Urban greenways have the potential to increase physical activity levels cost-effectively

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Introduction

According to the World Health Organization (WHO), approximately 3.2 million deaths each year are attributable to insufficient physical activity.1 Physical inactivity, a modifiable risk factor for numerous chronic diseases, represents a growing global public health problem, with attendant increases in healthcare expenditure, loss in economic productivity and for the individual, increased absenteeism from work and reduced quality of life.2

To address these issues, there is a need for more research and evaluation of longer-term prevention strategies.3 Public health interventions are typically complex and often have to span a range of sectors and mechanisms, and adopt a long-term perspective. The role of the built environment in public health, and in particular physical activity, has received increasing attention both in research and policy agendas. Indeed, government policies in both the UK (Foresight report, 2007) and USA (Institute of Medicine and National Research Council of the National Academies, 2009) have recommended improving the built environment to help tackle public health issues.

Multiple studies have consistently identified associations between access to public open spaces, trails and parks and physical activity,4–8 and environmental interventions have been found to be generally more cost-effective than other prevention programmes.9 This is thought to be owing to their potentially large cumulative population effect, and although they may have substantial initial costs, they are usually permanent with lasting effects.

We aimed to estimate the potential health impacts and cost-effectiveness of an urban regeneration project to promote physical activity. We used the PREVENT model,10 adapted to the Northern Ireland (NI) context, using data from a household survey. We modelled the impact on the burden from cardiovascular disease, colon and breast cancer, given the strong evidence of the association between physical activity and their incidence.11

Methods

Intervention

The Connswater Community Greenway, a major urban regeneration project, will take 4 years to complete. It is funded by a Big Lottery
Living Landmarks Award, obtained by a voluntary organization called the East Belfast Partnership. It will create improved opportunities for physical activity and active transport by constructing 19.4 km of new cycle and walkways and providing accessible and safe green space (www.communitygreenway.co.uk). The UKCRC Centre of Excellence for Public Health (http://coe.qub.ac.uk) obtained grant funding to independently evaluate the Greenway leading to the PARC study: Physical Activity and the Rejuvenation of Connswater.

**Baseline household survey**

The PARC study involves a quasi-experimental before-and-after household survey of the Greenway population, in tandem with a parallel (before-and-after) survey of the rest of NI. The survey took place over a 12-month period (February 2010 to January 2011) using a random sample of addresses from the Postcode Address File stratified by electoral ward. There are 29 wards within the vicinity of the Greenway with a total population ~110,600, and 22 wards (~87,500 residents) with a geographical centroid within a 1 mile radius. Seven of the wards are within the top 25% most deprived wards in NI. In each household, using the last birthday rule, an adult (16 years or older) was interviewed (n = 1209). The response rate to the survey was 63%. We compared the age, gender and working status of our sample with the NI population, and steps were taken to redress the lower percentage representation of the economically active, men and young people. Subsequently, the survey was weighted to reflect seasonal variations in physical activity and the age and sex distribution of the Greenway population. The survey included the Global Physical Activity Questionnaire. This was used to determine the number of minutes of physical activity performed per week per interviewee. We then calculated, by age and sex, the proportion of those meeting the current physical activity recommendations of 150 minutes per week of moderate physical activity.

**Data sources**

A detailed description of data sources and the various derived variables is provided in Supplementary Appendix 1. There were four main categories of input data, including (i) population, (ii) risk factor, (iii) disease and (iv) cost inputs.

1. **Baseline 2009 population, fertility and mortality estimates** were obtained from the Northern Ireland Statistics and Research Agency (NISRA) (www.nisra.gov.uk). For background population disability weights, UK EQ-5D data were used.

2. **Baseline Greenway population physical activity levels** were obtained from the baseline household survey (table 2). Participants were categorized as either ‘active’, if they met the current UK physical activity recommendations of greater than 150 minutes of moderate intensity physical activity per week, or ‘inactive’, if they did not. Relative risks were obtained from the literature for the protective effects of physical activity on disease-specific incidence (Supplementary Appendix 2). As type 2 diabetes is considered a risk factor for ischaemic heart disease, we also included the relative risk of ischaemic heart disease given diabetes in our model, taken from the literature.

