Effect of increasing active travel in urban England and Wales on costs to the National Health Service

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Increased walking and cycling in urban areas and reduced use of private cars could have positive effects on many health outcomes. We estimated the potential effect of increased walking and cycling in urban England and Wales on costs to the National Health Service (NHS) for seven diseases—namely, type 2 diabetes, dementia, cerebrovascular disease, breast cancer, colorectal cancer, depression, and ischaemic heart disease—that are associated with physical inactivity. Within 20 years, reductions in the prevalences of type 2 diabetes, dementia, ischaemic heart disease, cerebrovascular disease, and cancer because of increased physical activity would lead to savings of roughly UK£17 billion (in 2010 prices) for the NHS, after adjustment for an increased risk of road traffic injuries. Further costs would be averted after 20 years. Sensitivity analyses show that results are invariably positive but sensitive to assumptions about time lag between the increase in active travel and changes in health outcomes. Increasing the amount of walking and cycling in urban settings could reduce costs to the NHS, permitting decreased government expenditure on health or releasing resources to fund additional health care.

Introduction

Increasing urban active travel (mainly walking and cycling) could yield many benefits, including improvement of public health by increasing physical activity and reducing air and noise pollution,[1,2] traffic congestion, and CO_2 emissions.[1–4] Woodcock and colleagues[5] used London and New Delhi as examples to assess the potential health effects from implementation of increased active transport strategies. For London, they estimated that doubling of average distances walked per day and an eight-fold increase in the amount of cycling could lead to substantial reductions in the burden of disease due to type 2 diabetes, dementia, depression, ischaemic heart disease, cerebrovascular disease, breast cancer, and colon cancer. The results of a sensitivity analysis showed that smaller increases in distances walked and cycled resulted in benefits to health.

We estimated the potential economic effect of increased walking and cycling in urban England and Wales on the National Health Service's (NHS) expenditure on type 2 diabetes, dementia, cerebrovascular disease, breast cancer, colorectal cancer, depression, and ischaemic heart disease. We focused on the health gains made because of increased physical activity, because in a previous study[5] increases in physical activity resulted in more health gains than did reductions in air pollution. We included the effect of road traffic injuries as a potential harmful side-effect of increased walking and cycling. Reductions in long-term and geographically disparate effects of climate change were not modelled and are associated with uncertainty.

Active travel scenarios

Panel 1 shows the two active travel scenarios. The transport and carbon simulation visioning and backcasting for transport (VIBAT) London programme was used to design the scenarios.[6] An average daily cycling distance of 3·4 km is assumed in the main active travel scenario, compared with an average distance of 3 km in Copenhagen during 2010.[7,8]

We assumed that the increase in walking and cycling previously modelled for London also occurred throughout all urban areas in England and Wales. Urban areas were defined as settlements of 20 000 residents or more, representing roughly 82% of the population of England and Wales. Although car use is lower in London than in other urban areas, we assumed that the potential for increasing the amount of walking and cycling and the corresponding improvement in health outcomes would be similar. The potential physical activity benefits could be greater in urban areas outside London than in London because of lower numbers of people walking and cycling and less public-transport provision.[9]

For the purpose of the analysis, we assumed that the increase in walking and cycling in urban areas occurred immediately in 2012, perhaps through measures such as a substantial fuel tax on private vehicles, road-usage charges, and restrictions on most private motor vehicles in urban areas, combined with a political and cultural shift towards walking and cycling for short journeys. Although such a policy might seem unfeasible, many public health policies—eg, bans on smoking in public places—face initial resistance and hostility but are quickly accepted once implemented. A 2009 report of cycling uptake in the UK showed that, in London, the number of people cycling had increased by 91% since 2000 (and the proportion of cycling deaths and serious injuries had fallen by 33%). These data suggest that people are willing to cycle in urban areas and that, as the numbers of cyclists increase, the number of cycling-related deaths and injuries could fall. The results of an Australian study[10] showed an average increase of 22% in cycling in urban areas between 2001 and 2006 because of publicly funded programmes that encouraged cycling for commuting. Furthermore, the European Cyclists' Federation reported that if the citizens of countries in the European Union cycled as much as the people of Denmark (roughly 600 miles per year on average), transport-related greenhouse-gas emissions would fall by 25%. The Federation also pointed to cities such as Seville to show that once infrastructure and policy are in place, the amount of cycling and walking can increase substantially.[11]

Although the introduction of the policy was assumed to exert its effect immediately, we assumed that the lag period between the increase in walking and cycling and the corresponding reduction in disease incidence would be long (the effect on road traffic injuries was assumed to be immediate). Because this analysis focused on the health sector only, we did not factor-in the cost of infrastructure development, although this expenditure might be offset by reductions in spending on infrastructure for motor vehicles.

