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Interventions to increase active travel: A systematic review☆

Eleanor Roaf[a,*], Harriet Larrington-Spencer[b], Emma R. Lawlor[c]

[a] Dept of Public Health and Epidemiology, School of Health Sciences, Faculty of Biology, Medicine and Health, University of Manchester, UK
[b] Active Travel Academy, University of Westminster, UK
[c] School of Cardiovascular and Metabolic Health, University of Glasgow, UK

ABSTRACT

Introduction: Active travel is beneficial to human and planetary health. This systematic review aims to synthesise the evidence on interventions aiming to promote active travel.
Methods: Studies that included an intervention aiming at increasing active travel with pre- and post-intervention measurement of active travel levels were identified through searches of seven databases, with methodological quality assessed using the Mixed Methods Appraisal Tool.
Results: Of 3895 studies (3934 papers) identified, 78 were eligible for inclusion and synthesised narratively within five categories: studies relating to children (n = 10), social/behavioural/policy interventions (n = 18), interventions offering access to/subsidies for bicycles (n = 16), interventions including infrastructure/environmental change without other interventions (n = 20) and those that included multicomponent interventions (n = 14). Most studies (72/78) had a medium or high risk of bias often due to small sample sizes or high participant loss at follow-up. Multicomponent interventions had the highest impact on active travel levels. Interventions that only included social/behavioural/policy elements generally had little impact and had to be repeated/sustained for any impact to be maintained. Increasing the walkability of an area increases walking rates, but small-scale cycling infrastructure improvements without other supportive measures often leads to route substitution rather than an increase in cycling rates. E-bike loans increased active travel and reduced car use, at least in the short term. In studies targeting children, walking buses/cycle trains showed positive impacts.
Conclusion: Interventions combining infrastructure change with behavioural/social programmes, interventions involving e-bikes, and cycle-sharing schemes had most impact on active travel levels. Policy makers and planners should ensure that interventions that *only* address behavioural or social aspects of active travel have long- not short-term funding. If population level change is to be achieved, such interventions should also be accompanied by environmental and infrastructure changes, including road space reallocation and access to e-bikes. This requires political buy-in and public engagement.

1. Introduction

Active travel is when physical activity is incorporated into the practice of travelling (Cook et al., 2022, p154). The most common methods include walking, wheeling (using a mobility aid such as a wheelchair) and cycling. The starting premise is that active travel is good for people's mental and physical health (WHO, 2018) and that modal shift from private car use is essential to reduce the myriad health and environment inequalities (including climate change, air quality, physical activity, and road deaths and serious injuries) that are contributed to by private car ownership and ensuant hypermobility (Walker et al., 2022; Miner et al., 2024). Active travel is included by the Intergovernmental Panel on Climate Change (IPCC, 2022) in their list of key adaptation and mitigation elements in

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* Corresponding author.
E-mail address: Eleanor.roaf@postgrad.manchester.ac.uk (E. Roaf).

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cities and is increasingly promoted by local authorities and national governments to reduce car usage and deliver health and economic benefits. The Partnership for Active Travel and Health (PATH, 2023) reviewed the 64 International Transport Forum (ITF) member countries and found 84% had a walking policy and 45% a cycling policy. However, whilst policies to support active travel are becoming more widespread, many barriers to engaging in active travel remain, for example infrastructure, air quality, public controversy, weather and seasonality, and are present across the life course (Buttazzoni et al., 2023; Cavill and Davis, 2021; Jessiman et al., 2023).

Questions remain about what interventions are the most effective in increasing active travel, as literature reviews have generally concentrated on particular types of intervention or population groups. Reflecting this, the aim of this systematic literature review is to review recent evidence (data collected in or after 2013) on the impact of different types of active travel interventions on active travel across different population target groups. This is important in supporting decision making by policy makers, charities, transport authorities and other funders on how to use scarce resources to maximum impact.

2. Methods

The protocol was registered on PROSPERO at the stage of full text screening (https://www.crd.york.ac.uk/prospero/; CRD42023439230). This review adheres to the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) statement (Moher et al., 2009).

2.1. Eligibility criteria

Studies were included based upon a) timeframe (data collected in or after 2013), b) design (pre- and post-intervention measurement; pre-intervention could be retrospective (i.e. based on recall by participants), with no control group necessary, c) outcome (primary outcome being active travel, measurement of active travel could be counts, frequency, distance, or duration), d) setting (any country or setting except where populations were not living independently – e.g. hospital or care home). Studies that were aimed at increasing physical activity (e.g. workplace interventions aimed at increasing step count within the workplace) were excluded. Only peer-reviewed studies were included.

2.2. Information sources and search strategy

A systematic search of seven electronic databases (MEDLINE, Embase, CINAHL, the Cochrane Central Register of Controlled Trials (CENTRAL), Web of Science, Transport Research International Documentation database (TRID) and GeoBase) was conducted in May 2023 and updated on 11th December 2023. Online databases were searched using the following terms: 1) “active travel”, 2) cycling, 3) bicycling, 4) wheeling, 5) walking, 6) 1 OR 2 OR 3 OR 4 OR 5, 7) “mixed methods”, 8) intervention, 9) trial, 10) 7 OR 8 OR 9, 11) 6 AND 10.

2.3. Study selection process

The results from the database searches were imported into Covidence software. Duplicate articles were removed. The study titles and abstracts were independently screened by two researchers (EJR *and* ERL or HL-S) to eliminate articles that clearly did not meet the inclusion criteria. Any discrepancies were discussed. Full-text papers were obtained when titles and abstracts were relevant, or eligibility was unclear. The full-text articles were then screened by one researcher (EJR) and 20% checked by a second researcher (ERL or HL-S). This second researcher also screened any articles where there were queries about eligibility.

2.4. Data collection process and data items

Data was extracted (by EJR) based upon an adapted version of the Covidence data collection form. Data included: general information (e.g., study authors, publication year, country), study aim, study design, participants, intervention description, comparator/control (if appliable), context (e.g., socio-economic status, important geographical features), data collection methods and assessment tools, outcomes (e.g., change in active travel levels), funding and conflict of interest. Study authors were contacted if necessary to check eligibility, for example clarifying data collection dates.

2.5. Quality assessment

The quality of each study was assessed against the Mixed Methods Appraisal Tool (Hong et al., 2018), The Mixed Methods Assessment Tool was chosen as we had a wide inclusion criterion for study designs. As the MMAT is suitable for appraising the evidence of multiple study designs we felt it was most inclusive, allowing the same tool to be consistently used across all our eligible studies. This was conducted by one researcher (EJR) and a subset (20%) checked by a second researcher (HL-S).

2.6. Data synthesis

A narrative synthesis of the available data was conducted by all research team members. Due to the heterogeneity of the outcomes and interventions, no meta-analysis was undertaken. To aid interpretation, the authors categorised the studies into five groups as follows, based upon key characteristics of the interventions.

1) Studies aimed primarily at children. Studies aimed at increasing active travel in children (aged under 18) were a separate category, as children's active travel (especially travel amongst younger children) may be subject to influences different from adults, with parents' attitudes and support for active travel being a key element.
2) Studies that only included social, behavioural or policy intervention, such as changes in the law, with no bicycle provision or infrastructure changes.
3) Studies primarily aimed at facilitating cycling through either the provision of or subsidies for bicycles or e-bikes.
4) Studies that made physical changes to the infrastructure or environment, such as changes to road design or public transport, or restricted access to motorised vehicles.
5) Studies that included a multi-component intervention together with infrastructure changes.

3. Results

After duplicate removal, 2733 titles and abstracts of papers were screened, and 268 full text articles were assessed. In total 89 papers relating to 78 studies met the inclusion criteria. Fig. 1 shows the PRISMA flow chart.

