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Physical Activity and the Environment: Economic Modelling Plan

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INVESTORS IN PEOPLE

Contents

Section 1: Introduction

1.1 BACKGROUND

The level of individual physical activity has a clear and strong association with physical and mental health status. Those with sedentary lifestyles or with low levels of physical activity are at a higher risk of a large number of conditions including coronary heart disease, stroke, cancer and depression.[1] There are also additional benefits to increasing physical activity such as walking and cycling through reducing the use of vehicles that present mortality risks and pollute the environment.

The World Health Organization's 2010 report on physical activity identified it as the fourth leading risk factor in global mortality and liable for 6% of annual global mortality.[2] These figures do not include the quality of life reductions resulting from living with and being treated for the health conditions that physical inactivity has caused, making this health burden even greater. These health consequences translate into significant financial costs for the NHS and society, with direct costs to the NHS estimated at £1.06bn[3] and wider social costs at £6.5bn, stemming from lost productivity and premature death resulting from sickness.[4]

The benefits of increasing physical activity in the population are reflected in its prominence in public health campaigns. Since NICE began developing public health guidance in 2005, five guidelines have been produced, covering numerous approaches to physical activity promotion including work place initiatives (PH13) and interventions targeting children and young adults (PH17), and have identified a number of cost-effective policies.

The economic model proposed in this report will contribute towards updating the guidance produced in 2008 on how the built and natural environment can be developed to improve physical activity levels in the population (PH8). This guideline recommended the prioritisation interventions targeting those with impaired mobility and developing and maintaining cycle paths, amongst others. The model that we outline here will allow for a wider range of interventions, as outlined in the scope, to be evaluated on their cost-effectiveness and utilise new evidence to support updated recommendations.

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[1] Department of Health. 'Start Active, Stay Active: A report on physical activity for health from the four home countries' Chief Medical Officers', 2011.
[2] World Health Organization, 'Global Recommendations on Physical Activity for Health', 2010. http://apps.who.int/iris/bitstream/10665/44399/1/9789241599979_eng.pdf
[3] Allender S, Foster C, Scarborough P and Rayner M (2007).The burden of physical activity-related ill health in the UK. *Journal of Epidemiology and Community Health* 61: 344–348.
[4] Ossa D and Hutton J (2002) *The Economic Burden of Physical Inactivity in England.* London: MEDTAP International.

1.2 OBJECTIVES

This work will contribute toward the achievement of the objectives set out in the NICE scope. A de novo economic model will be developed to estimate the impacts of additional physical activity on health. This model will take a 'generalised approach', in that it does not aim to model the specifics of any interventions during the development phase.

However, the completed model will allow for specific interventions to be modelled to estimate expected cost-effectiveness. The types of interventions that will be evaluated have been outlined in the scope and have informed the NICE effectiveness review currently being undertaken.

The key questions from the scope are as follows:

1. Which interventions in the built or natural environment are effective and cost-effective at increasing physical activity in the general population?
   - **1.1** Which transport interventions are effective and cost-effective?
   - **1.2** Which interventions related to the design and accessibility of public open spaces in the built and natural environment are effective and cost-effective?

2. Does the effectiveness and cost-effectiveness of these interventions vary for different population groups (particularly those less able to be physically active)?

3. Are there any adverse or unintended effects?
   - **3.1** How do these vary for different population groups (particularly those less able to be physically active)?
   - **3.2** How can they be minimised?

4. Who needs to be involved to ensure interventions are effective and cost-effective for everyone?

5. What factors ensure that interventions are acceptable to all groups?

Section 2: Modelling Approach

2.1 MODEL FORMAT

The model will be built using Microsoft Excel and will be designed in a flexible, user-friendly format whereby the user can access a full range of input sheets and run various scenarios by choosing from the options provided in an initial set-up sheet. Supplementary statistical work will be performed in R and Stata.

As stated above, the model will take a 'generalist' approach, so that all major inputs related to the intervention can be easily changed by the model user, including costs and effectiveness. This will facilitate the evaluation of:

- Interventions identified in the NICE review;
- Alternative interventions of interest to public health commissioners where key parameters can be estimated.

The model can also be structured so that parameters can be specified for two interventions so that comparisons on cost-effectiveness can be made.

