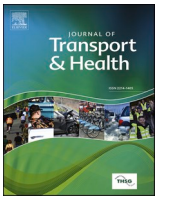
Journal of Transport & Health 27 (2022) 101488

Contents lists available at ScienceDirect

Journal of Transport & Health

journal homepage: www.elsevier.com/locate/jth



Which transport policies increase physical activity of the whole of society? A systematic review

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ARTICLE INFO

Keywords:
Transport policy
Active travel
Physical activity
Transport mode

ABSTRACT

Purpose: There is strong evidence of the links between car-dependence and the physical inactivity pandemic. Physical inactivity accounts for 6–10% of major non-communicable diseases. Research consistently shows that unlike passive transport, active transport is associated with higher total daily physical activity (PA). While there are public policies that support PA in transport and, as a result, overall PA levels, the specific quantitative effect of such policies on PA behaviour has not been sufficiently investigated. The aim of this systematic review is to determine the level and type of evidence for policies in the area of transport that contribute to higher PA levels of the whole of society.

Methods: Six databases (MEDLINE (Ebsco), SportDiscus, Cinahl, Cochrane library, Web of Science, and Scopus) were searched for key concepts of policy, transport, evaluation and PA. Methodological quality was assessed using standardized tools. The strength of the evidence of policy impact was described based on pre-determined categories of positive, negative, inconclusive or untested.

Results: 17 of 2549 studies were included in the data synthesis. The authors identified three main transport policy areas with 51 individual policy actions that had a direct or indirect effect on PA. These were: convenient transport infrastructure development, active travel promotion, and shift of transport mode. More than half of the policy actions identified had a positive effect on PA. Study quality ratings were moderate to good.

Conclusions: PA levels can be increased by implementing policies that provide convenient, safe, and connected walking and cycling infrastructures, promote active travel and give strong support to public transport. There is also clear evidence that active travel policies work best when

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https://doi.org/10.1016/j.jth.2022.101488
Received 1 February 2022; Received in revised form 1 August 2022; Accepted 7 August 2022
Available online 5 September 2022

implemented in a comprehensive way. This may include infrastructure and facility improvements as well as educational programmes to achieve substantial shifts towards active modes of travel.

1. Introduction

Active travel can significantly increase the level of regular physical activity (PA). Research consistently shows that those who walk, cycle or use public transport generally have higher total daily PA levels than those who drive a car (Chakrabarti and Shin, 2017; Mackett and Brown, 2011; Oh et al., 2018; Rissel et al., 2012; Wood Johnson, 2009). Since journeys by public transport involve walking to transit stops at the beginning and at the end of the journey, this way of travelling is also included within the definitions of active transport (Cole et al., 2010). There is strong evidence of the links between car-dependence and the global physical inactivity epidemic (Chakrabarti and Shin, 2017; Mackett and Brown, 2011). According to Lee et al., elimination of physical inactivity would remove for 6–10% of major non-communicable diseases (NCDs) that are the leading cause of death globally (Lee et al., 2012). Global organizations such as the World Health Organisation (WHO) are sounding the alarm and call for comprehensive actions to reverse the trend of PA decrease (World Health Organization, 2013). The 'Physical Activity Strategy for the WHO European Region 2016–2025' (World Health Organization, 2015) strongly highlights entry points for transport-related policies that influence PA levels in society. Its recommendations include the promotion of active travel, investing in a mix of accessible walking and cycling infrastructures, developing measures to promote active commuting and the use of public transport to travel to work, introducing innovative measures to calm speed and reduce motor traffic to promote cycling and walking, and using mechanisms to change people's behaviour taking account of age, income, gender or other factors to enhance their shift from motor-powered transport to active transportation (World Health Organization, 2015).

Also referred to as active transport, whether on its own or in combination with public transport, walking and cycling for transport can provide a significant part of the daily PA recommended by WHO guidelines, e.g. in the 'Global Recommendations on Physical Activity for Health' and the 'WHO Guidelines on Physical Activity and Sedentary Behaviour' (World Health Organization, 2010, 2020). Being active for transport purposes is an inherent component of social life and, in contrast to sports or exercise, does not require additional time. Hence, travel-related PA has the potential to benefit the whole population, including those who may be less receptive to sports and exercise or who cannot afford it due to socio-economic determinants (Sahlqvist et al., 2012). Shifting people's behaviour from passive to active transport is currently a common objective of diverse transport policies that focus, for example, on reducing congestion, noise, climate change, and on improving road safety and accessibility of services, and can increase PA levels indirectly.

The global need to shift the urban culture of mobility towards active forms of transport results from the temporary challenges the transport sector is facing (congestion, road safety, pollution, increased health problems, climate change due to CO2 emissions, etc.) (Volf et al., 2020). It must be highlighted that while the impact of transport is felt on a global scale, the problems occur on the local level and this is where interventions should be applied. Nevertheless, the European Commission states that local authorities cannot face all these issues on their own. There is a need for cooperation at all levels: local, regional and national with European level co-ordination (Okraszewska et al., 2019). Therefore, the European Commission provides frameworks and tools to tackle transport and mobility in urban areas (Rupprecht Consult, 2019). A key strategic document designed to contribute to meeting European targets outlines the 'Sustainable Urban Mobility Plan (SUMP)'. Evidence from comparative analyses of the effectiveness of policies, programmes and actions confirms that SUMPs or 'Cities Transport Plans' are the most suitable means for increasing transport-related PA, as demonstrated by town and city-wide interventions (Davis, 2019). Spain's Bilbao or Dutch's Eindhoven are good examples of how effective a good and consistently implemented transport policy can be, especially if integrated with urban policy. The Bilbao's share of walking is more than 50% and Eindhoven in the Netherlands boasts cycling shares of up to 44% (Gerike et al., 2016).