3.1. Study characteristics

Regions represented in the included studies were USA/Canada (23 studies; 29%), Northern Europe (23 studies; 29%), Western Europe (8 studies; 10%), Eastern Asia (7 studies, 9%), Australia and New Zealand (6 studies, 8%), Southern Europe (6 studies, 8%), South America (2 studies; 3%), Central America (1 study; 1%), and Eastern Europe (1 study; 1%). Four studies collected data from more than one country: Austria and Germany; the UK and Austria; the USA and Canada; and Italy, Belgium, Austria and Sweden.

3.2. Population and intervention characteristics

The types of intervention varied widely, with some covering very small areas (e.g. streets) or specific population groups (e.g. children, older people), and others being wider in scope and scale (e.g. at a neighbourhood or city level). Some studies investigated the implementation of several different interventions. The length of the intervention, follow up periods and the measures of active travel varied greatly.

3.3. Risk of bias (quality) assessment

Overall, 6 (8%) studies were assessed as being at low risk of bias. Most were at medium ($n = 40$; 52%) or high risk ($n = 32$; 40%) of bias, but this was not necessarily because the studies were poorly designed. However, some studies had very small samples and short follow-up periods, often only a matter of weeks. Those with larger samples had a large loss to follow-up, thus large amounts of missing outcome data. Some studies targeted population subgroups (for example, drivers wanting to change behaviour) and were able to provide good evidence in relation to the specific groups but this would not be generalisable to a wider population. The short follow-up periods (often due to funding issues) mean that the longer-term impacts of the interventions were in most cases very difficult to ascertain. Detailed quality assessments have been published elsewhere (Roaf et al., 2024).

3.4. Findings related to five identified intervention types

3.4.1. Overview of results: children

Ten studies were aimed at increasing active travel in children and are summarised in Table 1 below. The interventions all took place in or around schools.

Interventions aimed only at increasing knowledge or skills, or changing attitudes seem to have little impact on active travel behaviour, although Stark's 2018 study among secondary school children showed increased cycling in the intervention group. Stark (2018) and Aranda-Balboa et al. (2022) reflected that family and friends' attitudes and behaviours regarding active travel can have a strong influence on outcomes but that this was not always assessed. Interventions such as walking or cycling buses[1] show positive impacts but require long-term funding and consistent communication and engagement. The two studies of such interventions included here (Mendoza et al., 2017; Perez-Martin et al., 2018) appear to have used self-selected children/families, so their impact may have been maximised.

Gamification interventions (for example, where rewards are offered for participating, or where people compete against each other or themselves) aimed at school children without any associated infrastructure changes can increase cycling/walking rates, but this is

[1] Walking or cycling buses work much like a school bus. A group of children, chaperoned by one or more adult, will walk or cycle a specified route together at a specified time. There may be one meeting place where the bus begins its journey, or there may be multiple pickup points along the route.

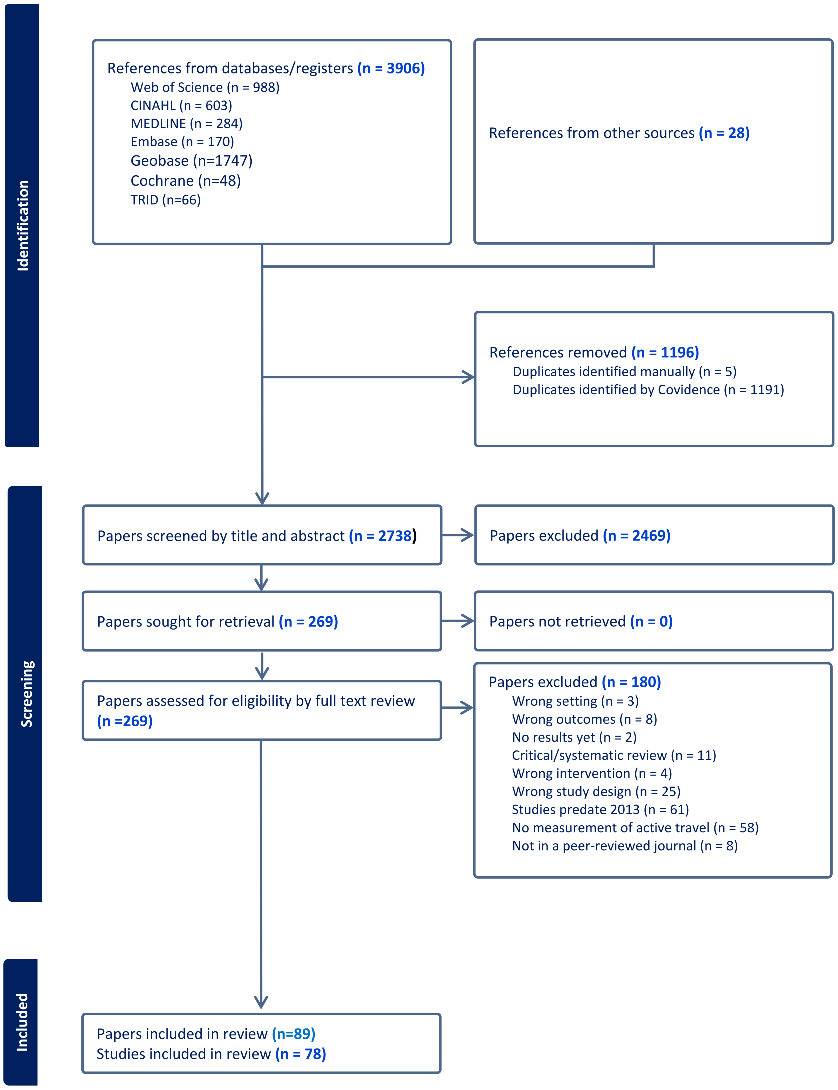

Fig. 1. PRISMA flow chart.

generally not maintained and repeating the intervention seems to be required. The two gamification studies included (Biondi 2022; Coombes, 2016) were aimed at primary school children (aged 5–11) and may not be generalisable to older children or teenagers. Three studies on infrastructure improvements near schools found little impact on active travel rates, possibly because changes close to schools do not change enough of the journey to make the whole route feel safe to children or their parents/carers. In Rothman et al.'s (2022) study of implementing safety zones near schools chosen for higher collision rates, levels of active travel (non-significantly) increased to the level of control schools. Additionally, Lambe et al. (2017) commented that there may have been insufficient traffic calming and car-restrictions introduced to complement the new motorised-traffic free routes which they felt, while politically sensitive, are essential to supporting active travel policies.

3.4.2. Overview of results: social, behavioural or policy intervention

Eighteen studies contained only social or behavioural interventions (including policy level interventions such as whole city approaches or legal changes). Table 2 below gives more details of these. Interventions included campaigns and social marketing (including targeted information), gamification, and cycle training.

Four studies featured workplace intervention, including travel planning and public transport salary sacrifice (Petrunoff et al., 2016), workplace-based walk to work promoters (Audrey et al., 2019), use of social, moral and financial 'nudges' (Olsson et al., 2021) and educational campaigns (Bopp et al., 2018). All found these made little difference to active travel rates, particularly where longer follow up periods were used.

One study investigating the impact of non-workplace personal travel planning (Ahmed 2020) found a significant increase in active mobility for the intervention group compared to the control group, however the follow up period was one week from the treatment.

Table 1
Studies relating to children.