Modelling of health effects

The health benefits of increased active transport were modelled for the period 2012–31 with the WHO comparative risk assessment method, which is defined as "the systematic evaluation of the changes in population health which result from modifying the population distribution of exposure to a risk factor or a group of risk factors".[12] Seven health outcomes for which the link between physical inactivity and increased disease risk is well established were included—ie, type 2 diabetes, dementia, depression, ischaemic heart disease, cerebrovascular disease, breast cancer, and colon cancer.[5]

To model the effect of increased walking and cycling on disease burden we estimated the decrease in disease incidence that would be expected because of increased physical activity. The numbers of new incident cases at baseline were taken from published work.[13–18] If incidence data were only available for one age group, we assumed that this rate was the incidence for the entire population (ie, no other age group was assumed to have any new cases).

We assumed that the total percentage reductions calculated by Woodcock and co-workers[5] for years lived with disability corresponded to the percentage reduction in incident cases for each disease. Woodcock and colleagues calculated the percentage reductions for each disease by applying relative risk functions based on changes to the median age-group-specific amount of physical activity (in units of metabolic equivalent of task hours per week, combining walking, cycling, and other physical activity) to estimate the change in years lived with disability (panel 2). We assumed that the effect of increased walking and cycling applied only to new incident cases of the seven diseases, with no effect on prevalent cases. Table 3 shows the starting incidence for each disease and the scale of the yearly reductions expected.

We estimated changes with time by assuming that there would be a time lag between the change in exposure to physical activity and the full corresponding change in health outcomes. We used a sigmoid lag curve, which allows for a delay in effect when little or no change is noted, followed by a gradual increase to a steady level after a transition period that varied by disease. For type 2 diabetes, we assumed a 3·2 year lag period before 50% of the effect on new cases was achieved (8 years before full effect achieved).[21] For depression, ischaemic heart disease, and cerebrovascular disease, we assumed a delay of 2 years before 50% of the effect on new cases was achieved (6 years before full effect achieved). For dementia, breast cancer, and colon cancer, we assumed a delay of 17 years before 50% of the effect on new cases was achieved (20 years before full effect achieved).[22] The largest reduction in the number of cases was for depression, followed by ischaemic heart disease, type 2 diabetes, and dementia.

Panel 1: Mean distance travelled per head per day in the two modelled scenarios

The London low carbon scenarios draw on work done in the visioning and backcasting for transport (VIBAT) London study[6] for 2025 and 2050, which was developed in the transport and carbon simulation model for the city. In the VIBAT London study, seven pathways toward an 80% decrease in CO_2 emissions by 2050 were considered, and transport was assumed to have a role in emissions reduction. The modelling examines combinations of more than 120 policy interventions that can help to reduce transport CO_2 emissions, which were grouped into 11 policy packages. The large increase in walking and cycling in the increased active travel scenario was based on an extrapolation of a high growth rate for cycling to 2030, the assumption that total travel distances for all future scenarios were fixed, and assumed maximum plausible walking and cycling distances (based on Copenhagen cycling statistics[7] for 2010). The sensitivity analysis for the increased active travel shorter distances scenario broke with the assumption about constant total travel distances and represents alternative assumptions about how travel patterns can change with a shift from car to active travel. Table 1 shows the modelled changes in average daily distances travelled per head for various modes of transport.

