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Shifting from car to active transport: A systematic review of the effectiveness of interventions

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ABSTRACT

Introduction: A promising way to stimulate physical activity is to promote the choice for active modes of transport (walking and cycling). Over the past years, several interventions and policies have been implemented to stimulate this mode shift. However, information concerning the effectiveness of these interventions and policies is still limited. The aim of the present study was to systematically review the effectiveness of interventions designed to stimulate a shift from car use to cycling or walking and to obtain insight into the intervention tools that have been used to promote and/or implement these interventions.
Methods: Five databases were searched and articles published in English, Dutch, German, Danish, Norwegian and Swedish were included. Only studies that focussed on a mode shift from car use towards active transport in a general adult population, which were published in peer reviewed journals and which investigated effectiveness were included. Intervention tools used were categorized by using the model of Hoogerwerf & Herweijer, as either legal, economic (subsidy, reward system, penalty), communicative (written materials, behavioural tools) and physical tools (providing bicycles, providing better bicycle facilities at work, adjustment of the environment).
Results: Nineteen studies met our inclusion criteria. Studies included described workplace-based interventions, architectural and urbanistic adjustments, population-wide interventions, and bicycle-renting systems. Nearly all studies (except three) showed positive effects concerning a mode shift. Most of the included studies used more than one intervention tool and the tools used differed between types of interventions. However, information about the statistical significance of these results was often lacking and the study methodologies used were not of high quality.
Conclusion: Nearly all studies showed results in a positive direction. However, the quality of the included studies was mostly low and intervention characteristics were poorly described.

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1. Introduction

Globally 5.3 to 5.7 million deaths from non-communicable diseases could theoretically have been prevented in 2007, if people who were inactive would instead have been sufficiently active (Kohl et al., 2012). Therefore, interventions effectively stimulating physical activity are of great importance. One way to stimulate physical activity is by influencing people's choices regarding transport modes in favour of active transport modes (walking or cycling for the purpose of going somewhere). Several studies have shown that active transport has a protective effect on cardiovascular outcomes (Hamer and Chida, 2008) and is inversely associated with Body Mass Index (BMI), obesity, triglyceride levels and insulin levels (Gordon-Larsen et al., 2009). The Toronto Charter for Physical activity stated that transport policies and systems that prioritize active transport are amongst the best investments for stimulating physical activity since active transport is the most practical and sustainable manner to increase physical activity on a daily basis (Global Advocacy for Physical Activity (GAPA) the Advocacy Council of the International Society for Physical Activity and Health (ISPAH), February, 2011).

Stimulating active transport by enhancing the substitution of short distance car trips by walking or cycling (active transport) trips has generally become a common objective of transport policies (Ogilvie et al., 2004). In the recent past, at least three reviews investigating the effectiveness of interventions on a mode shift have been published (Ogilvie et al., 2004, 2007; Pucher et al., 2010; Yang et al., 2010). Our study differs from the earlier reviews in a couple of ways. First of all, we included studies that report on effect measures either on both ends of the shift or effects within subject on changing transport mode. This included either or both walking and cycling at the one end of the shift and car use at the other end. Other studies were less strict and included studies reporting on either one of these effect measures. Second, we included studies irrespective of size. Whereas, others focused only on population-wide strategies. And third, we restricted our review to studies published in peer-reviewed journals as opposed to other reviews additionally including studies from grey literature. Although several interventions targeting a mode shift have been developed and published, information concerning the effectiveness of these interventions on inducing a mode shift is missing (Pucher et al., 2010). The aim of the present study was not only to gain knowledge about the possible effectiveness of interventions with the aim to induce a mode shift from car trips to walking and/or cycling, but we also tried to obtain insight into the intervention tools that have been used in these interventions. To this end, we systematically reviewed studies that have investigated the effects of interventions that aim to stimulate a mode shift from passive to active transport. The results of this study may help to develop suitable policies/interventions inducing a mode shift.

2. Methods

2.1. Search strategy

We searched five electronic databases (Medline, Embase, SciSearch, Social SciSearch, PsycInfo) for studies investigating the effectiveness of an intervention on a mode shift from passive to active transport, published from the earliest possible start date up until 18 March 2014. We chose to not specifically include a start date, since existing reviews did not match our research question closely enough to perform an updated search. In this study, we only focused on peer-reviewed articles and thus we did not search databases such as TRID (Transport Research International Documentation) or databases set-up as part of international projects like THE PEP (Transport, Health and Environment. Pan-European Programme). In our opinion, a first step in gaining knowledge about the effectiveness of intervention with the aim to induce a mode shift is to be aware of the results of interventions published in peer-reviewed research papers. Because of situational differences between for example cities, a second step will be to investigate policy measures/interventions implemented in the area of interest. This second step, however, has not been done in this study.

The search strategy used is depicted in Fig. 1. Articles published in English, Dutch, German, Danish, Norwegian and Swedish were included. We evaluated the identified studies on their suitability for data-extraction first by abstract and eventually by reading the full text. If the researchers disagreed about the eligibility of a publication when evaluating the studies on abstract, the full text of the study was checked. If there was disagreement in the phase of evaluating studies on full text reviewers discussed arguments until agreement was reached. Studies that met the following criteria for data-extraction were included: the studies (i) had to investigate and quantify the effect on a mode shift of one or more interventions that aimed for a mode shift from car use towards active transport; and (ii) had to be performed in a general adult study population (18 years or over). The search strategy resulted in 2106 records (after exclusion of duplicates). All records were examined by two researchers (CS, WWV). Based on the examination of abstracts, 2015 publications were excluded (Fig. 2). Of the remaining 91 publications, full texts were retrieved, completely read and again assessed for matching our inclusion criteria. The reviewers disagreed about the inclusion of the study of Cairns et al. (2010). After discussing the arguments concerning inclusion and exclusion, it was decided to exclude this study since the methodology of this study was biased (selection bias since only positive case studies were selected and no access to the original results of the case studies). A total of 55 studies were excluded, which left us with eleven studies (twelve publications) and 25 reviews. The main reasons for exclusion were no information on effectiveness on a mode shift and no intervention study. Reference lists of the eleven included studies were also screened, which resulted in no additional studies. The reference lists of these 25 reviews were also examined, which resulted in eight additional studies included in this systematic review. In total, 20 publications were eligible for data extraction. Of these 20 publications, two publications described the same study (Merom et al., 2005, 2008) which left us with nineteen original studies.