3. **The Northern Ireland Cancer Registry (NICR) provided baseline incidence, mortality and remission rates** (www.qub.ac.uk/nicr). By using these parameters in DISMOD II (a WHO software tool used to check the consistency of disease parameters), we derived the prevalence of colon and breast cancer. For cardiovascular diseases, prevalence was obtained from the 2005/2006 NI Health & Social Wellbeing Survey and the 2009 Quality and Outcomes Framework. Furthermore, cardiovascular disease mortality was taken from NISRA, whereas the incidence of ischaemic heart disease and stroke was obtained from the General Practice and Research Database; and the incidence of type 2 diabetes mellitus was estimated using DISMOD II. Disease weights were taken from the Global Burden of Disease study.

4. The estimated construction and maintenance costs of the Greenway, over 41 years, were obtained from the construction company. Annual cardiovascular disease, colon and breast cancer disease costs were taken from the literature (Supplementary Appendix 3).

**Statistical analyses**

To model the impact of the intervention, a macro-simulation model, PREVENT 3.01, was used. By utilizing the epidemiological effect measure ‘potential impact fraction’, it estimates the effect of changes in risk factor prevalence, adjusted for population changes, on disease occurrence and mortality. In effect, after specifying a change in risk factor prevalence due to an intervention, PREVENT estimates future disease incidence and mortality by applying the potential impact fraction to current disease incidence and mortality rates.

The intervention effectiveness of the Greenway will take 4 years to be determined. To obtain realistic effect estimates, we looked to the evidence for trails, access to public open spaces, ‘walkability’ and physical activity, which are all major components of the Greenway. The quantified effect of ‘walkability’ on physical activity was the most consistently measured using accelerometer data. Therefore, we used ‘walkability’ effect sizes on moderate-to-vigorous physical activity from two European studies (3.1 and 6.8 min/day). By adding these to our baseline survey physical activity scores, we found the number of ‘active’ people would increase by 7 and 10%, respectively. Therefore, we decided on three conservative ‘what if’ intervention scenarios, A, B and C, which equate to 2, 5 and 7 and 10%, respectively. Therefore, a drop-off in physical activity levels has been found with short-term interventions, the Greenway is a permanent intervention, so we assumed no attenuation of effects.

We used PREVENT to compare the projected future disease incidence and mortality with and without the intervention. In addition, we calculated the gains in life expectancy (LE) and disability-adjusted life expectancy (DALE) expected for intervention beneficiaries and the years lived with disability (YLD) saved by the Greenway population. The intervention was applied at the baseline year (2009) and the baseline physical inactivity levels were recalculated depending on the particular scenario, and these new physical activity levels remained until 2050.

As the beneficial effects of physical activity on disease incidence and mortality will not emerge instantaneously, PREVENT accommodates this using two time lags: (i) the time that the risk remains unchanged after a decline in risk factor exposure (LAT), and (ii) the period during which the changes in risk factor exposure gradually affect the risk of disease, eventually reaching risk levels of the non-exposed (LAG). The time between increasing physical activity and achieving reductions in all-cause mortality, and in particular cardiovascular disease, is relatively short, and so in respect to physical activity and its impact on breast and colon cancer, we used a LAT of 5 years and a LAG of 15 years, whereas for cardiovascular diseases, we used a LAT of 1 year and a LAG of 5 years. These time lags broadly correspond to those observed in the epidemiological studies we used to provide relative risk estimates for the protective effect of physical activity on disease incidence (Supplementary Appendix 2).

**Cost-effectiveness analyses**

Our aim was to present the incremental cost-effectiveness ratios (ICERs) of the Greenway intervention by identifying the additional costs associated with the intervention per additional unit of health outcome generated by each scenario, compared with no intervention. We conducted our analysis from a health-care payer perspective; however, the additional costs were compared with the baseline scenario to provide a relative cost-effectiveness analysis.
perspective to compare its effects with alternative health interventions and discounted both cost and health gains by 3.5%, in line with the National Institute for Health and Clinical Excellence reference case. All costs were derived in pounds sterling (£).

The Greenway construction and maintenance costs related to physical activity were extracted from the overall costs (Supplementary Appendix 3). To calculate the total cost savings through diseases averted, we first estimated the ‘annual cost per prevalent case per disease’. For breast cancer, we could obtain this directly from the literature for the period 1995/1996 and inflate to 2009. For the other diseases, we found the total UK health-care system expenditure for a particular disease in a given year, inflated it to 2009 and divided by its prevalence in 2009, except for colon cancer, where we used the estimated prevalence in 2008, as it was the most recently available estimate. For each scenario, we then multiplied the number of incident cases averted each year, for each disease, by its respective ‘cost per prevalent case per disease’, and summed over all diseases to obtain the total disease cost savings (Supplementary Appendix 3). As a result of the intervention, more people may live longer, but we did not consider the future costs of an ‘aging’ population. Health outcomes were derived in disability-adjusted life years (DALYs), recommended by WHO, instead of quality-adjusted life years primarily because the PREVENT model uses disability rather than utility weights.

