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Cycling for transport and public health: a systematic review of the effect of the environment on cycling

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Background: Active transport policies are being developed across Europe designed to have health and environmental benefits. There is little evidence of impact on physical activity of active transport strategies which modify the built environment. Cycling represents one virtually carbon-neutral form of transport that can help to address declining levels of exercise. **Methods**: A systematic literature review of experimental or observational studies that objectively evaluated the effect of the built environment on cycling. **Results**: A total of 21 studies met the inclusion criteria, all of which were observational studies. Eleven studies identified objectively measured environmental factors with a significant positive association with cycling. The environmental factors identified as being positively associated with cycling included presence of dedicated cycle routes or paths, separation of cycling from other traffic, high population density, short trip distance, proximity of a cycle path or green space and for children projects promoting 'safe routes to school'. Negative environmental factors were perceived and objective traffic danger, long trip distance, steep inclines and distance from cycle paths. Of the seven studies which focused primarily on the impact of cycle routes, four demonstrated a statistically significant positive association. **Conclusion:** Although the study identified environmental factors with positive and negative associations with cycling behaviour, many other types of environmental policies and interventions have yet to be rigorously evaluated. Policies promoting cycle lane construction appear promising but the socio-demographic distribution of their effects on physical activity is unclear. The wider impact of active transport policies on health and inequalities across Europe must be explored.

Keywords: cycling, environment, physical activity, policy, transport

Introduction

EU member states have placed different emphasis on active transport and the use of urban design to facilitate cycling and walking.[1,2] The Netherlands and Denmark have a strong culture of cycling, and since the 1980s both countries have long standing cycling strategies and extensive cycle networks. Germany and Switzerland have also developed urban and transport planning in urban areas to increase cycling.[3,4] Italy, Belgium and France have been slower to incorporate cycling measures in laws and in planning or transport policy guidance. The UK government's 'National Cycling Strategy', launched in 1996, aimed to quadruple the percentage of trips made by bicycle by 2012 by creating local and national cycle networks.[5] UK transport strategies now include a focus on active travel including tax breaks for work cycle schemes, cycle training for children and the development of cycling cities and towns.[2,5,6] More recent population level cycling interventions have included the public bike hire schemes in Paris and London. However, active transport is not a high priority in the European Union's (EU) sustainable development or public health strategies.[7] Reducing the use of vehicles and increasing distances walked and cycled could have important health co-benefits by reducing both urban air pollution and the prevalence of physical inactivity and associated burden of chronic non communicable disease.[8]

Links between physical activity and health outcomes are well documented. Clear causative associations exist between increased physical activity and reduced morbidity and mortality from cardiovascular disease, hypertension, obesity, diabetes, respiratory disease, certain cancers, musculoskeletal and mental health problems.[9] There is also some evidence of the specific benefit of cycling on health outcomes including reductions in mortality and weight gain.[10,11] Despite this evidence, levels of physical activity have declined in many countries over recent years.

Interventions aiming to increase physical activity through individual behaviour change have shown varying degrees of effectiveness,[12,13] and there are significant challenges in tackling the magnitude of the problem through these approaches, not least the need to reduce inequalities. It is therefore essential to consider population level approaches, including how the built environment affects physical activity in the population.[14] At a community level, greater density of footpaths and street lighting, access on foot to shops and recreational areas,[15–18] and perceived neighbourhood attractiveness and safety are all associated with greater physical activity.[19–21] At a 'macro' level, research has identified the negative influence of urban sprawl and positive influence of improving urban aesthetics on physical activity.[22] Most research has considered environmental impacts on walking with less research on cycling and its role in tackling physical inactivity.[23]

Cycling is increasingly forming an important component of both public health recommendations and active transport policy,[24] but considerable uncertainty still remains about whether alterations to the built environment and other transport interventions improve cycling rates. This review aimed to systematically synthesize worldwide evidence from published observational and experimental studies examining the impact of the built environment on cycling behaviour.

Methods

The objective was to consider the effect of all interventions or physical factors on cycling in any population group, including cycle paths or routes, road design and other urban planning policies including provision of parks, trails or other open spaces for cycling purposes.

The primary outcome was cycling prevalence as measured by numbers or rates of people cycling, including active commuting or leisure cycling. Studies where overall exercise or physical activity were measured were included if the effect on bicycling or cycling was reported separately. Study inclusion was conditional on having an objective measure of the physical environment. Policy reports or surveys exclusively investigating changes in municipal, regional or national policy rather than measuring cycling or exercise rates were excluded. Studies with potential for conflict of interest, for example, commissioned by construction companies or bicycle manufacturers were excluded.