	NO	SEARCH EXPRESSION
C=	1	ME66; EM74; IS74; IN73; PI67
S=	2	FT=(ACTIVE COMMUT*;ACTIVE TRANSPORT*;ACTIVETRAVEL*;BICYCL*; BIKE*;BIKING;CYCLE HIRE;CYCLING;CYCLIST*;ECOLOGICAL COMMUT*; ECOLOGICAL TRANSPORT*;ECOLOGICAL TRAVEL*; GREEN* COMMUT*;GREEN TRANSPORT*;GREEN TRAVEL*;GREENWAY*;NON-AUTO)/TI
	3	FT=(NON-MOTORISED;NON-MOTORIZED;PEDESTRIAN*;WALK*)/TI OR CT=(BICYLING;CYCLING;WALKING)
	4	FT=(ACTIVE COMMUT*;ACTIVE TRANSPORT*;ACTIVE TRAVEL*;BICYCL*; BIKE*;BIKING;CYCLE HIRE;CYCLING;CYCLIST*;ECOLOGICAL COMMUT*; ECOLOGICAL TRANSPORT*;ECOLOGICAL TRAVEL*;GREEN* COMMUT*; GREEN*TRANSPORT*;GREEN TRAVEL*;GREENWAY*;NON-AUTO)/(AB;CT;UT)
	5	FT=(NON-MOTORISED;NON-MOTORIZED;PEDESTRIAN*;WALK*)/(AB;CT;UT) OR CT=(BICYLING;CYCLING;WALKING)
	6	(FT=(PHYSICAL ACTIV*)/TI OR CT=(MOTOR ACTIVITY;PHYSICALACTIVITY)) AND (4 OR 5)
	7	2 OR 3 OR 6
	8	FT=(AUTOMOBILE*;AUTO USE*;CAR;CARS;COMMUT*;CONGESTED;CONGESTION; DRIVER*;MECHANISED TRANSPORT*;MECHANIZED TRANSPORT*;MOTORING; MOTORIST*;MOTOR* TRANSPORT;MOTORIZED TRANSPORTATION;PERSONAL TRANSPORT*;ROADUSE*;TRAFFIC;VEHIC*)/(TI;AB;CT;UT)
	9	CT=(TRANSPORTATION;TRAFFIC;TRAVEL) OR CT D (MOTOR VEHICLES;MOTOR VEHICLE)
	10	8 OR 9
	11	FT=(MODAL;MODE)/TI AND FT=(ANALYS*;ANALYZ* CHOICE*;DISTRIBUTION; EFFECT*;SELECTION*;SHIFT;SPLIT*;SUBSTITUT*;SWITCH*;TRANSFER*; TRANSPORT*;USE*)/TI
	12	FT=(TRANSPORT*;TRAVEL)/TI AND FT=(BEHAVIOR;BEHAVIOUR;CHANG*; DEMAND*;HABIT*;IMPACT*;PATTERN*;SHIFT*;SUBSTITUT*)/TI
	13	FT=(DECREAS*;DISCOURAG*;DISINCENTIV*;ENCOURAG*;INCENTIV* ;INCREAS*; INTERMODAL DISTRIBUTION;MODE;TRANSPORT;PROMOT*;REDUC*;RESTRAIN*; RESTRICT*)/TI
	14	CT=(HEALTH BEHAVIOR;HABITS;HABIT;BEHAVIOR;BEHAVIOR) OR FT=(PROXIMITY;PROXIMATE)/TI
	15	11 OR 12 OR 13 OR 14
	16	FT=(INTERVENTION*;TRIAL;TEST;POLICY;POLICIES;PROGRAM;PROGRAMS; CAMPAIGN;PROJECT;PROJECTS;SCHEME;PROMOTING;PROMOTION;PROMOTE; ENCOURAG*;INCREAS*;IMPACT;PATTERN;PATTERNS;SHIFT)/TI
	17	FT=(INTERVENTION*;TRIAL;PROGRAM;PROGRAMS;PROJECT;PROJECTS; CAMPAIGN)/(AB;CT;UT)
	18	CT=(HEALTH PROMOTION;HEALTH PLAN IMPLEMENTATION;INTERVENTION STUDIES;INTERVENTION STUDY;PILOT PROJECTS;PILOT STUDY;PROGRAM DEVELOPMENT;PROGRAMEVALUATION;META-ANALYSIS;META ANALYSIS; ENVIRONMENT DESIGN) OR CT D (CLINICAL TRIALS;CLINICAL TRIAL)
	19	16 OR 17 OR 18
	20	7 AND 10 AND 19
	21	7 AND 10 AND 15
	22	FT=(AUTOMOBILE*;AUTO USE*;CAR;CARS;COMMUT*;CONGESTED;CONGESTION;
	30	FT=(SAFETY;SAFE BEHAVI?R;ACCIDENT*;CRASH*;INJUR*;TRAUMA;HELMET*; ALCOHOL* ;STAIR CLIMBING)/TI OR CT=(ANIMALS;ANIMAL)
	31	FT=(CARDIOVASCULAR;CARDIOPULMONARY;CARDIORESPIRATORY;CARDIAC; CORONARY;ARTERIAL;VASCULAR;BLOOD PRESSURE;BODYCOMPOSITION; OBESITY)/TI
	32	FT=(OBESE;DIET*;FOOD;EATING;DIABET*;OSTEO*;ARTHRIT*;LIPO PROTEIN*; OXYGEN;ENDURANCEEXERCISE;AEROBIC EXERCISE;STRETCHING;MUSCLE ACTIVATION;MUSCLEACTIVITIES;METHANE CYCLING;PHOSPHATE CYCLING)/TI
	33	FT=(CHILD*;INFANT*;ADOLESCENT*;NEWBORN;NEONATAL;PRENATAL)/TI OR CT=(CHILD;INFANT) OR (CT=ADOLESCENT NOTCT=ADULT)
	34	FT=PATIENT*/(TI;CT;UT) OR CT=(PATIENT;PATIENTS)

Fig. 1. Search strategy abbreviations: ME66 = Medline, EM74 = Embase, IS74 = SciSearch, IN73 = Social SciSearch, PI67 = PsycINFO, FT = free term, /TI = searched in title, CT = controlled term, AB = abstract, DT = document type, UT = uncontrolled term, CT D = controlled term with all underlying keywords, ∗=truncation sign: stem word + all possible endings, LA = language.

2.2. Data-extraction

From the included studies, we extracted information regarding (i) study characteristics: year of publication, location of study, methodology, ascertainment of outcome indicators, measurement moments; (ii) study population; (iii) the intervention: aim, design, who initiated/commissioned the intervention; (iv) measurement of the effectiveness of the intervention:

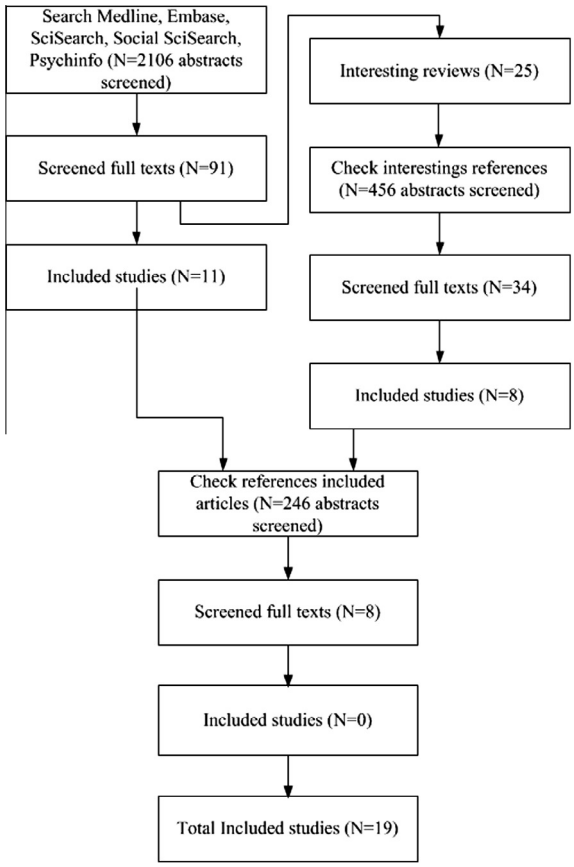

Fig. 2. Flow chart of included studies ∗ given numbers are the numbers after the exclusion of duplicate.

results and significance; (v) tools used in the different interventions since interventions can be made up of different tools. In analysing the intervention tools used, we used the model mentioned by Hoogerwerf & Herweijer (Hoogerwerf and Herweijer, 2008). In this model, a distinction is made between legal, economic, communicative and physical tools. For the economic tools we made a distinction between subsidy, reward systems and penalties. Communicative tools were distinguished in written materials and tools aimed at directly changing the behaviour of persons (behavioural tools) and for the physical tools a distinction was made between on the one hand adjustments in the environment in general, and on the other hand the provision of better bicycle facilities and the provision of bicycles.

3. Results

Studies were categorised into four categories. Of the nineteen studies included in this systematic review, six were work-place-based interventions focussing on a mode shift from car to active transport for commuting purposes. Eight studies focused on architectural and urbanistic adjustments with the purpose of stimulating a mode shift. Population-wide interventions to stimulate a mode shift were evaluated by another three studies and two studies focussed on a bicycle-renting system. More detailed information about the included studies can be found in Tables 1–3.

3.1. Work-place-based interventions

Six studies focused on the effectiveness of work-place-based interventions on a mode shift for trips made for commuting purposes. Mutrie et al. (2002) described effectiveness of the "Walk in to Work Out" pack implemented at three workplaces in the city of Glasgow, Scotland. This self-help intervention promoted active commuting through educational and practical information. The intervention targeted those who were considering active commuting and those who were irregular active commuters. Written materials and behavioural intervention tools were used to stimulate active transport, namely educational and practical information on choosing routes, maintaining personal safety, shower and safe cycle storage information, useful contacts, an activity diary in the form of a wall chart, a workplace map, distances from local stations, local cycle retailers and outdoor shops, contacts for relevant organisations, local maps, and reflective safety accessories. Participants

Table 1
Characteristics of included studies.

