Physical activity and the environment update

Effectiveness and Cost-Effectiveness Evidence Review 2: 'Ciclovia' and Street Closures, Trails and Safe Routes to Schools

FINAL

Jean Bennie, Olivia Crane, Adrienne Cullum, Paul Levay, Diana O'Rourke, Alice Murray, Karen Peploe, Clare Wohlgemuth, Hugh McGuire

July 2017

National Institute for Health and Care Excellence

Table of Contents

1. Introduction

A review of NICE guideline PH8 on physical activity and the environment identified that some sections of the guideline were in need of update as new evidence was available (see review decision). The update also has a particular focus on those who are less able to be physically active (see scope).

The update focuses on interventions in the following environments:

- Built environment including roads, pavements, the external areas of buildings and open 'grey' space, such as urban squares and pedestrianised areas.
- Natural environment, including 'green' and 'blue' spaces. Green spaces include: urban parks, open green areas, woods and forests, coastland and countryside, and paths and routes connecting them. Blue spaces include: the sea, lakes, rivers and canals.

A series of evidence reviews was undertaken to support the guideline development. This second evidence review focuses on the effectiveness and cost effectiveness of the following interventions – trails, safe routes to schools and 'Ciclovia' (the closure of streets to motorised traffic for the purpose of increasing physical activity).

2. Methods

This review was conducted according to the methods guidance set out in 'Developing NICE guidelines: the manual' (October 2014).

2.1. Review questions

1. Which interventions in the built or natural environment are effective and cost-effective at increasing physical activity among the general population?
   1.1 Which transport interventions are effective and cost effective?
   1.2 Which interventions related to the design and accessibility of public open spaces in the built and natural environment are effective and cost effective?
2. Does the effectiveness and cost effectiveness of these interventions vary for different population groups (particularly those less able to be physically active)?
3. Are there any adverse or unintended effects?
   3.1 How do these vary for different population groups (particularly those less able to be physically active)?
   3.2 How can they be minimised?

4. Who needs to be involved to ensure interventions are effective and cost effective for everyone?
5. What factors ensure that interventions are acceptable to all groups?

Any available evidence relating to the cost effectiveness of interventions was also included in this review. The full economic analysis is presented separately.

2.2. Searching, screening, quality assessment and data extraction

Searching

Two systematic searches of relevant databases were conducted (one largely covering transport interventions and the other open spaces) from 22 to 24 June 2016. Two separate searches were carried out because although the two areas shared some outcomes, others were specific to either transport interventions or open spaces. A search of websites was conducted from 1 to 5 August 2016 to identify relevant evidence for this review (see Appendix 3).

PH8 searches were conducted in 2006, and included all relevant publications up to that point. For this update guideline, sources were searched from 2006 to June 2016. The decision was made not to revisit evidence included in PH8 because public health is a fast-moving area and the context in which recommendations are being implemented has changed significantly since 2006. This was for several reasons;

- The Surveillance report and update decision for PH8 stated that no evidence had been identified suggesting that any of the existing recommendations should be reversed, but that new evidence suggested that recommendations could be updated and strengthened.

- The search strategies for PH8 did not exclude interventions targeted at people with limited mobility. It is therefore expected that any interventions targeted at people with limited mobility prior to 2006 would have been captured by PH8.

Review protocol

The protocol outlines the methods for the review, including the search protocols and methods for data screening, quality assessment and synthesis (see Appendix 3). To note:

- During title/abstract screening, two exclusion codes were used - 'weed out' and 'non-comparative studies'. Non comparative studies included cross-sectional surveys and correlation studies.
- Qualitative studies were only included if they were UK-based AND linked to an intervention of interest as outlined in the review protocols. If few effectiveness or intervention-linked qualitative studies were included the committee agreed to consider UK-based qualitative studies that were not linked to an intervention of interest
- Systematic reviews of interventions of interest were not included but the reference lists of 18 relevant systematic reviews were checked. Twenty three studies were identified via this method and were screened at title and abstract. Full papers were ordered for 7 studies. Of these, 4 were included as evidence for this guideline.
- Modelling studies (that were not economic modelling studies) were excluded.
- Cost benefit studies which only included (or included majority) 'prospective' or 'hypothetical' costs were also excluded. Any studies of this type were forwarded to the modelling team at the Economic and Methods Unit (EMU) for information.
- As agreed at PHAC 0 the following were considered out of scope: interventions involving school playgrounds, and interventions involving "fitness zones" in parks. Interventions involving school playgrounds were excluded as they were noted as being accessible usually only by pupils at the school and during school hours, as opposed to being accessible by the public in general. Fitness zones were excluded as they were considered to be equipment that people may choose to use to change their behaviour at an individual level, rather than an environmental intervention.

<u>Screening</u>

All references from the two database searches were screened on title and abstract by a single reviewer against the criteria set out in the protocol. A random sample of 10% of titles and abstracts was screened independently by a second reviewer, with differences resolved by discussion. Agreement at this stage was 95% for the transport database and 94% for the open space database. Full-text screening was carried out by a single reviewer and a second reviewer independently screened 10% of all full-text papers. Agreement at this stage was

100% for the transport database papers. Agreement at this stage was 83% for the open space papers – the 2 mismatched papers were resolved. Reasons for exclusion at full paper stage were recorded (see below and Appendix 3).

In addition to the database search, a search of websites identified 259 documents or sites containing potentially relevant information. Each of these documents or sites were considered by one reviewer and potential includes checked by a second.

Data extraction

Each included study was data extracted by one reviewer, with all data checked in detail by a second reviewer. Any differences were resolved by discussion between the reviewers.

Where data are reported effect sizes, means, standard deviations and 95% confidence intervals have been included. In all instances the most complete data available have been presented in the review findings and evidence statements. For Evidence Statements, please see below.

Quality Assessment

Included studies were rated individually to indicate their quality, based on assessment using a checklist. Each included study was assessed by one reviewer and checked by another. Any differences in quality rating were resolved by discussion. The tool used to assess the quality of studies and summaries of the QA results of all included studies are documented in Appendix 3. The quality ratings used were:

++ No Risk of Bias: All or most of the checklist criteria have been fulfilled, and where they have not been fulfilled the conclusions are very unlikely to alter.

+ Low Risk of Bias: Some of the checklist criteria have been fulfilled, and where they have not been fulfilled, or are not adequately described, the conclusions are unlikely to alter.

– High Risk of Bias: Few or no checklist criteria have been fulfilled and the conclusions are likely or very likely to alter.

Presentation of Evidence

Each included study is summarised in narrative format. This contains information on research design, setting, quality assessment and results as relevant to each review.

In addition:

- GRADE (Grading of Recommendations Assessment, Development and Evaluation) was used to synthesise and present the outcomes from quantitative studies, of which there were 26 for this Review. These are presented as Evidence Statements.
- Qualitative evidence was considered disparate and sparse for this review, with only two mixed methods studies including some qualitative results. Studies are therefore summarised by presentation of their key themes. These are presented in Evidence Statements.
- Cost effectiveness studies, of which there are 5 for this review including a study which was primarily an effectiveness study, are summarised by key findings, presented as Evidence Statements.

GRADE

GRADE was used to appraise and present the quality of the outcomes reported in included studies – see Appendix 4 for full GRADE tables for Review 1 by outcome. This approach considers the risk of bias, consistency, directness, and precision of the studies reporting on a particular outcome. Critical outcomes for GRADE were the primary outcomes listed in the scope. Important outcomes were the secondary outcomes listed in the scope. (For more details about GRADE, see Appendix H of the NICE Methods Manual (2014) and the GRADE working group website). The quality ratings used to assess the evidence base were: high, moderate, low and very low. Appraisal of the evidence using GRADE methodology starts from 'Low' for evidence derived from observational studies.

Evidence Statements for Review 2 are presented below. For studies of effectiveness, quality of evidence was appraised using GRADE. Evidence statements for qualitative and economic studies were constructed using quality appraisal tools and in line with the NICE manual.

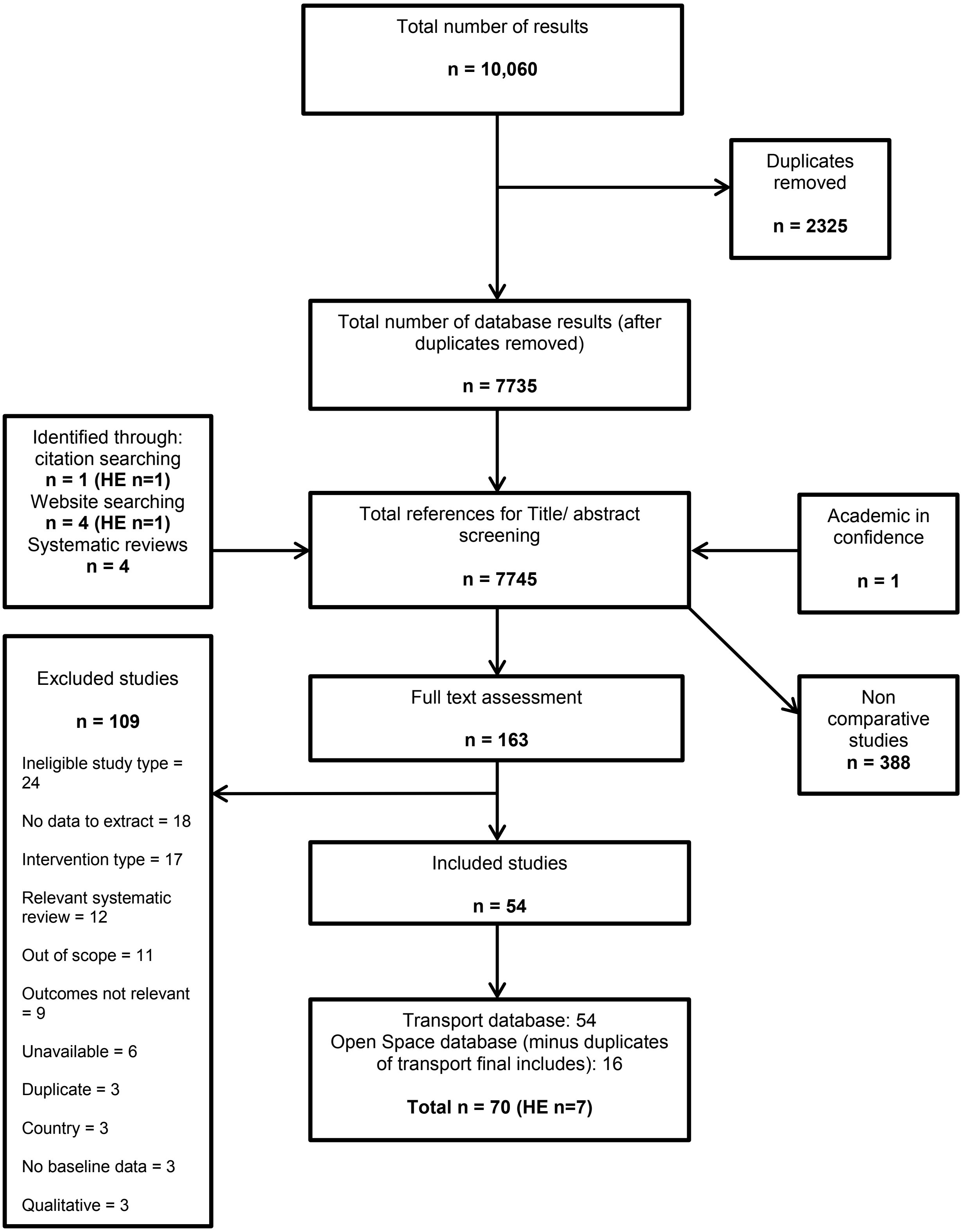
3. Results

3.1. Flow of literature through the review

A total of 70 studies met the inclusion criteria for the evidence reviews to support the guideline on physical activity and the environment.