Although transport policies that prioritise walking, cycling and public transport are regularly recommended due to their direct and indirect effect on PA (Rupprecht Consult, 2019; The European Commission, 2017), the many publications that are relevant in this field often have conflicting or inconsistent results. It is relevant to systematically summarize appraise the current evidence. This study aims to fill this gap and provide a full and accurate picture of all those policies that actually affect behaviour change that contribute to improved population PA. The systematic review focuses therefore only on transport policies that had a robust and measurable impact on PA and determines the level and type of quantitative evidence for this type of policies. This is also the first study in the area of PA in transportation where only policies are considered, not all interventions or activities undertaken to increase PA levels. The reason is the review will contribute to the development of the Physical Activity Environment Policy Index (PA-EPI), which aims to support policy makers by facilitating the development and benchmarking of all policies which work towards achieving WHO's public health targets regarding PA participation. The contribution of transport is an important part of these policies.

For the purpose of this paper, public policies are defined as 'decisions, plans and actions that are enforced by national or regional governments or their agencies (of any level) which may directly or indirectly achieve specific health goals within a society' (Volf et al., 2020). Importantly, policy interventions are not to be confused with other types of programmes or environmental interventions; policy interventions provide the framework in which the programmes or infrastructural (environmental) changes are tendered, developed, financed or implemented (Gelius et al., 2020).

2. Methods

Policy actions identified within this research were grouped into three policy areas: convenient transport infrastructure, active

transport promotion and shift of transport mode. Each refers to a key area of the transport system (Fig. 1). They follow the methodological approach towards key elements of the transport system, based on Haddon's approach to transport safety (Haddon, 1980). We have considered them at three levels of human social activity: individual, organizational and community.

The review is structured according to the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA).

2.1. Search strategy and eligibility criteria

A systematic search of the following electronic databases was conducted in March 2020: four databases focused on the science of health and sport - MEDLINE (Ebsco), SportDiscus, Cinahl, Cochrane, and two multidisciplinary reputable databases - Web of Science and Scopus. Online databases were searched using key search terms: policy, physical activity, impact, transport policy.

Only scientific peer-reviewed journal articles were considered for inclusion. Studies were included based on a) study type (empirical studies), b) participants (general population), c) exposure/intervention (studies need to address some direct or indirect policy-related actions to promote transport-related PA), d) outcomes (a change in PA associated with travelling, assessed by means of self-report, geographic information system or wearable devices (e.g., pedometer, accelerometer) and/or a change in features of the physical and social environment (e.g., changes in traffic volume, number of pedestrians and cyclists), and e) language (only studies in English). Grey literature was excluded.

2.2. Screening of studies & data extraction

After removing duplicate references all retrieved titles and abstracts were screened using the systematic review software Rayyan (Ouzzani et al., 2016). After initial title and abstract screening, full texts were retrieved and crosschecked against the inclusion criteria. Eligible studies were also cross-checked in the case of contradictory inclusion decisions. Disagreements were resolved through discussion between the authors.

Data were extracted using pre-defined criteria for all study designs. This included: study design, country of origin, policy level, population, and policy description and content. To ensure that the impact of the policy identified can be interpreted, information was collected on how the outcome of interest was changing (PA and/or physical/social environment). Three reviewers shared the work of data extraction. Finally, all data were checked by a fourth reviewer.

2.3. Quality assessment process

The risk of bias was assessed by one reviewer and checked by another. Discrepancies were resolved by consensus, where necessary in consultation with a third researcher. Similarly, to a review by Messing et al., the percentages of criteria met per study, based on criteria applicable to the type of study design were calculated. The quality of the articles ranged between 44% and 94% and lower ratings were generally associated with the designing or the sampling bias (Messing et al., 2019). The quality of the quantitative studies was assessed by means of an adapted 'Downs and Black' checklist tool (Downs and Black, 1998). The tool was slightly modified to meet the aims/context of this review.

2.4. Data synthesis

Due to substantial heterogeneity of study designs, outcomes and other characteristics, a narrative synthesis approach was chosen to interpret and summarize the extracted data. The outcome data was tabulated to determine the direct and indirect impact of policy on PA, and outline how policy areas were defined, delineated and identified. Evidence on the effectiveness of policy was described using a method proposed by Panter et al. (Panter et al., 2019); the observed effects of policy actions were coded as:

- "significant-positive" (++) – more than 50% of the outcomes had a positive significant effect,

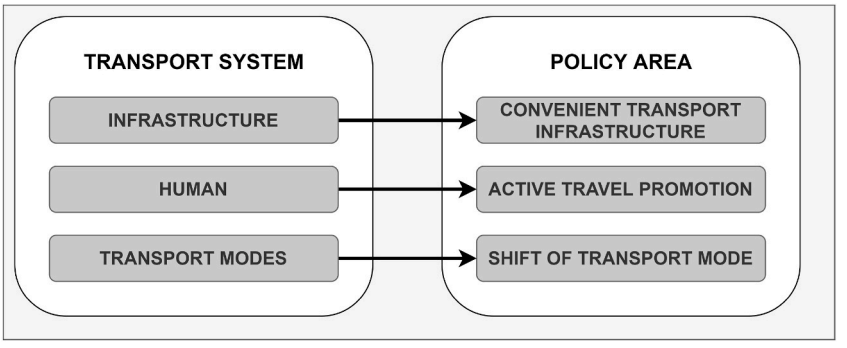

Fig. 1. Policy areas influencing PA defined within the whole transport system.

- "significant-negative" (–) – more than 50% of the outcomes had a negative significant effect,
- "non significant-positive" (+) – overall positive effect but the change/difference was not significant,
- "non significant-negative" (−) – overall negative effect but the change/difference was not significant,
- "positive-untested" (0+) – overall positive effect without significance tests,
- "negative-untested" (0-) – overall negative effect without significance tests,
- "inconclusive" (X) – mixed results without unambiguous conclusion.