First author, year and country	Intervention	Participants	Key findings	Risk of bias
Aranda-Balboa et al., 2020, Spain	School-based knowledge and awareness sessions (RCT).	122 secondary school age children aged 13/14, intervention n = 60, control n = 62.	At the end of the one-month intervention, changes in knowledge levels but not in active travel rates.	Medium
Biondi et al., 2022, Poland	Cycling promotion campaign in May in Gdansk: social marketing and some rewards/gamification. Lodz as control.	All kindergarten and primary school children, their families and teachers in Gdansk, repeated annually.	In Gdansk 61% of target engaged by 2019.18% increase in cycling in Gdansk (using observed daily cycle counts) during the campaign, with a drop afterwards although the number of participants in Cycle May has increased annually. Greater increase in cycling Gdansk than Lodz although more cycle counters in Gdansk.	Medium
Coombes 2016, UK	Gamification of active travel to school. (9 week Beat the Streets programme).	Children aged 8–10 in one intervention school (150 children invited, 51 took part) and one control (56 children invited, 29 took part).	Intervention ran in summer term (May–July). At mid-intervention both intervention and control had non-significant increase in active travel. At 5 month follow up (October) active travel increased at intervention and decreased at control school (both non-significant).	Medium
Humberto (2021), Brazil	Four-month school-based education and activities.	299 kindergarten children aged 5–6 and their carers from 3 pre-schools.	Measures taken at start, 2 months and end (4 months). No significant increase in active modal share identified among children but a significant positive impact detected in self-reported active travel behaviour and social norms of caregivers.	Medium
Lambe et al., 2017, Ireland	Impact of new infrastructure on travel to school with linked promotional work.	Primary school children (yrs 5/6) in 2 intervention (14 schools) and one control town (7 schools).	At 2-year post intervention follow up, student awareness of school promotion of active travel significantly higher in the intervention towns. No effect on active travel to/from school but (non-significant) increase in cycling among boys in intervention town 2. Cycling increase possibly due to less walking.	Low
Mendoza et al., 2017, USA	Bicycle Trains to school.	421 children in 4th or 5th grade at 4 schools, living within 2 miles of school, invited to take part. 2 intervention schools (children n = 24) 2 control schools (children n = 30).	At follow up 5–6 weeks after intervention started, intervention participants showed significant increase in mean percentage of daily commutes by cycling compared with controls.	Medium
Perez-Martin et al., 2018, Spain	Walking bus to school.	450 primary school children aged 5–12 at one school in Spain invited, 55 children from 31 families took part.	Intervention ran April–October with a summer break. At study end participants who did not already walk to school either fully or partially changed travel mode, with a greater modal shift in those living further than 1500 m from the school, especially those living between 1500 and 2000m away.	High
Rothman et al., 2022, Canada	School safety zone including flashing beacons, road and pavement markings, speed feedback signs.	Children at state primary/secondary schools in Toronto. Intervention arm n = 34 schools, control arm n = 45 matched schools.	At 12 month follow up the proportion of students using active school travel increased from 59% to 64%. There was no change in active travel in the control group (65% pre-intervention and post intervention). At intervention schools, cars speeding decreased and students using active travel increased.	Medium
Smith (2020), New Zealand	New road layouts near schools.	Children in in years 5–8 and their parents from 2 schools involved in a school travel intervention. 123 children and 88 parents at baseline, 152 children and 91 parents at follow up.	The proportion of children travelling to school by car increased by 15% at 12-month post-intervention follow up ($p < 0.01$). Counts of (all age) pedestrians in the intervention area increased.	High
Stark et al., 2018, Austria, Germany	School based promotion of active travel.	2 classes per school (one intervention (total n = 90 children), one control (total n = 79 children) at each of 4 schools.	At 12-month follow up positive change in attitudes to cycling in both groups and significant increase of public transport use in the control group, with non-significant reductions of car use and bicycle use. Both groups had similar decrease of car passenger use, but the control group reduced cycling in favour of walking and public transport. The test group cycled significantly more than the control.	High

Table 2
Studies of social/behavioural interventions.

First author, year and country	Intervention	Participants	Key findings	Risk of bias
Ahmed et al., 2020, Belgium	Personal travel planning.	60 adults with driving licences and smartphones recruited for 1 month intervention, 52 completed.	Car dependency decreased in intervention group and active travel increased.	High
Andersson et al., 2023, Sweden	Provision of free bus pass.	60 participants employed by Botkyria Municipality (Stockholm County) and 15 controls from other towns in Stockholm County.	At one-month follow up both control and intervention groups increased public transport use and decreased car use. Reduction in car use was linked to increased walking and public transport.	High
Audrey et al., 2019, UK	Workplace promotion of walking commuting (RCT).	Working age adults employed at participating workplaces. 654 people at baseline and 477 at 12 months.	10-week workplace training and promotion did not change active travel nor physical activity levels at 12-month follow-up.	Medium
Bhattacharyya 2019, USA	Use of nudges (focalism and visualisation) to affect choices at house move (RCT).	Adults planning to move house within 3 months. 380 people at baseline. 184 moved house and completed follow up 37 did not move, 159 lost to follow up.	At 3 month follow up focalism group significantly increased active travel; visualisation increased active travel, but non-significantly. No change in control group.	High
Bopp et al., 2018, USA	Campaign to promote active travel to university campus.	Staff (n = 999) and students (n = 563) at a US university.	After the 7-month intervention, self-reported active travel increased significantly among students but not among staff. Campaign awareness was linked to increased active travel, but awareness was low.	High
Fruhen et al., 2021, Australia	Impact of minimum overtaking distance law on cyclist numbers.	Data from cycle counters on on-road and off-road routes, collected for 1 year before and 2 years after the law change.	The number of cyclists on off- or on- road paths did not change following the law change.	Medium
Geng et al., 2016, China	Tailored information based on assessed attitudes and motivations.	452 residents of XuHuo city sent messages for 6 days with follow up at 14 days.	Targeting information based on attitudes/ motivations of different subgroups of the population made some difference to rates of active ravel at least in the short term.	High
Geng et al., 2020, China	Impact of different types of messaging.	146 car owners in a specified area of Hefei City: 1 week intervention with follow up at 14 days.	Messages with only environmental information failed to improve walking and cycling. Combining environmental and health information had some effect in encouraging non-motorised travel and reducing car use.	High
Hino et al., 2019, Japan	Pedometers to reduce car use.	6000 randomly selected middle aged and older participants in Yokohama Walking Programme, with full data supplied by 2023 people.	At 2.5 year follow up, those living further from railway stations and with high bus stop density self- reported a shift from cars to public transport. Those living closer to railway stations may already have walked more.	High
Huang et al., 2021, Netherlands	Mobile phone app ‘challenges’ to encourage cycling.	5525 people included with 1868 using the app at least once, the remainder were the control group.	Data was collected for 15 months. Challenge-and-reward interventions may be effective for short-term behavioural change., but it may be that people only recorded data at challenge periods.	High
Lowry, 2024, USA	Multimodal travel tour for new students.	University students, 798 respondents to the survey, 14 people took the tour.	At 6 month follow up, those who completed the tour reported increased active travel compared to a control group.	High
Ma et al., 2017, Australia	Social marketing.	313 households at baseline and 201 households with full or partial data at follow up.	Travel Smart increased walking and bus trips at 12 month follow up with stronger effects on travel behaviour for the participants living in high-walkable neighbourhoods than for those living in low-walkable neighbourhoods.	High
Nielsen 2019, Denmark	Health-related cycling campaign (Smart phone app, small prizes).	11798 people (surveyed in waves) aged between 10 and 85 living in 4 municipalities in Denmark, using national travel survey data and market research.	At 9 month follow up enhancement of the national campaign in four local areas increased self-reported cycling rates in three of the four areas.	Medium
Olsson et al., 2021, Sweden	Cycling Campaign comparing different ‘nudges’.	380 members of staff from 10 local companies at baseline, 296 at 2 week follow up (wave 2) and 172 at 3 month follow up (wave 3).	Nudges led to statistically significant short-term behaviour change but cycling increase non-significant at wave 3, with a marginally significant effect for decreased car use, also diminishing over time. The financial incentive nudging condition may have had a larger impact than the social norm nudge; the moral norm condition had no significant impact.	Medium
Petrunoff et al., 2016, Australia	Workplace travel plan.	Hospital staff via annual survey (response rate varied between 18 and 26%, n = 682–904).	Small yet consistent 4–6% increase in active travel compared to baseline, significant in 2012 and 2013 but non-significant in 2014.	High