2.2 MODEL OVERVIEW

The model will be developed in line with the NICE methods manual.[5] The model will be developed from an NHS, personal social services (PSS) and local authority perspective. The model will allow for various time horizons to be selected by the model user, but will incorporate a lifetime time horizon in order to capture all relevant costs and benefits. Discount rates of 3.5% for both costs and benefits will be applied as stipulated in the NICE methods manual. The major outcome from specific intervention evaluations will be the ICER, expressed as the incremental cost per quality-adjusted life year (QALY), for the comparison between interventions.

The model will also execute threshold analyses that will deliver a second set of key outcomes: the expected required increase in average physical activity that a hypothetical intervention would have to achieve in order for it to be cost-effective, contingent upon a fixed set of parameters (i.e. intervention cost). The model will also incorporate other outcomes for which data are available, such as:

- The amount of additional physical activity generated across a population;
- Mortality and morbidity;
- Cost savings.

[5] NICE. Developing NICE guidelines: the manual. 2014. Available from: https://www.nice.org.uk/media/default/about/what-we-do/our-programmes/developing-nice-guidelines-the-manual.pdf.

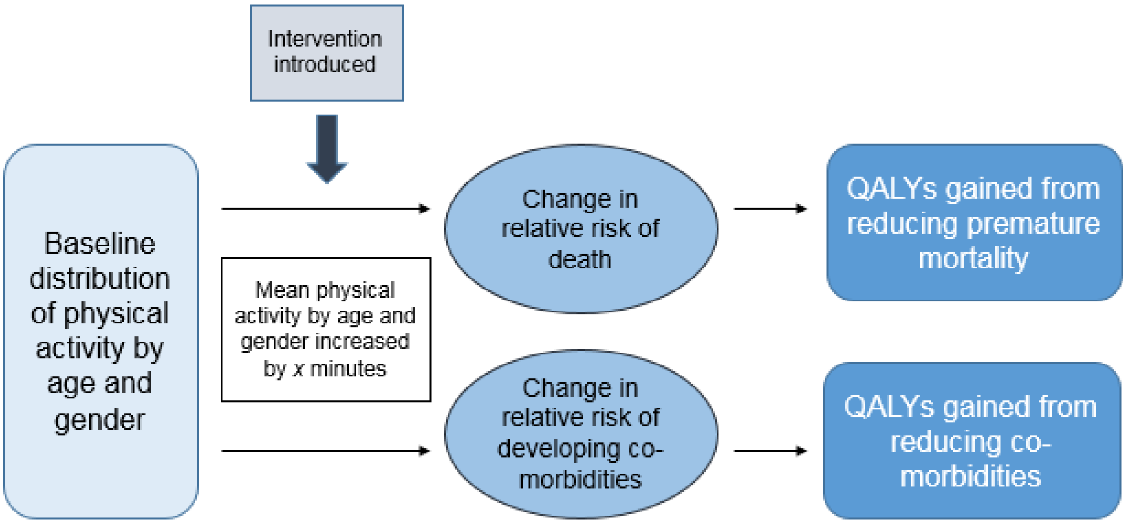
The NICE scope outlines a range of transport and public space interventions to be evaluated in this guideline. The final number of interventions to be modelled will be decided with the NICE team, Committee input and data availability. However, the model structure will not be dependent upon the intervention and is provided in Figure 2.1. This approach differs from the approach taken in the economic modelling conducted in the previous edition of this guidance (PH8) in the following ways:

- The number of related conditions for which cost and health consequences will be modelled will be increased from three to five in order to account for impacts on colon and breast cancer incidence;
- Epidemiological data from the UK will be used to determine the probability of developing a condition, rather than from the USA;
- The relative risk reductions of increasing physical activity will not be dependent upon intervention being considered. Previous modelling 'matched' a physical activity outcome from one intervention study to a similar outcome used in individual clinical effectiveness studies (that measured the relative risk of related conditions) to estimate health impacts. The present approach will incorporate the best available evidence linking physical activity and health into the model for all interventions and then convert intervention studies' outcomes into a common measure;
- A continuous measure of physical activity is utilised in the model so that results from a wide range of effectiveness studies to be incorporated.