Standardized definitions and terminology for policy-related concepts and their inter-relations (Fig. 2) were used (Lakerveld et al., 2020). Previous reviews have noted the importance of separating "policies" from "interventions" (Gelius et al., 2020; Rütten et al., 2016; Volf et al., 2020). Thus, the expression 'Intervention' means an action, programme or environmental change used to promote PA. 'PA Programme' determines specific opportunities for increasing PA behaviour, attitudes or knowledge in a target population for a specific period of time. 'PA Environment' stands for relevant physical and social features of the transport environment that are hypothesized to support changes in PA behaviour. 'PA Policy' includes decisions, plans and actions that are enforced by national or regional governments, or their agencies which may impact PA directly or indirectly. 'Policy Level' determines laws, national/state, regional/local-level codes and regulations. 'Policy Area' indicates specific content areas for policy actions within the transport system, e.g. development of convenient infrastructure. 'Policy Action' includes actions defined as actual options selected by policymakers. They are specific actions put into place by any level of government and associated agencies to achieve the PA objective directly or indirectly. They may be written into broad strategies, action plans, official guidelines/notifications, calls to action, legislation, or rules and regulations. An action may have its own exclusive policy document, or may be part of a larger document (Volf et al., 2020).

Policy actions identified within this review were grouped into three policy areas referring to the classical approach proposed by Haddon (1980) (originally introduced as an approach to transport safety). Haddon defined three main elements of the transport system: human, vehicle and environment (Fig. 1). Everything that happens within the transport system happens within these three elements, and neither of them can appear separately. Considering that and by analogy we proposed to classify the policy actions identified in this review into three groups: active transport promotion (policy actions aimed at human factors), shift of transport mode (policy actions focused on the vehicle/transport mode) and infrastructure development (policy actions aimed at the environment). This approach guarantees that the results of the study are comprehensive and all identified policy actions cover the whole transport system.

3. Results

3.1. Characteristics of the studies

In total, 3840 publications were identified, of which 1291 were removed as duplicates. The remaining 2549 titles and abstracts were screened. 2375 were removed based on the inclusion/exclusion criteria. 76 of these publications were excluded due to the fact that they concerned specific age, disable or ethnic groups, rather than the entire population (population criterion). Another 2165 were both not related to active travel, and were not strictly policies following our definition presented in chapter 1 (exposure criterion). 143 of the removed publications had other than PA outcomes, and 15 contained results from which it was difficult to extract PA indicators (outcome criterion). This left 174 publications for full text screening.

142 studies were excluded during full text screening, leaving a total 32 papers. At this stage similar inclusion/exclusion criteria were used: population, exposure and outcome, adding one more: study design. The most common reasons for excluding studies after full text screening was not measurable or not related to active transport (AT) policy outcome (e.g., related to environmental pollution

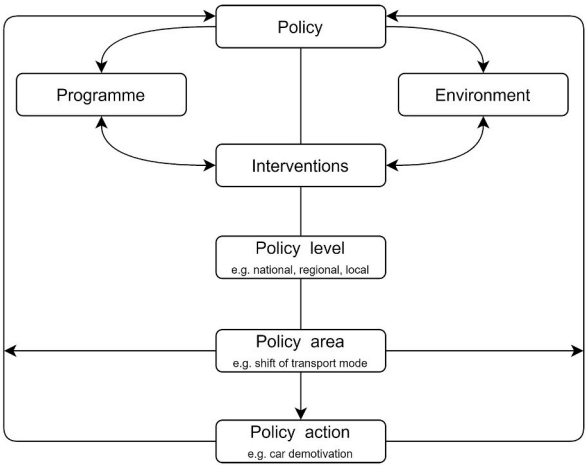

Fig. 2. Diagram of inter-relations between policy-related concepts used in this review.

or traffic fatalities). 15 of the remaining papers was literature reviews papers thus were not considered for further analysis. Finally, 17 full text articles were included for data extraction (see Fig. 3 Study inclusion flowchart).

3.2. Summary findings

Of the 17 studies included, 7 were pre-post studies, 5 were quasi-experimental, 4 were cross-sectional, and one was a mixed methods study. Most studies were conducted in the USA (35%), followed by the UK (24%), Australia (17%), Belgium (6%), Canada (6%), Spain (6%) and Portugal (6%). Quality ratings ranged from 44% to 94%, with the average rating of 70%, suggesting at least moderate methodological quality according to current standards and conventions. The primary search identified ten specific groups of policy actions for which there was evidence of effectiveness (Table 1).

These groups were assigned to three policy areas (according to the classification provided in chapter 2.6) in the next step. The bulk of the evidence relates to convenient infrastructure design. Over half (51%) of all policy actions evaluated in the data synthesis were coded as "significant-positive", while 8% were coded as "non-significant-positive", 16% were coded as "positive-untested", 12% were coded as "inconclusive", and the 2% were coded as "non-significant-negative".

3.2.1. Population and exposure

The main assumption was to include those policies which by their nature had an effect on AT in the widest possible population. In 13 articles the age difference was considered. Three of them were focused on children (up to 12 years old), two on adolescents (12–16 years old), seven on adults (over 16 years old) and one on older people (over 70 years old). Four articles referred to the general population.

Studies typically reported on state, district/regional or local public policies, e.g., active transport promotion. Others reported on organizational policies, e.g. commuting to work programmes or Safe Routes to School (Vaughn et al., 2009).