(continued on next page)

Table 2 (*continued*)

First author, year and country	Intervention	Participants	Key findings	Risk of bias
Ralph 2019, USA	Use of house move as change moment.	Incoming graduate students: At baseline, n = 1583 in intervention and control groups, Final sample of 561 respondents (intervention n = 260 and control n = 301).	At 3 month follow up no significant impact although movers increased transit use and decreased driving. There was possible contamination between the groups.	High
Sersli et al., 2019, Canada	Bicycle skills training and test of impact of short vs longer training.	Working age adults who registered for cycle training. Baseline intervention group n = 135 and control 43 with intervention n = 134 and control n = 43 at 12 month follow up.	At one month follow up, intervention participants increased bicycling for all trip types, with no increase in controls. No change in the number of days per month participants rode bicycles. For leisure cycling, the overall change between baseline and 12 month follow up was not significant. No difference in change in bicycling for any trip type between people who took the short vs. longer cycling course.	Medium
Tsirimpa et al., 2019, UK, Austria	App based promotion of active travel (gamification).	76 working age adults of whom 64 registered for rewards.	At 6 week follow up registered users used more public transport and active travel at baseline and increased travel more. Car users increased sustainable travel during the challenge but did not cycle more.	High

Five studies reviewed the impact of taking a social marketing/advertising approach to messaging on the benefits of active travel, such as use of social media, or rewards. These may have some impact (Geng et al., 2016; Ma 2017; Bopp et al., 2018; Hino et al., 2019; Geng et al., 2020), but it was highlighted that the messages need to be properly targeted (Geng et al., 2016; Geng et al., 2020) as well as extensively publicised otherwise people do not become aware of them (Bopp et al., 2018). The social and behavioural interventions appeared to be more effective when the environment is also more conducive to walking and cycling. Ma et al. (2017) following a targeted social marketing campaign with 12 month follow up found walking increased more in high-walkable neighbourhoods although this effect took time to build. Similarly, Hino (2019) noted the importance of maintaining good public transport (buses and trains) to create a modal shift from cars.

There were three studies of campaigns to increase cycling included in this review. These generally included a gamification element and seem to have some impact, especially when intensive local campaigns enhance strong national messaging (Nielsen and Haustein, 2019), but they need to be repeated for the effect to be maintained. Gamification seems popular among people already using active/sustainable travel (Tsirimpa et al., 2019) with some evidence of increases in active travel being due to increased frequency of recording of activity during the challenge periods rather than changes in active travel rates (Huang et al., 2021). Similarly, cycle training may increase cycling in the short term but the impact reduces after one year (Sersli et al., 2019).

Two studies focused on policy interventions without additional changes, with neither finding an impact. Fruhen et al. (2021) used cycle count data to investigate the impact of the change in the law in Australia, requiring a greater passing distance for motorists when overtaking cyclists. It found no change in the number of cyclists using either on- or off-road routes. Andersson (2023) in a small study of the impact of free bus passes found no difference between intervention and control groups, with both groups decreasing car use and increasing walking and use of public transport.

Two studies investigated how moving to university might create an opportunity to change travel behaviours. Ralph and Brown (2019) found no impact from sending active travel information to new graduate students. Lowry (2024) investigated the impact of a multimodal tour for new students, with self-reported rates of active travel increasing. However, the participants were self-selected and there was a high loss to follow up.

3.4.3. *Overview of results: interventions aimed at facilitating cycling through either the provision of or subsidies for bicycles or e-bikes*

Sixteen studies investigated the impact of providing people with access to bicycles or e-bikes, sometimes alongside other support such as cycle training or mentorship, but without environmental or infrastructure changes. Table 3 below gives more details of these studies.

Four studies focused on loans of pedal bicycle, with results suggesting it is most effective for people who self-refer into programmes or who have very limited access to other forms of transport (Schneider et al., 2018; Kearns et al., 2019; Dalton et al., 2022). However, effects were not always maintained with longer follow up (Schneider et al., 2018). The three studies on shared pedal cycle schemes found mixed results. Jia and Fu (2019) found a non-significant increase in cycling, in the context of a national decline in cycling. Bicycle sharing schemes that are linked to good infrastructure may be more effective, Hosford (2018) found that people needed to both live and work in an area of good cycling infrastructure for behaviour to change. Hosford et al. (2019) carried out a study of cycling in cities with existing, new, or no bike sharing schemes and found self-reported cycling (using either a shared or personal cycle) increased at two-year follow-up among people living within 500 m of a new bicycle-share scheme relative to people in cities without such a scheme.

Loans of e-bikes showed a positive effect on cycling rates and reduced car usage (Fyhri et al., 2017; Soderberg et al., 2021), and were more popular and effective than pedal cycle loans (Bjørnarå et al., 2019), with a suggestion of a greater impact when it is linked to a workplace (Cairns et al., 2017, Ton and Duives, 2021). People who regularly cycled more than 20 km/week, however, were less

Table 3
Studies that offered loans or subsidies for pedal bicycles or e-bikes.

First author, year and country	Intervention	Participants	Key findings	Risk of bias
Bjørnarå et al., 2019, Norway	Loan bikes: intervention group all given a 3-month trial of each of 3 types of bicycle.	36 parents of kindergarten children recruited and matched in pairs before being randomly assigned to intervention (n = 18) or control (n = 18) groups.	At the end of the 9-month intervention, it was found that the intervention group significantly increased frequency of cycling to work compared to controls (p = 0.04), with e-bikes having largest impact.	Medium
Cairns et al., 2017, UK	Provision of e-bike loans (workplace based).	Staff employed in either of 2 workplaces – 80 in total.	At 12 m follow-up (75% response) four households had acquired an e-bike. Self-reported cycling rates went up but walking rates went down. 43% reported driving less.	Medium
Connell et al., 2022, UK	Bicycle provision and training (workplace based).	68 office-based staff at 3 locations (intervention halted at one site due to Covid restrictions).	Significant increase in cycling and reduction in use of motorised transport at follow up (3 weeks after intervention complete).	High
Cooper et al., 2018, UK	Provision of e-bikes.	99 people newly diagnosed with Type 2 diabetes invited to take part, 28 expressed interest, 20 took part and 18 completed the 20-week programme.	At programme end e-bikes were popular and removed barriers to active travel. 14 people purchased e-bikes at the end of the study. Cycle trainers were important in developing confidence. Sample too small for significance testing.	High
Dalton et al., 2022, UK	Free pedal bicycle loans (1 scheme aimed at asylum seekers, 1 at the general public).	Asylum seekers scheme: 214 people at baseline and 65 at 3 month follow up. General population scheme: 613 people at baseline, 413 at 4 week follow up.	Increase in cycling especially among new cyclists. 75% of general public non-cyclists at baseline said at follow up that they intended to access a cycle in the next month and 95% of asylum seekers said they were more likely to walk or cycle.	Medium
Fyhri et al., 2017, Norway	Provision of e-bike loan to car drivers.	Of 1425 drivers interested in trying an e-bike 220 of these randomly selected to intervention group and 81 took part; control group was remaining 1205 people of whom 214 completed follow up questionnaire sent 2–4 weeks after getting the bike.	Most (72%) used the bike primarily for work commute. 77% reported increased cycling, and 56% said that the bike allowed them to cycle further. Both groups expressed increased interest in buying an e-bike.	Medium
Grimes 2020, USA	Free membership of shared bike scheme (RCT).	Undergraduate students aged 18+ living within 5-mile radius of the campus. N = 56 (29 intervention, 27 control).	At 3 week follow up no significant differences in overall steps or increased biking behaviour between the two groups.	High
Hosford et al., 2019, USA/Canada	Shared bicycle schemes.	Samples of people living near new bicycle sharing scheme: 7829 respondents in 2012, 7979 in 2013, and 8093 in 2014.	Increase in cycling in Year 2 (OR 1.8) for residents living within 500 m of bike sharing schemes in cities with new bicycle sharing schemes compared to those without.	Medium
Hosford et al., 2018, Canada	Shared bicycle scheme.	Population based sample of Vancouver residents surveyed prior to implementation (n = 1111), in the early phase of implementation (n = 995) and 1 year post-implementation (n = 966).	Significant increase (OR 2.26) in cycling in those living within the area at 12 month follow up but not 2 year.	Medium
Jia 2019, China	Bicycle sharing scheme. (dockless).	1180 people aged between 12 and 70 from 12 selected neighbourhoods.	Using retrospective analysis 12 months after the advent of dockless bicycle sharing, self-reported cycling increased (ns) against a national reduction.	High
Johnson et al., 2023, USA	E-bicycle subsidy/rebate schemes.	575 people applying for a subsidy for an e-bike – 3 different schemes.	The three schemes had different follow up periods (1, 12, and 18 months) and found in short-term e-bikes replaced some car trips but usage declined with time.	High
Kearns et al., 2019, Canada	Cycling mentorship programmes.	Working age adults, mainly new immigrants. 197 in total in 2 programmes. High loss to follow up at 1 year.	Significant increase in cycling to work/ school and shopping initially, at 1year rate of cycling s still higher than baseline, but ns.	Medium
Schneider et al., 2018, USA	Provision of pedal bicycle and training.	Lower income adults of working age, 20 in intervention (with bike and training) and 29 in control group. 38 people provided baseline data and 26 provided full follow up data at 12 and 20 weeks.	Bicycling for leisure/non-work trips increased significantly in intervention group at 12 weeks, no significant difference in bicycling to work. No difference between groups at 20 week follow up.	High
Soderberg et al., 2021, Sweden	Loan of e-bike for 5 weeks.	Working age adults (regular drivers) at one employer. 98 people started and 65 completed all measures (40 treatment and 25 control).	At 10 week follow up cycling increased by 25%, car travel decreased among those loaned e-bikes.	Medium
Sundfor 2022, Norway	Subsidy of purchase of e-bikes.	Oslo residents interested in subsidised e-bike purchase: 382 in e-bike group, main control n = 658 and prospective buyers n = 214.	Follow up varied between 1 and 4 months. All groups incresed cycling mode share but this was greatest in e-bike group who also increased share of daily travel by bicycle.	Medium