National Institute for Health and Clinical Excellence recommends a lifetime time horizon for chronic disease interventions, but we chose 41 years. This may lead to an underestimation of the long-term benefits of increasing physical activity, but a longer time horizon would have involved making larger assumptions about the demographics of our study population, disease incidence, mortality rates and costs.

**Sensitivity analyses**

PREVENT’s projections are dependent on the data and assumptions that populate the model. To assess the impact of parameter uncertainty, we repeated the main analysis using the following different scenarios:

1. Lower and upper relative risk estimates, taken from their respective 95% confidence intervals.
2. A LAG time of 10 and 20 years for colon and breast cancer and a LAG time of 2 and 8 years for cardiovascular diseases, respectively.
3. A discount rate of 0, 3 and 5% applied to cost and health benefits.

**Table 1** Socio-demographic characteristics of the Connswater Community Greenway population

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Proportion (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>41</td>
</tr>
<tr>
<td>Female</td>
<td>59</td>
</tr>
<tr>
<td>Age</td>
<td></td>
</tr>
<tr>
<td>16–24 years</td>
<td>7</td>
</tr>
<tr>
<td>25–44 years</td>
<td>36</td>
</tr>
<tr>
<td>45–64 years</td>
<td>30</td>
</tr>
<tr>
<td>65+ years</td>
<td>27</td>
</tr>
<tr>
<td>Working status</td>
<td></td>
</tr>
<tr>
<td>Economically active</td>
<td>51</td>
</tr>
<tr>
<td>Economically inactive</td>
<td>49</td>
</tr>
<tr>
<td>Socio-economic status*</td>
<td></td>
</tr>
<tr>
<td>Most deprived</td>
<td>18</td>
</tr>
<tr>
<td>2</td>
<td>18</td>
</tr>
<tr>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>4</td>
<td>19</td>
</tr>
<tr>
<td>Least deprived</td>
<td>37</td>
</tr>
</tbody>
</table>

a: According to NIMDM ranking, Northern Ireland Multiple Deprivation Measures.

**Table 2** The percentages of the Connswater Community Greenway population not meeting the recommended physical activity guidelines at baseline

<table>
<thead>
<tr>
<th>Age group</th>
<th>Males (%)</th>
<th>Females (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>16–34 years</td>
<td>14.2</td>
<td>25.1</td>
</tr>
<tr>
<td>35–44 years</td>
<td>21.2</td>
<td>36.6</td>
</tr>
<tr>
<td>45–54 years</td>
<td>38.9</td>
<td>55.6</td>
</tr>
<tr>
<td>55–64 years</td>
<td>49.3</td>
<td>58.3</td>
</tr>
<tr>
<td>65–74 years</td>
<td>51.7</td>
<td>75.7</td>
</tr>
<tr>
<td>75+ years</td>
<td>68.5</td>
<td>82.7</td>
</tr>
<tr>
<td>Total</td>
<td>35.3</td>
<td>52.6</td>
</tr>
</tbody>
</table>

**Table 3** The absolute number (and relative percentage decrease) of prevented incident cases and deaths for the Connswater Community Greenway population by 2050

