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Urban Greenways have the Potential to Increase Physical Activity Levels

Cost-effectively.

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1 Abstract

2 Background: For many, physical activity has been engineered out of daily life, leading to
3 high levels of sedentariness and obesity. Multi-faceted physical activity interventions,
4 combining individual, community and environmental approaches, have the greatest potential
5 to improve public health but few have been evaluated.

6

7 Methods: Approximately 100,000 people may benefit from improved opportunities for
8 physical activity through an urban regeneration project in Northern Ireland, the Connswater
9 Community Greenway. Using the macro-simulation PREVENT model, we estimated its
10 potential health impacts and cost-effectiveness. To do so we modelled its potential impact on
11 the burden from cardiovascular disease, namely ischaemic heart disease, type 2 diabetes
12 mellitus and stroke, and colon and breast cancer, by the year 2050, if feasible increases in
13 physical activity were to be achieved.

14

15 Results: If 10% of those classified as ‘inactive’ (perform less than 150 minutes of moderate
16 activity/week) became ‘active’, 886 incident cases (1.2%) and 75 deaths (0.9%) could be
17 prevented with an incremental cost-effectiveness ratio of £4,469/DALY. For effectiveness
18 estimates as low as 2%, the intervention would remain cost-effective (£18,411 /DALY).

19 Small gains in average life expectancy and disability-adjusted life expectancy could be
20 achieved and the Greenway population would benefit from 46 less years lived with disability.

21

22

23 Conclusion: The Greenway intervention could be cost-effective at improving physical
24 activity levels. Whilst the direct health gains are predicted to be small for any individual,

25 summed over an entire population they are substantial. In addition, the Greenway is likely to
26 have much wider benefits beyond health.

27

28 Keywords: Physical activity; built environment; cost-utility analysis.

29 Introduction

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

35

36

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

45

46

47 Multiple studies have consistently identified associations between access to public open
48 spaces, trails, parks and physical activity⁴⁻⁸ and environmental interventions have been found
49 to be generally more cost-effective than other prevention programmes.⁹ This is thought to be
50 due to their potentially large cumulative population effect and whilst they may have
51 substantial initial costs they are usually permanent with lasting effects.

52

53

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

59

60

61 Methods

62 Intervention

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

71

72

73 Baseline Household Survey

74 The PARC study involves a quasi-experimental before and after household survey of the
75 Greenway population, in tandem with a parallel (before and after) survey of the rest of NI.¹²
76 The survey took place over a 12 month period (Feb 2010-Jan 2011) using a random sample of
77 addresses from the Postcode Address File stratified by electoral ward. There are 29 wards

78 within the vicinity of the Greenway with a total population ~110,600 and 22 wards (~87,500
79 residents) with a geographical centroid within a one mile radius. Seven of the wards are
80 within the top 25% most deprived wards in NI. In each household, using the last birthday
81 rule, an adult (16 years or older) was interviewed ($n=1209$). The response rate to the survey
82 was 63%. We compared the age, gender and working status of our sample to the NI
83 population and steps were taken to redress the lower percentage representation of the
84 economically active, men and young people. Subsequently, the survey was weighted to
85 reflect seasonal variations in physical activity and the age and sex distribution of the
86 Greenway population. The survey included the Global Physical Activity Questionnaire.¹³
87 This was used to determine the number of minutes of physical activity performed per week
88 per interviewee. We then calculated, by age and sex, the proportion of those meeting the
89 current physical activity recommendations of 150 minutes per week of moderate physical
90 activity.¹⁴

91

92 Data Sources

93 A detailed description of data sources and the various derived variables are provided in
94 Appendix A. There were four main categories of input data including (1) population, (2) risk
95 factor, (3) disease and (4) cost inputs.

96 1. Baseline 2009 population, fertility and mortality estimates were obtained from the
97 Northern Ireland Statistics and Research Agency (NISRA) (www.nisra.gov.uk). For
98 background population disability weights, UK EQ-5D data were used.¹⁵

99 2. Baseline Greenway population physical activity levels were obtained from the
100 baseline household survey (Table 2). Participants were categorised as either ‘active,’
101 if they met the current UK physical activity recommendations of greater than 150
102 minutes of moderate intensity physical activity per week¹⁴ or ‘inactive,’ if they did

103 not. Relative risks were obtained from the literature for the protective effects of
104 physical activity on disease specific incidence (Appendix B). Since type 2 diabetes is
105 considered a risk factor for Ischaemic heart disease we also included the relative risk
106 of Ischaemic heart disease given diabetes in our model, taken from the literature.¹⁶