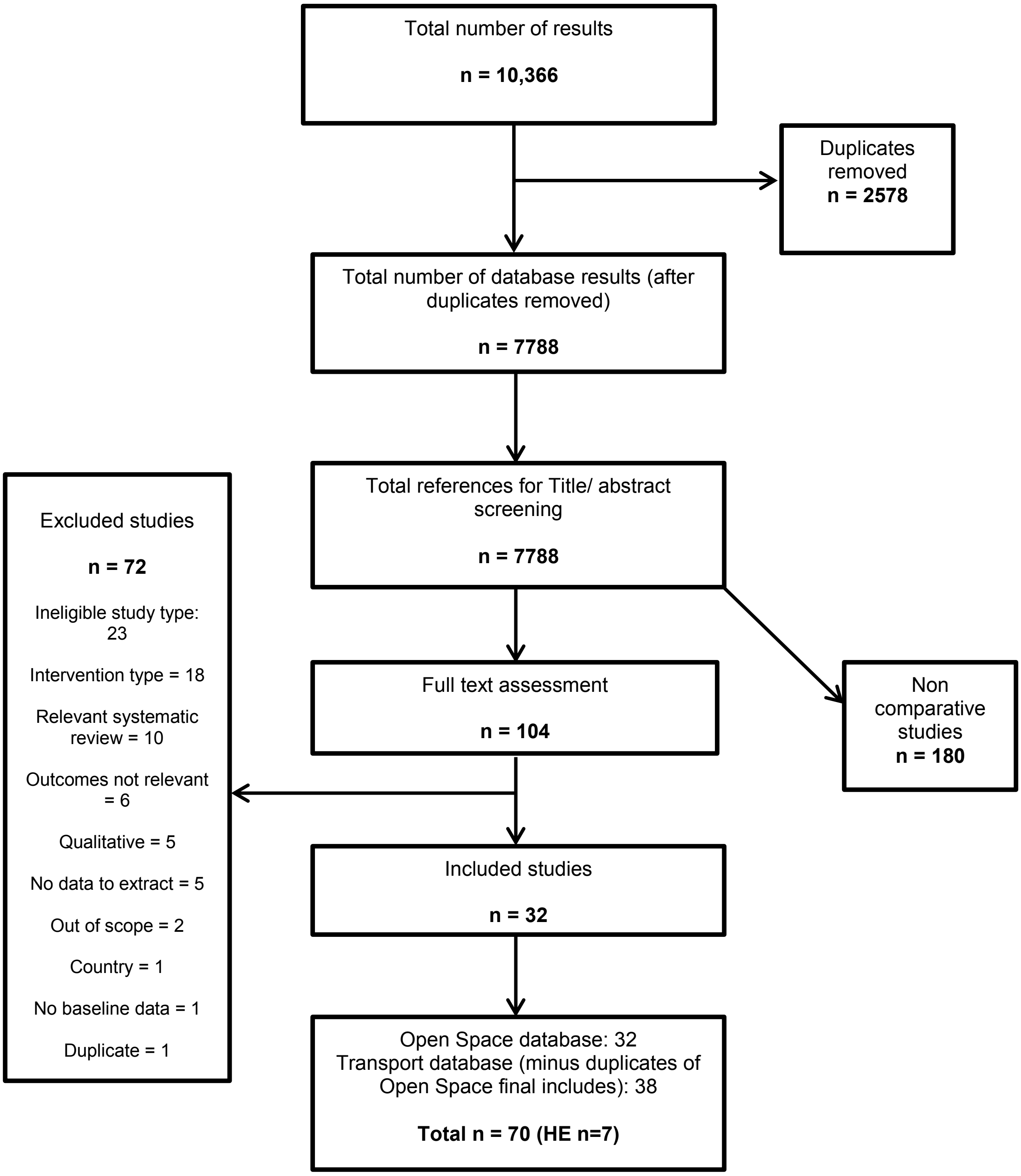
Of these 70, 60 studies were identified from two searches of databases for transport and open space interventions. An additional 1 paper was provided to NICE on an academic in confidence basis. 1 was identified through citation searching and 4 from systematic review included studies. From the website search, 4 new studies were identified that met the review inclusion criteria (one on public transport (included in this review), one on parks, one multi-component, one on cycling infrastructure). Figures 1 and 2 below show the flow of literature through the review. [To note that there are 16 final includes which are duplicated across the two databases, hence the total number of studies from the two flow charts is more than 70].

Figure 1. Flow of literature through the review: transport database (2006-present)



HE = Health Economics. These papers either have the primary aim of conducting an economic analysis, or contain a portion of economic analysis.

Figure 2. Flow of literature through the review: open space database (2006-present)



3.2. Characteristics of the included studies

The table below outlines the main themes of the 70 papers that met the inclusion criteria for the evidence reviews.

Theme	Number of papers
Review 1	
Public Transport	18
Review 2	
Ciclovia	3
Trail: trails and paths	14
Trail: Cycle Infrastructure	4
Trail: On-street cycle lanes	4
Safe Routes to School	5
Review 3	
Neighbourhood	6
Parks	12
Multi-component	4
TOTAL	70

Characteristics of all 70 included transport and open space studies are given in Appendix 1.

Papers included in this review are: 22 trail studies (trails and paths, cycle infrastructure, on-street cycle lanes); 5 Safe Routes to School studies; and 3 Ciclovia studies. Full details of the 30 studies included in this review are given in the evidence tables in Appendix 2. The table below shows the characteristics of the studies included in this review.

Characteristics of studies included in Review 2 - Trails, Safe Routes to School, Ciclovia

Study Author, Date	Study Type (author's description)	Population group	Intervention details	Theme
Adams and Cavill 2015	Uncontrolled before and after study	Count: whole community survey: over 16 only. UK, multiple cities.	Fitter for Walking (FFW). Improvements to footpath access, safe crossings, lighting, and aesthetics	Trail: trails and paths
Bjornskau et al 2012	Controlled before and after study	18 and over only. Cyclists, pedestrian, and car drivers. Norway, Oslo.	Counter-flow cycling permitted, cycle lanes installed	Trail: On-street cycle lanes

Study Author, Date	Study Type (author's description)	Population group	Intervention details	Theme
Clark et al 2014	Controlled before and after study (quasi experimental control design)	All trail users (adults and children). USA, Southern Nevada.	Behavioural: marketing campaign. Environmental: development of trails	Trail: trails and paths
Department for Transport 2010	Benefit-cost analysis	6 Cycling Demonstration Towns. UK, multiple cities.	Cycling Demonstration Town programme	Trail: Cycle Infrastructur e
D'Haese et al 2015	Controlled before and after study	School children. Belgium, Ghent.	Play streets offering safe, car-free areas near homes	Ciclovia
Dill et al 2014	Controlled before and after study (natural experimental study)	Adults with a child (5-17yrs) with cycling ability. USA, Oregon.	Bicycle boulevard installation on 8 street segments	Trail: trails and paths
Fitzhugh et al 2010	Controlled before and after study (quasi-experimental research design with multiple controls)	Children and adult users of park. USA, Tennessee.	Pedestrian infrastructure	Trail: trails and paths
Goodman et al 2013a	Controlled before and after study (Longitudinal, controlled natural experimental study)	16 - 74 yrs only. 18 intervention towns. UK, multiple.	Environmental and behaviour change ("3:1 ratio") cycle lanes and parking, training and promotion.	Trail: Cycle Infrastructur e
Goodman et al 2013b	Uncontrolled before and after study (cohort design)	18 and over only. UK, multiple.	Connect2. Traffic free routes for walking and cycling. Traffic free bridge; creation of boardwalk	Trail: Trails and Paths

Study Author, Date	Study Type (author's description)	Population group	Intervention details	Theme
Goodman et al 2014	Observational before and after study (cohort design)	18 and over only. UK, multiple.	Connect2. traffic free routes for walking and cycling. Traffic free bridge; creation of boardwalk	Trail: trails and paths
Gustat et al 2012	Controlled before and after study (serial cross-sectional study design)	18-70 years only. USA, New Orleans.	Installation of walking path	Trail: trails and paths
Hendricks et al 2009	Uncontrolled observational before and after study	Elementary school children (Kindergarten to grade 6); working age adults. USA, Michigan.	Behavioural. Environmental: lockers, bike racks, company bike rental scheme.	Trail: Cycle Infrastructur e
Hoelscher et al 2016	Controlled before and after study	School children. USA, Texas.	Behavioural (education, encouragement etc.). Environmental (pavements, road crossings). Community involvement.	Safe Routes to School
Hunter et al 2009	Uncontrolled before and after study	All ages. Users of cycle lanes. USA, Florida.	Introduction of 2 new cycle lanes	Trail: On-street cycle lanes
Krizek et al 2009	Controlled before and after study	Whole population and cyclists. USA, Minnesota.	Cycle infrastructure improvements over a decade	Trail: trails and paths
Montes et al 2011	Cost-benefit analysis using existing data	18 and over only. Event users. USA (San Francisco) and Mexico.	Ciclovia - community-based programmes closing streets to cars for use for leisure and physical activity (event)	Ciclovia

Study Author, Date	Study Type (author's description)	Population group	Intervention details	Theme
Muennig et al 2014	Cost effectiveness study	School children. USA, New York City.	SR2S: education, encouragement, road improvements near schools	Safe Routes to School
Orenstein et al 2007	Whole programme effectiveness analysis	570 Safe Routes 2 Schools programmes. USA, California.	Safe routes to schools	Safe Routes to School
Ostergaard et al 2015	Controlled before and after study (quasi-experimental controlled study)	School children. Denmark, multiple.	Environmental (road surface, signposting and traffic regulations like one-way streets) and behavioural	Safe Routes to School
Parker et al 2011	Uncontrolled before and after study	All ages. Cyclists. USA, New Orleans.	Installation of bicycle lanes along a highway	Trail: on street cycle lanes
Parker et al 2013	Controlled before and after study	All ages. Cyclists. USA, New Orleans.	Introduction and striping of a 1 mile bike lane	Trail: on street cycle lanes
Poindexter et al 2007	Uncontrolled before and after study	No age range given. Residents around bicycle facilities. USA, Minnesota.	"Bicycle facility" - infrastructure improvements, safety analysis	Trail: trails and paths
Rissel et al 2015	Controlled before and after study (longitudinal, quasi-experimental design)	18-55 years only. No disability preventing from riding a bike. Australia, Sydney.	New bicycle path separated from road in inner Sydney	Trail: trails and paths
Sahlqvist et al 2015	Mixed methods - uncontrolled before and after study	18 and over only. Within 5km of planned changes. UK, multiple.	Connect2. Traffic-free routes for walking and cycling. Traffic free bridge; informal riverside footpath turned into boardwalk	Trail: trails and paths

Study Author, Date	Study Type (author's description)	Population group	Intervention details	Theme
Sinnett and Powell 2012	Cost Benefit Analysis	Pedestrians. UK, multiple.	Fitter for Walking (FFW). Improvements to footpath access, safe crossings, lighting, and aesthetics	Trail: trails and paths
Sloman et al 2009	Evaluation of intervention using multiple secondary data sources	Whole population. UK, multiple.	Cycling England / Department for Transport Cycling Demonstration Town programme	Trail: Cycle Infrastructur e
Stewart et al 2014	Uncontrolled before and after study (one group pre-test and post-test)	Schools affected by safe route to schools project, and projects themselves. USA, multiple.	State-funded safe routes to school programme	Safe Routes to School
Torres et al 2016	Longitudinal cohort study	Whole population. USA, Atlanta.	Open Streets: making streets temporarily traffic-free (event) to promote physical and pedestrian activity	Ciclovia
West and Shores 2011	Uncontrolled before and after study	No age range given. Property owners in population. USA, exact location not given.	Environmental: creation of 5 miles of greenway along a river	Trail: trails and paths
West and Shores 2015	Controlled before and after study	Home owners in population. USA, exact location not given.	Extension of a greenway by 1.93 miles	Trail: trails and paths

3.3. Review findings

Thirty studies that addressed Ciclovia / street closure interventions, trails interventions, and Safe routes to school interventions are considered here. For GRADE profiles see Appendix 4, and for Evidence Statements, please see below.

Studies were grouped by the type of intervention:

- Ciclovia (3 studies)
- Trails (22 studies)
  - Cycle infrastructure (4 studies)
  - On-street cycle lanes (4 studies)
  - Trails and paths (14 studies)
- Safe routes to schools (5 studies)

<u>‘Ciclovia’</u>

‘Ciclovia’ programmes involve the closure of streets to motorised traffic for the purpose of increasing physical activity. Three studies reported on the effects of such programmes. One controlled before and after study (D’Haese et al., 2015 [+]) in Belgium; one cost benefit analysis (Montes et al 2011[-]) in Mexico and USA; and one repeated cross sectional observational study (Torres et al 2016 [-]) in USA.