Study	Location	Study characteristics			Study population	Intervention			Effectiveness of the intervention
		Design	*Ascertainment of outcome indicators*	*Measurement moment(s)*		*Design*	*Aim*	*Initiator*	*Results*
Work-place based interventions									
Mutrie et al., 2002	Glasgow, Scotland	Randomised controlled trial	Questionnaires and focus groups	Baseline, 6 months	Employees of three workplaces in the city of Glasgow Baseline: intervention: $n = 145$ Control: $n = 150$ 6 months: Intervention: $n = 102$ Control: $n = 92$	Walk in to work out pack: a self-help intervention promoting active transport through educational and practical information.	Increase of active commuting behaviour	Researchers	*Questionnaire:* • Increase in walking time for the group that never walked before ($n = 14$) as well as for the already walking group ($n = 61$) compared to the control group (significant). • An estimated average relative increase in the time spent walking to work was found for someone given the intervention of 1.93 times (95%CI: 1.06–3.52) any increase in walking time for a corresponding control who walked the same amount at baseline. • No differences were found for cycling time. *Focus groups:* Declining regular lifts in other peoples' cars, using public transport more and in one instance selling the car were methods used for changing behaviour in favour of active transport modes.
Merom et al., 2005	Australia	Before-after study	Questionnaire	Pre-campaign questionnaire, Post-campaign questionnaire	1100 employed adults livings in major Australian metropolitan areas	Walk to Work day: an annual short-term campaign encouraging more walking, reduced car use and increased public transport among urban-dwelling working adults.	Encourage walking, reduce car use and increase the use public transport among urban-dwelling working adults	Governmental and non-governmental agencies with interests in transport, the environment and health	• Decreases in "car only"(-3.1%, not significant) and "public transport only" trips (-6.3%, $p < 0.005$) were accompanied by a significant increase in trips that combined walking and public transport to work (+9%, $p < 0.005$) in New South Wales. • In other metropolitan areas there was a significant increase in "walking/cycling only" (+3.2%, $p < 0.05$). However, this increase was offset by a significant decrease in the proportion combining walking and public transport (−7.3%, $p < 0.05$).*
Brockman and Fox, 2011	Bristol, UK	Ecologic study, comparing groups in time	Questionnaire	Baseline, 1 year	Staff members of Bristol University: 1998, $n = 2292$ 2001, $n = 2332$ 2003, $n = 1950$ 2005, $n = 2647$ 2007, $n = 2829$	Workplace transport plan, including parking measures, improvement of changing facilities, cycle storage, a subsidized bicycle purchase scheme, a car-sharing scheme and public transport measures.	Ease congestion, parking problems, and release parking spaces for building	University and city council	• Increase from 19 to 30% in respondents reporting they usually walk to work. • Increase from 7 to 12% in respondents reporting they usually cycle to work, but year comparisons with 2007 failed to reach significance. • Decrease from 50 to 33% in respondents usually commuting by car ($p < 0.001$)

Table 1 (*continued*)

Study	Location	Study characteristics			Study population	Intervention			Effectiveness of the intervention
		Design	*Ascertainment of outcome indicators*	*Measurement moment(s)*		*Design*	*Aim*	*Initiator*	*Results*
Wen et al., 2005	Sydney, Australia	Before-after study	Questionnaire	Baseline, 1 year	51 health service employees working in the Queen Mary Building	Workplace active transport programme consisting of both a social marketing strategy and an individualized marketing strategy	Increase of active commuting behaviour	Unknown	• Increase from 37 to 45% in staff reporting use of active transport modes as their usual mode of transport to work ($p = 0.125$). • Reduction of 20% in the proportion of staff reporting driving 5 days a week ($p = 0.012$)
O'Fallon, 2010*	New Zealand	Before-after study	Questionnaire	Baseline, 1 year	1587 employees of the 27 joining workplaces	Bike Now Programme: Aim of this programme was to explore specific actions that are suitable to stimulate people to take up and/or continue to cycle to work.	Explore specific "actions" that could be undertaken to encourage people to take up (and continue) cycling to work	Unknown	• 32% of the 675 respondents answering the question if they rode their bike more to work stated that they were cycling to work more often than before the intervention. • 150 (69%) of those riding more frequently said they were riding "over one hour more per week", while the remainder were riding up to "1 h more per week". • Nearly one-half (49%) said they replaced "drive a car" with cycling trips. • 20.3% of the 1553 respondents answering the question if they ride their bike more often for other reasons than going work, stated that they cycled more often than before the intervention.
Shoup, 1997	California	Before-after study	Questionnaire	Baseline and 1, 2 & 3 years after cashing out began (depending on the length of time for which post-cash-out data were available)	1694 employees of the 8 firms that have complied with California's cash-out requirements	Cashing out employer-paid parking	Reduce traffic congestion and reduce air pollution	Unknown	• Decrease from 76 to 63% in solo-driver share at the eight firms. • Increase from 14 to 23% in carpool share. • Increase from 6 to 9% in transit share. • Increase from 3 to 4% in the combined walk and bicycle share.
Architectural and urbanistic adjustments									
Arentze et al., 2001	Voorhout, The Netherlands	Before-after study	Activity diaries	Baseline (before opening of the railway station), 1 year	360 inhabitants of Voorhout	Opening of a new railway station	Unknown	Unknown	• Significant change between 1997 and 1998 in percentage car drives, slow modes, public transport users and car passengers ($\chi^2 = 46.65$). • Decrease of 20% in the car driver mode. • Increase of 12% in travelling as a slow mode. • Increase of 130% in travelling as a car passenger.
Burbridge and Goulias, 2009	West Valley (Utah), US	Before-after study	Questionnaire and activity diaries (AD)	Baseline,4 months (prior to the trail's construction; AD1), 1 year (AD2; one month after the neighbourhood trail construction), 1 year and 5 months (AD3)	Households living within one mile of the (proposed) trail in West Valley Baseline: $n = 796$ AD1: 175 AD2: 144 AD3: 107	Development of a neighbourhood trail	Serve the public as both a transportation and recreation facility	Unknown	• Increase from 81.4 to 87.3% from AD1 to AD3 in car use. • Decrease from 13.7 to 9.9% in walking from AD1 to AD3. • Decrease from 0.6 to 0.5% in cycling from AD1 to AD3. • Significant decrease in the total number of walking trips taken ($p = 0.008$). (No information concerning a significant change for car trips)

(*continued on next page*)

Table 1 (*continued*)

Study	Location	Study characteristics			Study population	Intervention			Effectiveness of the intervention
		Design	*Ascertainment of outcome indicators*	*Measurement moment(s)*		*Design*	*Aim*	*Initiator*	*Results*
Topp and Pharoah, 1994	Bologna, Italy; Lubeck, Germany; Aachen, Germany	Ecologic study, comparing groups in time	Amongst other things, traffic counts were used.	Bologna, Lubeck & Aachen: unknown	Unknown	Car-free city centre	Increase the attractiveness and economic vitality of the city centres by reducing the presence of parked and moving vehicles, and encouraging access by "urban compatible" means of travel	Unknown	*Bologna* • A reduction of more than 60% in the total number of passenger cars entering and leaving the town. • Most people visiting the town take the bus (78%), only a few use the car (11%) or go by bike or motorbike (8%) *Lubeck:* • 40 to 80% less cars entering the city centre (depending on the time of the day). • Out of those who formerly drove by car into the city centre, 12% switched to public transport, cycling and walking. *Aachen:* • Decrease from 44 to 36% in car use for travel to the centre. • At the same time the proportion of travel on foot and by bus increased.
Weisbrod, 1982	Boston, US	Before-after study	Questionnaires and counts	Baseline, 1 year (during construction), 2 year (after project completion)	Questionnaires: pedestrians, area employees, bus riders, parking lot users, and merchants. Counts: unknown	Boston's Downtown crossing automobile restricted zone	Increase the attractiveness and economic vitality of the city centres by reducing the presence of parked and moving vehicles, and encouraging access by "urban compatible" means of travel	Unknown	• A decrease from 0.11 to 0.06 (a 45% drop) in the automobile mode proportion for Downtown Crossing visitors. • An increase in the number of pedestrians entering the Downtown Crossing centre of 11% for weekdays and of 10% for Saturdays.
Meland, 1995	Trondheim, Norway	Before-after study	Questionnaires and travel diaries	1 year before (n = 6000) and 1 year after (n = 3900) the introduction of the Toll Ring	Household members over the age of 13 in a random sample of 4000 households in the Trondheim administrative area	The Trondheim Toll Ring	Raise revenue to be used to finance the 'Trondheim package' (includes a range of improvements to the local transport system)	Unknown	• Results do not give evidence that the Toll Ring reduced the overall car use during the whole week. • The Toll Ring seems to have caused a ahift in timing of car trips, away from the toll charging periods to the periods when no tolls are charged. • In Trondheim as a whole there was a decrease in bicycle trips of 14 to 15 per cent. However there was no change for the inbound trips. • There was a decrease in walking trips during all time periods. This decrease was slightly smaller during the tolled periods.
Jones, 2012	Stafford, UK	Cross-sectional study	Questionnaire	¾ year after completion of The Isabel Trail	Residents living in the Beaconside neighbourhood: n = 111 Residents living in the Rickerscote neighbourhood (control area): n = 94	UK National Cycle Network	Encourage people to take up cycling for the first time or to start cycling again	Sustrans	• Levels of cycling were perceived to be declined slightly in both neighbourhoods. • Walking and car driving has been increased slightly in both neighbourhoods.