107 3. The Northern Ireland Cancer Registry (NICR) provided baseline incidence, mortality,
108 and remission rates (www.qub.ac.uk/nicr). By employing these parameters in
109 DISMOD II (a WHO software tool used to check the consistency of disease
110 parameters),¹⁷ we derived the prevalence of colon and breast cancer. For
111 cardiovascular diseases, prevalence was obtained from the 2005/06 NI Health &
112 Social Wellbeing Survey¹⁸ and the 2009 Quality and Outcomes Framework.¹⁹
113 Furthermore cardiovascular disease mortality was taken from NISRA whereas the
114 incidence of Ischaemic heart disease and stroke was obtained from the General
115 Practice and Research Database (GPRD); and the incidence of type 2 diabetes
116 mellitus was estimated using DISMOD II.¹⁷ Disease weights were taken from the
117 Global Burden of Disease Study (GBD).²⁰

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

121

122

123 Statistical Analyses

124 To model the impact of the intervention, a macro simulation model, PREVENT 3.01 was
125 used.^{10, 21, 22} By utilising the epidemiological effect measure ‘potential impact fraction’ (PIF),
126 it estimates the effect of changes in risk factor prevalence, adjusted for population changes,
127 on disease occurrence and mortality. In effect, after specifying a change in risk factor

128 prevalence due to an intervention, PREVENT estimates future disease incidence and
129 mortality by applying the PIF to current disease incidence and mortality rates.

130

131

132 The intervention effectiveness of the Greenway will take four years to be determined. To
133 obtain realistic effect estimates we looked to the evidence for trails, access to public open
134 spaces, ‘walkability’ and physical activity, which are all major components of the Greenway.
135 The quantified effect of ‘walkability’ on physical activity was the most consistently measured
136 using accelerometer data.²³⁻²⁶ Therefore we utilised ‘walkability’ effect sizes on moderate-to-
137 vigorous physical activity from two European studies (3.1 and 6.8 mins/day).^{25, 26} By adding
138 these to our baseline survey physical activity scores, we found the number of ‘active’ people
139 would increase by 7% and 10%, respectively. Therefore we decided upon three conservative,
140 ‘what if’ intervention scenarios, A, B and C, which equate to 2%, 5% and 10% of those
141 physically ‘inactive’ becoming ‘active,’ respectively. Whilst a drop-off in physical activity
142 levels has been found with short term interventions, the Greenway is a permanent
143 intervention so we assumed no attenuation of effects.²⁷

144

145

146 We used PREVENT to compare the projected future disease incidence and mortality with and
147 without the intervention. In addition, we calculated the gains in Life Expectancy (LE) and
148 Disability-adjusted Life Expectancy (DALE) expected for intervention beneficiaries and the
149 Years Lived with Disability (YLD) saved by the Greenway population. The intervention was
150 applied at the baseline year (2009) +1 when baseline physical inactivity levels were
151 recalculated depending on the particular scenario and these new physical activity levels
152 remained until 2050.

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Since the beneficial effects of physical activity on disease incidence and mortality will not emerge instantaneously, PREVENT accommodates this using two time lags: (1) the time that the risk remains unchanged after a decline in risk factor exposure (LAT) and (2) 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 of physical activity and its impact on breast and colon cancer, we used a LAT of 5 years and a LAG of 15 years while for cardiovascular diseases, we used a LAT of 1 year and a LAG of 5 years.^{28, 29} 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 (Appendix B).

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 to no intervention. We conducted our analysis from a healthcare payer perspective in order 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 (NICE) reference case.³⁰ All costs were derived in pounds sterling (£).

178

179 The Greenway construction and maintenance costs related to physical activity were extracted
180 from the overall costs (Appendix C). To calculate the total cost savings through diseases
181 averted, we first estimated the ‘annual cost per prevalent case per disease’. For breast cancer
182 we could obtain this directly from the literature for the period 1995/96 and inflate to 2009.
183 For the other diseases we found the total UK healthcare system expenditure for a particular
184 disease in a given year, inflated it to 2009 and divided by its prevalence in 2009, except for
185 colon cancer where we used the estimated prevalence in 2008 since it was the most recently
186 available estimate. For each scenario, we then multiplied the number of incident cases
187 averted each year, for each disease, by its respective ‘cost per prevalent case per disease,’ and
188 summed over all diseases to obtain the total disease cost savings (Appendix C). As a result of
189 the intervention, more people may live longer but we did not consider the future costs of an
190 ‘aging’ population. Health outcomes were derived in Disability-adjusted Life Years
191 (DALYs), recommended by WHO, instead of Quality-adjusted Life Years (QALYs)
192 primarily because the PREVENT model utilises disability rather than utility weights.