D’Haese et al (2015)[+] conducted a controlled before and after study to test the effectiveness of *Play Streets* – set periods where neighbourhoods become traffic-free during school holidays – for increasing children’s moderate- to vigorous-intensity physical activity (MVPA) and for decreasing their sedentary time. The ‘19 Play Streets’ event lasted at least 7 consecutive days, taking place at times between 14:00 and 19:00; for each included Play Street a control neighbourhood (matched on comparable walkability characteristics (not defined) and annual household income) which had no play street was selected. Children in the intervention wore accelerometers for the duration of the study.

Overall 80.5% of children in the intervention group used the Play Street during the study period. The key findings were:

- Between baseline and follow-up mean daily minutes of sedentary time, measured between 14:00 and 19:00, increased in the control group (156.49 (SD41.69) to 164.61 (SD40.10)) but decreased in the intervention group (146.30 (SD38.36) to 137.74 (SD35.43)). This change between groups was significant (p = 0.048).
- Between baseline and follow-up the intervention group showed a greater increase (not statistically significant) in moderate and vigorous physical activity (MVPA), measured between 14:00 and 19:00, than the control group (p = 0.057). Differences as measured in mean daily minutes (standard deviation):
    - Control: baseline = 26.91 (16.92), follow-up = 24.32 (13.47)
    - Intervention: baseline = 26.70 (13.51), follow-up = 35.79 (24.93)

These changes remained significant when measured over the whole day (sedentary p = 0.012; MVPA p = 0.010) suggesting that intervention groups were not compensating for changes during other times of the day.

Torres et al (2016) [-] conducted a repeated cross-sectional observational study to investigate the influence of Atlanta Streets Alive (ASA) events – where streets were closed to vehicular traffic - on physical activity levels. The 5 events took place between 2010 and 2012, the closed sections of various streets were between 1.5 and 2 miles in length and closed for between 4-5 hours (starting as early as 10am and ending as late as 8pm). Repeat cross-sectional participant surveys were taken at the first, second, and fifth event.

23.3% of participants reported meeting the recommendation of doing 150 minutes or more of moderate to vigorous physical activity during the first event, 20.0% met the recommendation in the second event, and 16.4% in the fifth event. The total minutes, as reported in the surveys, spent performing physical activity at the events (standard deviation) fell from 109 minutes at event 1 (SD55) to 97 minutes (SD66) at event 2 and 95 minutes (SD 55) at event 5. Significance was not reported.

Montes et al (2011) [-] calculated the benefit-cost ratios of ‘Ciclovia’ programmes in Mexico and the USA. The programme in the USA began in 2008 and involves the closure of sections of road, varying in length from 7.3km to 9.7km, by 2010 the number of events had increased to 9, taking place on Sundays. The programme in Mexico began in 2004 and involves a 25km circuit, by 2009 this ran every Sunday.

The Direct Health Benefit (DHB) was calculated for the USA programme by estimating the difference in the direct medical cost for active persons and their inactive counterparts in the USA. In Mexico, as medical cost data were unavailable, alternative adjusted equations were used. In terms of costs: operational costs data were obtained from directors and managers; user costs (equipment) was weighted by users of that equipment at each location's events; costs of roads etc were not included, as they were assumed to be pre-existing.

In terms of activity types, in the USA of 15,000 adult participants per event, 46.2% (3,004) were bicyclists, 35.5% (2,308) were pedestrians, and 18.2% (1,185) were skaters or other. In Mexico, of 51,761 adult participants per event 84% (51,761) were bicyclists, 13% (416) were pedestrians, and 3% (22) were skaters or other.

The costs and benefits were calculated to be as follows:

In Mexico:

- Annual Costs: $908,582
- Annual cost per capita (user): $6.5
- Benefit cost Ratio (BCR): DHB must be $51.1 (8.2% of USA's DHB) to obtain a cost-benefit ratio >1. BCR calculated as a range 1.02-1.23:1.
- According to the HEAT model, the mean annual benefit for mortality prevention ranged from $664,727 to $10,146,740.

In USA:

- Annual Costs: $1,763,368
- Annual cost per capita (user): $70.5.
- BCR: 2.32:1 ($2.32 saved in direct medical costs for every $1 invested in the program if the program occurs regularly every week). DHB must be more than $269.4 to achieve a BCR over 1. More than 11,200 users must take part for the BCR to be greater than 1.
- According to the HEAT model, the mean annual benefit for mortality prevention ranged from $5,107,159 to $5,837,363.

Key limitations to the ciclovia studies, include short measurement period, high drop-out and self-selected group (D'Haese et al (2015)); potentially inaccurate methods of counting participants and use of convenient, repeat cross sectional data (Torres et al (2016)); and inconsistent evaluation methods, use of self-reported activity and lack of discounting economic outcomes (Montes et al (2011))

Applicability: The evidence is only partially applicable to the UK because the studies were conducted in Belgium, Mexico, and the USA.

1. D'Haese et al (2015) [+]
2. Montes et al (2011) [-]
3. Torres et al (2016) [-]

Trails: Cycle infrastructure

Four studies reported on cycle infrastructure interventions. Three considered cycle demonstration towns in the UK (one UK based controlled before and after study (Sloman et al, 2009 [-]) with a linked cost-benefit analysis (Department for Transport, 2010 [-]) and one controlled before and after observational study (Goodman et al, 2013a [+])); and one uncontrolled before and after study on infrastructure in USA (Hendricks et al, 2009 [-]).

UK based interventions

Sloman et al (2009 [-]) *(linked to DfT 2010)* conducted a controlled study to investigate the change in prevalence of cycling following the implementation of Cycling Demonstration Towns (CDT) in the UK. The programme, which included changes to physical infrastructure, was implemented in 6 towns, with each receiving funding of equating to £10/head of population/year. Each of the CDT local authorities were the local authorities that was considered most similar using the National Statisitcs 2001 Area Classification where CDT was not implemented (town names not given).

The prevalence of adults cycling at least 30 minutes per month increased by 28% between baseline (2006) and follow up (2009) in CDTs (11.8% in 2006 to 15.1% in 2008; 3.3%-point difference). Matched towns increased by approximately 1%-point over the same time. The proportion of adult CDT residents who cycled regularly (≥30 minutes ≥12 times per month) increased from 2.6% in 2006 to 3.5% in 2008, an increase of 0.9%-points or 37%. Matched towns decreased by approximately 0.7%-point over the same period. The proportion of adult residents of the CDTs doing any cycling in a typical week in the previous year rose from 24.3% in 2006 to 27.7% in 2009, an increase of approximately 3.4%-points or 14%. The survey also revealed that the number of inactive people decreased by 10% in CDT towns between 2006 (26.2%) to 2009 (23.6%), a decrease of 2.6%-points. The trends observed in

CDT towns were reported to differ from underlying trends in cycling levels nationwide (levels not specified) which show stable levels or even slight decline.

For total physical activity, a survey of the residents of CDT towns only showed the proportion of adult respondents classed as inactive fell from 26.2% at baseline (2006) to 23.6% in 2009 (follow-up), a fall of 2.6%-points or 10%. The proportion of people of all ages in medium urban areas who cycled 'less than once a year' or 'never' was reported as stable at 68 or 67% in each year between 2005 and 2008.

Data on personal cycling injury incidents was reported for four of the CDT towns; three of which showed an increase in incidents (stated as not statistically significant, p not reported) and one showing a decrease (stated as statistically significant, p not reported).

A cost benefit ratio analysis of the Cycling Demonstration Towns (CDT) programme (**Department for Transport (2010) [-])**, estimated the impact on the six towns included the first phase, from 2006 to 2009. The authors estimate that for every £1 spent on the CDT programme that between £2.60 and £3.50 of benefits will be accrued due to reduced mortality and non-morbidity impacts.

Goodman et al (2013a [+]) examined, through a controlled before and after study, whether the town-wide 'cycling demonstration towns' or 'cycle cities and towns' influenced the proportion of people cycling to work at 10 year follow up (2011-2011). In total, 18 town-wide initiatives were implemented in urban areas of England outside of London. Interventions varied across towns; all had environmental interventions such as cycle lanes, cycle parking, cycle path improvements; and advanced stop lines. Three control groups were used: intervention towns were similar to the *matched comparison towns* in terms of a range of demographic, socio-economic, employment and industry characteristics identified using the National Statistics 2001 Area Classification for local authorities , , and were also reasonably similar to the *national comparison group* (similarity to *unfunded group* not detailed).

The percentage difference, at follow-up compared to baseline, in those cycling to work was greatest in intervention towns (95% CI): Intervention Towns: +0.97 (0.91, 1.03); Matched Comparison towns: +0.29 (0.23, 0.34); Unfunded Comparison towns: -0.05 (-0.07, -0.02); and National Comparison group: -0.26 (-0.27, -0.24). In intervention towns, cyclists as a proportion of commuters increased significantly more between baseline and follow up compared to comparison towns (see evidence tables for detail).

In intervention towns, walking and public transport use increased (+1.71 (1.62, 1.81) and +0.32 (0.24, 0.41) respectively), and driving decreased between baseline and follow up -3.01 (-3.13, -2.88). The increase in walking and decrease in driving was significantly greater in the intervention towns than all comparison groups; changes in public transport were similar to comparison groups.

There was evidence of larger effects in towns placing greater emphasis on workplace cycling initiatives, with this variable explaining around one third of the observed between-town heterogeneity (regression coefficient 0.75 (95% CI 0.30, 1.21, adjust R^2 41.9%). Cycling was reported to have increased significantly in all quintiles of deprivation (although smaller improvements were seen amongst most deprived).

US based intervention

Hendricks et al (2009 [-]) conducted an uncontrolled study to assess a variety of interventions to increase active commuting among adults in the USA. These included the installation of 6.5 miles of bike lanes on 13 urban roads; a 10-mile extension of the current rail trail linking city with another small village; installation of new bike racks; and the installation of bike carriers on all city transit buses. Observations took place at 10 intersections, at both baseline (pre-intervention) and then at follow up one year later, on the same days of the week and times of day (7-9.30am, 11-2pm, 4.30-6.30pm). Active commuting increased by 63% between baseline and 1 year follow up (from 1,028 to 1,853 active commuters)

Of those observed at follow-up, 67% were walking, 30% were biking, and 3% were using skateboard / rollerblades / another form of active transport. Of the 558 cyclists recorded at follow-up, 69% used the pavement for part of their travel. Authors report that this figure was lower on streets where there were bike lanes (figures not reported).

Key limitations to the cycle infrastructure studies include: the need for assumptions which reduce the robustness of the approach, high level analysis of results likely to obscure differences in benefits across sites (Department for Transport 2010); large effect size heterogeneity, lack of randomisation limiting causal inferences (Goodman et al 2013a); limited baseline data, potentially inaccurate methods of counting participants, lack of clarity about length of observation periods (Hendricks et al 2009); potential Interviewer bias, power not reported, use of convenient, repeat cross sectional data (Sahlqvist et al 2015); inconsistency in methods of counting, likely underestimation of change owing to categorisation of outcomes, possible influence of outside interventions on outcomes (Sloman et al 2009).

Applicability: The evidence is directly applicable to the UK as all but one study was conducted in the UK.

1. Department for Transport (2010) [-]
2. Goodman et al (2013a) [+]
3. Hendricks et al (2009) [-]
4. Sloman et al (2009) [-]

Trails: On-street cycle lanes

Four studies reported on the effectiveness of on-street cycle lanes; two controlled before and after studies, one conducted in Norway [-][1] and one conducted in the USA [-][4]; and two uncontrolled before and after studies both conducted in the USA [-][2],[-][3].

Bjornskau et al (2012) [-] evaluated, through a controlled before and after study, the effect of implementing marked on-road cycle lanes with signage in both directions of two one-way streets compared with two control streets where no implementation took place. Further details of control streets not given. At 10 month follow up, cycling volume increased by approximately 50% on both intervention streets compared with a decrease in the control streets (no figures given). Authors noted that "some of the increased cycle traffic may be the result of transfer of cycle traffic from neighbouring streets" rather than an increase in cycling per se. At follow up, cycling on pavements was also reduced in intervention streets but unchanged between baseline and follow-up in control streets (see evidence tables).