Table 1 (*continued*)

Study	Location	Study characteristics			Study population	Intervention			Effectiveness of the intervention
		Design	*Ascertainment of outcome indicators*	*Measurement moment(s)*		*Design*	*Aim*	*Initiator*	*Results*
Thakuriah et al., 2012	Chicago, US	Before-after study	Interviews	1 till 3 years after completion	Users of the implemented facilities: $n = 228$	8 bicycle and pedestrian facilities implemented in the metro area	Decrease air pollution	US federal Congestion Mitigation and Air Quality program	• Users of the pedestrian paths were more likely to have been switched from single occupant vehicle (SOV) than users of the bicycle paths. Nearly 21.5% of the pedestrian path users compared to 11% of the bicycle path users.
Goodman et al., 2013	England	Longitudinal, controlled natural experiment	English census data	1981, 1991, 2001, 2011	Inhabitants of the intervention towns and the comparison towns	18 town-wide cycling initiatives tailored to the specific setting consisting of a mixture capital investment and revenue investment	Increase cycling levels, increase the proportion of the population cycling, increase safety levels when cycling	/	• Comparison of the intervention group with the matched comparison group showed an intervention effect of + 0.69 (95%CI: 0.60–0.77) percentage points on cycling to work. An increase of 0.73 (95%CI: 0.59–0.87) percentage points was found for walking to work. • An intervention effect of -1.39 (95%CI: -1.57 - -1.20) percentage points was found for driving to work.
Population-wide interventions									
Thomas et al., 2009	Columbia, US	Cross-sectional study	Questionnaire	6 weeks after the bicycle proficiency classes	Adults participating in the bicycle proficiency education classes	Bicycle proficiency education classes (Bike, Walk and Wheel Week)	Encourage citizens of Columbia to use nonmotorized modes of transportation for recreation and transportation	The non-profit PedNet Coalition	• 75% of the respondents rode their bike more often. • 35% of the trips made by car were replaced with bicycle trips.
Alcott and DeCindis, 1991	Phoenix, US	Before-after study	Telephone interviews, traffic counts and bus ridership analysis	Interviews: February 24 to March 1 Traffic counts and bus ridership analysis: unknown	Interviews: 701 licensed drivers living in Maricopa County who own or lease at least one motor vehicle. Traffic counts and bus ridership analysis: unknown	Clean Air Force's "Don't Drive 1-in-5" campaign (October 11 till February 28)	Decrease air pollution	Unknown	• Interviews showed a decrease of 3% in driving alone as commuting mode and an increase of 1% in commuting by bike. • Traffic counts showed that morning commuter traffic was down by approximately 2% during the 1989–1990 campaign. However, all-day counts were virtually unchanged. • An increase in bus ridership during the campaign was found.
James and Brög, 2001	South Perth, Australia	Before-after study	Questionnaire	Baseline (1997), 4 months after the programme was delivered (2000)	Participants of the programme in the city of South Perth	Travelsmart® Individualised Marketing programme	Converting car trips to walking trips	Unknown	• Decrease of 14% in car driver mode use. • Increases of 35% in walking, 61% in cycling and 9% in being a car passenger. • Walking captured half of the changed car trips to alternative modes.
Bicycle renting system interventions									
Noland and Ishaque, 2006	London, England	Retrospective (cross-sectional study)	Questionnaire	1 year after the start of the pilot	46 customers of the smart bicycle system	Smart bicycle system	Increase and accommodate bicycle use.	Unknown	• 21% of the respondents shifted from walking to using the smart bicycle system. • 6% stated they shifted from car use to using the smart bicycle system.
Fuller et al., 2013	Montreal, Canada	Cross-sectional study	Telephone survey	At the end of the first and second season of implementation	Individuals (18 years and older) residing on the Island of Montreal First season measurement (2009): $n = 2502$ Second season measurement (2010): $n = 2509$	Public bicycle share program	Increase population access to cycling	Unknown	• 18% and 21% of the public bicycle share program users reported replacing walking trips with trips made with the public bicycle in 2009 and 2010 respectively. • 7.9% and 10.1% of the public bicycle share program users reported replacing motor vehicle use with trips made with the public bicycle in 2009 and 2010 respectively.

(*continued on next page*)

Table 1 (*continued*)

Study	Location	Study characteristics			Study population	Intervention			Effectiveness of the intervention
		Design	*Ascertainment of outcome indicators*	*Measurement moment(s)*		*Design*	*Aim*	*Initiator*	*Results*
									• However, 23.6% and 21.8% of the public bicycle share program users reported replacing trips made by their personal bicycle with trips made by the public bicycle in 2009 and 2010 respectively. • A modal shift of 5% of the trips were day was assumed based on the estimates of the total number of new trips generated by the public bicycle share program.

* Subgroup analyses are not omitted in this review.

Table 2
Tools used in the included interventions.

	Legal tools	Economic tools			Communicative tools		Physical tools		
		Subsidy	*Reward system*	*Penalty*	*Written materials*	*Behavioural tools*	*Providing bicycles*	*Providing better bicycle facilities at work*	*Adjustment of the environment*
Work-place based interventions									
Mutrie et al. (2002)					X	X			
Merom et al. (2005)					X	X			
Brockman and Fox (2011)		X		X		X	X	X	X
Wen et al. (2005)			X		X	X			
O'Fallon (2010)						X	X	X	
Shoup (1997)	X		X						
Architectural and urbanistic adjustments									
Arentze et al. (2001)									X
Burbridge and Goulias (2009)									X
Topp and Pharoah (1994)	X								X
Weisbrod (1982)	X								X
Meland (1995)				X		X			
Jones (2012)									X
Thakuriah et al. (2012)									X
Goodman et al. (2013)					X	X		X	X
Population-wide interventions									
Thomas et al. (2009)						X			
Alcott and DeCindis (1991)			X		X	X			
James and Brög (2001)						X			
Bicycle renting system interventions									
Noland and Ishaque (2006)							X		
Fuller et al. (2013)							X		

were matched according to the distance travelled to work (three categories with cut-off's at two and five miles) and then randomly assigned to a control and intervention group. The intervention group received the "Walk in to Work Out" pack immediately and the control group received the pack after six months. Measurement moments were at baseline, after six months and after 12 months. Focus groups were conducted after data from the six months measurement moment were collected. Results after six months showed a significant larger average time per week spent walking to work for those in the intervention group compared with the control group. For non-walkers (i.e., those who had not walked to work at the start of the study) a sample means of 125 min per week was found for the intervention group ($n = 14$) and of 61 min per week for the control group ($n = 12$). For walkers (i.e., those who already walked to work at the start of the study) the sample mean in the intervention group ($n = 61$) increased from 52 min per week at baseline to 79 min per week at six months, and the sample mean in the control group ($n = 43$) increased from 50 to 60 min per week. No differences were found for cycling time. Methods used by the participants to change their behaviour in favour of active transport modes were: adding walking to bus journeys by getting of the bus early; walking to the next bus stop; declining regular lifts in other peoples' cars, using public transport more; parking further away from normal destinations; taking a bicycle in the car and parking at the end of cycle route; and in one instance selling the car. Measurements performed after 12 months showed that the percentage of the control group changing their travel behaviour was the same as the results after six months for the intervention group. 25% ($n = 36$) of the intervention group ($n = 145$) had become regular active commuters after 12 months. Since no (quantitative) information was given concerning the effect on car use, it was unknown if a significant mode shift occurred.

Merom et al. (2005) described the effect of an Australian Walk to Work Day (WTWD) campaign initiated by governmental and non-governmental agencies with interests in transport, the environment and health. WTWD is an annual short-term campaign encouraging more walking, reduced car use and increased public transport among urban-dwelling working adults by using both written materials and behavioural intervention tools: newspaper advertisements and community service announcements through the major free-to-air television channels and radio stations. The campaign was coordinated by a

Table 3
Overview of the outcomes of the included studies.