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Table 3 (*continued*)

First author, year and country	Intervention	Participants	Key findings	Risk of bias
Ton 2021, Netherlands	Provision of e-bike (short terms workplace loan).	University staff or students at one university; 400 at baseline and 82 completed all follow up surveys. Final follow up at 3 months.	Significant change in overall cycling distance. Significant drop in car use (from 88% of days to 63%) and significant increase in e-bike (2%–18%) and pedal bicycle share (5%–12%).	Medium

interested in using an e-bike than less experienced cyclists (Fyhri et al., 2017). One small study showed promising results for e-bike usage in previously inactive people newly diagnosed with diabetes (Cooper et al., 2018); this approach could be helpful in developing responses to similar 'teachable moments'. Offering subsidies for the purchase of e-bikes increases cycling mode share (Sundfor and Fyhri, 2022; Johnson et al., 2023) although this effect declined with time in Johnson et al.

In one study, cycle training on its own did not appear to increase cycling (Sersli et al., 2019). However, with mentorship in the form of individual support over several weeks, it may be more successful (Kearns et al., 2019). Connell et al. (2022) showed an increase in cycling in a workplace-based programme of training and support, including the loan of a pedal cycle or e-bike.

Grimes (2020) found no impact from offering students subsidised bike-share scheme membership; and found that stated intentions did not lead to change in active travel levels. They commented that good, cheap public transport in the area lessened the need to cycle.

3.4.4. Overview of results: interventions that include infrastructure changes without other interventions

There were 20 studies focusing on environmental changes to promote active travel (see Table 4 below). Two of the studies investigated changes aimed at increasing walking, ten investigated changes aimed at increasing cycling, and nine were designed to increase walking and cycling. These were conducted in a variety of countries and included interventions described as 'complete streets'; the introduction of a motorway, 'greenway' developments, new public transport, and improved cycling infrastructure. It is likely that many of these programmes included public engagement or other activation programmes that seek to get people using new infrastructure. However, descriptions of these were not included in the study.

Two studies investigated the impact of new railway/metro lines and stops, without other environmental interventions, on active travel. Sun (2020) found a reduction in bus trips, walking and pedal bike usage, but no impact on car or e-bike usage. Morita (Morita et al., 2023) found older people walked more after the new railway line opened, but that working age women walked less. In two studies, it was found that even without public transport changes, improving an area's walkability score appears to lead to increases in walking rates (Cambra and Moura, 2020; Zeng and Shen, 2020).

Seven studies investigated the impact of infrastructure changes on either walking or cycling. Of these, Olson et al. (2016) reported that building a motorway (which they hypothesised might have removed motorised traffic from surrounding roads, thereby improving conditions for active travel) did not increase active travel in the local areas. Ottoni (2021), in a study of a 'greenway' intervention, found that cycling rates increased more than walking, and that while pedestrians using the greenway had expressed concerns about safety on a shared space with cyclists, specific built and social environment factors made them feel safer while walking. The remaining five studies investigated the impact of 'complete street' interventions, where changes are made to the street, pavements, and crossings. Three of these studies found no impact (Dill et al., 2014; Maisel et al., 2021; Lanzendorf et al., 2022), and one found a slight increase in active travel and reduction in car use (Kyriakidis et al., 2023). Aldred et al. (2021) in a study of the impact of improved infrastructure over a three-year period, including modal filtering and traffic calming, compared intervention ("high dose" and "low dose") and non-intervention areas and found sustained increases in the duration of active travel in the intervention areas, with a greater impact in the 'high-dose' areas.

Evidence on improvements to cycle infrastructure is mixed. Four studies found this led to an increase in cycling (Pedroso et al., 2016; Crane et al., 2017; Hong et al., 2020; Garber et al., 2022). Frank (2021) found no change to cyclist numbers but a marginally significant increase in trip frequency. Larger scale interventions, that included road space reallocation and increased safety tended to show greater impact (Xiao et al., 2022). Hyper-local changes, such as cycling infrastructure improvements to specific roads, appear to lead to a move of existing cyclists to the new routes, rather than an overall increase in cycling (Vasilev et al., 2018; Pritchard et al., 2019). Skov-Petersen (2017) found a small increase in new cyclists following route improvements but also a strong route substitution effect.

3.4.5. Overview of results: multiple component interventions, including infrastructure change

Fourteen studies examined the impact of infrastructure or environmental changes alongside other interventions. More details of the studies are included in Table 5 below. Overall, multi-component interventions, especially those covering a larger area, appear to have a positive impact, particularly when they include policy decisions supportive of active travel and access to bicycles. However, the patterns of results were complex, which is unsurprising given the heterogeneity of types and combination of interventions. For example, some studies found intervention effects to increase over time for some outcomes and to decline for others. Interventions did not always have the same impact on women as on men.

Three studies looked at infrastructure improvements alongside a bicycle sharing scheme, with positive results (Karpinski, 2021; Mateu and Sanz, 2021), with Felix et al. (2020) noting a particularly positive impact among women.

Tabe 4
Studies that investigated infrastructure changes without other interventions.