Hunter et al (2009) [-] used an uncontrolled before and after study design to investigate the effect of installing cycle lanes along two roads with previously low levels of cycling. Combining the results for both streets, at follow-up (5-11 months) there was a 17% increase (statistically significant $p = <0.0001$) in the number of bicycles counted per day after installation of the bike lanes, though absolute numbers were very small (averages: baseline

= 9.06, follow-up = 10.49). Cycle speeds were largely unchanged, as were results when counter flow cycling was included.

Parker et al (2011) [-] conducted an uncontrolled before and after study to examine the impact of 3.1 miles of marked on-road bike lane installed on both sides of the road. At 6-month follow-up the average number of daily cyclists was 142.5 (SD ±18.5) compared to 90.9 (SD ±21.7) at baseline (*p*=<0.001). The intervention appeared to have a greater impact on women than men (significance not reported). The average daily number of women riders observed in the street increased from 12.6 at baseline to 29.4 at follow up (133% increase *p*=<0.001). The average number of male riders increased from 77 at baseline to 111.2 at follow up (44% increase *p*=<0.001). Authors stated there were very few children observed at both time points (details not reported). The proportion of cyclists riding on the pavement did not significantly change after the intervention (24.6% to 24.4%, *p*=0.90).

Parker et al (2013)[-] conducted a controlled before and after study to examine the impact of a marked, on-road bike lane, on both sides of the road for 1 mile. The results of the intervention street were compared with two streets which were adjacent to the intervention street, with no bike lanes (to note that control streets had lower levels of cycling at baseline *p*=<0.000). Proximity of the intervention and control streets could lead to contamination,

At 3 month follow-up, the change in average number of cyclists per day, comparing intervention to control increased by 177.9 in the intervention street, and decreased by 18 in the 2 control streets (*p*=<0.000). The authors note that there may have been displacement of some of the cyclists using the control streets to the intervention street. The proportion of riders using the pavement instead of the street did not change from baseline to follow-up in the intervention street (baseline 93 %, follow-up 93 %; Z=−0.24, p=0.81). This was not reported in the control street, but the proportion of people traveling with traffic decreased in control streets (baseline 96.6 %, follow-up 93.5 %; p=0.002) implying that more were using the pavement.

Key limitations to the on-street cycle lane studies include the following: little information on matching of control and intervention streets and any wider influences on cycling in control streets (Bjornskau et al., 2012), lack of account of wider influences on cycling, lack of clarity on true length of intervention and follow up undertaken at different season to baseline potentially inflating results (Hunter et al (2009), lack of comparator street and inability to control for wider influences on cycling Parker (2011); short term follow up and potentially limited wider applicability of results due to being undertaken neighbourhood with low car ownership and highly walkable destinations Parker et al (2013).

Applicability: The evidence is only partially applicable to the UK because the studies were conducted in Norway and the USA. 1. Bjornskau et al., 2012 [-] 2. Hunter et al (2009) [-] 3. Parker et al (2011) [-] 4. Parker et al (2013) [-]

Trails and paths

14 studies reported on trails and paths. Eight controlled before and after studies, one conducted in Australia [-][10] and seven in the USA [+][2], [-][3], [+][4], [-][7], [-][8], [-][13], [+][14]; four uncontrolled before and after studies three from the UK, [-][1], [-][5], [-][6], and one from the USA [-][9]; a mixed methods study [-][11], and a cost benefit analysis [-][12] both conducted in the UK.

Adams and Cavill (2015 [-]) *[Linked with Sinnett and Powell 2012]* conducted an uncontrolled study to evaluate the change in pedestrian use of local routes following the implementation of 'Fitter for Walking' (FFW) areas in the UK. The programme, which includes changes to physical infrastructure, was implemented in 12 areas, 5 of which were evaluated in this study.

The prevalence of pedestrian route users for all 5 areas combined, over both weekdays and weekends, decreased by 19.4% between baseline and follow-up 1 (1-11 months after intervention). The reduction observed in 4 of the individual sites ranged from 10.4% to 42.1%. Only one site saw an increase, 14%. The overall reduction in prevalence of pedestrian route users remained when data was looked at separately for weekends (-35.3%) and weekdays (-3.3%) (p not reported). At follow-up 2 (3 -19 months after intervention) the prevalence of pedestrian route users for all 5 areas combined, over both weekdays and weekends, increased by 14.9%. The increase was observed at all 5 sites, ranging from 5.4% to 58.9%. The overall increase in prevalence of pedestrian route users remained when data was looked at separately for weekdays (37.6%) but decreased for weekends (-7.5%) (p not reported). ‘Walking only’ was the dominant mode of transport form at both baseline and follow-up 1 (79.9% and 80.7% of journeys).

Sinnett and Powell (2012 [-]) [*linked to Adams and Cavill 2015]* assessed the costs and benefits associated with the Fitter for Walking (FFW) project in five less affluent UK towns (London; Newcastle; Blackburn; Wolverhampton; Rotherham). A range of interventions to increase short-distance walking were adopted between locations: all locations included both infrastructural and promotional activity. See data extraction table for examples of infrastructural interventions. Costs included resources, capital, and staff time costs. Benefits were increases to average journey distance and/or average journey duration. The WHO’s Health Economic Assessment Tool (HEAT) tool was used which calculates only mortality, not morbidity, benefits.

At 12-month follow-up, average journey distance decreased in all locations except Newcastle and Wolverhampton, and average journey duration decreased in all locations except Wolverhampton. Benefit-cost ratios (BCRs) were negative for all locations (except Rotherham which shows positive BCR for journey duration). Benefit cost ratios ranged from -31.9:1 (Wolverhampton when considering journey distance) to 0.1:1.

At final follow-up point (varies by location: either 14-, 16-, or 18-month follow-up) London ratios remain negative, as do ratios using journey duration in Newcastle, and journey distance in Rotherham. Benefit-cost ratios range from -9.7:1 (London when considering journey duration) to 46:1 (Wolverhampton when considering journey duration), with most BCRs >1. This indicates that at final follow-up points, benefits of the programme are greater than costs (with the exception of London). Ratios are impacted by initial costs of the project: costs ranged from £104,481 (London) to £6,917 (Wolverhampton). Authors conclude that each location (with the exception of London) has a BCR of between 0.9 and 46:1 for at least one measure (journey duration or journey distance).

Clark et al (2014 [+]) used a controlled before and after study to compare the usage of 6 stretches of trail (between 3.1 miles and 8.7 miles long) which were altered by adding way-finding and distance signage, to usage on 4 unaltered control trails with at least one characteristic of the intervention trail e.g. commuter trail for cyclists, a trail paralleling a drainage channel in an urban setting, or park-like suburban trails, over a period of one year. The trails, in Southern Nevada, USA, differed in characteristics in terms of physical infrastructure and amenities. Between baseline and 1-9 month follow-up, intervention trail usage increased by 35%, and control trails by 31%, both significant increases (p = <0.01).

However, there was no significant difference in the change scores between the intervention and control groups (p = 0.3226). Between mid-intervention and 1-9 month follow-up, control trail use did not change significantly (p = 0.69), but intervention trails did decrease significantly (141 mean users per day to 107) (p = <0.01). The sharp increase at mid-intervention was, according to the study authors, due to a promotional campaign. Use then dropped for intervention trails to a level which was still an increase compared with baseline.

Dill et al (2014 [-]) conducted a controlled before and after study to investigate changes in physical activity and active transportation in intervention groups following the installation of 8 'bicycle boulevards' (0.9-4.2 miles long) in Oregon, USA. Implemented on low-volume streets, and involving the use of traffic calming methods, they were compared to 11 control streets (1.0-5.7 miles long), often parallel streets, similar to intervention streets in urban form and most demographic characteristics. Parallel streets may be subject to contamination, with users switching between intervention and control streets or visa versa.

Between baseline and 2-12 month follow-up a decrease of 2.9% (61.1% to 58.2%) in the number of participants making a bike trip was seen in the intervention group, compared to a decrease of 2.5% (55.4% to 52.9%) in the control group (no statistically significant difference between groups p = >0.10). The number of bike trips taken decreased in both groups between baseline and 2-12 month follow-up (intervention from 5.6 [SD4.9] to 4.4 [SD 4.2], control from 4.3 [SD 3.8] to 3.5 [SD 3.3]). The installation of a bicycle boulevard was statistically significantly negatively correlated with number of bike trips (*p* = 0.06). No between-group statistical significance reported. An increase was seen between baseline and follow up in the percentage of people biking more than 10 minutes in the intervention group (43.9% to 45.3%), while a decreased was observed in the control group (39.7% to 31.4%) (between group difference not statistically significant: p = >0.1). However, a decrease was seen in the intervention group in terms of mean minutes spent cycling (of trips >10 minutes) from 103.9 (SD 73.0) to 65.9 (SD 74.7). Study authors suggest this could indicate that, of those trips longer than 10 minutes, more were relatively short compared with baseline. More than 10 minutes spent biking was significantly negatively correlated with the installation of the bicycle boulevard (*p* = 0.00).

Fitzhugh et al (2010 [+]) conducted a controlled before and after study to assess changes in directly observed physical activity of adults and Active Transport to School (ATS) of children, following the installation of an asphalt greenway/trail (8 foot wide, 2.9 mile long) in Tennessee, USA. The greenway connected residential and commercial areas within a neighbourhood. The intervention neighbourhood was compared to two control neighbourhoods with no new greenway (reported to match in terms of socioeconomic measures). It is unclear how close to the intervention streets the control streets are. For the ATS, three intervention schools (2 elementary and one high school) and three control schools (2 elementary and one middle-school) were included.

Between baseline (2 months before Greenway constructed) and follow up (14-months post completion) there were significantly more adults walking and cycling in the intervention location than the control location (median and Inter-Quartile Range): intervention: 13.0 people per 2-hour data collection period compared with 1.0 in the control (p = 0.028). Significance remains when reporting for just walkers (p = 0.002) or just cyclists (p = 0.036), actual figures not supplied.

Total physical activity counts for adults were significantly higher in the intervention compared to control (from 4.5 people to 13.0 in intervention; 3.0 to 1.0 in control; p = 0.001). Intervention change and control change were significantly different for both pedestrian (p = 0.001) and cyclists (p = 0.038) counts.

At follow-up, there were more children undertaking ATS at control schools (median of 19 children per two-hour count) than intervention schools (median of 9 children per two-hour count). This difference was significant (p = 0.026). At baseline, the control group also had higher ATS counts (30) than intervention (8.5). This difference is stated to not be significant (figures not supplied). No significant difference was found between intervention group change, and control group change between baseline and follow up (p = 0.2061).

Goodman et al (2013b [-]) *[linked to Goodman et al 2014 and Sahlqvist et al 2015]* conducted an uncontrolled study to examine how local 'Connect2' interventions in 3 urban areas in the UK are used by adults, and factors associated with use. Interventions consisted of changes to infrastructure, such as the creation of new cycle and walking paths, bridges to improve access and connections in local areas. Adults living within 5km road network distance of any of the three Connect2 interventions were sent postal surveys including a seven-day recall instrument and a short-form of the International Physical Activity Questionnaire (IPAQ). Follow-up 1 was conducted 9 months after initiation of 2 of the interventions. Follow-up 2 was conducted 21 months after initiation of 2 of the interventions and 7 months after initiation of the third intervention.

Reported use of their nearest intervention was 32% at follow up 1, with a further 32% aware of it. By follow-up 2, 38% had used and a further 35% had heard of their nearest intervention. Statistical significance not reported. In terms of walking, 29% of the total sample (92% of those who had actually used the intervention routes) had used the intervention routes for any kind of walking at follow-up 1, rising to 35% at follow-up 2 (91%). In terms of cycling, 13% (39%) of respondents had used the intervention area for any form of cycling at follow up 1, rising to 16% (43%) at follow-up 2. For both cycling and walking, intervention routes were most commonly used for recreation, and least used for education and business. Living closer to the intervention site was a predictor of greater use: those living <1km away compared to those ≥4km away: follow-up 1 RR = 3.62 [2.27, 5.80]; follow-up 2 RR = 3.38 [2.35, 4.87]).