	Effect on active transport use			Effect on car driving	Total effect on a mode shift		
	Walking	Cycling	Walking and cycling or not specified		Cross-sectional study	Cohort study (results on population level)	Cohort study (results on individual level)
Work-place based interventions							
Mutrie et al. (2002)	+	0		–			+
Merom et al. (2005)	+/0	+/0		–		+	
Brockman and Fox (2011)	+	+		–	+		
Wen et al. (2005))			+	–		+	
O'Fallon (2010)*		+		–		+	
Shoup (1997)			+	–	+		
Architectural and urbanistic adjustments							
Arentze et al. (2001)			+	–		+	
Burbridge and Goulias (2009)	–	–/0		+		–	
Topp and Pharoah (1994)			+	–	+		
Weisbrod (1982))	+			–	+		
Meland (1995)	–	–		0	0		
Jones (2012)	+	–		+	0		
Thakuriah et al. (2012))	+	+		–	+		
Goodman et al. (2013)	+	+		–	+		
Population-wide interventions							
Thomas et al. (2009)		+		–	+		
Alcott and DeCindis (1991)		+		–	+		
James and Brög (2001)	+	+		–	+**		
Bicycle renting system interventions							
Noland and Ishaque (2006)	–	+		–	+		
Fuller et al. (2013)	–	+		–	+		

+ indicates an increase, – indicated a decrease and 0 means no effect.
* subgroup analyses are not omitted in this review.
** based on the results reported it is not possible to categorize this study, but it is highly likely that it is a cross-sectional study.

public-relations company in New South Wales, which also distributed promotional goods to interested councils and involved local councils in promoting community awareness and organizing local activities. Government departments also promoted the event among their employees through their intranet networks and by displaying posters in the workplaces. Pre-campaign (2–14 September) and post-campaign questionnaires (7–28 October) were used to determine the effect of the WTWD (3rd of October) (Merom et al., 2008). A decrease of 3.1% in trips only made by car and a decrease of 6.3% only made by public transport were found in New South Wales. A significant increase of 9% was found in trips that combined walking and public transport. However, in other metropolitan areas, an increase in "car only" trips was found (not significant) and although there was a significant increase in "walking/cycling only" this was offset by a significant decrease in the proportion combining walking and public transport. Overall, no significant effect on a mode shift was found.

Brockman and Fox (2011) investigated the effectiveness of a workplace transport plan, implemented at the University of Bristol in the United Kingdom, including the following economic, communicative and physical intervention tools: severely limited parking spaces and conditions for permits, increased parking charges, improved changing facilities for walkers and cyclists, new secure cycling storage, a subsidised bicycle purchase scheme, a car-sharing scheme, a free university bus service that served local train and bus stations, and discounted season tickets on buses. In addition, the Bristol City Council reduced the availability of non-resident parking in areas surrounding the University in 2001. The comparison of a travel questionnaire, which was posted to every staff member of the University of Bristol between 1998 and 2007 showed a significant effect on a mode shift. The number of respondents usually walking to work (four to five times per week) increased from 19% to 30%. The number of respondents usually cycling to work increased from 7% to 12% (but a year comparison with 2007 failed to reach significance) and decreased significantly from 50% to 33% for usually commuting by car.

Wen et al. (2005) evaluated a workplace transport plan in a health care setting implemented in Sydney, Australia. A combination of both social and individualised marketing strategies were used. The social marketing strategy consisted of four

events promoting active transport, specific campaign materials, e-mail newsletters, and messages on payslips and flyers (communicative intervention tools). During the events promoting active transport, an incentive of a healthy breakfast/lunch was provided (economic tool). The individualized marketing strategy was only delivered to the recruited study participants (communicative tool). This strategy was delivered in three stages, where in the final stage a transport plan was developed with the participant for the journey from home to work. A before-after analysis showed an increase from 37% to 45% of staff reporting use of active transport as their usual mode of transport to work after one year (not significant). Nevertheless, there was a significant reduction of 20% in the proportion of staff who reported driving to work five days a week. Since effects on active transport were not significant, overall no significant effects on a mode shift were found in this study. On Sundays, also a significant change in mode choice was found. An increase of 10% was found for staff members reporting trips without using a car and a 14% decrease in members reporting taking car trips "three to four times". However, this pattern of change was not found for weekdays.

O'Fallon (2010) investigated the effectiveness of the Bike Now programme implemented in 27 workplaces in New Zealand. The aim of this programme was to explore specific actions that are suitable to stimulate people to take up and/or continue to cycle to work. In this case, the focus was on interventions designed to overcome general misperceptions about cycling. Initiatives offered were the following communicative and physical intervention tools: improved/more secure bicycle parking, bicycle skills workshops, bike buddying (including route planning), bike bus, workplace bicycle fleet, bicycle 'lease', puncture workshops and provision of ironing facilities. Not every initiative was implemented in every workplace, since the focus was on identifying those interventions that had the greatest potential for successful implementation and uptake of cycling to work. In total, 27 workplaces made efforts to implement Bike Now initiatives. The questionnaire results showed that 32% of the 675 respondents, answering the question if they rode their bike to work more often, stated that they were cycling to work more often than before the intervention (one year earlier). 150 (69%) of those more frequently riding their bicycle said they were riding "over one hour more per week", while the remainder were riding up to "1 h more per week". Nearly one-half (49%) said they replaced "drive a car" with cycling trips. 20.3% of the 1553 respondents answering the question if they rode their bike more often for other reasons than going to work stated that they bicycled more often than before the intervention.

The last workplace based intervention was cashing out of employer-paid parking. In the study of Shoup (1997) eight case-studies in California, where a parking cash-out programme was implemented, were evaluated. In California, in 1992, a law was implemented that required employers of 50 or more persons who subsidize commuter parking to offer a parking cash-out programme. The aim of this parking cash-out programme was to reduce air pollution by stimulating people to choose for other transport modes than solo driving by making people aware that even a free parking space has an opportunity cost (the foregone cash). An economic tool (reward system) consisting of a cash allowance was offered by employers to employees who are not using their parking spaces because they are using other transport modes. This cash allowance is equivalent to the parking subsidy that the employer would otherwise pay to provide the employee with a parking space. Mode shares were measured in the base year, and in the first, second, or third year after cashing out began, depending on the length of time for which post-cash-out data were available. As a result of the cashing out of the employer-paid parking the solo-driver share at the eight firms fell from 76% to 63%, the carpool share rose from 14% to 23%, the transit share rose from 6% to 9% and the combined walk and bicycle share rose from 3% to 4%.

3.2. Architectural and urbanistic adjustments

Eight different studies focussing on architectural and urbanistic adjustments with effects on a mode shift were found. One of these studies investigated the effectiveness of the implementation of a new railway station (physical tool) in the Netherlands on a mode shift (Arentze et al., 2001). A questionnaire held under the inhabitants of Voorhout (n = 360) before and one year after the opening of the railway station showed that the new railway station resulted in a 10.6% decrease in the use of car driving as well as an increase of 5% in travel as a slow mode. Nevertheless, travelling as a car passenger also increased by 3.9%. Stratification for work/school trips showed a similar pattern with a decrease in car use of 10.5% and increases of 1.9% and 5% for respectively slow modes and travelling as a car passenger.

Another architectural and urbanistic adjustment stimulating a mode shift is the building of a neighbourhood trail (physical tool) in West Valley City in Utah (Burbridge and Goulias, 2009). The aim of the neighbourhood trail was to provide the public with a facility for transportation as well as recreation. The trail was adjacent to two major schools and created a 2.5 miles loop connecting two currently existing sidewalks. A questionnaire and three activity diaries were used to investigate the effectiveness of this intervention. As a result of the construction of the neighbourhood trail, car use increased from 81.4% to 87.3% after approximately five months. In the same period, walking decreased from 13.7% to 9.9% and bicycle use remained nearly the same.

In two studies the effectiveness of the introduction of car-free city centres and automobile-restricted zones was investigated. Topp and Pharoah (1994) described four case studies of car-free city centres of which the following three (Bologna, Italy; Lubeck, Germany; Aachen, Germany) report on the effectiveness of a mode shift. A car-free city centre is a city centre were motor traffic is limited by an area-wide ban to that which is considered to be functionally necessary (legal tool). In these city centres, city governments make efforts to increase the attractiveness and economic vitality by reducing the presence of parked and moving vehicles and by encouraging access by urban compatible means of travel (physical tool). Though, it is important to note that is does not necessarily imply a reduction of total vehicle kilometres driven in the city as a whole. The effectiveness of the different case studies was tested by comparing groups in time (e.g. traffic count). In Bologna, motor

vehicles were restricted in the old town between 7 am and 8 pm (legal tool). However, it should be mentioned that a large number of exemptions were present (about 25,000 residents' cars, 15,000 delivery vehicles and 10,000 holders of private parking spaces). This excess control was supplemented by limited parking space. As a result of this car restriction the total number of passenger cars entering and leaving the old town was reduced by more than 60% and most people visiting the town took the bus (78%), only a few used the car (11%), and 8% travelled by bike or motorbike. In Lubeck a car ban was implemented in three stages. First cars were restricted only on Saturdays when shops are open the whole day (one Saturday each month). Second, cars were restricted every weekend (Saturdays and Sundays) and third, cars were restricted for the whole week between 10 am and 6 pm (except for residents, deliveries and hotel access). Public transport facilities were improved during these car-free days. As a result of the car ban there was a reduction of 40–80% of cars (depending on the time of the day) entering the city centre. Twelve percent of the respondents switched to public transport, cycling and walking. Nevertheless, 58% of the respondents still used the car to get as near as possible to their destination and 30% used park-and-ride. Another positive mode shift was found in Aachen where on shop-open Saturdays a 100 hectare part of the city was closed to general traffic from 10 am to 5 pm. A reduction of 36% was found for cars entering the city centre as a whole and at the same time, there was an increase in walking and public transport (no numbers available). When we only look at the part of the city where the car-free city ban was implemented, then there was a reduction from 21% to 15% in car use after nearly 16 months. An increase from 71.8% to 77.5% was found for walking and the proportion cycling remained the same.