	Walking (km)	Bicycling (km)	Motorbike (km)	Car (km)	Bus (km)	Rail (km)
2010 data	0·6	0·4	0·2	13·8	2·9	7·2
Increased active travel	1·6	3·4	0·1	10·1	2·9	7·6
Active travel shorter distances	1·1	1·9	0·1	10·1	2·9	7·6

***Table 1:* Modelled changes in average daily distances travelled per head for various modes of transport**

Modelling of road traffic injuries

To include the effect of road traffic injuries, we used Woodcock and colleagues' data.[5] Their model estimated the change in road traffic injuries that would be expected from the combined effects of less motor-vehicle traffic (because of less exposure to cars by pedestrians, cyclists, and other motor-vehicle users) and increased walking and cycling (because of more exposure of pedestrians and cyclists to motor traffic). In addition to passenger travel, heavy goods vehicles have an especially strong effect on injury risk for cyclists.[23] In Woodcock and co-workers' model, percentage reductions in the per-head distance travelled by heavy-goods vehicles were similar to those for private cars. However, they did not assume that any additional measures were implemented to make walking and cycling safer.

Panel 2: **Woodcock and colleagues' model of active travel[5]**

Woodcock and colleagues converted total distances walked and cycled[19] into mean distances walked and cycled per person (table 2). Activity intensity was represented as metabolic equivalent of task (MET) hours, where 1 MET is the typical energy expenditure of an individual at rest (1 kcal/kg/h). Distance, time, speed, and activity intensity were modelled separately by age and sex because disease burdens were modelled in that manner. Because empirical active travel time distributions are skewed to the right, walking and cycling times in each scenario were modelled with log normal distributions, with the median travel time as the measure of central tendency and the geometric standard deviation of travel time as the measure of dispersion.

The distributions of walking and cycling times were converted into distributions of METs by multiplying by the tabulations of METs for different activities and speeds. The speed-to-MET ratios for walking and cycling were implemented as step functions assuming minimum values of 2·5 METs for walking and 4 METs for cycling.

Woodcock and co-workers used the median value for each age-specific and sex-specific distribution in their model of the health effects of changes in exposures. For the exposure–response relation between changes to exposure and changes to outcomes, a linear model with a maximum threshold was assumed. The response function and threshold for each specific disease was estimated on the basis of findings of systematic reviews.

No minimum threshold for activity was assumed, but walking and cycling trips for transport would probably be sufficient to achieve health benefits. The results of a subsequent systematic review[20] suggested that the relations between physical activity (including walking) and mortality is strongly non-linear, with the greatest benefit associated with moving from no activity to low amounts of activity.

	2010	Increased active travel	Active travel shorter distances
15–29 years			
Men and boys	95	329	198
Women and girls	107	371	223
30–44 years			
Men	86	299	180
Women	97	337	203
45–59 years			
Men	70	243	146
Women	79	273	164
60–69 years			
Men	77	267	161
Women	87	301	181
70–79 years			
Men	69	214	143
Women	77	241	161
≥80 years			
Men	50	155	105
Women	57	174	118

Table 2: **London median active travel times per week in minutes, by age group[5]**

The change in injuries was estimated with a risk-based and distance-based model that uses data reported in the STATS19 road accident database to calculate absolute numbers of deaths and injuries.[18] Woodcock and colleagues modelled that the injury rate increased overall because the effect of increased numbers of cyclists and walkers outweighed that of exposure to fewer motorised vehicles. In our model, we calculated the percentage change in deaths and injuries from the absolute numbers estimated for the active travel scenarios, and applied this method to the number of deaths and injuries in 2010 (the most recent year for which estimates were available at the time) for the urban areas of England and Wales outside London. We assumed that the change in exposure to traffic immediately led to a change in the incidence of injuries. We estimated that the increase in active travel would result in an additional 2625 serious injuries (head or spinal injury) per year.

Modelling of cost effects

We searched PubMed and disease-specific foundation reports in July 2011 with the search term "costs" and the name of the disease in question to obtain average yearly treatment costs per patient. Treatments costs were derived for the first year of diagnosis, as were yearly costs thereafter for the average duration of each disorder. The criteria for including a study were that the data had been gathered on or after Jan 1, 2001, and that the estimates were derived from a representative sample of patients, ensuring that different treatment-seeking behaviours and treatment practices were taken into account when the mean cost was calculated. We noted no published evidence for the yearly treatment cost of injuries, so we derived the mean costs per year on the basis of an NHS costing template for head injuries[24] and the Personal and Social Services Research Unit cost estimates,[25] which take into account costs associated with emergency services, general practitioners, and subsequent rehabilitation. The distribution of cost data is typically positively skewed because of a few patients with high treatment costs and the absence of costs below zero.[26] Thus, the median might be more appropriate for descriptive purposes; however, it does not easily allow estimation of the total costs of treatment. We used Monte Carlo simulation (10 000 iterations, log normal distribution, implemented in Microsoft Excel) and arithmetic mean estimates from published work to bootstrap a 95% CI around the estimate. For every Monte Carlo iteration, we multiplied the mean by the estimated number of cases averted to calculate total costs per year. Treatment costs were adjusted to 2010 prices with the consumer price index for health care in the UK.[27] We assumed that because costs were to be immediately reinvested each year, discounting was not appropriate in the main analysis. However, we also show the analysis with a 3·5% discount rate and an inflation rate of 2·9%.