First author, year and country	Intervention	Participants	Key findings	Risk of bias
Aldred et al., 2021, UK	Neighbourhood level infrastructure improvements.	Residents aged 16+ in defined areas. 3435 at baseline, over 1400 repeat respondents at each of the 3 annual follow up surveys.	At 3 year follow up, increases in active travel; cycling increase statistically significant for high-dose areas vs control group.	Medium
Cambra 2020, Portugal	Street improvements to increase walkability.	People walking in the defined areas (intervention and control) measured by pedestrian counts.	Pre-intervention, walkability scores for the two areas were similar and had no correlation to pedestrian volumes. At 6-month post intervention follow up, walkability and pedestrian volumes increased in the intervention area.	Low
Crane et al., 2017, Australia	New bicycle infrastructure.	846 working age adults living in either intervention or control areas, with the same people sampled before, at wave 2, 4 months post construction 60% retained and wave 3, 16 months post construction 47.5% retained.	Weekly cycling remained higher in the intervention group throughout the study period despite a downward trend in cycling across the city.	Medium
Dill et al., 2014, USA	New bicycle infrastructure.	Adults with children (n = 353) in Portland USA.	No change in cycling rates at 2–12 month follow up.	Medium
Frank et al., 2021, Canada	Greenway Infrastructure.	Adults aged over 18 living within 1 km of the greenway.1744 people invited, 524 people completed baseline and follow up surveys.	Marginally significant change in trip frequency at 2 year follow up.	High
Garber et al., 2022, USA	New infrastructure	Population study based on Strava data and stationary bike count data with 6–14 month follow up depending on area.	Five off-street paved trails/protected bike lanes had a small positive effect on bicycling, with two having greater impact.	High
Hong et al., 2020, UK	Improved bicycle infrastructure.	Data from Strava activity tracking app was collected at baseline and 12 months post intervention.	Cycling increased but not on all routes	Medium
Kyriakidis et al., 2023, Greece	Infrastructure improvements.	Respondents to online questionnaire (n = 401) undertaken post intervention.	Self-reported car and public transport declined with marginal positive change in cycling and walking (ns). The study took place during pandemic travel restrictions.	High
Lanzendorf et al., 2022, Germany	Infrastructure improvement.	445 households on the intervention road (one response per household). Different household members may have responded pre and post intervention.	At 3 weeks after the implementation of the cycling paths, there were no significant changes in the residents' regular mode use frequency.	High
Maisel et al., 2021, USA	Complete Street.	Sample of adult pedestrians and cyclists interviewed in the study area, 148 at baseline and 102 six months post-intervention, almost all pedestrians.	Complete streets implementation had a significant impact on participants' overall satisfaction of the street but no change to walking or cycling frequency. Females significantly perceived the traffic as creating difficult or unpleasant conditions for cycling than men did.	High
Morita et al., 2023, Japan	Railway improvement.	58643 existing Walking Points participants, intervention group lived within 1 km of the new station, control group lived over 1 km away.	After 12 months, older residents aged 75–84 years living close to the new station walked approximately 400 steps more than controls but women aged 45–64 walked approximately 200 steps less than controls.	Medium
Olsen et al., 2016, UK	New motorway infrastructure.	One year preintervention, 3706 people living in the identified area completed travel diaries, 4205 travel diaries were completed one year post intervention.	The motorway did not appear to have an impact on active travel in the local area.	Low
Ottoni et al., 2021, Canada	Urban greenway: infrastructure.	Counts of people using the greenway and interviews with older adults.	Greenway use increase of 61% from 2017 to 2019, mainly from cyclists.	Medium
Pedroso et al., 2016, USA	Bicycle infrastructure.	Data from the American Community survey (random address sampling) between 2005 and 2014.	Cycling increased in commuting to work in men and women, but difference only significant in men.	High
Pritchard et al., 2019, Norway	New bicycle infrastructure.	113 adult residents from the intervention area participated at baseline and 4 months.	Bicycle trips increased in the intervention street and decreased in the two nearest parallel routes in the same neighbourhood. Bike modal share did not increase significantly.	Medium
Skov-Petersen et al., 2017, Denmark	Improved bicycle infrastructure.	Data from automatic bicycle counting stations, and 3 surveys of cyclists undertaken before, and 1 and 2 years after, implementation.	Large increase in cycling on the route but mainly through route substitution – however an estimated 4–6% increase in new cyclists.	Medium
Sun et al., 2020, China	New infrastructure (metro station).	5627 local residents completed a pre-intervention travel behaviour survey and 1770 completed a post intervention survey at 12 months.	Switch from bus to metro use. Walking and pedal cycling time decreased significantly. Car and e-bike usages remained largely unchanged.	Medium

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Tabe 4 (*continued*)

First author, year and country	Intervention	Participants	Key findings	Risk of bias
Vasilev et al., 2018, Norway	New infrastructure to promote cycling.	690 local people who had used the street pre and post changes.	Based on post intervention recall, cycling significantly increased post implementation, but decreased on neighbouring parallel streets.	Medium
Xiao et al., 2022, France	New infrastructure to support cycling including road space reallocation.	Count of cyclists using any of 18 intervention streets, with data also collected from control streets without interventions. Counts taken 6 months pre and 6 months post interventions.	Significant increases in cycling at half (7/15) of the sites and no change at the rest. Removing car parking and traffic lanes and increasing cycle lanes were associated with a significant increase in cycling. Adding a public transport stop showed a negative association. Improving safety and increasing space were positively associated with increased cycling.	Medium
Zeng and Shen, 2020, China	New infrastructure to promote walking.	82 people living in the intervention area were asked after the intervention to describe changes in their walking habits.	Self-reported walking frequency increased.	High

Two studies combined social and behavioural interventions alongside infrastructure change, with mixed results. In a workplace study, Aittasalo et al. (2019) found no change to active travel among the workplace intervention group (although the six-month follow-up period was curtailed due to delays in infrastructure completion). Prins (2019) found both social and infrastructure changes increased walking rates among older people but found no difference between single or combined interventions.

Seven studies included improved public transport alongside other environmental changes designed to promote active travel. Overall, this appears to have a positive impact on walking rates, especially among women (Jensen et al., 2017), who also found that that highly walkable streets tended to have more female walkers using them. Baldovino-Chiquillo et al. (2023) found no impact from a new cable car line, but walking rates were high already. In Chang's (2017) study, walking rates increased because the new stops were further apart than previously. Hong et al. (2016) found that previously inactive people were more likely to walk after a new station opened. Hagen and Tennøy (2021) in a study of people working in Oslo city centre, found only a weak change in modal choice post-intervention among commuters, with public transport usage decreasing and walking and cycling increasing. Car commuting also increased (from a low base), potentially because many driving commuters could park in workplace garages. Public transport improvements appear to have less impact on cycling (Brown et al., 2016). Limb et al. (2020) studied people wishing to move to an area of housing built using active design principles. Those that moved there (intervention group) showed no substantial improvement in levels of walking and cycling but daily private vehicle travel decreased and public transport use increased compared with those who had wished to move there, but had not (control group).

There were two studies of whole area/city interventions. Keall (2022) compared New Zealand's two walking and cycling 'Model Communities', which had investment in infrastructure improvements and promotion, with two control cities. At the five-year follow-up, there were still significantly higher odds of active travel compared with the baseline year, although this effect had reduced with time and despite the interventions, cycling rates remained low. The Physical Activity Through Sustainable Transport Approaches (PASTA) study (Sulikova and Brand, 2022) was a multi-level longitudinal study of people's physical activity patterns and travel behaviours in cities in Europe. Every city had mobility plans and city-wide policies, with further supplementary city-specific interventions delivered. The authors concluded that walking is easier than cycling to influence and maintain after an intervention. Relative to each city's control group, they found a significant increase in walking and e-biking in all four cities at the 3 or 5 year follow up. The authors commented that while in many cases, an intervention may appear to be successful in the first year after implementation, the effectiveness of the intervention may fade with time.