193

194

195 NICE recommends a lifetime time horizon for chronic disease interventions but we chose 41
196 years.³⁰ This may lead to an underestimation of the long-term benefits of increasing physical
197 activity but a longer time horizon would have involved making larger assumptions about the
198 demographics of our study population, disease incidence, mortality rates and costs.

199

200

201 Sensitivity Analyses

202 PREVENT's projections are dependent on the data and assumptions that populate the model.

203 To assess the impact of parameter uncertainty, we repeated the main analysis using the

204 following different scenarios:

- 205 1. Lower and upper relative risk estimates, taken from their respective 95% confidence
206 intervals (95% CIs);
- 207 2. A LAG time of 10 and 20 years for colon and breast cancer and a LAG time of 2 and
208 8 years for cardiovascular diseases;
- 209 3. A discount rate of 0%, 3%, and 5% applied to cost and health benefits.

210

211

212 Results

213 Baseline Characteristics

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

217

218 Preventable Incident Cases & Deaths

219 The number of potentially preventable incident cases and deaths, by 2050, increases for each
220 disease on moving from intervention scenario A to C, as expected (Table 3). In absolute
221 terms, it is estimated that the greatest number of incident cases could be prevented for type 2
222 diabetes with 376 cases prevented in scenario C. However, the greatest relative decline in
223 incident cases could be achieved for ischemic heart disease, approximately 2% in scenario C.
224 In both absolute and relative terms, the greatest number of deaths could be prevented for
225 ischemic heart disease, approximately 1.1% in scenario C. Compared to the cardiovascular

226 diseases, substantially fewer cancer incident cases and deaths might be prevented, but with a
227 comparable relative decrease.

228

229

230 Life Expectancy and Disability-adjusted Life Expectancy Gains and Years Lived with
231 Disability Averted.

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

242

243

244 Cost-effectiveness Analyses

245 We found all three scenarios to be cost-effective with ICERs ranging from £4,469/DALY to
246 £18,411/DALY (table 4). These are below the UK cost-effectiveness threshold which is
247 £20,000- £30,000/QALY or DALY.³¹

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249

250 Sensitivity Analyses

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

254

255

256 Discussion

257 We have described how potentially feasible increases in physical activity levels achieved
258 through an urban regeneration project, could be a cost-effective way to increase physical
259 activity levels. This comes at a time when the potential for environmental modifications to
260 influence health has caught the attention of policy makers since it has become clear that
261 individual, social, and physical environmental factors, all have an interrelated role to play in
262 promoting physical activity.³² This modelling study therefore provides a timely addition to
263 the evidence base to inform policy and practice in this area.

264

265

266 We have demonstrated that if 10% of those classified as ‘inactive’ became ‘active’, a total of
267 886 incident cases (1.2%) and 75 deaths (0.9%) from ischaemic heart disease, type 2
268 diabetes, stroke, colon and breast cancer could be prevented by 2050 in the Greenway
269 population. Also, small individual gains in average LE and DALE could be achieved which
270 summed over an entire population are substantial. It is difficult to directly extrapolate our
271 results (for an inner city urban district) to the whole population of NI, a largely rural part of
272 the UK, yet similar increases in physical activity in rural areas have been achieved through
273 walking/cycling trails.³³

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275

276 Strengths and Limitations

277 The strengths and limitations of the PREVENT model have been discussed in detail
278 elsewhere¹⁰ and the limitations of this study pertain to the inputs and assumptions we have
279 made. The relative risk estimates for the association between physical activity and disease
280 occurrence, except for breast cancer, were taken from recent, large meta-analyses (Appendix
281 B). We tested our main results through a series of one-way sensitivity analyses and found the
282 conclusion that increases in physical activity can prevent a substantial proportion of chronic
283 diseases in our population is robust. However, an analysis of extremes would have been a
284 more powerful test of uncertainty. As regards the baseline household survey, only
285 participants aged over 16 years were included and therefore we assumed that all individuals
286 less than 16 met the recommended physical activity levels. As the health outcomes included
287 in our model predominantly affect the elderly and our time horizon is relatively short, 41
288 years, this assumption should not impact greatly on our results. In order to calculate the YLD
289 saved, we used disease-specific disability weights as reported by the GBD²⁰ and disability
290 weights for the background population using UK population norm EQ-5D data.¹⁵ However
291 these weights were obtained through different techniques and so to check their compatibility,
292 we compared background population disability weights taken from the Australian Burden of
293 Disease study³⁴ with UK EQ-5D data and the values were comparable.