Table 4 summarises mean treatment costs for the year when the disease episode occurred and for subsequent years. Breast cancer and colon cancer were the most expensive to care for per case in both the short and long term. We excluded social-care costs from the main analysis to focus only on costs to the NHS. For breast cancer and colon cancer, we assumed that no further costs were

	Incidence per 100 000 population	Incident cases in urban England and Wales	Source	Relative risk reduction from 2·5 h per week moderate physical activity*	Yearly change in incident cases at full effect*	Estimated time to achievement of 50% of effect
Type 2 diabetes	348	158 183	Gonzalez et al[13]	–0·19	–11·5%	3·2 years[21]
Dementia	480	218 043	Matthews et al[14]	–0·11	–6·5%	17 years[22]
Cerebrovascular disease	181	82 232	British Heart Foundation[15]	–0·23	–10·8%	2 years
Breast cancer	78	35 528	Cancer Research UK[16]	–0·13	–11·6%	17 years[22]
Colorectal cancer	65	35 538	Cancer Research UK[16]	–0·08	–5%	17 years[22]
Depression	2993	1 359 942	Singleton et al[17]	–0·07	–4·1%	2 years
Ischaemic heart disease	382	173 572	Scarborough et al[15]	–0·23	–10·5%	2 years
Road traffic injuries	480	12 500	STATS 19, Transport statistics for Great Britain[18]	N/A†	21%	0 years

*Data are from Woodcock and colleagues.[5] †Data for road traffic injuries were calaculated by a different method.

Table 3: **Incidence of disease and road traffic injury in 2010, and subsequent yearly effect of active travel**

	Sample size	Description of sample population	Year data were collected	Costs in the year of diagnosis (95% CI)	Subsequent cost per year after the event (95% CI)	Duration	Reference
Type 2 diabetes	749	Study centres in the UK (Bradford, Jersey, and Salford); resource-use data gathered for 12 months	1998	£2980 (2804–3535)	£2980 (2804–3535)	16·35 years	Williams et al[28]
Dementia	All patients with dementia in the UK population	Top-down, cost-of-illness study of UK statistics for usage rates and unit costs; includes drugs, outpatient visits, and hospitalisations	2008	£2425 (1874–4149)	£2425 (1874–4149)	4·35 years	Luengo-Fernandez et al[29]
Ischaemic heart disease	5102	Patients with type 2 diabetes followed up for 20 years; their use of health-care resources was used to build a regression model to predict costs of ischaemic heart disease	1998	£2952 (2699–3698)	£870 (764–1053)	10 years†	Clarke et al[30]
Cerebrovascular disease	346	Stroke patients from the Oxford vascular study population	2006	£3578 (3270–4505)	£466 (425–586)	7·8 years	Clarke et al;[30] Luengo-Fernandez et al[31]
Breast cancer	199	Data collected at the Western General Hospital, Edinburgh, of women with early breast cancer who experienced a recurrence, defined as either a contralateral primary tumour or a relapse of the original breast cancer	2004	£14 006 (12 800–17 575)	£3451 (2537–6263)	5 years†	Karnon et al[32]
Colorectal cancer	All patients with colorectal in the UK population	Top-down cost-of-illness study of UK statistics for usage rates and unit costs (includes drugs and inpatient and outpatient visits)	2007	£10 921 (9982–13 922)	£3000† (2742–3745)	5 years†	Cooper et al[33]
Depression	All patients with depression in the UK population	Top-down cost-of-illness study of UK statistics for health-care usage rates and unit costs (includes inpatient and outpatient care)	2007	£1481 (1353–1855)	£1481 (1354–1875)	0·75 years	McCrone et al[34]
Road traffic injuries	UK population	Authors' calculation based on UK National Health Service cost of head injury template	2008	£11 892 (10 866–14 857)	£668 (610–843)	2 years†	UK National Health Service[24]

*Costs based on 2010 prices. †Although disease might occur beyond this period, we have assumed no additional cost to the National Health Service.