4. Discussion

By synthesising the available research, several practice and policy-related recommendations can be made. These are summarised below, together with a brief discussion of the evidence on which they are each based. Although almost all the studies were at medium or high risk of bias, the number of studies included in each category, and the relative consistency in the results, lead the authors of this review to have a good degree of confidence in our findings. The results were also in line with other recent reviews of infrastructure interventions such as that of Xiao et al. (2023) and Timmons (2024).

Recommendation #1: Infrastructural improvements are necessary to increase levels of walking and cycling, but social/behavioural/policy interventions also have their place.

Increasing the walkability of an area appears to increase the number of people walking (Ma et al., 2017; Cambra and Moura, 2020), but improving cycling infrastructure is not on its own sufficient to ensure increases in cycling, at least if it is on a small scale (Vasilev et al., 2018). Despite potential political challenges, interventions to increase active travel must support cycling as it extends the distance that can be travelled and so offers additional opportunities for modal shift from vehicle to active transport compared to

Tabel 5
Multicomponent interventions, including infrastructure or environmental change.

First author, year and country	Intervention	Participants	Key findings	Risk of bias
Aittasalo et al., 2019, Finland	RCT of workplace based behavioural strategies following infrastructure improvement.	Working age adults in businesses near new infrastructure. 700 people in intervention, 528 in control at start. At 2 month follow up 206 people in intervention and 86 in control.	No change in active commuting following infrastructure improvement; self-reported move away from cars in control group. Increase in general public use of paths following infrastructure improvement.	High
Baldovino-Chiquillo et al., 2023, Colombia	New cable car infrastructure.	Residents within 800 m of cable car stops (intervention); residents within 800 m of proposed cable car stops in neighbouring area (control). 2052 people in total.	At 3 month follow up the new cable car had not reduced transportation related walking in a population with high levels of walking and few alternatives.	Low
Brown 2016, USA	Complete Street Infrastructure and new railway stations.	Adults living within 2 km of the intervention. 910 people at baseline, 536 at follow up (under 1 year post intervention).	Walking in the area increased with a greater impact in those living nearer the complete street areas. Residents nearer the complete streets were more likely to cycle than the other three groups but cycling rates were low.	Medium
Chang et al., 2017, Mexico	Public transport and streetscape improvements.	Working age adults, randomly selected from within 500 m of intervention area. Baseline respondents 1067, follow up 1420.	Three years post intervention, respondents spent more minutes walking post intervention, in part because the bus rapid transit stops were further apart than the bus/trolley bus services they replaced. The cycle lanes did not lead to a statistically significant increase in cycling.	Medium
Felix et al. (2020), Portugal	Cycling infrastructure and bike-sharing (pre and post intervention measures).	People cycling on the infrastructure at the counting points and times (all age) - manual counts undertaken at 45 locations in 2016, 2017, 2018.	Significant increase in cycling from 2016 to 2017 in intervention areas and a significant increase in cycling from 2017 to 2018 in areas served by the bike-sharing system. From 2017 to 2018, women's share increased from 16% to 22%, mostly driven by bike-sharing, which accounted for 34% of all observed trips in 2018.	Medium
Hagen 2021, Norway	Street-space reallocation, parking restrictions, parking charges and improved public transport.	Commuters to the city centre, accessed via annual survey sent to staff via participating employers, sub categorised as 'city centre users' (n = 5457–6018) and 'city centre workers' (n = 548–1611). Number of responses varies by year.	12 months after the interventions, public transport usage decreased, while walking and biking increased. Car shares were already low before the interventions were implemented.	High
Hong et al., 2016, USA	Public transport improvements with improved walking environment.	People living less than half a mile (intervention group) or more than half a mile (control group) from the new light rail station. 279 people in initial survey (5–7 months before the new line) and 204 at follow up (5–7 months after).	Living closer to light rail station increased active travel in those previously inactive.	High
Jensen et al., 2017, USA	Complete street infrastructure improvements and new light rail stations.	Count of people using 4 street sections (2 intervention, 2 control) before, immediately after, and 2 years after interventions complete.	Changes to make street more walkable increased walking.	Medium
Karpinski, 2021, USA	Protected bike lanes and bike-share,	People using the Boston bike share scheme, with a control group from the same area. The groups were distinguished by the recommended routes between origin and destination. Data collected from 2012 to 2019, follow up was 1 year post intervention.	Immediately after an initial section of the bike lane was completed, the treatment group experienced an atypical jump in ridership followed by another large increase when the bike lane was completed, significantly above levels seen in the control group.	Low
Keall et al., 2022, New Zealand	Infrastructure improvements and campaigns/promotion,	Samples of residents in 2 towns in New Zealand where infrastructure improvements were made compared to samples from 2 similar towns without such improvements. The study contains baseline data and 1, 2, and 5 year follow up.	Statistically significant net increase in the odds of active travel from baseline to postintervention although cycling rates remained low. No difference in the time spent physically active relative to the controls. Effect still significant at follow up but decreased with time. Results suggest that those living closer to the infrastructure changed behaviour more quickly but those further away took more than a year to change.	Medium

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Tabel 5 (*continued*)

First author, year and country	Intervention	Participants	Key findings	Risk of bias
Limb et al., 2020, UK	Impact of moving to walkable area (with good public transport).	Adults seeking to move into East Village; Those who did subsequently move were the exposed group, the remainder were the controls. 1287 originally recruited, and 877 followed up, of whom half moved to East Village. Longitudinal analysis of 578 people with valid GPS data at baseline and follow up.	At two-year follow-up there was no change in the time spent walking or cycling among those who moved to East Village compared with those living elsewhere but their vehicle travel had decreased.	Medium
Mateu 2021, Spain	Infrastructure and policy changes, bike share scheme.	Data from bicycle counters collected annually 2016–2020.	Cycling rates have been increasing each year in Valencia, based on trips recorded by the route-based counters. The bike share scheme was considered facilitative, as was the long-term, cross-political party support.	Low
Prins et al., 2019, Netherlands	Social and infrastructure.	Adults aged 55+ living in the selected neighbourhoods. 639 participants at baseline with 342 people included in at least one follow up wave (undertaken at 3 and 6 months).	Participants in neighbourhoods with new walking routes (physical intervention), or walking groups (social intervention), were more likely to increase total walking and utilitarian walking compared to those in an area without interventions. No statistically significant differences between the combined and single interventions.	Medium
Sulikova 2022, Italy, Belgium, Austria Sweden	Multicomponent including infrastructure in 4 European cities	Adult residents of each of the four cities, with continuous recruitment, with 3239 at baseline, and 4366 post treatment phase. 3 year follow up in Rome and Antwerp and 5 year in Vienna and Orebro. 308 valid responses at final follow up.	Significant increase in walking and e-biking for all four cities. Antwerp and Örebro both show a statistically significant increase in cycling (and decrease in public transit use) whereas Rome and Vienna show an increase in public transport use and decrease in cycling (ns in Rome). For some modes, the intervention effect decreased over time (walking, public transit, driving in Vienna; cycling and driving in Örebro), but for others, the effect became stronger in the second follow-up (notably e-bike use in Örebro).	Medium

walking. It is also of value to people on low incomes, who may not have other affordable options (Dalton et al., 2022).

Although social and behavioural interventions are often cheaper and quicker to implement than infrastructure changes, they are unlikely to be effective without some additional support, especially for cycling interventions. Examples could be to include the enforcement of regulations, or environmental and infrastructure changes such as road space reallocation. These are required to make walking, cycling, and wheeling feel safer and more pleasant. In urban areas, such infrastructure changes will require changes to where motorised vehicles are driven and parked (Xiao et al., 2022). This should be complemented by a continued programme of public promotion of walking and cycling, and enhanced access to e-bikes and e-cargo bikes (Mateu and Sanz, 2021). The potential impact and role of e-scooters (not covered in this review) also needs to be considered.