3.2.2. Outcome measurement

The studies used a range of PA outcome measures such as self-report (n = 11) (Brockman and Fox, 2011; Brownson et al., 2000; Dubuy et al., 2013; Folta et al., 2013; Hunter et al., 2016; Malakellis et al., 2017; Norwood et al., 2014; Panter et al., 2016; Pérez et al., 2017; Petrunoff et al., 2016; Vaughn et al., 2009) observational methods (n = 3) (Arsenio and Ribeiro, 2015; Heath and Bilderback, 2019; Sayers et al., 2012) and mix-methods (n = 3) (Brennan et al., 2015; Rachele et al., 2018; Thompson et al., 2014). The following measurement tools were used: pedometers (Dubuy et al., 2013), accelerometers (Thompson et al., 2014), cameras (Arsenio and Ribeiro, 2015; Heath and Bilderback, 2019) surveys and questionnaire (manual counting) (Brennan et al., 2015; Sayers et al., 2012) and other systems (Geographical Information Systems) (Rachele et al., 2018). The assessment tools comprised several measures of effectiveness such as the number of pedestrian (and/or cyclist) participation (n = 7), pedestrian (and/or cyclist) volume (n = 3) (Arsenio and Ribeiro, 2015; Heath and Bilderback, 2019; Sayers et al., 2012), number of steps (n = 1) (Dubuy et al., 2013), number of trips made in a specific time period (n = 2) (Folta et al., 2013; Pérez et al., 2017) of physical activity (n = 2) (Panter et al., 2016; Thompson et al., 2014) and other kinds of measures (n = 2) (Brennan et al., 2015; Vaughn et al., 2009).

3.3. Findings related to policy areas and policy actions

3.3.1. Convenient transport infrastructure

In the policy area Convenient Transport Infrastructure, four groups of policy actions that have an effect on PA were identified from 15 publications (Arsenio and Ribeiro, 2015; Brennan et al., 2015; Brockman and Fox, 2011; Brownson et al., 2000; Folta et al., 2013; Heath and Bilderback, 2019; Hunter et al., 2016; Norwood et al., 2014; Panter et al., 2016; Pérez et al., 2017; Petrunoff et al., 2016;

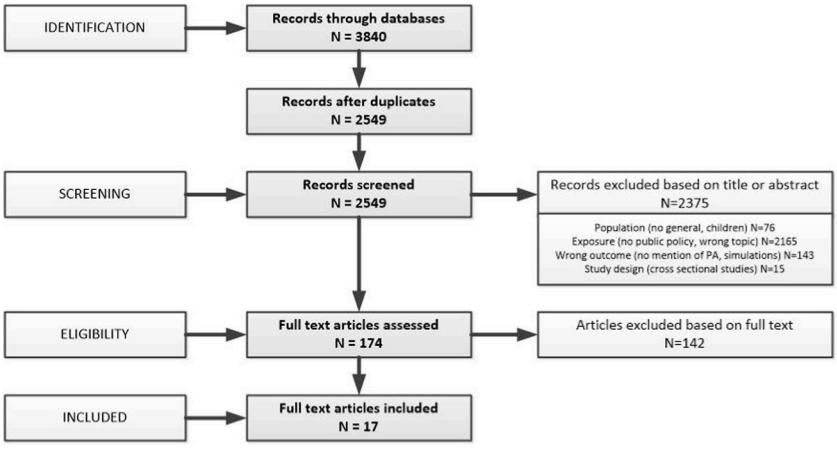

Fig. 3. Study inclusion flowchart.

Table 1
Frequency table of the publications investigating each policy action.

Transportation policy action				Evaluation				
				++	+	X	0+	–
Convenient Transport Infrastructure	1. Pedestrian infrastructure development	1.1	added sidewalks	(Heath and Bilderback, 2019)				
		1.2	existence of convenient walking paths	(Thompson et al., 2014)				
		1.3	pedestrian crossings paths	(Norwood et al., 2014)				
		1.4	foot paths	(Norwood et al., 2014)				
		1.5	walking trail construction	(Brownson et al., 2000)				
		1.6	new traffic-free walking routes			(Panter et al., 2016)		
		1.7	pedestrian priority zones				(Pérez et al., 2017)	
		1.8	road intersection modifications				(Sayers et al., 2012)	
	2. Bicycle infrastructure development	2.1	added bicycle lanes			(Heath and Bilderback, 2019)	(Sayers et al., 2012), (Pérez et al., 2017)	
		2.2	new traffic-free cycling routes	(Panter et al., 2016)				
		2.3	new cycle ways	(Norwood et al., 2014)				
		2.4	cycle facilities	(Norwood et al., 2014)				
		2.5	secured cycle storage		(Brockman and Fox, 2011), (Petrunoff et al., 2016)			
		2.6	install bike racks			(Hunter et al., 2016)		
		2.7	stripped bicycle lines				(Sayers et al., 2012)	
		2.8	Bike storage/parking				(Brennan et al., 2015)	
	3. Public transport infrastructure development	3.1	new bus shelters	(Heath and Bilderback, 2019)				
		3.2	new bus lines	(Norwood et al., 2014)				
		3.3	public transport stops				(Brennan et al., 2015)	
		3.4	proximity of public transport stops	(Rachele et al., 2018)				
		3.5	new bus network			(Panter et al., 2016)		

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Table 1 (*continued*)