Goodman et al (2014 [-]) [*linked to Goodman et al 2013b and Sahlqvist et al 2015]* conducted an uncontrolled study to investigate the extent to which proximity to Connect2 interventions in 3 urban areas in the UK predicts changes in physical activity levels. Interventions consisted of changes to infrastructure, such as the creation of new cycle and walking paths, bridges to improve access and connections in local areas. Adults living within 5km road network distance of any of the 3 Connect2 interventions were sent postal surveys including a seven-day recall instrument and a short-form of the International Physical Activity Questionnaire (IPAQ) at baseline, follow up 1 and 2. Follow-up 1 was conducted 9 months after 2 interventions running. Follow-up 2 conducted 21 months after first 2 interventions and 7 months after third intervention running.

At follow up 1 no statistically significant evidence was found that proximity to the intervention predicts changes in activity levels. In terms of total walking and cycling an increase of 4.6 minutes per week was found per km closer to the intervention [CI -4.2, 13.4, *p* not reported, but CI demonstrates no statistical significance). For total physical activity an increase of 0.9 minutes per week was found per km closer to the intervention [CI -6.8, 8.5, *p* not reported, but CI demonstrates no statistical significance)

At follow up 2 total walking and cycling was found to increase by 15.3 minutes per week per km closer to the intervention [CI 6.5, 24.2, *p* = <0.001]). When adjusting for outliers, the increase was found to be 9.2 minutes per week per km closer to the intervention [CI 0.6, 17.9, *p* not reported, but CI demonstrates statistical significance]). Total physical activity was found to increase by 12.5 minutes per week per km closer to the intervention [CI 1.9, 23.1, *p* not reported, but CI demonstrates statistical significance]). When adjusting for outliers, the increase was found to be 10.5 minutes per week per km closer to the intervention [CI 1.8, 19.2, *p* not reported, but CI demonstrates statistical significance])

Sahlqvist et al (2015 [+]) *[linked to Goodman 2013b and Goodman et al 2014]* examined differences in awareness and use of local 'Connect2' interventions in 3 urban areas in the UK through a qualitative study. Interventions consisted of changes to infrastructure, such as the creation of new cycle and walking paths, bridges to improve access and connections in local areas. Quantitative survey data and qualitative interviews were used to examine differences between the three sites.

Residents' perceptions of personal safety for walking and cycling, presence of cycle lanes, pleasantness, presence of pavements, having low crime, and paths being well lit all significantly improved between baseline and 2-years post-baseline in Cardiff. Results for the two study areas were mixed: all measures increased for Kenilworth (some with statistical significance), and most increased for Southampton (some with statistical significance) although non-statistically significant reductions were seen for presence of pavement, walk safety, and perceptions of low crime. Qualitative data revealed that residents' perceived need for the schemes varied across sites (see tables for more detail).

Gustat et al (2012 [-]) conducted a controlled before and after study to evaluate the extent to which the installation of a path and playground in a neighbourhood in New Orleans, USA increased community-wide physical activity. The path was 8 foot wide and 6 blocks long, and connected a park in another neighbourhood to a commercial area. The intervention neighbourhood was compared to two control neighbourhoods (one 1.5 miles and the other 5.4 miles from the intervention neighbourhood) with no interventions taking place.

Follow up was conducted about 10 months following implementation of the intervention, with baseline data collected about 1 year before this. The intervention neighbourhood was split into 2 groups – the first was area of path, the second was area of playground. Households were randomly sampled to select participants to be surveyed. In addition, observers collected data by driving through the neighbourhood (not limited to the new path) counting anyone observed being sedentary or engaging in moderate (walking) or vigorous physical activity.

Between baseline and follow up the survey (self-report) revealed that use of the walking trail increased slightly but non-significantly (from 21.9% to 29.6%) p value not reported. The direct observations found a significant increase in the proportion of people engaged in moderate and vigorous activity in those in the area of the path between baseline (36.7%) and follow-up (41.0%) (p = <0.001). No significant change in those in the area of the playground. Whereas in control areas a significant decrease was seen in control area for the path (p = <0.001, no figures provided). No significant change in control area for the playground.

Krizek et al (2009 [-]) [*linked to Poindexter et al 2007]* conducted a controlled study to evaluate the impact of constructing bicycle facilities in Minnesota, USA, including on-street and off-street bicycle paths and bridges, on the share of commuting journeys made by bicycle. Follow up was conducted 10 years from baseline, it is not clear when the interventions were implemented within this time period.

Areas for analysis were defined by: pre-set Traffic Analysis Zones (TAZ), which are areas of land defined by government, typically 100-400 metres across. There were two intervention analysis areas, described as 'buffer 1' (TAZs with a central point within 1.6km of any intervention site) and 'buffer 2' (an extension of the buffer at either end of the trail for 0.8km). Control areas were TAZs with central points greater than 1.6km away from an intervention site.

Between baseline and follow up, bicycle mode share in 'buffer 1' increased from 1.563% of all journeys to 1.775%, a significant result (p not reported); in 'buffer 2' it increased from 1.023% to 1.491% (2 SDs). The control zones also saw an increase from 0.510 to 0.627% (2 SDs).Trips crossing the river by bicycle, between baseline and follow up, also increased significantly (3.021% to 4.604% of all journeys crossing the river, 2SDs). Study authors note that this was in a context of generally increasing bicycle mode share.

Poindexter et al (2007 [-]) *[linked to Krizek et al 2009]* conducted an uncontrolled investigation to examine the impact of building a bicycle facility in Minnesota, USA, on the number of bicycle crashes in the intervention area. The intervention, 'a Greenway' is an off-street bicycle 'expressway' with on-off ramps, it is traffic free, with pedestrian lanes separated from cycling lanes. It forms part of larger network of 73 miles of continuous off-street cycle facilities.

The analysis included cyclists who had undergone an accident which resulted in either bodily injury or $1,000 in property damage within a 2.5km zone around the intervention. Baseline was 3 years prior to the Greenway construction, with follow up post construction.

At baseline, there were 78.33 (SD 8.33) crashes, at follow-up, this reduced to 50 crashes/year (reported as a significant difference, but no p-value or SD given). When the buffer area was stratified by distance from the intervention, this decrease was only significant in 0.0km-0.5km (crashes reduced from 26.57 to 12) and in0.5km-1.0km (crashes reduced from 17 to 15) categories (see evidence table for data relating to longer distances).

Rissel et al (2015 [-]) conducted a controlled before and after study to evaluate the impact of a new 2.4km bi-directional bicycle path separated from motor vehicles in Australia (part of the City of Sydney's expanding bicycle network) on awareness of and use of the bicycle path, and differences in these factors between intervention groups living less than 2.5km from the intervention, and control groups living a similar distance as the intervention groups from the central business district, and with similar demographic profiles. Participants were between 18 and 55, and must have ridden a bicycle before.

Although two objective count locations on the new route demonstrated increased bicycle counts (at location 1 count increased by 23% from 812 at baseline to 1,001 at 4-month follow-up; at location 2 count increased by 97% from 201 at baseline to 395 at 4-month follow-up) and surveys showed significantly higher intervention-group compared with control-group awareness of the new path (intervention 60% aware at 4-month follow-up; control group 19%; p = <0.001), there was no significant change over time in proportion of survey respondents reporting that they had cycled in the past week (intervention 29.2% at baseline to 25.8% at 4-month follow-up; control 22.4% to 23.2% at 4-month follow-up, p-value not clearly reported). Authors note that this could indicate the cycle route funnelling existing riders to the new cycle path, rather than creating new riders.

Despite the stability in numbers reporting that they had cycled in the past week, participants in the intervention area were significantly more likely than participants in the control area to agree/strongly agree that compared to 12 months ago there were more people walking (54% vs 38%, p = <0.001) and more people cycling (75% vs 59%, p = <0.001) in their local area.

West and Shores (2011 [-]) conducted a controlled before and after study to investigate the effect of extending an existing riverside greenway in a midsized Southeastern US city by 5 miles on activity levels of home owners living within 0.5 miles of the greenway in a straight line, compared with home owners living between 0.51 and 1.0 miles away (the control group). This control group is methodologically poor, due to geographical proximity. Statistical significance of differences between groups not reported, but groups appear similar.

Greenways are described by the authors as open-space corridors reserved for recreational use or environmental preservation that connect urban centres.

According to self-reported surveys, both groups saw increases between baseline and 11-month follow-up in the mean number of the past 7 days which the respondent achieved ≥30 minutes of walking (intervention group 3.0 to 3.48 days; control groups 2.48 to 3.10 days), the mean number of the past 7 days in which the respondent achieved ≥30 minutes of moderate PA (intervention group 1.76 to 2.39 days; control groups 1.63 to 2.11 days), and the mean number of the past 7 days in which the respondent achieved ≥20 minutes of vigorous PA (intervention group 1.41 to 1.87 days; control groups 1.25 to 1.71 day). For intervention and control groups combined, increases in walking, moderate-, and vigorous physical activity are significant ($p = 0.003$, 0.000, and 0.000 respectively). However, the difference between the increase in the intervention group, and the increase in the control group is not significant ($p = 0.363$, 0.476, 0.962 respectively)

Authors state that this indicates that nearer participants did not increase their activity significantly more than the further group of participants, and that the control group and intervention group may not have been different enough in distance to observe an effect.

West and Shores (2015 [+]) used a controlled before and after study to evaluate the effect of extending an existing greenway in North Carolina, USA by 1.93 miles on activity levels of home owners living within 1 mile of the greenway in a straight line, compared with home owners living in a neighbourhood located 2-3 miles from the greenway (the control group). Authors state that groups have similar sociodemographic composition.

Results of a self-reported survey demonstrate that the intervention group did not increase their activity significantly more than the control group. Although the mean number of the past 7 days which the respondent achieved ≥30 minutes of walking increased for both groups between baseline and 11-month follow-up (intervention group 2.57 to 2.91; control group 2.71 to 2.88, significance of change scores not reported), differences in change scores between intervention and control were not significant ($p = 0.998$). The mean number of the past 7 days in which the respondent achieved ≥30 minutes of moderate PA decreased for both groups between baseline and 11-month follow-up (intervention group 1.68 to 1.60; control group 1.94 to 1.76, significance of change scores not reported), but differences in change scores between intervention and control were not significant ($p = 0.998$). The mean number of the past 7 days in which the respondent achieved ≥20 minutes of vigorous PA decreased for both groups between baseline and 11-month follow-up (intervention group

1.42 to 1.40; control group 1.86 to 1.51, significance of change scores not reported), but differences in change scores between intervention and control were not significant (p = 0.982).

Authors find that the only significant predictor of activity after the intervention was previous physical activity (walking before intervention predictive of walking after intervention, p <0.00; moderate activity before intervention predictive of moderate activity after intervention, p<0.00; vigorous activity before intervention predictive of vigorous activity after intervention, p<0.00).

Key limitations to the trails and paths studies include the following: variation in length of follow-up between sites, self-selection of participants and lack of survey information at follow-up (Adams and Cavill, 2015); unquantified effects of on-going behavioural interventions, infra-red sensor's inability to detect groups of people walking, and use of only one sensor per trail (Clark et al 2014); variation between projects creating multiple intervention conditions, higher retention in intervention groups and premature follow-up data collection due to delays in intervention installation (Dill et al 2014); lack of description of sample groups or differences between them, use of assessor's judgement to identify who were students [participants] (Fitzhugh et al 2010); low response rates, lack of a comparator city and use of self-reported data (Goodman et al 2013b; Goodman et al 2014); variation in outcome measures at baseline, inability to control for all confounding variables, subjective definitions of vigorous physical activity (Gustat et al 2012); potential self-selection of intervention groups if routes are implemented as a result of demand; lack of description of sample groups or differences between them, lack of clarity of length of follow-up time (Krizek et al 2009); underrepresentation of cycle-cycle accidents or those not resulting in bodily or >$1,000 of property damage (Poindexter et al 2006); sample younger than target population so may not be representative, high loss to follow-up, non-validated survey questions (Rissell et al 2015); potential interviewer bias introduced by multiple interviewers; increase in awareness (one of the outcomes) caused by repeated surveying of the same sample rather than by the intervention (Sahlqvist et al 2015); baseline measures taken after implementation of some interventions, lack of consistency in final follow-up times (Sinnett and Powell 2012); potential contamination between intervention and control groups, subjective measures of moderate and vigorous physical activity (West and Shores 2011); small sample size, self-reported data and short follow-up times (West and Shores 2015).