In July 2009, the following electronic databases were searched from the earliest record—MEDLINE, EMBASE, HMIC, CINAHL, Cochrane library, Centre for Reviews and Dissemination (University of York), UK National Research Register, Campbell collaboration, UK Transport database. This was complemented by a search for unpublished literature, through the Internet, including SUSTRANS, Department of Transport, National Institutes for Health and Clinical Excellence. References cited in relevant articles were also searched. Both free text and relevant thesaurus terms (Mesh-Medline, Cochrane and Emtree-EMBASE) were used. Free text terms included cycle, cycling, bicycle, bicycling, exercise, health and environment, urban planning and transport. Mesh terms included 'Environment design', 'Transportation', 'Bicycling', 'City planning', 'Exercise'. (An example of the search strategy is available in the Supplementary Appendix).

The review included any study published in English up to June 2009. Research from all countries, in both rural and urban settings, was included. Abstracts were screened by the first author and rejected if the article clearly did not report a relevant intervention or if inclusion criteria were not met. If there was uncertainty, the full text was obtained. All studies meeting inclusion criteria were independently read by two reviewers to confirm that the inclusion criteria were met.

Methodological quality of included studies

Study quality was assessed using a tool developed by Thomas and colleagues[25,26] recognized as being suitable for use with both randomized and non-randomized studies.

Meta-analysis was not attempted due to marked heterogeneity of study designs, interventions, outcome measures and analytical approaches among the included studies.[27] We followed the Cochrane handbook guidance supporting the use of a systematic, narrative approach when meta-analysis is inappropriate,[28] and synthesized the study results according to study design and the environmental explanatory variables assessed (e.g. trip distance, provision of cycle lane).

Results

A total of 812 unduplicated papers on relevant subjects were identified from the search strategy of which 791 were excluded because they did not meet inclusion criteria. The number of studies excluded at each stage and reasons exclusion of studies in which full texts were obtained are shown in figure 1. The final pool consisted of 21 observational studies reporting a wide range of study designs and interventions.[29–50] No studies were rated as 'strong', six were classified as 'moderate' and 15 'weak'. Due to the limited evidence base, no studies were excluded from the results.

General characteristics of included studies are summarized in table 1. Details of all the studies including intervention type and quality rating can be found in the Supplementary Appendix.

Study design

Of the 21 studies, 16 were cross-sectional surveys of which eight also conducted spatial analysis using GIS. Three studies were quasi-longitudinal surveys. One study was an observational census of cycle routes and one was a secondary analysis of census information. Only three studies included an intervention (the construction of cycle lanes, the 'safe routes to school programme' and the development of a disused railway into a multi-use trail). Only two studies included a control group. The nature of the studies meant that none could incorporate blinding, and cross-sectional designs precluded assessment of loss to follow-up. These weaknesses meant that overall the studies did not score highly in the quality assessment tool.

Environmental explanatory variables

Eleven of the studies identified an objectively measured environmental factor associated with higher rates of cycling that was statistically significant. Three of these were graded methodologically 'moderate' and eight were 'weak', mainly due to the study design chosen, the lack of specific intervention, the lack of a control group and the inability to control for potential confounding variables.

Objectively measured environmental factors showing statistically significant positive associations with rates or frequency of cycling were dedicated cycle routes (on and off road), 'Safe Routes to School' initiatives, short distance of trip, separation from traffic, short distance to a cycle path and presence of green space or recreational land. Objectively measured factors negatively associated with cycling included traffic danger, sloping terrain and long trip distance. Ten studies (three 'moderate' and seven 'weak') did not identify an objectively measurable physical environment factor that was positively associated with cycling.

Eleven studies specifically included cycle routes or paths as part of their objective environment measures (as opposed to more general measures such as 'street connectivity'). Of those eleven studies, five demonstrated a positive association with cycling rates that was significant at the 5% level, and six did not. Three of these eleven studies were graded 'moderate' quality and eight 'weak'.

Neighbourhood environment characteristics

Characteristics of neighbourhood environments formed the primary focus of seven of the studies, (six conducted in the USA and one in The Netherlands). Environment themes included land use mix, urban form, population density, aesthetics, recreational facilities and transportation environment. The US studies reported a range of factors of the objective and perceived environment associated with cycling.