Transportation policy action				Evaluation				
				++	+	X	0+	–
		4.1	safer urban and streets design	(Thompson et al., 2014)			(Brennan et al., 2015)	
		4.2	safe routes to school	(Vaughn et al., 2009)	(Folta et al., 2013)			
		4.3	safer parking design	(Thompson et al., 2014)				
		4.4	traffic calming	(Vaughn et al., 2009), (Thompson et al., 2014)				
		4.5	reduce traffic volume	(Thompson et al., 2014)		(Rachele et al., 2018)	(Pérez et al., 2017)	
		4.6	limiting parking spaces	(Brockman and Fox, 2011)				
	4. Friendly infrastructure and urban design	4.7	improving changing facilities for walkers and cyclists	(Brockman and Fox, 2011)				
		4.8	increase pedestrian priority areas				(Pérez et al., 2017), (Arsenio and Ribeiro, 2015)	
		4.9	street connectivity	(Rachele et al., 2018)				
		4.1	cul-de-sac (length of streets)			(Rachele et al., 2018)		
		4.11	street block length			(Rachele et al., 2018)		
		4.12	green space development	(Heath and Bilderback, 2019), (Thompson et al., 2014)				
Active Travel Programing and Promotion		5.1	advertisement in media	(Sayers et al., 2012), (Norwood et al., 2014), (Dubuy et al., 2013)				
	5. Active travel programs – community level	5.2	active travel training and events	(Norwood et al., 2014)				
		6.1	promotional activities on active transport	(Vaughn et al., 2009)				
	6. Active travel programs – organizational level	6.2	physical activity lessons at elementary (6–8 years) school, walk to school campaigns		(Folta et al., 2013)			
		6.3	active transport to school program					(Malakellis et al., 2017)
		6.4	school walking program			(Hunter et al., 2016)		

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Table 1 (*continued*)

Transportation policy action				Evaluation				
				++	+	X	0+	–
	7. Active travel programs – individual	7.1	personal travel planning	(Norwood et al., 2014)				
		7.2	individual active travel guidelines	(Dubuy et al., 2013)				
		7.3	work place travel program promotion in social media		(Petrunoff et al., 2016)			
Shift of Transport Mode		8.1	ticketing improvements	(Norwood et al., 2014)				
		8.2	discounted season tickets on busses, free university bus service	(Brockman and Fox, 2011)				
	8. Support for public transport	8.3	increase public transport				(Pérez et al., 2017)	
		8.4	transit service				(Brennan et al., 2015)	
		8.5	public transport frequency	(Rachele et al., 2018)				
	9. Support for cycling	9.1	subsidised cycle purchase scheme		(Brockman and Fox, 2011)			
		9.2	public bicycle sharing programs				(Pérez et al., 2017)	
	10. Car demotivation	10.1	increased parking charges	(Brockman and Fox, 2011)				
		10.2	reducing car use through resident only parking				(Pérez et al., 2017)	

Rachele et al., 2018; Sayers et al., 2012; Thompson et al., 2014; Vaughn et al., 2009) They were: 1) pedestrian infrastructure development, 2) bicycle infrastructure development, 3) public transport infrastructure development, and 4) friendly infrastructure and urban design. The evidence on these four groups is summarized below.

Policy actions aimed at **pedestrian infrastructure development** appeared in seven publications (Brownson et al., 2000; Heath and Bilderback, 2019; Norwood et al., 2014; Panter et al., 2016; Pérez et al., 2017; Sayers et al., 2012; Thompson et al., 2014). The existence or construction of convenient footpaths, walking trails, pavement, pedestrian crossings paths (Brownson et al., 2000; Heath and Bilderback, 2019; Norwood et al., 2014; Thompson et al., 2014) was found as having a statistically significant effect on enhancing PA (significant-positive). In an article by Brownson et al., for example, 55.2% of people reported that they had increased their amount of walking since they began using the provided walking trail. The authors reported the effect of providing walking infrastructure as: five times extra walking per week and 30 min walking per occasion (Brownson et al., 2000). Other policy actions such as pedestrian priority zones (Pérez et al., 2017) and road intersection modifications to improve pedestrians' comfort (Sayers et al., 2012) were also found to have a positive effect on PA although their statistical evidence was not provided (positive-untested). The effect of new traffic-free walking routes was assessed as inconclusive (Panter et al., 2016).

The effect of **bicycle infrastructure development** to influence PA across society was identified in nine publications (Brennan et al., 2015; Brockman and Fox, 2011; Heath and Bilderback, 2019; Hunter et al., 2016; Norwood et al., 2014; Panter et al., 2016; Pérez et al., 2017; Petrunoff et al., 2016; Sayers et al., 2012). The evidence, however, differed slightly depending on the specific action. It was strong and clear in the case of new cycle infrastructure (traffic-free cycling routes, cycle ways, cycle facilities). These policy actions were coded as significant-positive based on two studies (Norwood et al., 2014; Panter et al., 2016). In one of them the authors observed an increase in total time spent cycling by 113.5 min/week ($p < .001$) following investments in bicycle infrastructure (Panter et al., 2016). In the case of new bicycle lanes the evidence was inconclusive in (Heath and Bilderback, 2019) and positive - untested in (Sayers et al., 2012) (Pérez et al., 2017). The effect of adding facilities such as bike storage/parking or striped bicycle lines (Brennan et al., 2015; Sayers et al., 2012) was found as positive but its statistical significance was not tested so the effect was coded as positive-untested.

The evidence for secured cycle storages was positive with no statistical significance (Brockman and Fox, 2011; Petrunoff et al., 2016). Installing bike racks was found inconclusive (Hunter et al., 2016).

The provision of **public transport infrastructure**, e.g. new bus lines and new bus shelters (Heath and Bilderback, 2019; Norwood et al., 2014), was reported as significant-positive in two publications. The same effect was found for the proximity to public transport stops. In their article (Rachele et al., 2018) the authors proved that the frequency of total walking for transport can increase by up to 69.2% ($p < .001$) if the bus stops are located within 400 m from starting destination. In the case of transit stops the effect was found positive but its statistical significance was not tested (coded as untested) (Brennan et al., 2015). No conclusion was provided in the study examining the effects of a new bus network (Panter et al., 2016) and was coded as inconclusive.