Applicability: The evidence is only partially applicable to the UK because the studies were conducted in the USA, Australia as well as the UK.

1. Adams and Cavill (2015) [-]
2. Clark et al (2014) [+]
3. Dill et al (2014) [-]
4. Fitzhugh et al (2010) [+]
5. Goodman et al (2013b) [-]
6. Goodman et al (2014) [-]
7. Gustat et al (2012) [-]
8. Krizek et al (2009) [-]
9. Poindexter et al (2007) [-]
10. Rissel et al (2015) [-]
11. Sahlqvist et al (2015) [-]
12. Sinnett and Powell (2012) [-]
13. West and Shores 2011 [-]
14. West and Shores 2015 [+]

<u>Safe routes to schools</u>

5 studies reported on Safe Routes to School (SRTS) interventions. Two controlled before and after studies were included, one was conducted in Denmark [-][4] and one in the USA [-][1]. Three additional US based studies were included; one uncontrolled before and after study [-][5], one cost effectiveness study [+][2], and one study that included a controlled before and after, a qualitative, and a cost benefit section [-][3].

Hoelscher et al (2016 [-]) conducted a controlled before and after study to investigate the effects of schools being allocated an infrastructure SRTS project or a non-infrastructure SRTS project compared with demographically matched unfunded control schools on proportion of students engaging in active commuting to school (walking, cycling, or a combined walking and cycling measure). Infrastructure projects were environmental, for example improving pavements or crossings. Non-infrastructure projects were behavioural only.

No actual figures are presented for this study and no comparison is made between infrastructure and non-infrastructure projects, only with control. Authors state that the increase in percentage of children actively commuting to school in the morning was significantly higher in the infrastructure group (p=0.024) and the non-infrastructure group (p=0.013) compared with the control group. However, the percentage of children actively commuting from school in the afternoon decreased significantly more in the non-infrastructure group than in control group (p=0.009), but non-infrastructure schools still had marginally higher afternoon rates compared with control schools (p=0.084) due to their higher rates at baseline (afternoon change in infrastructure group are not reported).

Infrastructure schools had marginally higher (p = 0.078) and non-infrastructure schools had higher (p=0.036) rates of active school commuting average over the whole day compared with control schools. Results indicate that both infrastructure and non-infrastructure projects may be associated with higher rates of active commuting in the morning, but not in the afternoon.

Muennig et al (2014 [+]) assessed the cost-effectiveness of multiple SRTS programmes which targeted high risk intersections in New York City through various interventions (including construction of new pavements, bus lanes, crossings to calm traffic, improved signage) compared with status quo. Effectiveness was calculated both for whole population, and for school aged children. Costs included SRTS capital costs, injury and death costs, and transportation costs.

Results of the calculations suggest that over a period of 50 years, the programmes may result in large financial savings. Total benefit for school-aged SRTS users in New York City is estimated as $220,826,117. For all pedestrians, the net societal savings was $230,047,354. Quality Adjusted Life Years (QALYs) are also gained: for school-aged SRTS users, the incremental gain is 417 QALYs, compared with status quo. For all pedestrians, the incremental QALYs were 2,055 compared with status quo. This means that the intervention both saves money and results in QALYs gained. Authors state that this analysis is robust to all sensitivity analyses.

Orenstein et al (2007 [-]) conducted a controlled before and after study with a qualitative survey and cost benefit analysis to investigate the effects of multiple SRTS projects in Californian schools with students aged 5-18 on change in active commuting and traffic-related injuries in comparison to nearby schools with no SRTS interventions, and conducted a cost benefit analysis to determine whether projects deliver greater benefits than costs. Projects varied across schools, but included improvements to pavements, traffic calming, improved traffic signals, upgrades to crossings, and bicycle paths. Some behavioural components were also included.

Only three out of 125 participant intervention schools provided active commuting data, and these reported increases of between 8% and 304.5% for walking and between 8% and 160% for biking between baseline and follow-up, compared with a general State-wide trend of decreased active commuting. Large range, potentially rare events in the case of cycling, and varied data collection periods between schools mean this may not be reliable. Although according to State Traffic Records, control areas saw a greater decrease (15%) in traffic-related injuries involving children aged 5-18 between 1998 and 2005 than the intervention group (13%, 95% CI -2%, 23%), authors state that, based on the background trends of decreased active commuting outside of SRTS areas, the estimated road safety benefit of the programme may range from no net change to a 49% decrease in collision rate among children. As these figures involve assumptions, this conclusion is tentative.

Authors consider costs as initial programme costs only, and benefits as avoiding cost of fatalities and injuries to children as a result of SRTS programmes. Results showed that, over one year of the project, the cost of preventing a collision varied from $282,779 to $40,397 depending on the percentage increase in walking and biking delivered by the SRTS programmes (from 10% to 100%). Authors do not draw conclusions on whether or not this justifies the costs of the programme.

Ostergaard et al (2015 [-]) conducted a controlled before and after study to investigate the effectiveness of a school cycling promotion programme implemented at 13 primary schools (“Safe and Secure Cycling to School” [SSCS]) on increasing physical activity, increasing active commuting to school, and decreasing injury frequency of 10-11 year old children in intervention schools compared with children of the same age in 12 control schools in the same city with no intervention. The SSCS programme included environmental interventions (i.e. road surfacing, traffic regulation like one-way streets and car drop-off zones) and behavioural interventions (i.e. competitions, traffic policies, training).

The changes observed in the intervention group between baseline and 1-year post-baseline follow-up and the changes observed in the control group over the same time were not statistically significantly different for any outcome: change in leisure time physical activity (beta coefficient -0.09; 95% Confidence Interval -0.21, 0.03; p = 0.124); change in general method of transport to and from school (beta coefficient -0.02; CI -0.10, 0.05; p = 0.485); change in cycling last week beyond school cycling (beta coefficient -0.04; CI -0.14, 0.05; p = 0.355); change in method of transport to and from school in the past week (beta coefficient 0.15; CI -0.25, 0.54; p = 0.463). This indicates that the programme was not associated with increased physical activity.

There were no significant differences in incidence of traffic injuries, severe traffic injuries, or injury by transport mode between intervention and control group at either baseline or follow-up (see Evidence Table for non-significant figures).

Stewart et al (2014 [-]) conducted an uncontrolled before and after study to investigate assessed changes in rates of active school transport after implementation of SRTS projects in schools in multiple states in the USA between baseline and follow-up, which authors state was usually one to several months after project completion. SRTS projects could be infrastructure (for example improving pavements or crossings), non-infrastructure (behavioural interventions only) or a combination of both, and projects of all types were combined in the analysis – no control was used. Data was obtained from the SRTS database, and only projects with both baseline and follow-up data were included.

When results for all SRTS projects were combined (no analysis was presented comparing infrastructure and non-infrastructure separately), there was a statistically significant increase in all measures of activity compared to baseline. Overall active school transport rates increased by 39% (4.9 percentage points, 12.7% to 17.6%, p = <0.0001). Walking increased by 30% (2.7 percentage points, 9.0% to 11.7%, p=<0.0001), and bicycling increased by 50% (0.8 percentage points, 1.6% to 2.4%, p=0.011) compared to baseline. Authors found a significant negative relationship between baseline rates of bicycling to school, and changes in rates of bicycling to school (p=0.009), indicating that schools with low rates at baseline underwent larger increases than schools with high rates at baseline.

Key limitations to the SRTS studies include the following: selection bias in schools that applied for SRTS funding compared with controls, reporting bias in the omission of actual figures and subjectivity in self-reported measures (Hoelscher et al 2016); lack of consideration of social or health benefits associated with increased exercise underestimating effect (Muennig et al 2014); wide confidence intervals and uncertainty of results due to rare events, variation in data collection methods between schools, potential assessor bias, and low response rates likely to reduce reliability (Orenstein et al 2007); varied and short follow-up periods between projects mean outcome behaviours may not have embedded, presence of significant differences in outcome measures between groups (Ostergaard et al 2015); inclusion of behavioural intervention aspects which could affect results, variation in implementation and data collection methods across projects, and non-representativeness of the sample to the population (Stewart et al 2014).

Applicability: Evidence is only partly applicable to the UK, as four studies were conducted in the USA, and one in Denmark.

1. Hoelscher et al 2016 [-]
2. Muennig et al 2014 [+]
3. Orenstein et al 2007 [-]
4. Ostergaard et al 2015 [-]
5. Stewart et al 2014 [-]

4. Discussion

Strengths and limitations of the review

Overall, the quality of the studies was poor. As noted in section 3.3, none of the studies were graded [++] and only 6 studies were graded [+]. The remaining 24 studies were graded [-]. 5 economic evaluations were identified.

Consistent themes do emerge across the studies:

- Improvements to walking and cycling infrastructure are more likely to impact on the physical activity of people living close by.
- While on street cycle lanes may significantly increase levels of cycling, the absolute increase, in terms of number of individuals, is likely to be very small.

- Changes to physical infrastructure did not always result in participants increasing their physical activity levels significantly more than control groups, this may have been the result of the groups not being different enough in terms of distance to observe an effect.
- Increases in physical activity levels may not be in those people who were previously inactive but rather the result of infrastructure changes funnelling existing cyclists and walkers to new paths/streets/trails.
- Insufficient follow up times may impact of whether interventions were found to significantly increase physical activity levels; adequate time is required to allow behaviour change to take place.
- There is a need to be mindful of what else might be happening in an intervention area; one of the trail studies observed a sharp increase in physical activity levels at mid-intervention owing to a promotional campaign, after which levels tailed off.
- Although health economics data was of low quality, interventions in this review tend to be cost effective.

Several limitations were present across many of the studies, some of which are common to this field of study, and some of which are specific to this review.

Many studies did not use a control group to control for other influences on outcome measures. Of the 30 studies in this review, 16 included control groups. Several do not include enough information on the control group to determine whether it is sufficient to reduce confounding (i.e. no information on distance from intervention site or similarity to intervention group). Four others (Parker et al 2013; Dill et al 2014; Krizek et al 2009; West and Shores et al 2011) use control groups which are unlikely to effectively reduce confounding, normally due to the intervention being so close to the control streets as to cause contamination, or due to intervention population / area being separated from the control with no buffer in between.

For several types of intervention, self-selection occurred where participants were required to apply for funding for particular projects, or where projects are likely to be the result of demand in that area. Several interventions had behavioural elements which may have impacted the outcomes reported, but which could not be separated from environmental aspects. For several studies evaluation methods were inconsistent, particularly where data was collected by participant groups, and for other studies the methods used to count participants were potentially inaccurate. Self-reported data was widely used and may be subject to social desirability bias. Many studies were either unclear about the length of measurement periods and when they took place in relation to the intervention and baseline data collection, or had very short measurement periods. Where studies included multiple areas, results were often high level, obscuring differences in benefits across sites. Finally, there is a lack of reporting on the impact of interventions on those with mobility problems or disabilities.

Further detail of the strengths and weaknesses of individual studies can be found in the evidence tables (Appendix 2).

Adverse effects

Few studies actively considered adverse effects.

- Increasing the number of people engaged in active travel, such as cycling, has the potential to increase the absolute number of accidents, even if these decrease as a proportion of all cyclists. After implementation of the Cycle Demonstration Towns programme, one study (Sloman et al 2009) showed that three out of four towns underwent a non-significant increase in incidents. The remaining town showed a significant decrease. A further study, Poindexter et al (2006) specifically looked at the number of cyclists who had undergone an accident following the installation of a greenway. While the number of accidents was reported to have decreased it only accounted for those which resulted in either bodily injury or $1,000 in property damage and therefore the rate of cycle-cycle accidents is not known.
- Interventions may require additional consideration to make them accessible and available to the population regardless of socioeconomic status, to ensure that they contribute to reducing rather than exacerbating health inequalities. One study of cycling demonstration towns (Goodman et al (2013a) reported that cycling had increased significantly in all quintiles of deprivation but that smaller improvements were seen amongst most deprived.
- The provision of on-street cycle lanes may have been expected to lead to declines in the level of cycling on pavements, however, this was often not the case (for example, see Parker et al (2011) and Parker et al (2013)). This may be perceived as a negative behaviour: in some places it is unlawful, and may also pose a risk to pedestrians and other users of pavements, particularly those with disabilities. If prevalent, it could be speculated that it might discourage these individuals from walking on pavements, or wanting to walk at all. Some types of interventions may even potentially increase levels of pavement cycling, for example, a study by Hendricks et al (2009) of a variety of intervention to increase active commuting observed increases of 63%, 30% of which were cycling, however, of these 69% used the pavement for part of their travel.