Weisbrod (1982) investigated the effectiveness of the Downtown Crossing project implemented in Boston in the US. The primary objective of this project was to encourage pedestrian activity and ultimately strengthen the retail area. In this project, vehicular traffic was separated from the main shopping streets with high pedestrian volumes (legal tool). Physical intervention tools used were the widening of sidewalks, streamlining the automobile pattern in a more direct pattern of primary streets. On-street parking was also eliminated to improve traffic flow and transit use was encouraged by the addition of bus services to the automobile restricted zones. Moreover, some physical improvements were made to make the retail area more attractive. The effectiveness of this intervention was tested by questionnaires and traffic counts. As a result of the Downtown Crossing project, after two years a 11% increase in pedestrians entering the intervention area was found for weekdays and a 10% increase for Saturdays. This increase in pedestrian volumes is largely attributable to the presence of a large office work force nearby. During the investigated period, there was a 5% increase in downtown office employment, which in itself would account for a 2% increase in pedestrian volume. The automobile mode proportion decreased from 0.11 to 0.06 (a 45% drop) for Downtown Crossing visitors.

Meland (1995) investigated the effectiveness of the Trondheim Toll Ring implemented in Trondheim, Norway. This Toll Ring started operating on 14 October 1991 and the main aim was to raise revenue to be used to finance the 'Trondheim package' (includes a range of improvements to the local transport system). The Toll Ring was aligned in such a way that 60% of the inhabitants were living outside the boundary, while the majority of jobs, shops, recreational and other public services are inside the boundary. Operating hours are from Monday to Friday, 6 am till 5 pm. Toll was collected from inbound traffic only and public transport vehicles and motorcycles are exempted (economic tool). In the last months before opening of the Toll Ring a vigorous promotional campaign was held and tags were handed out free of charge (communicative tool). The effectiveness of this intervention was tested by questionnaires and travel diaries. Results do not give evidence that the Toll Ring reduced the overall car use during the whole week nor did it increase active transport. However, a shift in the timing of car trips was found. In fact, in Trondheim as a whole there was a decrease in bicycle trips of 14 to 15 percent. However there was no change in the number of bicycle trips for the inbound trips. A decrease in walking trips was found during all time periods. This decrease was slightly smaller during the tolled periods.

Another study included, investigated the effectiveness of the UK National Cycle Network on a mode shift (Jones, 2012). As part of this UK National Cycle Network, which is a policy intervention aimed at creating a cycling culture initiated by Sustrans, The Isabel Trail was constructed in Stafford. Respondents living in a neighbourhood close to the Isabel Trail (Beaconside neighbourhood) were compared with respondents living in a neighbourhood where the traffic-free paths of the National Cycle Network are far less accessible (Rickerscote neighbourhood). Data were collected by using questionnaires. Comparison of the questionnaires of the respondents living in the two neighbourhoods showed that levels of cycling were perceived to be slightly declined in both neighbourhoods. On contrary, levels of walking and car use were increased slightly in both neighbourhoods. Overall, no effect on a mode shift was found in this study.

Thakuriah et al. (2012) evaluated the implementation of 3 bicycle and 5 pedestrian facilities implemented in the metro area of Chicago in the US. The project was initiated by the US federal Congestion Mitigation and Air Quality program. Bicycle facilities implemented were bike paths or lanes and all the pedestrian facilities were sidewalks (physical tools). A questionnaire was conducted at each intervention site and a total of 228 respondents participated in this study. Results showed that the users of the pedestrian paths were more likely to switch from single occupant vehicle (SOV) than users of the bicycle paths, respectively 21.5% of the pedestrian path users versus to 11% of the bicycle path users.

The last architectural and urbanistic adjustment we included in this review was the implementation of 18 town-wide cycling initiatives implemented in England (Goodman et al., 2013). Aim of these initiatives was to increase cycling levels, increase the proportion of the population cycling and increase the safety levels when cycling. These cycling initiatives were tailored to the specific setting and consisted of a mixture of capital investment and revenue investment. In this study a combination of physical tools (e.g. building cycle lanes, creating cycle parking) and communicative tools (e.g. promotional activities, cycle training) was used. English census data were used to evaluate the effectiveness of these interventions in which the travel behaviour of inhabitants of the intervention towns was compared with comparison towns. Results showed

an intervention effect of +0.69 (95% CI: 0.60–0.77) percentage points on the prevalence of cycling to work. An increase of 0.73 (95% CI: 0.59–0.87) percentage points was found for the prevalence of walking to work. An intervention effect of −1.39 (95% CI: −1.57 to −1.20) percentage points was found for the prevalence of driving to work.

3.3. Population-wide interventions

Three population-wide interventions were found with the aim to induce a mode shift. All three used behavioural intervention tools. Of which one intervention used a combination of intervention tools. Thomas et al. (2009) evaluated the effect of a bicycle proficiency education programme (behavioural tool) during the Bike, Walk and Wheel Week, which is an annual event designed to encourage citizens of Columbia to use non-motorized modes of transportation for recreation and transportation during a designated week in May. During the programme, approximately 300 children and adults completed the bicycle proficiency classes. A questionnaire conducted under the adult graduates six weeks after the classes showed that 75% rode their bicycles more often and 35% of the automobile trips were replaced with bicycle trips.

The Clean Air Force Campaign in Phoenix in the US aimed to decrease air pollution by asking drivers to reduce their vehicle-miles by not driving their car one day a week (behavioural tool; Alcott and DeCindis, 1991). Campaign participation was stimulated by using various media, for example, radio, TV and newsletters (communicative intervention tools) and by the opportunity to win prizes when participating (reward system). Telephone interviews under 701 licensed drivers living in Maricopa County who own at least one motor vehicle showed a decrease of 3% in driving alone as a commuting mode compared to one year earlier. For cycling with the purpose of commuting, an increase of 1% was found. Traffic counts showed that morning commuter traffic was down by approximately 2% during the 1989–1990 campaign. However, all-day counts remained virtually unchanged. In addition, an increase in bus travel was found during the campaign.

James and Brög (2001) evaluated the effect of a TravelSmart® individualised marketing strategy, implemented in South Perth, Australia, aiming at a mode shift from car driving to walking, public transport, cycling and tele-access (behavioural tool). The large-scale application of this intervention was delivered to 35,000 people in 15,300 households. The project was delivered in February to June 2000 with the first after-questionnaire undertaken in October 2000. The results showed a decrease of 14% in car driver mode as a result of the intervention. Increases of 35%, 61% and 9% were found for respectively walking, cycling and travelling as a car passenger. Half of the car trips that were replaced by other travel modes were replaced by walking.

3.4. Bicycle-renting system interventions

Two bicycle-renting system interventions were found to have an effect on a mode shift. One of these interventions aimed at inducing a mode shift by supplying a bicycle renting system in London in the United Kingdom (OYBike; physical tool). (Noland and Ishaque, 2006). The aim of this system was to provide enhanced mobility options for local residents and for those employed within the borough. The OYBike is an innovative approach to bicycle rental. The system, which is a network of street-based rental station, operates from 6:30 AM to 6:30 PM. Bicycles can be rented by using a mobile phone and returned at later hours. One year after the start of the pilot, an on-line questionnaire among existing customers was performed. This questionnaire showed that the main reason for persons to use the OYBike is leisure or recreation (68%). Only 11% used the OYBike for commuting to work or school. A mode shift from car to OYBike was found for 6% of the respondents.