Friendly infrastructure and urban design are policy actions assigned to the provision of safe, green and calm environment were pedestrians have solid priority. Safer urban and street design was identified as affecting PA in two publications. In one study (Thompson et al., 2014) the effect was coded as significant positive and in another study (Brennan et al., 2015) as positive untested. Although Safe Routes to School addressed by Vaughn (Vaughn et al., 2009) had a significant-positive effect on PA in a study by Folta et al. the same effect was found as non significant-positive (Folta et al., 2013). Safer parking provision and design (Thompson et al., 2014), limiting parking spaces and improving changing facilities for walkers and cyclists (Brockman and Fox, 2011) were found as significantly positive similarly to speed reduction and traffic calming. These policy actions were found to have a significant-positive effect on PA in two papers (Thompson et al., 2014; Vaughn et al., 2009). Traffic volume reduction was found to have no effect on PA (coded as inconclusive) (Rachele et al., 2018). In Thompson et al.'s research (Thompson et al., 2014) this type of action was found as significant–positive and in another study (Pérez et al., 2017) as positive but untested. An article by Thompson et al. explains that participants of an intervention group thought that they were more active after the intervention than they were two years before which was significantly more than in the comparison group ($p = .040$) (Thompson et al., 2014).

While an increase in pedestrian priority areas coupled with a complete street redesign and new lighting showed a positive effect, it was still coded as positive-untested due to a lack of a significance test (Brennan et al., 2015; Pérez et al., 2017). Another article (Arsenio and Ribeiro, 2015) examines street reconstruction to introduce shared space for active transport and motorized traffic with a complete ban for cars. This policy action was classified as positive-untested. Adding more green space e.g. increasing the number of parks, green spaces and recreational sites is another group of policy actions with a positive effect on PA (Heath and Bilderback, 2019; Thompson et al., 2014) just like street connectivity (Rachele et al., 2018). Street block length (smaller block size) and the length of cul-de-sac streets were identified as having an inconclusive result on PA (Rachele et al., 2018).

3.3.2. *Active travel programming and promotion*

In the policy area associated with active travel programming and promotion, three policy actions referring to three levels people activity (community, organizational and individual) were identified from eight publications (Dubuy et al., 2013; Folta et al., 2013; Hunter et al., 2016; Malakellis et al., 2017; Norwood et al., 2014; Petrunoff et al., 2016; Sayers et al., 2012; Vaughn et al., 2009). Only one of them, active travel programmes and promotion at **community level**, was entirely classified as statistically significant-positive. It was found in three publications (Dubuy et al., 2013; Norwood et al., 2014; Sayers et al., 2012).

One of the examples was an extensive governmental campaign in Columbia, Missouri designed to raise awareness among citizens of active mobility (Sayers et al., 2012). Another example was a govermental state-wide programme in Flanders ('10 000 Steps' project) (Dubuy et al., 2013) which resulted in a significantly higher average daily step count of the population. Flemish respondents reported more physical activity in several domains (household, at work, leisure time). Norwood et al., the third example, reports on the high

effectiveness of a wide range of different general promotional activities in Scotland covering health walks, healthy lifestyles, calorie maps, and other health promoting materials and activities such as e.g. cycle promotion (Norwood et al., 2014).

Another policy action: active travel programming and promotion at **organizational level** was identified in four publications. In first publication the effects of travel-related PA lessons at elementary school and "walk to school" campaigns (development and dissemination of community resource guides; regular local media placement; and the development of community-wide policies), conducted in Somerville, Massachusetts were assigned as non significant-positive (Folta et al., 2013). School walking programmes and active transport school programmes appeared in second publication by Hunter et al. and were coded as inconclusive (Hunter et al., 2016).

An active transport to school program presented in Malakellis et al. focused on multiple initiatives at individual, community, and school policy level to support healthier nutrition and physical activity was coded as non significant – negative (Malakellis et al., 2017). Vaughn et al. gathered information from coordinators of Walk to School (WTS) events in US schools. Analyses used to examine WTS programme characteristics showed that the number of promotional and educational activities implemented in a single school is closely associated with increases in children walking (Vaughn et al., 2009). Thus, it was coded as significant-positive.

The evidence for policy actions aimed to change individual human behaviour (**individual level**) was provided in three publications (Dubuy et al., 2013; Norwood et al., 2014; Petrunoff et al., 2016). In Norwood, P. et al. we found recommendations for trainings and events designed to improve people's ability to travel independently, proposals for cycling skills training, and events to raise awareness of sustainable transport (Norwood et al., 2014). The effect of setting of these actions was coded as significant-positive. The Liverpool Hospital Travel Plan 2011–2014 aimed to promote active forms of transport and decrease the proportion of staff driving to work by 10% by 2014. According to Petrunoff et al., this policy action resulted in an increase of walking/cycling to work among surveyed staff by 5% ($p = .030$) in 2012, 7% ($p = .003$) in 2013 and went back to 5% ($p = .006$, insignificant) in 2014 (4% was the baseline) (Petrunoff et al., 2016). Thus, this policy was coded as non-significant – positive.

3.3.3. *Shift of transport mode*

Three policy actions from five publications (Brennan et al., 2015; Brockman and Fox, 2011; Norwood et al., 2014; Pérez et al., 2017; Rachele et al., 2018) focused on changing habits (behaviour) toward more proactive ways to travel. These were car demotivation interventions and support for cycling and public transport.

Policies focused on higher parking charges as a **car use demotivator** were recognized as having significant-positive effects on PA in one study (Brockman and Fox, 2011). The change appears to be stimulated by the introduction of a range of costs, such as limited and more expensive parking, accompanied by increasing the attractiveness of alternative modes of transport to the car. Brockman and Fox were unable to identify the effects of individual strategies of the plan, so the relative effects of the 'stick' measures (mainly parking restrictions) and 'carrot' measures (such as improved public transport and facilities for walkers and cyclists) cannot be determined; although they found that the percentage of respondents who usually commuted by car decreased from 50% to 33% ($p < .001$). Another study (Brockman and Fox, 2011) shows that a workplace transport plan aimed at decreasing car usage through restricted parking can significantly increase active travel through walking and cycling. The amounts of walking or cycling achieved among the active travellers were sufficient to meet a large percentage of the weekly recommended amounts for health benefits. Reducing car use through resident-only parking was presented in Pérez et al. measured PA as walking and cycling trips on working days. Because interventions are often implemented simultaneously (for example in a mobility plan) and can have overlapping effects, it is difficult to assign the resulting benefits to any specific intervention (Pérez et al., 2017). As a result of these concerted actions, the effects of individual policy actions identified in this publication were coded as positive-untested.