Table 4: **Average treatment cost per patient in the year of diagnosis and thereafter for seven key diseases and for road traffic injuries***

accrued after 5 years. On the basis of published reports, type 2 diabetes has the longest estimated average duration (16·35 years), followed by ischaemic heart disease and cerebrovascular disease.

Figure 1A shows the long-term and yearly changes in treatment costs averted by increased walking and cycling in urban areas in England and Wales. The model estimates that roughly £17 billion (in 2010 prices) could be released from the NHS budget after 20 years. Most of these released funds are because of a decrease in the expected number of cases of type 2 diabetes, leading to a saving of roughly £9 billion in 20 years. The increase in road traffic injuries is projected to cost about £722 million during the period; however, the spending averted though reduction of the burden of type 2 diabetes only greatly outweighs these costs.

The steep increase in expenditure averted towards the end of the 20-year period should be noted. This rise is largely due to the increase in the number of cases of dementia and cancers averted. If the analysis is extended by another 10 years, the total amount of expenditure averted is roughly £30 billion. Table 5 shows the potential yearly spending averted at 10-year timepoints because of increased walking and cycling in relation to

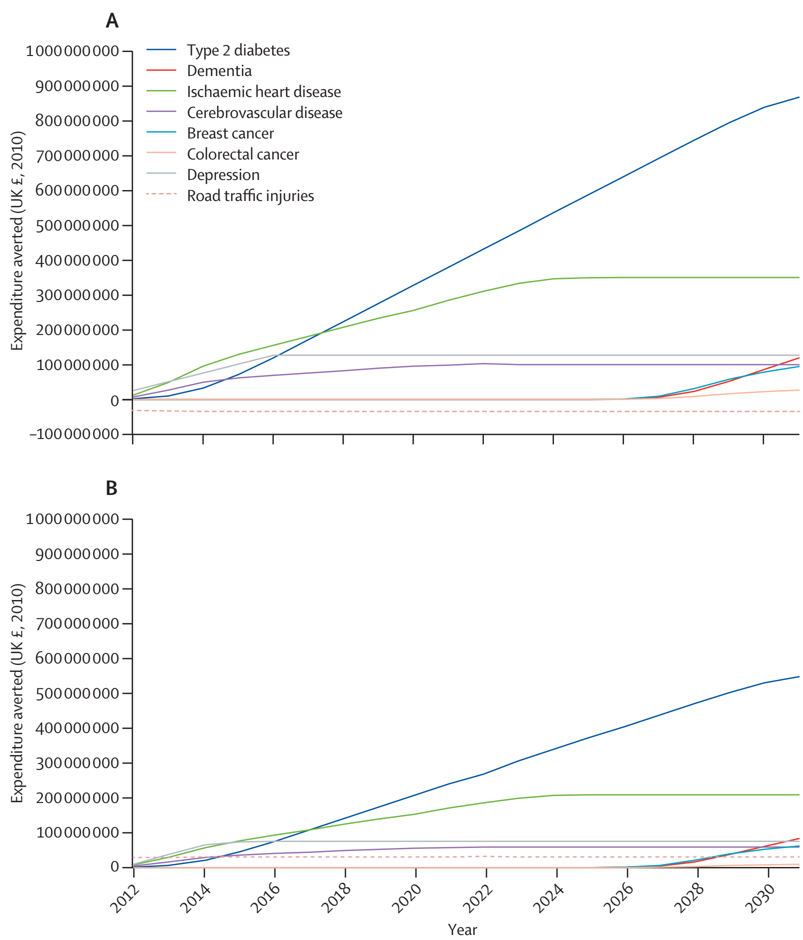

Figure 1: **Potential yearly National Health Service expenditure averted by year and health outcome from increased active travel scenario (A) and shorter distances scenario (B)**

	Yearly National Health Service programme budget expenditure	Expenditure averted by active travel (%)
2012	£107 000 000 000	£15 073 571 (0·01)
2014	£113 516 300 000	£213 350 782 (0·19)
2016	£120 429 442 670	£397 426 586 (0·33)
2018	£127 763 595 729	£531 146 644 (0·42)
2020	£135 544 398 708	£655 907 606 (0·48)
2022	£143 799 052 590	£774 012 597 (0·54)
2024	£152 556 414 893	£870 250 405 (0·57)
2026	£161 847 100 559	£976 967 538 (0·60)
2028	£171 703 588 984	£1 142 576 091 (0·67)
2030	£182 160 337 553	£1 360 441 001 (0·75)

*Model assumes a 3% yearly increase in expenditure.

