar general on deaths by cause, sex and age, in England & Wales, 2003. Series DH2 no30. London: Office for National Statistics, 2005.

[47] Sullivan PW, Slejko JF, Sculpher MJ, et al. Catalogue of EQ-5D scores for the United Kingdom. Med Decis Making 2011;31:800-4.

[48] Clarke P, Gray A, Holman R. Estimating utility values for health states of type 2 diabetic patients using the EQ-5D (UKPDS 62). Med Decis Making 2002;22:340-9.

[49] Zhang P, Brown MB, Bilik D, et al. Health utility scores for people with type 2 diabetes in U.S. managed care health plans: results from Translating Research Into Action for Diabetes (TRIAD). Diabetes Care 2012;35:2250-6.

[50] Coffey JT, Brandle M, Zhou H, et al. Valuing health-related quality of life in diabetes. Diabetes Care 2002;25:2238-43.

[51] Lidgren M, Wilking N, Jonsson B, et al. Health related quality of life in different states of breast cancer. Qual Life Res 2007;16:1073-81.

[52] Ness RM, Holmes AM, Klein R, et al. Utility valuations for outcome states of colorectal cancer. Am J Gastroenterol 1999;94:1650-7.

[53] National Clinical Guideline Centre. Hypertension: clinical management of primary hypertension in adults (update). (Clinical guideline 127). National Clinical Guideline Centre, the Royal College of Physicians, 2011.

[54] Ara R, Pandor A, Stevens J, et al. Early high-dose lipid-lowering therapy to avoid cardiac events: a systematic review and economic evaluation. Health Technol Assess 2009;13:1-74, 75-118.

[55] Ward S, Lloyd Jones M, Pandor A, et al. A systematic review and economic evaluation of statins for the prevention of coronary events. Health Technol Assess 2007;11:1-160, iii-iv.

[56] Clarke P, Gray A, Legood R, et al. The impact of diabetes-related complications on healthcare costs: results from the United Kingdom Prospective Diabetes Study (UKPDS Study No. 65). Diabet Med 2003;20:442-50.

[57] Gordois A, Scuffham P, Shearer A, et al. The health care costs of diabetic nephropathy in the United States and the United Kingdom. J Diabetes Complications 2004;18:18-26.

[58] Thompson Coon J, Hoyle M, Green C, et al. Bevacizumab, sorafenib tosylate, sunitinib and temsirolimus for renal cell carcinoma: a systematic review and economic evaluation. Health Technol Assess 2010;14:1-184, iii-iv.

[59] Tappenden P, Chilcott J, Eggington S, et al. Option appraisal of population-based colorectal cancer screening programmes in England. Gut 2007;56:677-84.

[60] Ara R, Brennan A. Economic evaluation of sibutramine for the treatment of obesity in adults without other co-morbidities in the UK. Company submission to NICE (available in section 6 of NICE Guideline 43). 2005.

[61] Curtis L. Unit Costs of Health and Social Care 2011. Canterbury: Personal Social Services Research Unit, University of Kent, 2011.

[62] Joint Formulary Committee. British National Formulary (BNF) 64. Pharmaceutical Press, 2012.

[63] Department of Health. Reference costs guidance for 2011-12. Available from: <http://www.dh.gov.uk/prod_consum_dh/groups/dh_digitalassets/@dh/@en/documents/digitalasset/dh_133719.pdf> (accessed 22 October 2012) [Accessed 22 October 2012].

[64] Vanni T, Karnon J, Madan J, et al. Calibrating models in economic evaluation: a seven-step approach. Pharmacoeconomics 2011;29:35-49.

[65] Weinstein MC. Recent developments in decision-analytic modelling for economic evaluation. Pharmacoeconomics 2006;24:1043-53.

[66] Eddy DM, Hollingworth W, Caro JJ, et al. Model transparency and validation: a report of the ISPOR-SMDM Modeling Good Research Practices Task Force--7. Value Health 2012;15:843-50.

[67] Sattelmair J, Pertman J, Ding EL, et al. Dose response between physical activity and risk of coronary heart disease: a meta-analysis. Circulation 2011;124:789-95.

[68] Woodcock J, Franco OH, Orsini N, et al. Non-vigorous physical activity and all-cause mortality: systematic review and meta-analysis of cohort studies. Int J Epidemiol 2011;40:121-38.

[69] Diep L, Kwagyan J, Kurantsin-Mills J, et al. Association of physical activity level and stroke outcomes in men and women: a meta-analysis. J Womens Health (Larchmt) 2010;19:1815-22.

[70] The Information Centre for Health and Social Care. Quality and Outcomes Framework. 2011.

[71] Scarborough P, Bhatnagar P, Wickramasinghe K, et al. Coronary heart disease statistics 2010 edition. London: British Heart Foundation, 2010.

[72] Roberts R, Goodwin P. Weight approximations in multi-attribute decision models. J Multi-Crit Decis Anal 2002;11:291-303.

[73] Kim JJ, Kuntz KM, Stout NK, et al. Multiparameter calibration of a natural history model of cervical cancer. Am J Epidemiol 2007;166:137-50.

[74] Orrow G, Kinmonth AL, Sanderson S, et al. Effectiveness of physical activity promotion based in primary care: systematic review and meta-analysis of randomised controlled trials. BMJ 2012;344:e1389.

[75] Bravata DM, Smith-Spangler C, Sundaram V, et al. Using pedometers to increase physical activity and improve health: a systematic review. JAMA 2007;298:2296-304.

[76] Kang M, Marshall SJ, Barreira TV, et al. Effect of pedometer-based physical activity interventions: a meta-analysis. Res Q Exerc Sport 2009;80:648-55.

[77] Belanger-Gravel A, Godin G, Amireault S. A meta-analytic review of the effect of implementation intentions on physical activity. Health Psychology Review 2013;7:23-54.

[78] Wu S, Cohen D, Shi Y, et al. Economic analysis of physical activity interventions. Am J Prev Med 2011;40:149-58.

[79] Ainsworth BE, Haskell WL, Herrmann SD, et al. 2011 Compendium of Physical Activities: a second update of codes and MET values. Med Sci Sports Exerc 2011;43:1575-81.

[80] Shaw R, Fenwick E, Baker G, et al. 'Pedometers cost buttons': the feasibility of implementing a pedometer based walking programme within the community. BMC Public Health 2011;11:200.

[81] Office for National Statistics. 2011 Census: Population estimates by single year of age and sex for local authorities in the United Kingdom [Table HH01UK]. Available from: <http://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates/datasets/2011censuspopulationestimatesbysingleyearofageandsexforlocalauthoritiesintheunitedkingdom> [Accessed 22 August 2013].

[82] Public Health England. NHS Health Check Single Data List Returns: A brief guide for local authorities. Available from: Available from <http://www.healthcheck.nhs.uk/document.php?o=537> [Accessed 14 November 2014].