- Certain studies observed decreases in physical activity following interventions. Dill et al (2014), for example, found the installation of a bicycle boulevard was statistically significantly negatively correlated with number of bike trips taken ($p = 0.06$). Likewise, Fitzhugh et al (2010) found that following the installation of a greenway, there were more children undertaking active travel to school at control schools than intervention schools (median of 19 children and 9 children per two-hour count respectively, $p = 0.026$).

Applicability

Seventeen of the 30 studies were from the US with 8 from the UK, 1 was from Mexico and USA, 1 from Norway, 1 from Denmark, 1 from Belgium, and 1 from Australia. The applicability of studies from other countries may be limited if cultural differences affect population acceptability and use of public transport, active modes of travel and car ownership, as well as habits related to travel such as riding on pavements. Where these are different from in the UK, this will reduce applicability

Gaps in the evidence

Insufficient evidence was identified to answer the following questions:

- Does effectiveness and cost effectiveness vary for different population groups (no evidence on those less able to be physically active and none on those with disabilities; limited evidence by socioeconomic group; limited evidence for children (except for studies on safe routes to schools))
- Are there any unintended or adverse events (few data reported)
- Who needs to be involved to ensure intervention are effective for everyone (unclear from evidence)
- What factors ensure interventions are acceptable to all groups (some evidence on factors that might ensure acceptability but not for all groups)?

For more information on gaps in the evidence and Expert Testimony, see Appendix 7.

5. Evidence Statements

The committee noted that the majority of studies included in the evidence reviews were considered poor quality. However, they also noted that the body of evidence as a whole indicated a consistent 'direction of travel' whereby sympathetic changes to the environment and/or public transport provision increase physical activity.

The committee noted that the complexity and scale of the interventions makes this an extremely challenging area of research. It may not be possible, practical or ethical to undertake a randomised controlled trial and natural experiments may be the most valid approach. They also noted that variations in methodology used to evaluate the impact of interventions in different groups over different time points meant that the committee did not feel comfortable pooling the heterogeneous outcome data. For example, for the following reasons:

- Physical activity outcomes being presented both as continuous (i.e change in METmins achieved) and dichotomous (i.e. whether guidelines on physical activity were met).

- Outcomes measured at follow-up points which were varied in length i.e. immediately after intervention implementation compared with 18 months after implementation.

Ciclovia / Street Closures

GRADE Evidence Statement 2.1– Ciclovia / Street Closures

One study from the USA[1] with 589 participants presented very low quality evidence showing implementing street closures may contribute to participants meeting the recommended 150 minutes of physical activity, as an average of 19.4% participants over three events met the recommendation.

One study from Belgium[2] with 122 participants presented low quality evidence showing that implementing play streets increased time spent engaging in moderate and vigorous physical activity in children when compared to children residing in non-participating streets.

The same study also presented very low quality evidence showing implementing play streets had no effect on mean minutes of sedentary time per day. The study from the USA[1] presented very low quality evidence that between 34% and 55% of individuals attending the street closures events would have been sedentary if they had not attended the events.

[1]Torres et al, 2016

[2]D'Haese et al, 2015

Non-GRADE Evidence Statement 2.2: Ciclovia Cost Benefit

One cost benefit analysis[1] with high risk of bias [-] conducted in Mexico and USA reported data suggesting that Ciclovia programmes are cost effective.

According to the HEAT model, the benefit cost ratio (BCR) for the programme in Mexico was 1.02-1.23 (between $1.02 and £1.23 in benefits for every $1 in costs). For the programme in the USA, the BCR was 2.32 ($2.32 in benefits for every $1 in costs). The difference in the medical cost for an active person and their inactive counterparts must be $51.10 in Mexico and $269.40 in the USA to achieve a ratio over 1. As this was achieved in both instances, both programmes were beneficial.

[1] Montes et al (2011) [-]

Trails and Paths

GRADE Evidence Statement 2.3 – Improvement of cycle infrastructure for active commuting

One USA study[1] with 1853 participants presented very low quality evidence that improvement of cycle infrastructure (including installation of bike lanes, extension of an existing trail, new bike racks in public places and bike carriers on public buses) increased the total number of active commuters by 63% (of which 67% were walking and 30% were cycling) at 1 year follow up.

[1]Hendricks et al, 2009

GRADE Evidence Statement 2.4 – Cycle Demonstration Towns

One UK study[1] examining data from 6 towns with 1,266,337 participants presented very low quality evidence showing that introducing a variety of cycling interventions (included school travel planning; cycle facilities at schools, pedestrian bridges) increased the proportion of individuals self-reporting that they cycle regularly (≥30 minutes ≥12 times per month) by 0.9 percentage points, and increased observed cycling by 27% (absolute numbers not reported) between baseline and 1-3 years follow up. The same UK study presented very low quality evidence that introducing a variety of cycling interventions increased active travel (cycling to work) in intervention towns compared to the control groups at 10 year follow up.

One UK study[2] with more than 9000 participants presented very low quality evidence showing that introducing a variety of cycling interventions decreased the number of respondents describing themselves as inactive by 2.6 percentage points at 3 year follow up.

One UK study[1] presented low quality evidence that introducing a variety of cycling interventions increased public transport use by 0.32%-points, decreased driving by 3% between baseline and follow up and increased walking by 1.71% at 10 years follow up. Cycling increased in all quintiles of deprivation although smaller improvements were seen amongst most deprived areas.

[1]Goodman et al, 2013a

[2]Sloman et al, 2009

Non- GRADE Evidence Statement 2.5: Cycle Demonstration Towns [CDTs]

One study[1] with a high risk of bias [-] based in the UK conducted a cost-benefit analysis which presented data suggesting that CDTs are likely to be cost saving.

For every £1 spent on the CDT programme, between £2.60 and £3.50 of benefits are reported to be accrued due to reduced mortality, accidents and absenteeism, as well as decongestion and amenity impacts.

[1] Department for Transport 2010 [-]

GRADE Evidence Statement 2.6 – Various on-street and off-street bicycle paths and bridge improvements

One USA study[1] presented very low quality evidence showing that introducing on-street and off street bicycle paths and bridge improvements increased the proportion of all journeys which were taken by bicycle in those living within 1.6km of the intervention in relation to other types of transport by between 0.21 and 0.47 percentage points (13.4 – 45.9% increase) between baseline and 10 year follow up.

[1]Krizek et al 2009

GRADE Evidence Statement 2.7 – A new greenway for cyclists

One USA study[1] presented very low quality evidence showing that a new greenway for cyclists decreased the number of reported accidents involving cyclists by 28 crashes (from 78 crashes to 50) per year within 2.5km radius at 1 to 2 year follow up, this reduction was only meaningful up to 1km from the intervention.

[1]Poindexter et al 2007

GRADE Evidence Statement 2.8 – Extension of the existing greenway

Two USA studies[1, 2] with 343 participants presented very low quality evidence that extending a greenway made no difference to the mean number of days spent engaging in at least 30 minutes of walking, moderate and/or vigorous physical activity in residents living within 1 mile of the greenway (at 11 month / 1 year follow up).

[1]West and Shores 2011

[2]West and Shores 2015

GRADE Evidence Statement 2.9 – Improvement to routes (Infrastructural changes)

One UK study[1] with 3541 participants presented very low quality evidence showing that improving trail routes increased the number of pedestrians walking along the route by 14.9% at 3-19 months follow up.

[1]Adams and Cavill 2015

GRADE Evidence Statement 2.10 – Bicycle only road and off street bicycle facility

One Australian study[1] with 1396 participants presented very low quality evidence showing that introducing a bicycle boulevard and off street bicycle facility increased cycling along the route by 23% and 97% compared to 3% across the control areas at 4 month follow up.

One USA study[2] with 154 participants presented very low quality evidence showing that introducing a bicycle only road and off street bicycle facility had no effect on the number of participants taking cycling and walking trips.

The same study also presented very low quality evidence showing that introducing a bicycle only road[1] and off street bicycle facility increased the proportion of participants taking bicycle journeys, however, the mean minutes spent cycling (of trips lasting more than 10 minutes) decreased from 103.9 minutes (SD 73.0) to 65.9 minutes (SD 74.7) between baseline and 2-12 month follow up.

[1]Rissel et al 2015

[2]Dill et al 2014

GRADE Evidence Statement 2.11 – 6 trails with new way-finding signage

One USA study[1] presented very low quality evidence showing that introducing way finding signage had no impact on the mean number of trail users at 1-9 months follow up.

[1]Clark et al 2014

GRADE Evidence Statement 2.12 – Greenway/Path connecting residential and commercial areas

One USA study[1] presented very low quality evidence showing that introducing a greenway connecting residential and commercial areas increased the number of individuals walking (p=0.001) and cycling (p=0.038) but had no effect on the number of children engaging in active transport to school at 14 month follow up.

[1] Described as a boulevard

One USA study[2] presented very low quality evidence showing that introducing a greenway connecting residential and commercial areas increased the proportion of individuals observed engaging in moderate and/or vigorous physical activity by 4.3 percentage points and 2 percentage points ($p<0.001$) respectively. The same study presented very low quality evidence showing that the same intervention had no effect on the proportion of people reporting use of the trail for leisure and for transportation between baseline and 10 months follow up.

[1]Fitzhugh et al 2010

[2]Gustat et al 2012

GRADE Evidence Statement 2.13 –Connect2 interventions including traffic free bridges and new riverside boardwalks

One UK study reported in two publications[1] with 3516 participants presented very low quality evidence showing that Connect2 interventions (including traffic free bridges and new riverside boardwalks) increased walking and cycling along the intervention routes. The study also presented very low quality evidence showing a decrease in moderate to vigorous physical activity at both 9 months and 21 months follow up. There was no association between the proximity of residents to the intervention route and time spent on either walking, cycling and moderate to vigorous physical activity at one year follow up, however individuals residing 1 km away from the intervention had an increase of between 9.2 min/wk and 15.3 min/week spent in walking and/or cycling at 2 years follow up.

The same study presented very low quality evidence showing that the respondents had greater awareness of the three Connect2 interventions (including traffic free bridges and new riverside) boardwalks at 1 year follow up compared to baseline and reported use was greater in the area with the highest proportion of awareness.

[1]Goodman et al 2013b, Goodman et al 2014

Non-GRADE Evidence Statement 2.14: Connect2 interventions including traffic free bridges and new riverside boardwalks

One mixed methods study[1] with low risk of bias [+] based in the UK included qualitative interviews with 17 participants to explore the use and impact of Connect2 interventions (including traffic free bridges and new riverside boardwalks) in three sites (Cardiff, Kenilworth, and Southampton), prior to implementation.

Expected primary use of the intervention, whether mainly commuting or mainly recreational, varied between sites, depending on whether affected routes led into a main town (mainly commuting), or across countryside (mainly recreational).

Where current trails were perceived as particularly unsafe or isolated, there was a higher perceived need for the improvements. In order for routes to be well used, participants reportedly perceived coherence of destinations and feeder routes to be important.

[1] Salhqvist et al 2015 [+]

GRADE evidence statement 2.15: On-Street Cycle Lanes

Four studies with 19,535 participants, one from Norway[1] and three from USA[2, 3, 4], presented low quality evidence showing that introducing on-street cycle lanes, separated from traffic by road markings only, increased the number of cyclists counted per day at 3 to 11 months follow up (increases of between 17 and 224.6%). Baseline numbers ranged from 9 to 91 cyclists observed per day, and at follow-up ranged from 10 to 257 cyclists observed per day.

Two studies[3,4] based in the USA with 6,297 participants presented low quality evidence that implementing on-street cycle lanes increased the percentage of cyclists cycling with traffic rather than against it at 3 to 6 months follow up (between 2.8 and 8.5%-point increase, or between 3 and 11.6% increase)).