Long-term epidemiological data on mortality and disease incidence will be incorporated into the model. QALYs will be used to capture changes in both quality and length of life resulting from changes in physical activity.

2.3 SUGGESTED MODEL STRUCTURE

Figure 2.1: Model structure



Note: QALYs = Quality-adjusted life years

The suggested model structure is shown in Figure 2.1. The population distribution of physical activity is estimated from pooled Health Survey for England data from 2012-2014, from which mean physical activity levels are calculated by age and gender. We will use metabolic equivalent time as our physical activity outcome measure, which adjusts the time spent on an activity according to its intensity. Successful interventions generate physical activity gains that are often reported as a mean population increase. Since the increase in activity may not be equal to the mean for every individual, a skewness parameter will be included in the model that sets how uneven the gains will be across the population.

The activity gains by age and gender will be plugged into risk functions relating physical activity levels to all-mortality to obtain a relative risk of death following the intervention. These functions, which model physical activity continuously, will be estimated from data in Anderson *et al*. (2000) and allow for the impacts of even small changes in physical activity to be modelled.[6] The relative risk is applied to a baseline mortality risk; from this we can calculate the change in the number of deaths over time and the associated number of QALYs resulting from this mortality reduction. This is the same technique used by Brennan *et al*. (2012) in the economic modelling for PH41.[7]

Given that physical activity also reduces the incidence of a number of diseases, we adopt a similar approach to capture these effects. Continuous risk functions for five co-morbidities are taken from Kyu *et al*. (2016) and used to calculate the relative risk of developing each disease for a given physical activity increase.[8] The five conditions to be included in the model are:

- Stroke;
- Coronary heart disease (CHD);
- Diabetes;
- Breast cancer;
- Colon cancer.

Incidence data by age and gender for each of the conditions is used to calculate the baseline probability of developing each condition. We adjust these probabilities, and then simulate two cohorts (pre- and post-intervention) over their lifetime to obtain an estimate of the numbers developing each disease. Since each case is associated with a QALY loss, the difference in the number of cases will be used to estimate the health gains from the intervention; adding together the QALY gains from reducing mortality and co-morbidities will then provide the total health benefit. Only the QALY loss of living with the disease, and not those from premature death caused by the disease, will be calculated. This is because the mortality reductions

[6] Anderson L B, Schnohr P, Schroll, M, Hein H O. 'All-Cause Mortality Associated With Physical Activity During Leisure Time, Work, Sports, and Cycling to Work'. Arch Intern Med, 2000; 160: p1621-8

[7] Brennan A, Blake L, Hill-McManus D, Payne N, Buckley Woods H, Blank L. '*Walking and cycling: measures to promote walking and cycling as forms of travel or recreation: Health economic and modelling report*.' National Institute for Health and Clinical Excellence, 2012.

[8] Kyu HH, Bachman VF, Alexander LT, Everett Mumford J, Afshin A, Estep K, Veerman J Delwiche K, Iannarone ML, Moyer ML, Cercy K, Vos T, Murray CJL, Forouzanfar MH. 'Physical activity and risk of breast cancer, colon cancer, diabetes, ischemic heart disease, and ischemic stroke events: systematic review and dose-response meta-analysis for the Global Burden of Disease Study 2013'. *BMJ*. 2016;354:i3857

attributable to these diseases will be captured in the estimated changes to all-cause mortality, described above. We will also include the quality of life gains associated with improved physical activity level in the absence of co-morbidities in the model.

The model will assume that risk reductions for both mortality and disease are conferred immediately after increasing physical activity. However, the model will be able to incorporate lagged effects if evidence suggests this it more appropriate, and for use in sensitivity analysis. The model will also capture cost-savings associated with the reduction in related conditions. Finally, in accordance with the scope, we will estimate the health impacts for the population with restricted mobility, using the same structure described above.

2.4 MODEL INPUTS

This section outlines the key inputs necessary to populate the model. Searches will be carried out to extract data from the literature. Where possible, data from previous analyses can be utilised, though the PHAC or NICE review may identify more up-to-date literature that can be used to populate the model.