Support **for cycling** provided via a subsidised bicycle purchase scheme was examined in one publication (Brockman and Fox, 2011) and had a non significant-positive effect. The authors showed that thanks to the introduction of a subsidised cycle purchase scheme the percentage of regular cyclists increased from 7.0% to 11.8%, but this result was found as not statistically significant ("the percentage of respondents who reported that they usually bicycle to work increased from 7% to 12%, but year comparisons with 2007 data failed to reach significance") (Brockman and Fox, 2011). Another supportive policy aimed at public bicycle sharing programmes was presented by Pérez et al. who analysed cycling trips on working days among a population of 20–64 year old in 2009–2013 in Barcelona. Between 2009 and 2013 the number of cycling trips increased there to 72.5% (Pérez et al., 2017). Because no statistical analysis was presented the policy action was coded as positive-untested.

One of the policy interventions aimed at supporting **public transport** was ticketing improvements. It was identified as having significant-positive effect on increasing PA by Norwood et al. (2014). Similar results were reported by Brockman and Fox for discounted season tickets and free university bus services (Brockman and Fox, 2011). They were also coded as significant-positive. Increased public transport (Pérez et al., 2017) and transit service (Brennan et al., 2015) were coded as untested. Although it was reported in one study (Pérez et al., 2017) that between 2009 and 2013 thanks to an increase in public transport the number of walking trips went up from 1.8 to 2.3 millions, similarly the number of cycling trips increased from 71.3 to 123.0 thousands. Public transport frequency was assessed in one paper (Rachele et al., 2018) and was coded as significant-positive. The study showed that participants with a more frequent public transport service (i.e., at least two public transport services per hour) had greater odds of walking for transport for 150 min per week or more (Rachele et al., 2018).

A graphical summary of the frequency of occurrence of particular types of policies areas (convenient transport infrastructure, active transport promotion and shift of transport mode) in articles and their quantitative evidence on the effectiveness is presented in Fig. 4 and Fig. 5 additionally takes into account the human activity levels of analysis policy.

The highest number of policy interventions was found in the area of convenient transport infrastructure, where 44 out of 51 and over 50% of all policy interventions (23) were coded as significant-positive (Fig. 4). Strong support was found for pedestrian and

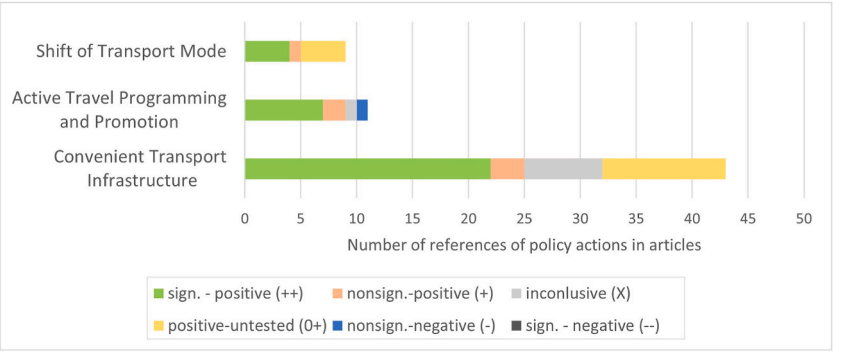

Fig. 4. Evidence code: Freq. & strength by policy area.

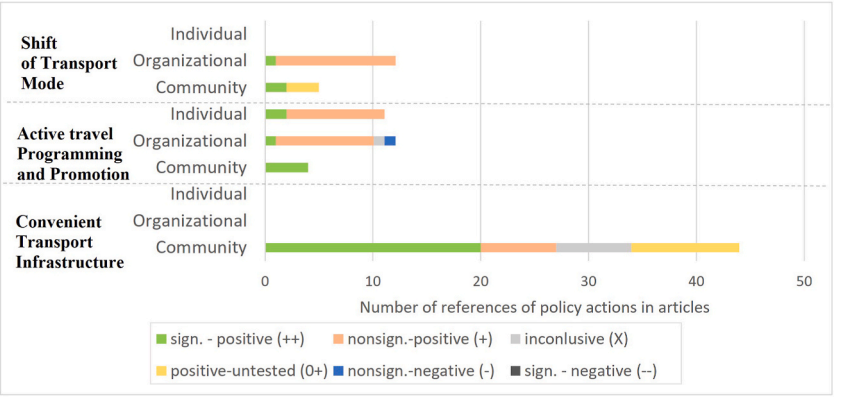

Fig. 5. Evidence code: Freq. & strength by policy level.

bicycling development. The analysis revealed three human activity levels addressed by AT policies: individual, organizational and community one. The authors were interested what kind of policy interventions appear at each level and how frequent they are (Fig. 5).

4. Discussion

This review presents the status of the scientific evidence on 51 policy actions that influence PA within the transport domain. We structured all policy actions into three core transport system elements: transport infrastructure component, active travel programming and promotion reflecting the human component, and shift of transport mode reflecting the way people change their behaviour into a more proactive one.