Three studies[1,3,4] with 6,297 participants, two from the USA and one from Norway, presented very low quality evidence that on-street cycle lanes had mixed effects on the percentage of cyclists riding on the pedestrian sidewalk. One study[1] reported a decrease in the proportion of cyclists cycling on the pavements - 47% to 23% in one street and 22% to 5% in another street from baseline to follow up. The same study reported that cyclists stated they cycled less on the pavements in the intervention streets after counter-flow cycling was permitted, however pedestrians felt more insecure on these intervention streets. The two remaining studies[3,4] reported no change in the proportions of cyclists cycling on the pavements (24.6% to 24.4%, p=0.90 and 93% to 93%; p= 0.8, respectively) at 3 to 11 months follow up.

[1] Bjornskau et al 2012

[2] Hunter et al 2009

[3] Parker et al 2011

[4] Parker et al 2013

Non-Grade Evidence Statement 2.16: Fitter for Walking programme

One study[1] with high risk of bias [-] based in five locations in the UK conducted a cost-benefit analysis which presented data suggesting that Fitter for Walking programmes may deliver benefits in excess of costs in some situations. The study reported benefit cost ratios (BCRs) for the project by individual location when using a) self-reported journey duration per week and b) self-reported journey distance per week at 14-20 month follow-up. HEAT, which takes into account only mortality benefits, was used.

Results found that using journey duration produced BCRs below 1 (i.e. lower benefits than costs) for 2 of the five locations (-9.6:1; -0.4:1), and above 1 for three locations (2.2:1; 46:6; 3.7:1). When using journey distance, three of five locations had BCRs below 1 (-6.6:1; 0.9:1; -4.1:1) and 2 had BCRs above 1 (9.6:1; 34:1). BCRs appear to be strongly affected by initial project costs: the most expensive programme (London: £104,481) had BCRs below 1 for both measures, and the only location with BCRs above 1 for both measures had the lowest costs (Wolverhampton: £6,917)

[1] Sinnett and Powell 2012 [-]

Safe Routes to Schools

GRADE evidence statement 2.17: Safe Routes to School [SRTS]

Two studies from the USA[1,2] targeting school children presented very low quality evidence showing that SRTS interventions (such as improved sidewalks and crossings, speed reduction, traffic signals, car drop off zones and non-infrastructure projects which were behavioural in nature) increased rates of active commuting to school in children at 1-month to 3-year follow-up. However one of these studies[1] presented very low quality evidence that these interventions did not increase total physical activity (number of days children achieved ≥30 mins outdoor physical activity), and another study[4] presented very low quality evidence that interventions did not cause a change to time children spent in leisure time physical activity.

One Danish study[4] with 2,401 participants presented very low quality evidence that SRTS interventions had no effect on changing the proportions of children cycling to school, contradicting two studies from the USA[2,3] which targeted school children and presented very low quality evidence that these interventions increased the percentage of children walking to school (by between 2.8 and 304.5%), and increased the percentage of children cycling to school (by between 0.8 and 160%) at 1-month to 7-year follow-up.

Two studies from the USA[3] and Denmark[4] targeting 2,401 students (reported by one study – the second does not report participant numbers) presented very low quality evidence that introducing SRTS interventions did not change the proportion of children involved in traffic incidents.

[1]Hoelscher et al 2016

[2]Stewart et al 2014

[3]Orenstein et al 2007

[4]Ostergaard et al 2015

Non-GRADE Evidence Statement 2.18: Safe Routes to School [SRTS]

One mixed methods study with high risk of bias [-] based in the USA included a qualitative survey to gather perceptions of changes in safety in schools which had implemented SRTS, with 114 SRTS projects providing responses.

The study reported that students, parents, teachers, administrators and school bus operators all appreciated the improved safety measures. It also reported that designated drop-off zones and areas for school traffic improved safety and decreased disruption to non-school traffic.

[1]Orenstein et al 2007 [-]

Non-Grade Evidence Statement 2.19: Safe Routes to School [SRTS]

Two studies considered costs of SRTS programmes; one of which reported data suggesting SRTS programmes are cost effective[1], and the other presenting too little data to be conclusive[2]. The first was a cost effectiveness study[1] with low risk of bias [+] based in the USA, and the second was a mixed methods study[2] with a cost benefit analysis with high risk of bias [-] also based in the USA.

The cost effectiveness study[2] results suggested that over a period of 50 years, savings are made both when considering school-aged SRTS users ($220,826,117) and all pedestrians ($230,047,354). QALYs are also gained for both school-aged SRTS users (417 QALYs) and all pedestrians (2,055 QALYs) compared with status quo, indicating that the intervention both saves money and results in QALYs gained.

The study looking at costs and benefits[2] did not report cost benefit ratios however, reported instead the cost per collision prevented for different levels of increased walking and biking. This ranged from $282,779 per collision reduced for a 10% increase, to $40,397 per collision reduced for a 100% increase.

[1] Muennig et al 2014 [+]

[2] Orenstein et al 2009 [-]

6. References for Review 2 included studies

Adams Emma J, and Cavill Nick. (2015). Engaging Communities in Changing the Environment to Promote Transport-Related Walking: Evaluation of Route Use in the 'Fitter for Walking' Project. *Journal of Transport & Health*, 2, pp.580-594.

Bjornskau Torkel, Fyhri Aslak, Sorensen Michael, and W J. (2012). Counter-flow cycling: Evaluation of counter-flow cycling in one-way streets in Oslo city centre. pp.51.

Clark S, Bungum T, Shan G, Meacham M, and Coker L. (2014). The effect of a trail use intervention on urban trail use in Southern Nevada. *Preventive Medicine*, 67(S1), pp.S17-S20.

Department for Transport, 2010. *Cycling Demonstration Towns Development of Benefit-Cost Ratios*. Department for Transport.

D'Haese S, Van Dyck , D , De Bourdeaudhuij , I , Deforche B, and Cardon G. (2015). Organizing "Play Streets" during school vacations can increase physical activity and decrease sedentary time in children. *International Journal of Behavioral Nutrition and Physical Activity*, 12(1), no pagination.

Dill Jennifer, McNeil Nathan, Broach Joseph, and Ma Liang. (2014). Bicycle boulevards and changes in physical activity and active transportation: findings from a natural experiment. *Preventive medicine*, 69 Suppl 1, pp.S74-8.

Fitzhugh Eugene C, Bassett David R, Jr, and Evans Mary F. (2010). Urban Trails and Physical Activity: A Natural Experiment. *American Journal of Preventive Medicine*, 39(3), pp.259-262.

Goodman A, Panter J, Sharp S J, and Ogilvie D. (2013a). Effectiveness and equity impacts of town-wide cycling initiatives in England: A longitudinal, controlled natural experimental study. *Social Science & Medicine*. 97: 228-237.

Goodman A, Sahlqvist S, and Ogilvie D. (2013b). Who uses new walking and cycling infrastructure and how? Longitudinal results from the UK iConnect study. *Preventive Medicine*, 57(5), pp.518-524.

Goodman Anna, Sahlqvist Shannon, Ogilvie David, and iConnect Consortium. (2014). New walking and cycling routes and increased physical activity: one- and 2-year findings from the UK iConnect Study. *American journal of public health*, 104(9), pp.e38-46.

Gustat Jeanette, Rice Janet, Parker Kathryn M, Becker Adam B, and Farley Thomas A. (2012). Effect of changes to the neighborhood built environment on physical activity in a low-income African American neighborhood. *Preventing chronic disease*, 9, pp.E57.

Hendricks Kristin, Wilkerson Risa, Vogt Christine, and TenBrink Scott. (2009). Transforming a small Midwestern city for physical activity: from the sidewalks up. *Journal of physical activity & health*, 6(6), pp.690-8.

Hoelscher Deanna, Ory Marcia, Dowdy Diane, Miao Jingang, Atteberry Heather, Nichols Donna, Evans Alexandra, Menendez Tiffni, Lee Chanam, and Wang Suojin. (2016). Effects of Funding Allocation for Safe Routes to School Programs on Active Commuting to School and Related Behavioral, Knowledge, and Psychosocial Outcomes: Results From the Texas Childhood Obesity Prevention Policy Evaluation (T-COPPE) Study. *Environment and Behavior*, 48(1), pp.210.

Hunter William, W , Srinivasan Raghavan, Martell Carol, and A . (2009). An Examination of Bicycle Counts and Speeds Associated with the Installation of Bike Lanes in St. Petersburg, Florida. pp.37.

Krizek, K. J., Barnes, G., and Thompson, K, 2009. Analyzing the effect of bicycle facilities on commute mode share over time. *Journal of Urban Planning and Development*. 135(2):66.

Montes et al., 2011. Do health benefits outweigh the costs of mass recreational programs? An economic analysis of four ciclovia programs. *Journal of Urban Health: Bulletin of the New York Academy of Medicine*. 89(1).

Muennig Peter A, Epstein Michael, Li Guohua, and DiMaggio Charles. (2014). The cost-effectiveness of New York City's Safe Routes to School Program. *American journal of public health*, 104(7), pp.1294-9.

Orenstein Marla, R , Gutierrez Nicolas, Rice Thomas, M , Cooper Jill, F , Ragland David, and R . (2007). Safe Routes to School Safety and Mobility Analysis. pp.74.

Ostergaard Lars, Stockel Jan Toftegaard, and Andersen Lars Bo. (2015). Effectiveness and implementation of interventions to increase commuter cycling to school: a quasi-experimental study. *BMC public health*, 15, pp.1199.

Parker Kathryn M, Gustat Jeanette, and Rice Janet C. (2011). Installation of bicycle lanes and increased ridership in an urban, mixed-income setting in New Orleans, Louisiana. *Journal of physical activity & health*, 8 Suppl 1, pp.S98-S102.

Parker Kathryn M, Rice Janet, Gustat Jeanette, Ruley Jennifer, Spriggs Aubrey, and Johnson Carolyn. (2013). Effect of bike lane infrastructure improvements on ridership in one New Orleans neighborhood. *Annals of behavioral medicine : a publication of the Society of Behavioral Medicine*, 45 Suppl 1, pp.S101-7.

Poindexter Gavin, Krizek Kevin, J , Barnes Gary, and Thompson Kristen. (2007). Optimization of Transportation Investments: Guidelines for Benefit-Cost Analysis of Bicycle Facilities: Refining Methods for Estimating the Effects of Bicycle Infrastructure on Use and Property Values. *U.S. Department of Transportation*.

Rissel C, Greaves S, Wen L M, Crane M, and Standen C. (2015). Use of and short-term impacts of new cycling infrastructure in inner-Sydney, Australia: A quasi-experimental design. *International Journal of Behavioral Nutrition and Physical Activity*, 12(1), pp.1.

Sahlqvist S, Goodman A, Jones T, Powell J, Song Y, and Ogilvie D. (2015). Mechanisms underpinning use of new walking and cycling infrastructure in different contexts: Mixed-method analysis. *International Journal of Behavioral Nutrition and Physical Activity*, 12(1), no pagination.

Sinnett, D., and Powell, J., 2012. Economic evaluation of Living Streets' Fitter for Walking project. *British Heart Foundation national Centre for Physical Activity and Health*.Slater Sandy, Pugach Oksana, Lin Wanting, and Bontu Anita. (2016). If You Build It Will They Come? Does Involving Community Groups in Playground Renovations Affect Park Utilization and Physical Activity?. *Environment and Behavior*, 48(1), pp.246.

Sloman L, Cavill N, Cope A, Muller L, and Kennedy A. (2009). Analysis and synthesis of evidence on the effects of investment in six Cycling Demonstration Towns. pp.33p.

Stewart Orion, Moudon Anne Vernez, and Claybrooke Charlotte. (2014). Multistate Evaluation of Safe Routes to School Programs. *American Journal of Health Promotion*, 28(3), pp.S89-S96.

Torres Andrea, Steward John, Strasser Sheryl, Lyn Rodney, Serna Rebecca, and Stauber Christine. (2016). Atlanta Streets Alive: A Movement Building a Culture of Health in an Urban Environment. *Journal of physical activity & health*, 13(2), pp.239-46.

West S T, and Shores K A. (2011). The impacts of building a greenway on proximate residents' physical activity. *Journal of Physical Activity and Health*, 8(8), pp.1092-1097.

West Stephanie T, and Shores Kindal A. (2015). Does building a greenway promote physical activity among proximate residents?. *Journal of physical activity & health*, 12(1), pp.52-7.