Table 5: **Projected National Health Service expenditure and potential expenditure averted from walking and cycling***

NHS expenditure for 2010–11.[35] We assumed that the NHS budget would increase by 3% each year and calculated the in-year expenditure averted as a percentage. The increase in road traffic injuries results in a 0·8% increase in injury and trauma expenditure per year initially, but only about a 0·5% rise per year by the end of the study. After 20 years, spending averted by increased walking and cycling represents roughly 0·8% of estimated yearly NHS expenditure. Although comparison of our findings with programme budget information suggests increasing potential for aversion of expenditure, the programme budgeting information uses a different costing method from our study and therefore might not be directly equivalent.

Sensitivity analysis

We did several sensitivity analyses to test the assumptions made in the model. In the main scenario, per-head travel distances were assumed to remain constant. However, per-head travel times are much more consistent than are per-head travel distances, so a move to typically slower modes of transit might lead to a reduction in travel distances.[36] Therefore, a second (shorter distances) scenario was modelled in which we assumed that the increase in walking and cycling was only half that in the main analysis. To test how assumptions about the lag between the intervention and the health outcomes affected the results, we did an analysis that measured the effect of use of a linear-lag relation instead of a sigmoid, and another that assumed all health effects did not reach full potential until 20 years after the intervention was in place. We did an analysis of our assumptions about disease duration, in which we halved and doubled disease duration. Because social-care costs account for most dementia costs, and the relation between social-care costs and NHS costs is not clear cut, we included a sensitivity analysis for the yearly NHS and social-care cost of caring for dementia patients. Finally, we ran a multiple-attribute scenario, which included all health outcomes taking 20 years to realise full benefit and halving of disease duration and the effect on the number of cases prevented.

In the shorter distances scenario, the health benefits associated with physical activity were less pronounced than were those in the main analysis. However, the overall number of road traffic injuries fell (2250 injuries were estimated to be prevented in the shorter distances scenario, whereas 2625 more injuries occurred in the full distance scenario) because, with less total travel, the reduction in road danger from less use of motor vehicles had a greater effect than did the increase in exposure to injury risk because of increased walking and cycling. Figure 1B shows the results of the analysis in terms of expenditure averted during the 20-year period for the shorter distances active travel scenario.

Figure 2 shows the results of the other sensitivity analyses. Each scenario kept all other variables the same as in the main analysis except for the multiple-attribute scenario, which assumed a 20-year benefit-realisation period, a reduction-of-health effect of 50%, and half the time of disease duration. Changing the shape of the effect curve from sigmoid to linear had a substantial effect on the results. A linear relation between exposure and response increased the total expenditure averted from £17 billion in 20 years to £27 billion in 20 years because of a more rapid effect on the number of cases of dementia, breast cancer, and colon cancer. If the sigmoid relation is assumed to hold, then much of the benefit from reduction of the frequency of dementia and some types of cancer accrues after 20 years (figure 3).

The most conservative of our sensitivity analyses showed a substantial reduction in the potential effect on the NHS budget, with savings of roughly £6 billion in 20 years. Irrespective of the scenario, the sensitivity analyses show that increased walking and cycling would have a positive effect on NHS expenditure.

Discussion

The money released from the NHS budget because of increased walking and cycling could result in health-care benefits if spent on other health priorities; however, to estimate these additional benefits was beyond the scope of our model. Our findings suggest that during the 20-year period as much as 1% of the yearly budget for health care in England and Wales (and possibly even more after 20 years) could be made available for reallocation by increased walking and cycling in urban areas. Aversion of further disease burden on the NHS could contribute to the efficiency savings of £20 billion per year that the UK Government has deemed necessary to cope with the ageing population and other factors.[37]

In terms of aversion of disease treatment expenditure, the economic benefits from reduction of the incidence of type 2 diabetes will probably be much larger than those from any other disease. Care for type 2 diabetes cost the NHS roughly £9·8 billion in 2010–11,[38] and yearly expenditure of about £15·1 billion is predicted by 2035. Our model estimates that nearly £1 billion of expenditure on type 2 diabetes alone could be averted per year by 2030, thereby freeing up substantial funds to be spent elsewhere.