Providing new walking and/or bicycle infrastructure was strongly associated with increased levels of PA. Such policies have high potential to increase the number of people walking (Heath and Bilderback, 2019) or commuting on foot and by bicycle (Panter et al., 2016). In particular, the results of increasing PA while commuting actively are very promising since travelling for transport (to work) purposes as an integrated component of social life does not require additional time or motivation (Sahlqvist et al., 2012). This finding is helpful when developing transport policies. Positive effects were also identified for the provision of public transport infrastructure e.g. new bus shelters (Heath and Bilderback, 2019) and proximity to public transport stops (Rachele et al., 2018). It means that better access to convenient public transport infrastructure may encourage people to choose active travelling, which indirectly influences their everyday PA levels.

Friendly infrastructure and urban design is a policy action assigned among others to safer urban and street design (Thompson et al., 2014), safer parking provision and design (Thompson et al., 2014), traffic calming (Thompson et al., 2014; Vaughn et al., 2009) reduced traffic volume (Thompson et al., 2014), limiting parking spaces and improving changing facilities for those who walk and cycle (Brockman and Fox, 2011). All of these were associated with a significant-positive effect on PA. Evidence for this latter has previously also been highlighted in the grey literature. Improving road safety, promoting compact urban design and prioritizing access for pedestrians, cyclists and public transport users to destinations and services helps to reduce the use of personal motorized transportation and increase the level of transport-related PA. Increasing the number of parks, green spaces and recreational sites had a significantly positive effect on PA (Heath and Bilderback, 2019; Thompson et al., 2014). Street connectivity was also found to have a positive effect (Rachele et al., 2018).

The research shows that within the convenient transport infrastructure area no interventions were reported on the individual and organizational level. This is understandable since mostly governments invest in infrastructure. On the other hand, policy actions at all levels may influence active travel programming and promotion. This is a very important and promising finding in the context of 'health in all policies'. Unfortunately, as it turned out, assessing their real effect is a real challenge: most interventions were coded as insignificant-positive. It means they had a positive effect but it was difficult to assess with statistical significance.

Most of 'shift of transportation mode' policy actions appeared at the organizational level. There were a few at the community level and none at the individual level. It is a clear message that interventions such as ticketing improvements (facilities for passengers), increasing public transport frequency or increasing parking charges, all with a statistically significant positive impact on PA, are effective in influencing PA levels and as such should be considered by community and organizational bodies.

Similarly to other review focussed on school policies (Volf et al., 2020), we found that the evidence for active transport policy actions within the school-setting is inconclusive. However, although the evidence for this review was limited, this research suggests that policies promoting active transport to school as part of a multi-component approach can have a positive effect (Volf et al., 2020). The difference in the results may be due to the fact that state-level policymakers may influence active transport policy, but the ability of individual schools to impact levels of active commuting by students is limited if the physical environment, external to the school, is unsupportive (Volf et al., 2020).

The feature that distinguishes this literature review from others is that its focus is on public policies rather than measures or interventions implemented outside the remit of governmental bodies or documents. This is a strength of this research, as public policies have the potential to reach the whole population, while the reach of other interventions and programmes is often limited. To the best of our knowledge, there have been no similar reviews within the transport area so far.

This review has also some limitations. Only literature in English was included. As a consequence, a lot of the evidence we have reviewed comes from studies conducted in a limited number of countries (mostly in the US), and therefore it may not be applicable to other geographical, cultural and political settings without appropriate 'translation' to local realities (e.g., cul-de-sac lengths). There are also limitations stemming from the liberal and ambiguous use of the term 'policy' in the literature. This review was focused on the results of the database searches and no additional analysis of the references from the articles and grey literature was performed. Likewise, there was considerable heterogeneity regarding the methodological aspects of studies, such as research designs, assessment procedures and types of outcomes reported, which created challenges when attempting to make coherent sense of the existing evidence.

Nevertheless, the findings from this study contributes to advancing knowledge and may help inform policymaker and practitioners on what transport policies are most effective in increasing PA.

Even though the present systematic review shows that transport-related policies result in an increase in PA, further questions still demand clarification: What type of policies are most effective? What level of policies is most effective? Which are the factors enhancing or impeding their effectiveness? Future research should use a meta-analytic approach to summarize the findings from available evidence. This would allow the information from relevant studies to be combined and summarized using statistical techniques allowing the pooled estimate of the results of included studies to be derived.

5. Conclusion

This study contributed to the literature by quantitatively evaluating the relative effects of the transport related policies on PA by inducing a mode shift from car use to active transport. Three transport policy areas and several transport policy actions were identified as associated with more walking and bicycling, and consequently with greater levels of PA. These were policy interventions aimed mainly at infrastructure development, but also educational programmes and promotion as well as interventions that have a potential to indirectly achieve substantial shifts towards active modes. The results indicate that at the community level the most frequently used policy interventions are those related to infrastructure development and improvement. At the organizational level the most common wisactive travel programing and promotion and actions focused on shift of transport mode. Policy actions at the individual level are the least numerous. Nearly all studies showed results in a positive direction indicating that policies, which are enforced by national or regional governments or their agencies (of any level) may achieve specific health goals within a society.

Due to the low methodological quality and high heterogeneity of analysed studies only qualitative synthesis was conducted. Further research is needed using studies with robust methodological designs to summarize in quantitative way the findings from the available evidence.

Financial statement

The research results published in this article are a part of the project PEN funded by the Joint Programming Initiative (JPI) "A Healthy Diet for a Healthy Life", a research and innovation initiative of EU member states and associated countries. The funding agencies supporting this work are (in alphabetical order) Germany: Federal Ministry of Education and Research (BMBF); Ireland: Health Research Board (HRB); Italy: Ministry of Education, University and Research (MIUR); The Netherlands: The Netherlands Organisation for Health Research and Development (ZonMw); Norway: Research Council of Norway (RCN); and Poland: National Center for Research and Development (NCBR).

Declaration of competing interest

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

Data availability

Data will be made available on request.

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