2.4.1 Cost Sources

Table 2.1: Costs parameters and sources

Parameter	Source/notes
Case study intervention costs	To be confirmed Previous NICE guidance
Disease costs	Previous models looking at the same conditions (i.e. smoking cessation guidance modelling costs of stroke and CHD. For other conditions, literature to be identified through targeted searches

The cost inputs and potential sources are outlined in Table 2.1. Whilst disease-related costs can be estimated via conventional means, such as using existing cost-studies or NHS reference costs, the same is not true for intervention costs. The generalised model does not require these to be specified. However, for the case study interventions, cost estimates may be found in the effectiveness review and potentially be adjusted if they are appropriate and UK-based. Some interventions may also have been costed in previous guidance such as PH41, which looked at walking and cycling interventions. However, where such information is not available, methods to identify interventions costs will be discussed with NICE and the PHAC.

2.4.2 Utility Sources

Utility parameters and sources are given in Table 2.2. Quality of life weights for each physical activity level will be estimated from Health Survey for England data. Regression analysis will be used to estimate the statistical relationship between physical activity and quality of life continuously, and will control for the fact that those included in the survey may have the health conditions of interest, so as to avoid double counting. Further targeted searches will be conducted to identify more recent estimates for utility scores for those conditions where values have been taken from Tengs and Wallace (2000).[11]

Table 2.2: Utility parameters and sources

Parameter	Source/Notes
Disease-free utilities	
Physical activity level	Health Survey for England (2012-2014)[9]
Disease state utilities	
Disease state utilities and health state utilities will be used to calculate disease disutility.	
Stroke (post)	0.528 (Golicki et al., 2015[10])
CHD	0.8 (Tengs and Wallace, 2000[11])
Diabetes	0.67 (Janssen et al., 2011[12])
Breast cancer	Tengs and Wallace (2000)[11]
Colon cancer	Average of 0.778 from four values (Tengs and Wallace 2000[11])

Note: CHD = coronary heart disease

2.4.3 Changes in physical activity

The impact of an intervention on physical activity does not need to be specified in the generalised model. As noted in section 2.3, health consequences and costs will be modelled based on a mean physical activity change. Since it is unlikely that this increase will be permanent for all affected individuals, additional parameters will be included in the model that determine how many people return to their initial activity state and how quickly.

For the case study interventions, the physical activity increases will be identified in the NICE review. The physical activity outcome measures adopted in these evaluative studies are likely to be variable. For instance, some may report the increase in the average minutes of active commuting, whereas others will measure the number of additional cycling trips. To achieve a consistency across these studies, each outcome will be converted into MET minutes using the Compendium of Physical Activity.[13]

[9] Health Survey for England 2014. http://www.hscic.gov.uk/catalogue/PUB19295
[10] Golicki D,Niewada M, Buczek J, Karlinska A, Kobyashi A, Janssen MF,Pickard AS. 'Validity of EQ-5D-5L in stroke', *Quality of Life Research*, 2015; 24(4): p845-50
[11] Tengs T, Wallace A. One Thousand Health-Related Quality-of-Life Estimates. *Medical Care*. 2000; 38 (6): p583-637
[12] Janssen MF, Lbetkin EI, Sekhobo JP, Pickard AS. 'The use of the EQ-5D preference-based health status measure in adults with Type 2 diabetes mellitus.' *Diabetic Medicine*. 2011; p395-413.
[13] Ainsworth BE, Haskell WL, Herrmann SD, Meckes N, Bassett Jr DR, Tudor-Locke C, Greer JL, Vezina J, Whitt-Glover MC, Leon AS. 2011 Compendium of Physical Activities: a second update of codes and MET values. *Medicine and Science in Sports and Exercise*, 2011;43(8):1575-1581

2.4.4 Epidemiology

Epidemiological data required for the model are shown in Table 2.3. The results of the model will be calculated for different age and gender characteristics and then weighted dependent on the known demographics of the population group. Population weights will be derived from the Office for National Statistics data for England and Wales. It is noted that the NICE scope covers the general population. Where the data are available, age-specific epidemiology data will be included for under 16s. If data are not available, then the data for the lowest age will be applied to all those younger and the impact of this will be discussed.