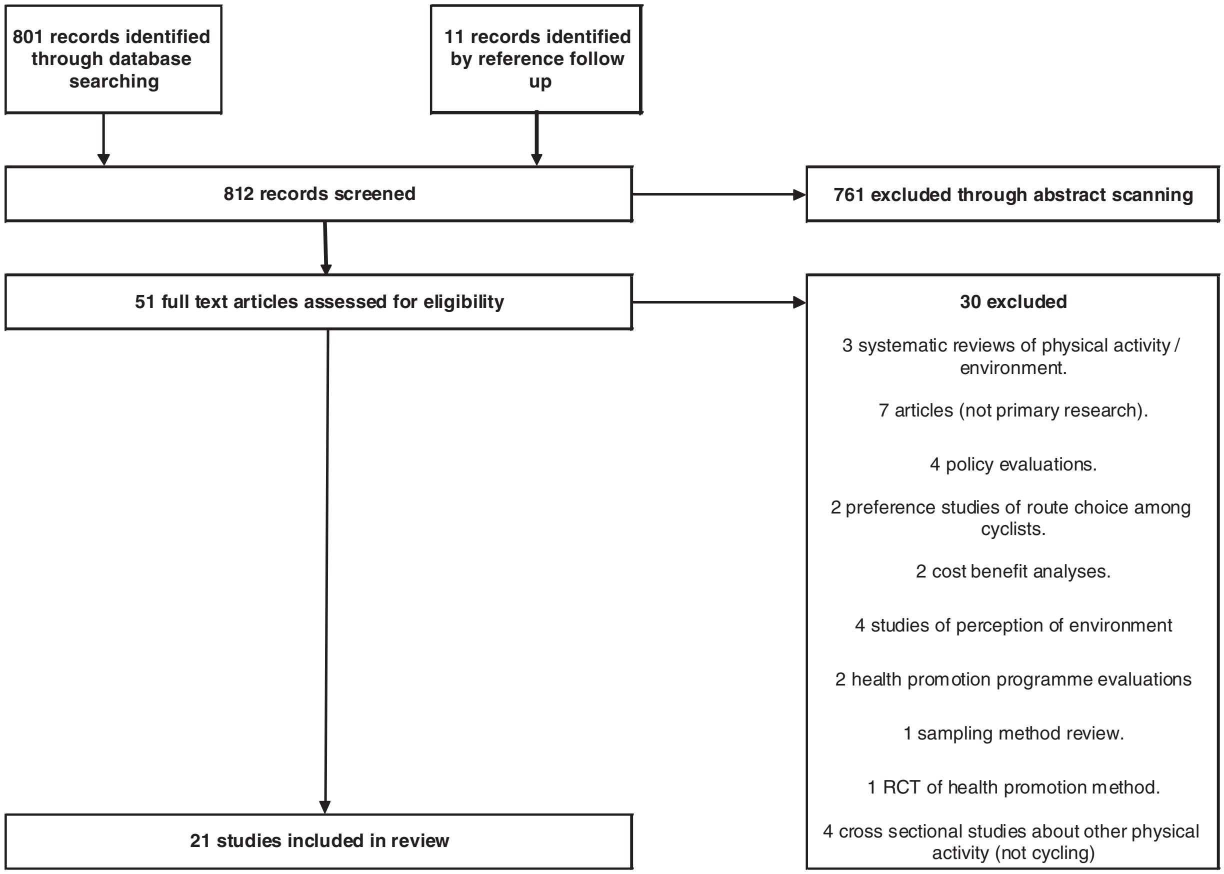

Figure 1 Flow diagram of the literature search

Table 1 Summary of the included studies

	Number of studies
Total	
Country	21
USA	14
Australia	3
UK	2
Canada	1
Netherlands	1
Study design	
Cross-sectional	8
Survey with environmental measures	7
Cross-sectional/quasi longitudinal	2
Ecological	2
Before and after	1
Qualitative with objective environmental measures	1
Age group	
Child(or child/parent combined)	7
Adult	10
Older adult (>55 years)	1
Not specified	3

Analysis of household survey data from San Francisco showed that short trip distance, number of bikes in household, male gender, purpose of trip for recreation and (absence of) darkness were positively correlated with cycling ($P < 0.05$).[34] Two studies (one USA, one Dutch) identified statistically significant associations between green and recreational space and cycling.[49,50] The US study in a university setting showed association between increasing sloping terrain and reduced cycle mode share.[44] A study using a mixed survey and qualitative design identified perceived safety as a barrier for older people.[46]

Cycle routes and cycle paths

Seven studies, of various designs, primarily addressed associations between designated cycle routes and paths (both segregated and not segregated from other traffic) and cycling (four US, two UK and one Australian).