The health benefits of physical activity for some diseases—eg, ischaemic heart disease—are well established, but the benefits for dementia were established more recently. Since the publication of a systematic review[39] about physical activity and neurodegenerative disease by Hamer and Chida in 2009, other studies have shown positive effects on the risk of both Alzheimer's disease[40] and vascular dementia.[41] The timing of the exposure–response relation has clear implications for this study, as noted in the linear-lag sensitivity analysis in which cases were averted from the beginning, therefore resulting in more averted expenditure. Dementia is also an important factor in the main analysis; however most of the economic and health benefits were accrued after 20 years.

Limitations

Our model does not take into account the effect of walking and cycling on environmental factors such as improved air quality because of reduced vehicle emissions, or on health-related outcomes such as a fall in the prevalences of overweight and obesity. An estimate[42] of the costs of obesity to the NHS suggests that these savings could amount to £2 billion per year by 2030. Thus, even slight reductions in obesity because of increased walking and cycling could have substantial additional economic benefits that have not been fully captured by our analysis.

Our study did not account for compensation mechanisms. Compensation could occur if activity in another domain decreased after an increase in physical activity associated with walking and cycling. Although such an effect is possible, increases in fitness in less active individuals could also lead to an increase in activity in other domains. Convincing empirical evidence is not yet available. Rebound effects that could occur through increases in food consumption are not relevant because we did not model the potentially additional benefits from changes in overweight and obesity.

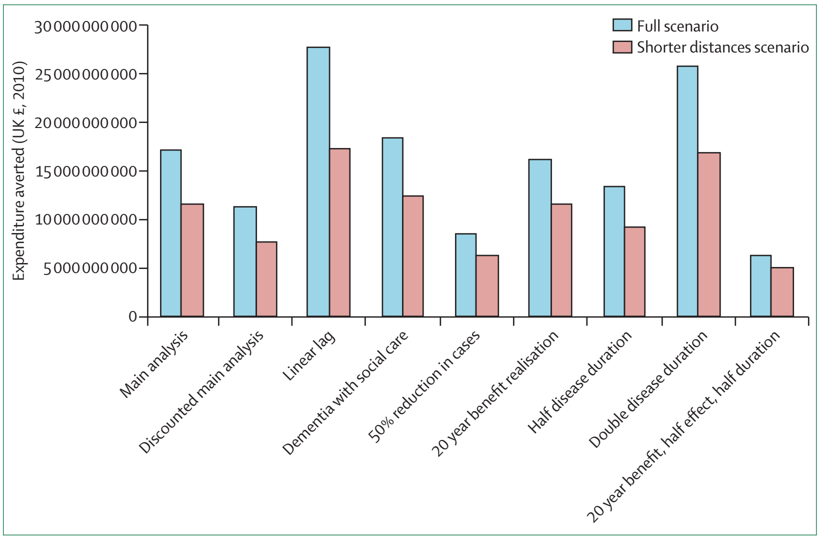

Figure 2: **Sensitivity analyses for effect on National Health Service expenditure over 20 years for various parameters**

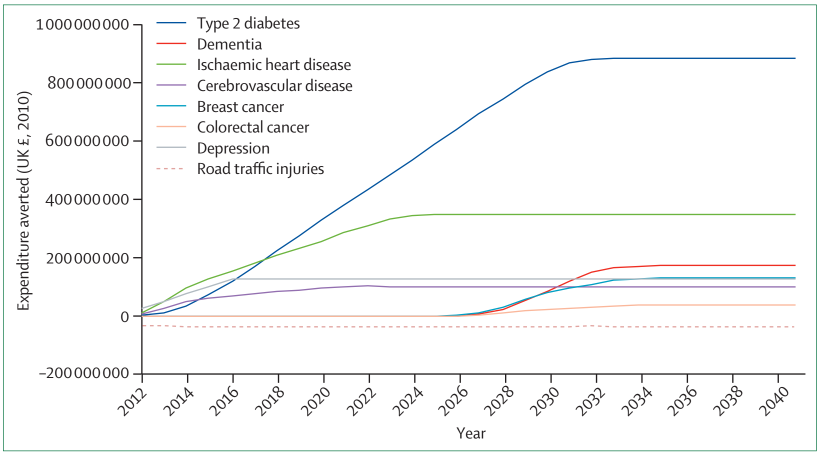

Figure 3: **Effect on National Health Service expenditure by disease over 30 years**