<table>
<thead>
<tr>
<th>Cases Prevented</th>
<th>A*</th>
<th>Bb</th>
<th>Cc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incident cases prevented</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Colon cancer</td>
<td>6 (0.2%)</td>
<td>11 (0.4%)</td>
<td>19 (0.7%)</td>
</tr>
<tr>
<td>Breast cancer</td>
<td>12 (0.3%)</td>
<td>20 (0.6%)</td>
<td>37 (1.0%)</td>
</tr>
<tr>
<td>Ischaemic heart disease</td>
<td>50 (0.4%)</td>
<td>125 (1.0%)</td>
<td>254 (2.0%)</td>
</tr>
<tr>
<td>Type 2 diabetes</td>
<td>76 (0.2%)</td>
<td>188 (0.5%)</td>
<td>376 (0.9%)</td>
</tr>
<tr>
<td>Stroke</td>
<td>40 (0.3%)</td>
<td>97 (0.8%)</td>
<td>200 (1.6%)</td>
</tr>
<tr>
<td>Deaths prevented</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Colon cancer</td>
<td>2 (0.2%)</td>
<td>5 (0.4%)</td>
<td>7 (0.6%)</td>
</tr>
<tr>
<td>Breast cancer</td>
<td>0 (0.0%)</td>
<td>2 (0.2%)</td>
<td>3 (0.3%)</td>
</tr>
<tr>
<td>Ischaemic heart disease</td>
<td>5 (0.2%)</td>
<td>14 (0.6%)</td>
<td>27 (1.1%)</td>
</tr>
<tr>
<td>Type 2 diabetes</td>
<td>0 (0.0%)</td>
<td>1 (0.1%)</td>
<td>2 (0.2%)</td>
</tr>
<tr>
<td>Stroke</td>
<td>10 (0.4%)</td>
<td>18 (0.7%)</td>
<td>36 (1.3%)</td>
</tr>
</tbody>
</table>

a: Scenario A: 2% of those classified as ‘inactive’ become ‘active’.
b: Scenario B: 5% of those classified as ‘inactive’ become ‘active’.
c: Scenario C: 10% of those classified as ‘inactive’ become ‘active’.

**Results**

**Baseline characteristics**

Socio-demographic characteristics (age, gender, employment and socio-economic status) are outlined in table 1. Fewer females were active than males, and for both genders, levels of physical inactivity were higher at older ages (table 2).

**Preventable incident cases and deaths**

The number of potentially preventable incident cases and deaths, by 2050, increases for each disease on moving from intervention scenario A to C, as expected (table 3). In absolute terms, it is estimated that the greatest number of incident cases could be prevented for type 2 diabetes, with 376 cases prevented in scenario C. However, the greatest relative decline in incident cases could be achieved for ischaemic heart disease, approximately 2% in scenario C. In both absolute and relative terms, the greatest number of deaths could be prevented for ischaemic heart disease, approximately 1.1% in scenario C. Compared with the cardiovascular diseases, substantially fewer cancer incident cases and deaths might be prevented, but with a comparable relative decrease.

**LE and DALE gains and YLD averted**

Had the intervention never occurred and baseline physical activity levels persisted, on average, the LE and DALE for men, as predicted by PREVENT, would be 77.5 and 69.1 years, and 81.8 and 71.4 years for a woman, respectively. DALE represents LE minus expected years of healthy life lost due to disability. For both men and women, on moving from scenarios A to C, larger gains in LE and DALE can be
achieved, although these are marginally greater for women. For scenario C, on average, a man can expect to increase his LE and DALE by 0.02 and 0.04 years, and 0.03 and 0.07 years for a woman, respectively. YLD is a measure of the years of healthy life lost due to disability. Again, had no intervention occurred, the baseline YLD would be 12 571 years for the Greenway population. For scenario C, a reduction of 46 YLD could be expected.

**Cost-effectiveness analyses**

We found all three scenarios to be cost-effective, with ICERs ranging from £4469/DALY to £18 411/DALY (table 4). These are below the UK cost-effectiveness threshold, which is £20 000–£30 000/quality-adjusted life year or DALY.31

**Sensitivity analyses**

Our results did not substantially change by varying relative risk or disease LAG estimates. When using a 5% discount rate, scenario A breached the cost-effectiveness threshold, with an ICER of £32 153/DALY. All other scenarios remained below the threshold.

**Discussion**

We have described how potentially feasible increases in physical activity levels achieved through an urban regeneration project could be a cost-effective way to increase physical activity levels. This comes at a time when the potential for environmental modifications to influence health has caught the attention of policy makers, as it has become clear that individual, social and physical environmental factors all have an interrelated role to play in promoting physical activity.22 This modelling study therefore provides a timely addition to the evidence base to inform policy and practice in this area.