The majority of social/behavioural/policy interventions implemented without infrastructure change in the studies included in this review had minimal impact, and any impact that was achieved required ongoing enforcement. Funders both of research and of interventions should think carefully before putting any more money into small scale or stand-alone interventions, however appealing or uncontroversial they are.

Recommendation #2 Identifying groups within the population who wish to change behaviour, or who are at a 'teachable moment' can be useful to demonstrate the potential for increasing active travel. This will not translate to population level change without substantial investment, although such investment is likely to deliver a high return.

Aiming interventions at sub-populations (for example, drivers wishing to change transport mode, or people with recently diagnosed health issues) offers opportunities to increase rates of active travel, and could be a positive, cost-effective way to demonstrate 'proof of concept' (Cooper et al., 2018). Whole-population interventions, however, require more substantial environmental and attitudinal change. Across the studies included in our review, we found few 'whole system' and policy-based studies. Mateu and Sanz's (2021) study in Valencia was a notable exception, discussing political dimensions of active travel uptake. Fruhen (2021), is a further example, investigating how changes in law impact upon active travel rates. Lambe (2017) described how politicians had bowed to pressure from traders and not implemented road-based traffic calming measures. Studies included in our review also tended not to evaluate cost-effectiveness or financial impacts of interventions, despite the substantial evidence of the return on investment from increasing active travel – see Aldred et al. (2024), for example.

Recommendation #3: Availability of high-quality public transport and of e-bikes is important in increasing active travel and creating a modal shift from private car use.

High-quality public transport supports a modal shift from car use, and coupling this with increased neighbourhood walkability appears to increase the frequency of walking, although the distances walked may decrease (Limb et al., 2020). There were fewer studies exploring the impact of improved public transport on cycling rates. However, where this was included, pedal cycling rates sometimes declined whereas e-bike use stayed stable (Sun et al., 2020). Offering e-bikes appears to have much greater positive impact on cycling rates than providing pedal bicycles (Bjørnarå et al., 2019).

Recommendation #4: Any intervention needs long-term funding to ensure sustainability.

Many of the interventions showed their impact to decline with time, and this was particularly true of social or behavioural interventions. At best, this would imply that longer-term investment is necessary and to achieve population level changes programmes should be either sustained (e.g. campaigns/promotional messaging) or repeated (for example, an annual repeat in Spring of gamification interventions aimed at cycling to bring back people who have stopped cycling in the winter) (Biondi et al., 2022). Evidence on infrastructural interventions was more mixed but again, it seems clear that maintaining the intervention is required. Route maintenance, long-term availability of bikes/e-bikes, and repetition of social and behavioural interventions should be built into any active travel programme.

Recommendation #5: Greater consistency in measurement tools for active travel interventions is needed, as well as longer follow-up periods and consideration of population demographic features and context.

Whist previous reviews on the efficacy of active travel interventions have focused upon a single type of intervention (e.g. behavioural, cycling), level (e.g. built environment) or sub-population (e.g. children travelling to school) – this systematic review has included *any study* which assessed an active travel intervention as at least part of its aim. Consequently, studies included are heterogeneous and even when similar methodologies have been adopted, both outcomes measured, and the methods of measurement, have been diverse. Within the included studies, we found that some used randomised controlled trials when a more straightforward use of robust pre- and post-measurement, in tandem with greater reflection upon participants and setting, and an identified comparator, if possible, would have enabled adequate assessment of impact. These factors have made study comparison difficult and meant that a meta-analysis was not possible. Greater consistency in measurement tools for active travel interventions, as well as longer follow-up periods, would support both comparison of studies and understanding of longer-term impacts.

Most studies included in the review had a medium or high risk of bias, largely due to small-scale nature of interventions, limited follow-up times, and self-selected participants. These characteristics were often because studies were either of pilot interventions, or because there was limited funding available. In a few cases where there had been an infrastructural intervention, follow-up time was short because of delays in implementation. These limited follow-up times mean it is usually not possible to know whether any observed changes in active travel were maintained or increased/decreased over time.

Within many of the included studies there were substantial gaps in terms of participant demographics and reflection upon their pertinence. For example, when gender was recorded, there was minimal discussion on why this matters, even though scholarship demonstrates that women have different transport patterns to men (Pollard and Wagnild, 2017; Goel et al., 2023; Sagaris et al., 2024) and are generally underrepresented in countries with low cycling rates (Aldred et al., 2016). Socio-economic status was also not always considered, despite scholarship demonstrating income-related differences in active travel (Rind et al., 2015; Lawlor et al., 2021) and that deprived and ethnic minority pedestrians are more likely to be a casualty of road danger (Agilysis and Living Streets., 2021). There is also some (Hino et al., 2019; Limb et al., 2020) evidence which suggests cycling infrastructure is often implemented in more affluent areas, although evidence collected here shows that lower income groups may be more reliant on cycling. Inequitable distribution matters as transport inequalities could rise, even with increases in rates of active travel (Smith et al., 2017). Furthermore, studies could include a greater analysis of social and cultural context, considering that private vehicles are often a gendered status symbol, whilst walking cycling, and use of buses is perceived more negatively, associated with being low-income (Jeske, 2016; Pojani et al., 2018). Across all included studies, there was very little consideration of disability, and when included tended to be in the context of older or retired adults only. Considering that disabled people are less likely to have access to a household vehicle than non-disabled people (DfT, 2021b; USDOT, 2022) and do not have equitable access to active travel infrastructure or public transport (Lindqvist and Lundälv, 2012; Iudici, 2015; Iudici et al., 2017; Wayland et al., 2022; Mindell et al., 2024), this under- representation matters.

4.1. Limitations

This review should be read alongside consideration of its limitations. Given the breadth of interventions included, the search strategy included systematic search of the seven electronic databases (which was undertaken twice) using a limited number of search strategy terms. The authors did not employ supplementary search techniques – for example using google scholar, citation searching, or inviting authors of included studies to identify missed studies, although where missed studies were identified to us, they were included. Most of the studies included in our review were based in high-income countries (HIC) which may limit the ability to generalise findings to low- and medium-income countries (LMICs). Furthermore, because of the broad focus upon any active travel intervention and the heterogeneity of study approaches and measurements, a meta-analysis of studies was not deemed appropriate. As we did not require control groups to be included, it is possible that some studies were affected by other contemporaneous interventions or trends. A couple of studies were affected by the pandemic, for example.

Other researchers might have chosen different categorisation of the studies: for example, the studies relating to children could have been separated by the characteristics of the intervention, rather than being treated as a group. Similarly, studies of the impact of policy upon active travel rates could have been a separate category, although only a few studies measured this. This may be because our inclusion criteria required pre- and post-measurements and publication in a peer-reviewed journal whilst evaluation of policies may be in grey literature. Finally, reviews are by definition behind the most recent evidence.

5. Conclusion

This systematic review contributes to the literature by focusing upon any study assessing an active travel intervention, rather than focusing upon a single type of intervention. Through this broader focus it demonstrates that the most effective active travel interventions are multi-component. This review also highlights several important gaps within studies on the efficacy of active travel interventions; limited studies included from LMICs, and the limited engagement with the demographic characteristics of participants, for example gender, income, and disability, and how these influence access to and uptake of active travel. Future research should address these gaps but should also attend to how to develop public and political support for larger scale active travel interventions. In addition, developing assessments of the cost-effectiveness of the interventions, especially if this could be presented alongside any trial, including costings of health, carbon reduction, air quality and productivity impacts, is likely to be of great value to policy makers.

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CRediT authorship contribution statement

Eleanor Roaf: Writing – review & editing, Writing – original draft, Validation, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Harriet Larrington-Spencer:** Writing – review & editing, Writing – original draft, Validation, Supervision, Methodology, Investigation, Data curation, Conceptualization. **Emma R. Lawlor:** Writing – review & editing, Writing – original draft, Validation, Supervision, Methodology, Data curation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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