The other intervention was a public bicycle share program (physical tool) implemented in Montreal in Canada (Fuller et al., 2013). Aim of this public bicycle share program was to increase the population access to cycling. In Montreal, 5050 bicycles were made available by 405 docking stations (Fuller et al., 2013). A telephone survey conducted at the end of the first and at the end of the second season of implementation was used to evaluate this intervention. Results showed that 18% and 21% of the public bicycle share program users reported replacing walking trips with trips made with the public bicycle in 2009 and 2010 respectively. 7.9% and 10.1% of the public bicycle share program users reported replacing motor vehicle use with trips made with the public bicycle in 2009 and 2010 respectively. However, 23.6% and 21.8% of the public bicycle share program users reported replacing trips made by their personal bicycle with trips made by the public bicycle in 2009 and 2010 respectively. A modal shift of 5% of the trips were day was assumed based on the estimates of the total number of new trips generated by the public bicycle share program.

4. Discussion

In this systematic review, we mapped the effectiveness of interventions aiming to induce a mode shift from car use to active modes of travel (walking or cycling). Interventions were categorised in work-place-based, architectural and urbanistic adjustments, population-wide, and bicycle-renting systems interventions. Nearly all studies (except three) showed positive effects concerning a mode shift from car use to active transport (Table 3). However, information about the statistical significance of these results was often lacking. The intervention tools used were either legal, economic (subsidy, reward system, penalty), communicative (written materials, behavioural tools) or physical tools (providing bicycles, providing better bicycle facilities at work, adjustment of the environment). In most cases, multiple intervention tools were used.

One of the behavioural intervention tools used in the included studies was mass media campaigns. All interventions using mass media campaigns, except for one, were showing positive effects on a mode shift. It has been argued that mass media campaigns are useful in increasing awareness and knowledge about the campaign, and are of importance in supporting other intervention tools (Kahn et al., 2002). In line with this, it was found that all mass media campaigns were used in combination with other intervention tools (i.e., economic and/or communicative tools). However, since evidence concerning the effectiveness of stand-alone mass media campaigns in increasing physical activity is modest and inconsistent overall (Brown et al., 2012), it can be questioned if this positive effect on a mode shift would also have been found in the event only a mass media campaign was used.

Four of the included studies (Alcott and DeCindis, 1991; Brockman and Fox, 2011; Meland, 1995; Wen et al., 2005) using a communicative tool also used a reward (incentives) or penalty system. Incentives used were a healthy breakfast/lunch (Wen et al., 2005) and the opportunity to win prizes when participating in the intervention (Alcott and DeCindis, 1991). Two studies contained a penalty system by increasing parking charges (Brockman and Fox, 2011) or having to pay a toll fee when entering the city centre (Meland, 1995). Three of the four studies showed a positive effect on a mode shift. It was mentioned by Jochelson that the use of incentives aimed at changing complex behaviour (like inducing a mode shift) was successful in that it increased participation in lifestyle change programmes, but once an intervention ceased individuals relapsed into their former behaviour patterns (Jochelson, 2007). In line with this, Kane et al. (Kane et al., 2004) showed that there is less evidence that incentives sustain the long-term lifestyle change required for health promotion. Only the introduction of the Trondheim Toll Ring did show no effect on a mode shift. In this study the introduction of the Toll Ring caused a shift in the timing of the car trips instead of a mode shift. Since this Toll Ring has been designed to raise revenue for the 'Trondheim package', it can be argued that this intervention was not designed effectively for stimulating a mode shift. As mentioned by Meland, only about one-third of the car drivers in Trondheim pay these tolls regularly, which could also have influenced these results (Meland, 1995). Future research should focus on the effectiveness of the use and height of reward or penalty systems on stimulating a mode shift as well as the influence of terminating these reward or penalty systems on the obtained outcome.

Another two studies show no positive effect on a mode shift. The development of a neighbourhood trail was the only intervention with a negative effect on a mode shift. In this study, there was only an environmental adjustment and no promotional activities concerning the use of this trail were implemented. Though as a result of the trail a loop of 2.5 miles was created, adequate signposting was missing, which possibly limited the trail's effectiveness. In line with this the authors mentioned that a lack of information could have influenced the negative effects (Burbridge and Goulias, 2009). The extension of the UK National Cycle Network (Jones, 2012) was also implemented without any additional tools and could therefore have resulted in no effect on a mode shift. However, Arentze et al. (2001) also used only an environmental adjustment and did show positive effects on a mode shift. It might be expected that, for example, the opening of a new railway station affects more people than the development of a neighbourhood trail and related to this less promotional activities are needed to stimulate the use of this railway station. Therefore, it can be argued, that it depends on the type of architectural and urbanistic adjustment whether other intervention tools are needed simultaneously.

The included studies support the notion that a combination of different intervention tools is more effective than using only one tool. More than half of the included interventions used a combination of several intervention tools. However, in the vast majority of these studies the intervention tools all focus on the same area, for instance, health promotion or an environmental adjustment. Interventions were implemented with, for example, the aim to increase physical activity levels, reduce air pollution or improve accessibility of a neighbourhood. Only one intervention focussed on multiple aims by using both behavioural intervention tools and an environmental adjustment. Previous research showed that a mode shift not only influences the level of physical activity, but also has beneficial health effects due to decreased air pollution emissions (De Hartog et al., 2010), greenhouse emissions (Lindsay et al., 2011) and noise levels (Van Kempen et al., 2010). The effect of a mode shift on road safety is claimed to be an improvement by Jacobsen (2003), but other authors showed that this effect depends on age and gender (Stipdonk and Reurings, 2012). Because of this diversity in (beneficial) effects on health and environmental quality, collaboration between the health, transport, spatial planning and environmental sector and thus a more intersectorial approach would be beneficial in developing (cost-efficient) interventions stimulating active transport. Related to this, it may be argued that not only a multi-sectorial health approach is needed, but also multi-sectorial transport and parking approaches.

4.1. Strengths and limitations of this review

Since we searched five databases, it can be argued that we captured most of the relevant research in this systematic review. However, there always remains the possibility that we missed some important studies due to poor indexing. To overcome this problem we checked all references of the included papers, as we expected that if we had missed any relevant studies these studies would be found in these reference lists. Since a large gap exists between implemented interventions and interventions tested for effectiveness and published in scientific journals, publication bias could also be an issue. However, Ogilvie et al. (2004) searched both peer-reviewed literature databases as well as some grey literature and found results in the same direction. A quick scan of THE PEP also showed similar results, therefore it can be argued that publication bias did not influence our results to a great extent.

In this study, we focussed solely on interventions designed to stimulate a mode shift from car use to active transport. However, we are aware that an increase in active transport use may occur as an unforeseen side effect of interventions with a different aim. For example, Lane (2005) showed that a carsharing programme in Philadelphia reduced vehicle ownership after one year and caused a mode shift from car driving to active transport and Meyer and Beimborn (1998) showed that the implementation of the UPASS (a pass which provides students with unlimited transit travel) reduced car use and increased transit use as well as walking. Future research could also include such interventions.

4.2. Strengths and limitations of the available evidence

Behaviour change in the general public is a complex research topic and quantification is difficult in this field. As can be seen from our results (Tables 1 and 3), the quality of the included studies was generally low since control groups were mostly missing and information concerning the participants was sometimes also missing. A number of studies used a cross-sectional or ecologic design, which made it impossible to draw conclusions regarding the individual effects. Also in the included cohort studies, results were often presented on a population level instead of individual level, which makes it impossible to draw conclusions regarding mode shifts on the individual level. Related to this, no conclusion concerning effectiveness on an individual level and personal characteristics could be drawn. Therefore, we recommend that future studies using a cohort design also report effects on an individual level.

Only four of the nineteen included studies tested (all) obtained results on significance (Table 1) and information about who initiated the intervention was often missing. Related to this, effects on a mode shift were sometimes badly reported and detailed information concerning the intervention tools used was missing in some cases. This badly reporting of intervention characteristics and outcomes could be explained by the fact that not all interventions included were implemented with the aim to induce a mode shift in the first place. This difficulty in finding relevant evidence may reflect the different priorities in the transport and health policy and research communities (Ogilvie et al., 2004). However, since most of the included studies did not test the obtained results on significance, it could be questioned if the positive effects on a mode shift really exist, or if these would be non-significant if tested. Because of these differences in design, research context (both population wide and specific cities/workplaces) and outcome measures we also decided that it was not possible to calculate a common outcome metric in a meaningful way. To be able to draw more definite conclusions concerning the effectiveness of interventions on a mode shift, future studies should report more precisely on their study design as well as test their results on significance. Future studies, should also focus on the effectiveness of the intervention tools used to be able to draw firm conclusions about which interventions tools are most effective.