294

295

296 We modelled the impact of physical activity on the incidence of the top five physical activity
297 related diseases but physical activity can impact on a number of other diseases and mediating
298 disease risk factors which we did not consider.³⁵⁻³⁸ Also, the Greenway may have ‘indirect’
299 health benefits for the surrounding residents through potentially better income and
300 employment and new residents attracted to the area may also avail of its health benefits.

301 Therefore, both our health impact and cost-effectiveness estimates could be considered
302 underestimates.

303

304

305 We performed a Cost Utility Analysis with outcomes measured in DALYs, but due to the
306 broad nature of the Greenway intervention, DALYs may not capture its full impact, as it may
307 have extra benefits beyond the health sector. It is possible the Greenway will impact on
308 quality of life through increases in social capital and some of its costs and consequences,
309 including reductions in carbon emissions, improvements in safety and reductions in crime
310 will fall on other sectors of the community such as education and business. Whilst our
311 analysis can provide insight into the health impacts of the Greenway, a cost-benefit analysis,
312 which is routinely used in the environment and transport sectors, may have been better suited
313 to capture its impacts beyond health.

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315

316 Areas for Future Research

317 It is likely not everyone living in the intervention area will be affected equally by the project.

318 Several factors may influence whether someone uses the new amenities, including many
319 intrapersonal and environmental factors and/or the distance they live from the nearest path.

320 There is some evidence to suggest that environmental interventions may benefit lower socio-
321 economic groups more and help tackle health inequalities.^{39, 40} Future analyses should
322 consider subgroup analyses to assess the impact of these factors on the use of the Greenway
323 and assess whether its effects have been equitable.

324

325

326 Conclusions

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

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Conflicts of Interest:

None of the authors have any financial disclosures.

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 resulting from an intervention, may be better suited to capture the broader impacts of public health interventions.

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

Characteristic		Proportion (%)
Gender	Male	41
	Female	59
Age	16 to 24 years	7
	25 to 44 years	36
	45 to 64 years	30
	65+ years	27
Working Status	Economically active	51
	Economically inactive	49
Socio-economic status ^a	Most deprived	18
	2	18
	3	8
	4	19
	Least deprived	37

^aAccording 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.

Age group	Males (%)	Females (%)
16 to 34 years	14.2	25.1
35 to 44 years	21.2	36.6
45 to 54 years	38.9	55.6
55 to 64 years	49.3	58.3
65 to 74 years	51.7	75.7
75+ years	68.5	82.7
Total	35.3	52.6

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

Incident Cases Prevented	A ^a	B ^b	C ^c
Colon cancer	6 (0.2%)	11 (0.4%)	19 (0.7%)
Breast cancer	12 (0.3%)	20 (0.6%)	37 (1.0%)
Ischaemic heart disease	50 (0.4%)	125 (1.0%)	254 (2.0%)
Type 2 Diabetes	76 (0.2%)	188 (0.5%)	376 (0.9%)
Stroke	40 (0.3%)	97 (0.8%)	200 (1.6%)
Deaths Prevented	A ^a	B ^b	C ^c
Colon cancer	2 (0.2%)	5 (0.4%)	7 (0.6%)
Breast cancer	0 (0.0%)	2 (0.2%)	3 (0.3%)
Ischaemic heart disease	5 (0.2%)	14 (0.6%)	27 (1.1%)
Type 2 Diabetes	0 (0.0%)	1 (0.1%)	2 (0.2%)
Stroke	10 (0.4%)	18 (0.7%)	36 (1.3%)

^aScenario A: 2% of those classified as ‘inactive’ become ‘active’.

^bScenario B: 5% of those classified as ‘inactive’ become ‘active’.

^cScenario C: 10% of those classified as ‘inactive’ become ‘active’.

Table 4: Incremental cost-effectiveness ratio calculations for scenarios A, B and C.

Scenario (estimate of effect)	Discounted Construction & Maintenance Costs	Discounted Disease Cost Savings	Incremental costs	Total DALYs saved	Total Discounted DALYs saved	£/DALY
A (2%)	£6,857,811	£211,811	£6,646,000	1479.25	361	£18,410.82
B (5%)	£6,857,811	£481,179	£6,376,633	2959.24	722	£8,830.10
C (10%)	£6,857,811	£946,088	£5,911,723	5420.19	1323	£4,469.45

DALY, Disability-adjusted Life Year