Table 2.3: Epidemiology parameters and sources

Parameter	Source/Notes
Mortality risk by age and gender	ONS life tables
Disease risk by age and gender	Previous models (i.e. smoking cessation) ONS Cancer Registration Statistics[14]
Level of physical activity by age and gender	Health Survey for England (2012-2014)[15]

Physical activity levels by age and gender will be taken directly from pooled Health Survey for England data from 2012 to 2014. Moderate and vigorous activity time per week will be converted into MET minutes and combined before extracting mean values.

Baseline risks for mortality and disease will be obtained from previous models where possible, with official statistics and epidemiological studies used elsewhere. The incidence of conditions will be used to calculate the number of people with each condition each year for a given physical activity level. In order to calculate condition incidence the following information is therefore required:

- The incidence, by age and gender, of each comorbidity in the general population;
- The relative risk of each condition for a change in physical activity level.

2.5 MODEL RESULTS

Results will be presented along with any other outcomes outlined in Section 2.2, with threshold analyses reported for all relevant parameters. Results can be reported by cost perspective. Comparisons between case-study interventions may also be presented, however caution must be taken in interpreting the results if the respective evidence sources are heterogeneous.

[14] Office for National Statistics, https://www.ons.gov.uk/peoplepopulationandcommunity/healthandsocialcare/conditionsanddiseases/bulletins/cancerregistrationstatisticsengland/previousReleases [Accessed December 2016].

[15] Health Survey for England 2014. http://www.hscic.gov.uk/catalogue/PUB19295

In addition, sensitivity analysis will be carried out. All uncertain parameters will be varied in univariate sensitivity analysis in order to identify the greatest causes of uncertainty in the model. Without point estimates for intervention-specific parameters (such as intervention cost), probabilistic sensitivity analysis (PSA) cannot be performed in the base case, but can be run for any identified case studies. The model will already be run for each age and gender in the base case and re-running this for many iterations to generate PSA results can be computationally burdensome. However, it is possible to add this if the Committee agree that it would be useful. Additional scenarios can also be run to test the robustness of results, the details of which can be discussed with the Committee.

2.6 DISCUSSION POINTS

This model plan was developed following discussions with the Committee and NICE about the need to incorporate a continuous measure of physical activity into the model. The previous approach used the proportion of the population in discrete activity thresholds to estimate their lifetime costs and QALYs, in line with Trueman and Anokye (2012) and the modeling conducted for PH8 by Beale *et al*. (2007).[16,17]

The present approach, more in line with Brennan *et al*. (2012), is better equipped to incorporate evidence from a variety of effectiveness studies and will model small improvements to physical activity levels.[7] The latter aspect will be particularly useful when investigating impacts on populations with low mobility.

After discussions with the Committee at PHAC 1, the following points were agreed and will be carried forward into the current modeling approach:

- Productivity costs - Diseases related to physical activity levels have considerable impacts on an individual's capacity to work as well their health. Therefore, interventions that move more individuals to the active state and reduce their risks of these conditions will also reduce productivity losses associated with them. Literature searches will be conducted to locate studies that estimate these costs and will be included in the model if the data are of sufficient quality.
- Case study intervention costs – Costs of infrastructure projects that affect transport and the built and natural environment are not wildly disseminated and will vary considerably depending upon their setting. Cost estimates utilised in previous physical activity guidelines and the forthcoming traffic-related air pollution guideline may be adapted where appropriate.

An additional point was agreed about investigating additional co-morbidities, including stress. However, given the new approach requires much greater evidence on the relationship between physical activity and disease risk, the number of conditions has currently been

[16] Beale S, Bending M, Trueman P. '*An economic analysis of environmental interventions that promote physical activity.*' York Health Economics Consortium, 2007.
[17] Trueman P, Anokye NK. 'Applying economic evaluation to public health interventions: the case of interventions to promote physical activity.' *Journal of Public Health*. 2012; 35(1): p32-39

reduced from seven to five. This number may change if additional suitable sources are found and should be discussed with the Committee at future meetings.

Section 3: Next Steps

Full timelines are available in the memorandum of understanding (MOU). The key steps are summarised below:

- Agree new model plan with the Committee at the next PHAC;
- Prioritise interventions;
- Develop economic model with PHAC input and present results.