5. Conclusions

The main focus of this systematic review was mapping effectiveness of interventions aiming at inducing a mode shift from car use to active transport. Nearly all studies showed results in a positive direction indicating that intervention tools were successfully implemented. However, the quality of the included studies was generally low and intervention characteristics were badly reported.

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References

Alcott, R., DeCindis, M.M., 1991. Clean air force campaign 1989–1990: programs, attitudes, and commute behavior changes. Transp. Res. Rec. 1321, 34–44.
Arentze, T., Borgers, A., Ponjé, M., Stams, A., Timmermans, H., 2001. Assessing urban context-induced change in individual activity travel patterns. Transp. Res. Rec. 1752, 47–52.
Brockman, R., Fox, K.R., 2011. Physical activity by stealth? The potential health benefits of a workplace transport plan. Public Health 125, 210–216.
Brown, D.R., Soares, J., Epping, J.M., Lankford, T.J., Wallace, J.S., Hopkins, D., Buchanan, L.R., Orleans, C.T., 2012. Stand-alone mass media campaigns to increase physical activity: a community guide updated review. Am. J. Prev. Med. 43, 551–561.
Burbridge, S.K., Goulias, K.G., 2009. Evaluating the impact of neighborhood trail development on active travel behavior and overall physical activity among suburban residents. Transp. Res. Rec., 78–86.
Cairns, S., Newson, C., Davis, A., 2010. Understanding successful workplace travel initiatives in the UK. Transp. Res. Part A: Policy Pract. 44, 473–494.
De Hartog, J.J., Boogaard, H., Nijland, H., Hoek, G., 2010. Do the health benefits of cycling outweigh the risks? Environ. Health Perspect. 118, 1109–1116.
Fuller, D., Gauvin, L., Kestens, Y., Morency, P., Drouin, L., 2013. The potential modal shift and health benefits of implementing a public bicycle share program in Montreal, Canada. Int. J. Behav. Nutr. Phys. Act 10, 66.
Global Advocacy for Physical Activity (GAPA) the Advocacy Council of the International Society for Physical Activity and Health (ISPAH) (February 2011). "NCD Prevention: Investments that Work for Physical Activity." Available: http://www.globalpa.org.uk/pdf/investments-work.pdf. Accessed 10 June, 2014.
Goodman, A., Panter, J., Sharp, S.J., Ogilvie, D., 2013. Effectiveness and equity impacts of town-wide cycling initiatives in England: a longitudinal, controlled natural experimental study. Soc. Sci. Med. 97, 228–237.

Gordon-Larsen, P., Boone-Heinonen, J., Sidney, S., Sternfeld, B., Jacobs Jr., D.R., Lewis, C.E., 2009. Active commuting and cardiovascular disease risk: the CARDIA study. Arch Intern. Med. 169, 1216–1223.
Hamer, M., Chida, Y., 2008. Active commuting and cardiovascular risk: a meta-analytic review. Prev. Med. 46, 9–13.
Hoogerwerf, A., Herweijer, M., 2008. Overheidsbeleid. Een inleiding in de beleidswetenschap. Kluwer, Alphen aan den Rijn.
Jacobsen, P.L., 2003. Safety in numbers: more walkers and bicyclists, safer walking and bicycling. Inj. Prev. 9, 205–209.
James, B., Brög, W., 2001. Increasing walking trips through TravelSmart® individualised marketing. World Transp. Policy Pract. 7, 61–66.
Jochelson, K., 2007. Paying the Patient; Improving Health Using Financial Incentives. King's Fund.
Jones, T., 2012. Getting the British back on bicycles-The effects of urban traffic-free paths on everyday cycling. Transp. Policy 20, 138–149.
Kahn, E.B., Ramsey, L.T., Brownson, R.C., Heath, G.W., Howze, E.H., Powell, K.E., Stone, E.J., Rajab, M.W., Corso, P., 2002. The effectiveness of interventions to increase physical activity. A systematic review. Am. J. Prev. Med. 22, 73–107.
Kane, R.L., Johnson, P.E., Town, R.J., Butler, M., 2004. A structured review of the effect of economic incentives on consumers' preventive behavior. Am. J. Prev. Med. 27, 327–352.
Kohl 3rd, H.W., Craig, C.L., Lambert, E.V., Inoue, S., Alkandari, J.R., Leetongin, G., Kahlmeier, S., 2012. The pandemic of physical inactivity: global action for public health. Lancet 380, 294–305.
Lane, C., 2005. PhillyCarShare: first-year social and mobility impacts of carsharing in Philadelphia, Pennsylvania. Transp. Res. Rec. 1927, 158–166.
Lindsay, G., Macmillan, A., Woodward, A., 2011. Moving urban trips from cars to bicycles: impact on health and emissions. Aust. N. Z. J. Public Health 35, 54–60.
Meland, S., 1995. Generalised and advanced urban debiting innovations: the GAUDI Project. 3. The Trondheim toll ring. Traffic Eng. Control 36, 150–155.
Merom, D., Miller, Y., Lymer, S., Bauman, A., 2005. Effect of Australia's Walk to Work Day campaign on adults' active commuting and physical activity behavior. Am. J. Health Promot. 19, 159–162.
Merom, D., Miller, Y.D., van der Ploeg, H.P., Bauman, A., 2008. Predictors of initiating and maintaining active commuting to work using transport and public health perspectives in Australia. Prev. Med. 47, 342–346.
Meyer, J., Beimborn, E.A., 1998. Usage, impacts, and benefits of innovative transit pass program. Transp. Res. Rec. 1618, 131–138.
Mutrie, N., Carney, C., Blamey, A., Crawford, F., Aitchison, T., Whitelaw, A., 2002. "Walk in to Work Out": a randomised controlled trial of a self help intervention to promote active commuting. J. Epidemiol. Community Health 56, 407–412.
Noland, R.B., Ishaque, M.M., 2006. Smart bicycles in an urban area: evaluation of a pilot scheme in London. J. Publ. Transp. 9, 71–95.
O'Fallon, C., 2010. Bike now: exploring methods of building sustained participation in cycle commuting in New Zealand. Road Transp. Res. 19, 77–89.
Ogilvie, D., Egan, M., Hamilton, V., Petticrew, M., 2004. Promoting walking and cycling as an alternative to using cars: systematic review. BMJ 329, 763.
Ogilvie, D., Foster, C.E., Rothnie, H., Cavill, N., Hamilton, V., Fitzsimons, C.F., Mutrie, N., 2007. Interventions to promote walking: systematic review. BMJ 334, 1204.
Pucher, J., Dill, J., Handy, S., 2010. Infrastructure, programs, and policies to increase bicycling: an international review. Prev. Med. 50 (Suppl. 1), S106–S125.
Shoup, D.C., 1997. Evaluating the effects of cashing out employer-paid parking: eight case studies. Transp. Policy 4, 201–216.
Stipdonk, H., Reurings, M., 2012. The effect on road safety of a modal shift from car to bicycle. Traffic Inj. Prev. 13, 412–421.
Thakuriah, P., Metaxatos, P., Lin, J., Jensen, E., 2012. An examination of factors affecting propensities to use bicycle and pedestrian facilities in suburban locations. Transp. Res. Part D: Transp. Environ. 17, 341–348.
THE PEP, 2012. Available: http://www.healthytransport.com/promising-practices/search/?p=6&search=mode shift and active transport. Accessed 7 December, 2012.
Thomas, I.M., Sayers, S.P., Godon, J.L., Reilly, S.R., 2009. Bike, walk, and wheel: a way of life in Columbia, Missouri. Am. J. Prev. Med. 37, S322–S328.
Topp, H., Pharoah, T., 1994. Car-free city centres. Transportation 21, 231–247.
Van Kempen, E., Swart, W., Wendel-Vos, W., Steinberger, P., Knol, A., Stipdonk, H., Reurlings, M., 2010. Exchanging Car Trips by Cycling in the Netherlands. A First Estimation of Health Benefits (RIVM Report 630053001/2010), RIVM, Bilthoven.
Weisbrod, G., 1982. Business and travel impacts of Boston's Downtown crossing automobile-restricted zone. Transp. Res. Rec. 882, 25–32.
Wen, L.M., Orr, N., Bindon, J., Rissel, C., 2005. Promoting active transport in a workplace setting: evaluation of a pilot study in Australia. Health Promot. Int. 20, 123–133.
Yang, L., Sahlqvist, S., McMinn, A., Griffin, S.J., Ogilvie, D., 2010. Interventions to promote cycling: systematic review. BMJ 341, c5293.