Researchers have attempted to monetise the value of lives saved through increased walking or cycling.[43] Investigators of a USA-based study estimated the benefits of reduction in air pollution and increases in physical activity as a result of curtailment of short car journeys and replacement with walking or cycling; the net saving associated with health benefits was US$7 billion (£4·6 billion) per year in a US Midwest population of around 30 million people.[44] These savings are considerably greater per head than are those calculated in our model, but include monetised valuation of health benefits in addition to health-care cost savings. Reductions in greenhouse-gas emissions from decreased use of motor vehicles will not only lead to health benefits, but will also contribute to national targets for emissions reductions set by the UK Committee on Climate Change.[45] Although strong evidence shows that increased physical activity leads to positive health effects (and therefore a reduction in health expenditure or release of funds), implementation of behaviour-change initiatives can be quite difficult. Activities that can become part of everyday life, such as walking or cycling to work or school, might be more likely to be sustained than are activities that necessitate attendance at specific venues.[46]

Perception of injury risk might be a disincentive to uptake of walking and cycling. Therefore, policies to improve the safety of walking and cycling—eg, provision of physically segregated infrastructure on roads on which speeds differ greatly between modes of transport (as is done in the Netherlands)—is important to ensure uptake.[47] Such policies could have double benefits—ie, lessening of the risk of road injury and encouragement of more people to cycle or walk, who will then reap the health benefits.

Woodcock and colleagues[5] did comparative risk assessment and did not estimate changes with time in the incidence and prevalence of different diseases. In our model, we assumed that the noted percentage reductions in disease burden were applied to the incidences of each disease. Although a time-varying change in disease risk because of step change in exposure can be incorporated into the comparative risk assessment approach,[48] Woodcock and co-workers applied the standard method of comparative risk assessment, which is based on an implicit multistate life table model that does not allow explicit direct modelling of changes in disease risk with time. Our extrapolation from these single-accounting-year values means that we cannot take into account the increase in competing causes of disease.

Do interventions that promote healthy lifestyles result in added years of life with increased morbidity in older age? Such a pattern could result in deferred increases in health-care costs that could offset earlier savings. Hubert and colleagues[49] investigated the effect of lifestyle on compression of morbidity to later life. They showed that people with no lifestyle-related risk factors (eg, smoking, drinking, obesity) had a slow rate of functional decline, whereas those with two or more risk factors were overall more disabled throughout the decade before death and had a further increase in disability 1·5 years before death. The rate of decline in people with moderate risks only increased substantially in the last 3 months of life. We did not model effects on different age groups but would argue that, although some additional costs might be incurred by the health service at some point in the future, increased walking and cycling releases funds in the short term that, if reinvested in the NHS now, could offset some of the increasing costs associated with an ageing population in the future. Furthermore, many of the benefits of averting cases of dementia accrue after the 20 years of the main analysis (figure 3). The dementia expenditure averted, especially when social-care costs are included, could outweigh the costs associated with other delayed disease, and increased active travel should also reduce social-care costs. Thus, the near-term economic and health benefits might offset to some degree the slow increase of costs in the future because of an ageing population. Researchers could investigate this issue with an explicit multistate life table model or individual-based modelling approaches.

Our results suggest that benefits to the NHS rise sharply towards the end of the study period because of the probable long lag period before reductions in some cancers and dementia. Thus, many benefits could accrue after 20 years, when they might account for a substantial proportion of the NHS budget. Our sensitivity analyses show that, even if we achieve a half-effective programme, the health benefits and the subsequent reallocation of funds could be pronounced.

Contributors

JJ, JW, and UKG planned and did the modelling. ZC, PE, and IR did epidemiological analysis, AH developed the original proposal, was the principal investigator for the grant that funded this work, and led the project management. JJ wrote the first draft, and all authors contributed to the drafting process.

Conflicts of interest

We declare that we have no conflicts of interest.

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