One US study of two census areas within which seven cycle routes were constructed demonstrated statistically significant change (>2 SD) in percentage of cycle commuters >10 years (1.2% 1990 vs. 1.4% 2000).[29,30] A US study across 35 cities found positive correlation of commuting by bicycle with density of bike lanes, with the strongest correlation reported for density of on street bike lanes as opposed to bike paths or shared use paths (0.45, $P < 0.01$).[35]

Two US studies examined factors associated with use of converted rail trails. Increased home to cycle path distance was associated with decrease in trail use [OR for every 0.25 mile increase in distance 0.7 (0.5–0.8)]. Absence of self-reported steep hill [OR 1.0 (1.0–3.3)] and busy street barriers [2.0 (1.1–3.6)] were associated with increased use.[48] Development of a multi use trail in North Carolina did not result in changes in cycling behaviour that were significant at the 5% level.[36]

The Australian study demonstrated gender differences in cycle routes use with female cyclists preferring those that allowed separation from traffic.[37]

The UK studies (both surveys graded ‘weak’ by the quality assessment tool) did not show statistically significant associations between cycling and the presence of cycle routes.[42,43]

Active travel in children

Seven studies investigated associations between environmental factors and mode of travel in children. (Four conducted in the USA, two in Australia and one in Canada).

Table 2 Summary of results of the included studies' findings with regard to associations between objectively measured environmental aspects and cycling, and study quality

Study quality	Objective association demonstrated between environment factor and cycling		
	No/non-significant association	Positive association	Total
Moderate	3	3	6
Weak	7	8	15
Total	10	11	21

Table 3 Objectively demonstrated factors positively associated with cycling significant at the 5% level (with associated study quality measure)

Positively associated factors	Number of studies and quality assessment
Dedicated cycle routes	
off road	1 (weak)
on road	1 (weak)
Safe routes to school alterations	1 (moderate)
Population density	1 (weak)
Land use mix	2 (1 moderate, 1 weak)
Short distance of trip	4 (1 moderate, 3 weak)
Separation from traffic	1 (weak)
Short distance to a cycle path	1 (weak)
Green space/recreational/parkland	2 (1 moderate, 1 weak)
Street trees	1 (weak)

Four studies (two Australian studies, the Canadian study and one US study) identified short distance to school as a predictor of active travel to school (cycling or walking).[33,39,41,47] One Australian study showed that a one unit increase in trip distance was associated with a 10-fold decrease in use of active transport modes including cycling.[39]

The California Safe routes to school (SR2S) programme provides funding for construction projects near schools aiming to improve pedestrian and cyclist safety and increase active transport to school. Two studies identified a positive association between SR2S alterations and cycling to and from school, including a cross-sectional evaluation which showed that 15.4% of school children in California walked or cycled more when the SR2S initiative was on their normal route compared to 4.3% of those for whom it was not (t-statistic 5.71, $P < 0.01$).[31,33]

Among Californian schoolchildren, high neighbourhood population density was correlated with cycling and walking ($P < 0.001$) (however, there was no relationship with physical environmental factors such as number of intersections per street mile).[32] This conflicts with the Canadian study in which active travel from school to home was associated with lower residential densities.[41]

Other factors showing significant positive correlation in the US, Australian and Canadian studies were higher land use mix, presence of street trees and having school transport policies, while busy road barriers, steep incline to school, adverse weather and perceived danger from crime and traffic showed negative association with cycling rates.[31–33,39,41,45,47] Among Canadian school children, short distance to school [OR 0.5 (0.4–0.7)], higher land use mix [OR 2.9 (1.6–5.1)], presence of street trees [OR 1.3 (1.0–1.6)] and higher residential density [OR 0.3 (0.1–0.5)] were positively correlated with active travel.[41] Barriers to active commuting to school in Australia included steep incline [adjusted OR 0.3 (0.1–0.8) for 5- to 6-year old] and busy road barrier [Adjusted OR 0.3 (0.1–0.9) for 10- to 12-year old].[47]

Discussion

This systematic review assessed whether modifying the built environment, for example, providing dedicated routes and paths for cycling, increased cycling in the general population. The finding that 11 of the 21 studies identified environmental factors that had a positive association with cycling is encouraging. At the time of conducting this review, three previous systematic reviews have examined the relationship between environmental factors and physical activity.[51–53] These reviews did not specifically assess impact on cycling, and they included a wide range of diverse interventions such as education to raise awareness of physical activity facilities, financial incentives and architectural alterations to encourage stair use.

