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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

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 activity[4-8] 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 week[14] 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 Survey[18] 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.

153

154

155　Since the beneficial effects of physical activity on disease incidence and mortality will not

156　emerge instantaneously, PREVENT accommodates this using two time lags: (1) the time that

157　the risk remains unchanged after a decline in risk factor exposure (LAT) and (2) the period

158　during which the changes in risk factor exposure gradually affect the risk of disease,

159　eventually reaching risk levels of the non-exposed (LAG). The time between increasing

160　physical activity and achieving reductions in all-cause mortality, and in particular,

161　cardiovascular disease, is relatively short and so in respect of physical activity and its impact

162　on breast and colon cancer, we used a LAT of 5 years and a LAG of 15 years while for

163　cardiovascular diseases, we used a LAT of 1 year and a LAG of 5 years.[28, 29] These time lags

164　broadly correspond to those observed in the epidemiological studies we used to provide

165　relative risk estimates for the protective effect of physical activity on disease incidence

166　(Appendix B).

167

168

169　Cost-effectiveness Analyses

170　Our aim was to present the Incremental Cost-effectiveness Ratios (ICERs) of the Greenway

171　intervention by identifying the additional costs associated with the intervention per additional

172　unit of health outcome generated by each scenario, compared to no intervention. We

173　conducted our analysis from a healthcare payer perspective in order to compare its effects

174　with alternative health interventions and discounted both cost and health gains by 3.5% in

175　line with the National Institute for Health and Clinical Excellence (NICE) reference case.[30]

176　All costs were derived in pounds sterling (£).

177

9

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]

248

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]

274

275

13

276   Strengths and Limitations

277   The strengths and limitations of the PREVENT model have been discussed in detail

278   elsewhere[10] 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 GBD[20] 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 study[34] 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.

14

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.

314

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.

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

[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.

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%)

[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'.

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