We have demonstrated that if 10% of those classified as ‘inactive’ became ‘active’, a total of 886 incident cases (1.2%) and 75 deaths (0.9%) from ischaemic heart disease, type 2 diabetes, stroke, colon and breast cancer could be prevented by 2050 in the Greenway population. Also, small individual gains in average LE and DALE and breast cancer could be prevented by 2050 in the Greenway (0.9%) from ischaemic heart disease, type 2 diabetes, stroke, colon and breast cancer could be prevented by 2050 in the Greenway (0.9%) from ischaemic heart disease, type 2 diabetes, stroke, colon and breast cancer could be prevented by 2050 in the Greenway (0.9%) from ischaemic heart disease, type 2 diabetes, stroke, colon and breast cancer could be prevented by 2050 in the Greenway (0.9%) from ischaemic heart disease, type 2 diabetes, stroke, colon and breast cancer could be prevented by 2050 in the Greenway (0.9%) from ischaemic heart disease, type 2 diabetes, stroke, colon and breast cancer could be prevented by 2050 in the Greenway. For scenario C, on average, a man can expect to increase his LE and DALE by 0.02 and 0.04 years, and 0.03 and 0.07 years for a woman, respectively. YLD is a measure of the years of healthy life lost due to disability. Again, had no intervention occurred, the baseline YLD would be 12 571 years for the Greenway population. For scenario C, a reduction of 46 YLD could be expected.

**Areas for future research**

It is likely not everyone living in the intervention area will be affected equally by the project. Several factors may influence whether someone uses the new amenities, including many intrapersonal and environmental factors and/or the distance they live from the nearest path. There is some evidence to suggest that environmental interventions may benefit lower socio-economic groups more and help tackle health inequalities.39,40 Future analyses should consider subgroup analyses to assess the impact of these factors on the use of the Greenway and assess whether its effects have been equitable.

**Conclusions**

By applying traditional techniques of cost-effectiveness analysis to the Connswater Community Greenway intervention, we have demonstrated that it could be cost-effective at improving physical activity levels, with wider benefits beyond health likely.

**Supplementary Data**

Supplementary data are available at EURPUB online.
Acknowledgements

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Conflicts of interest: None declared.

Key points

- By applying traditional techniques of cost-effectiveness analysis, we describe how potentially feasible increases in physical activity levels, achieved through an urban regeneration project, could be a cost-effective way to increase physical activity levels.
- This comes at a time when the potential for environmental modifications to influence health has caught the attention of policy makers, with research in this area beginning to emerge.
- This modelling study therefore provides a timely addition to the evidence base to inform policy and practice in this area.
- In addition, this study exemplifies how public health interventions typically have benefits beyond health, with costs and consequences falling on other sectors of the economy.
- Cost–benefit analyses, which aim to include all costs and consequences falling on other sectors of the economy, are better suited to capture the broader impacts of public health interventions.

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Using threshold messages to promote physical activity: implications for public perceptions of health effects

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Introduction

Physical activity (PA) reduces risk of morbidity and mortality from chronic diseases.1,2 Approximately 65% of Western adults self-report insufficient levels of PA.1,3 Studies using objective measurements show lower compliance with PA guidelines, at ~5% in adults.1,4 Increasing population PA therefore is a public health priority.1,2 Mass-media campaigns reach large sections of the population.5 To optimize effects, researchers have examined how message characteristics influence their persuasive appeal. Investigators have explored descriptive versus injunctive norms,6 fear appeals,7 tailoring,8 gain/loss framing,8,9 source credibility9 and specificity.10 One issue yet to be examined in the PA messaging field is the impact of ‘threshold’ information.

In behavioural domains, threshold messages implore individuals to attain a specified volume of behaviour (e.g. five fruit/vegetable portions a day). Many PA campaigns feature thresholds. For instance, the UK’s ‘Change4Life’ campaign11 and Singapore’s ‘Physical Activity Programme’12 encourage 150 min of moderate-to-vigorous physical activity (MVPA) per week. Similarly, earlier campaigns promoted 30 min of MVPA per day, e.g. ‘Get Active America’ (US)13, ‘Get a Life, Get Active’ (Northern Ireland)14 and ‘Find Your Thirty’ (Australia).15 Essentially, these campaigns directly cited PA guidelines of the day (e.g. ‘Swap 4 wheels for me own 2 feet to get me going for 150 minutes a week’ (Change4Life); ‘30 min of regular activity a day is good for your health’ (Get a Life, Get Active)).

Guidelines provide essential information on the minimum level of PA needed for health benefits. Consequently, they are invaluable for surveillance, planning interventions and policy. However, PA guidelines were not made to motivate individuals to adhere to being active. Brawley and Latimer16 discuss the importance of...