It is important to recognize this review's limitations. First, none of the studies achieved the criteria for being methodologically 'strong'. All were observational and many were based on broad surveys of large populations measuring cycling as one of several forms of physical activity. Only two studies included a control group and only two conducted 'before and after' measurements. Second, the majority did not specify the impact of cycle paths as a main objective, but included them as part of a broader assessment of urban environments. Although it is important to consider all factors influencing cycling choice, this may have weakened the results of the review by diluting the effect. Third, this review did not set out to consider issues of cycling safety or other perceived barriers. Considering both objective and perceived measures of environmental factors/barriers has been found to be important in other studies focusing on walkability.[54] Fourth, although we included studies from any country, none were found from low or middle income settings. One possible explanation is we did not have the resources to translate non-English literature.

This review reflects the difficulties of applying a clinical trials paradigm to studies evaluating the impact of the environment on physical activity. It also shows that relationships between objectively measurable environmental modifications and cycling have been less thoroughly examined than with walking or physical activity in general. In the UK, there have been calls to consider environmental changes, such as cycle route construction, as opportunities for good quality research.[24] Future research should consider economic evaluations, measures of population benefit and equity assessment, to examine whether built environment interventions impact on all population groups equally. However, as this review indicates, such interventions may be subject to an 'inverse evidence effect', whereby interventions having potential to influence population health the most are those in which controlled trials are least practicable.[55] The challenge for future research is to bridge this evidence gap with innovative research designs, and to avoid publication bias where possible.

Implications for policy

There is critical need for interventions to address the transport component of greenhouse gas generation and the lack of physical activity in the population,[56] with increasing calls to align the health and environmental co-benefits of introducing sustainable transport strategies that promote active transport.[1,2] Public health, urban planning and transport experts in many countries, as well as the WHO Healthy Cities initiative, have recognized the need to engage multi-sectoral policy makers in developing environmental designs that promote physical activity.[57–61]

This review suggests that transport strategies encouraging development of cycle routes may be one solution for improving both public health and the environment. It supports previous research on health effects of the built environment showing the importance of neighbourhood design characteristics in facilitating uptake of active transportation.[62,63] This is strengthened by evidence that building bike and pedestrian trails may also have cost benefits for public health.[64]

The UK National Institute for Health and Clinical Excellence (NICE) has recommended that policy makers focus on making changes in the built environment which are likely to encourage physical exercise, including re-allocating road space to 'support physically active modes of transport', 'creating safe routes to schools' and prioritizing accessibility to public open spaces for walking, cycling or other physically active modes of transport.[24,65] However, there is still little evidence of the effectiveness of such national policies. In the late 1980s and early 1990s, The Netherlands spent 1.5 billion guilders (US$945 million) on cycling infrastructure; however, statistics suggest that cycling levels stayed practically the same.[1,3]

One major factor limiting the public health benefits of active transport is the perceived and real safety concerns of cycling. A recent Dutch study estimated that for individuals who shift from car to bicycle use, the beneficial effects of increased physical activity are substantially larger than the potential mortality effect of increased inhaled air pollution and increased traffic accidents.[66] But cycling safety varies, as UK cyclists are three times more likely to die than cyclists in The Netherlands.[67] Evidence on the impact of cycle routes on the risk of cycling injury is currently mixed for urban roads. Creation of safe urban environments for active travel will mean improved research into built environment interventions prioritizing the needs of cyclists, which evaluates impacts on both rates of physical activity and road injury. Future policies should promote walking or cycling to become the most direct, convenient and safe option for most urban trips. Not only can urban planning policies promoting active transport result in environmental benefits to urban air pollution and long-term climate change, this review suggests that they may also improve population health.

Conflicts of interest: None declared.

Key points

- This review provides evidence for the positive association between certain built environment factors and cycling.
- Policies promoting cycle lane construction appear promising in helping to reduce physical inactivity and the transport component of greenhouse gas emission, but the socio-demographic distribution of their effects on physical activity is unclear.
- There is a need for further development of innovative research designs to bridge the evidence gap in population-level interventions supporting cycling.

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