Literature screening report

Scoping review on the effectiveness of movement-friendly environments on health: mobility infrastructures

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Abstract

Movement-friendly environments, in particular infrastructure that favours active mobility are important leverages for promoting physical activity and enabling healthy lifestyles. This scoping literature review aims at identifying the current evidence for links between mobility infrastructures and behaviour change, health outcomes as well as environmental co-benefits. The scoping review identified a total of 150 combined scientific articles and grey literature reports. The articles identified through the search examined the relationship between mobility infrastructure interventions and the three outcomes of interest. Among those, 21 were included through citations and grey literature additional searches.

Among the built environment features, walkability appears to be a major asset in promoting active travel across all age groups (increase in adult daily step count of 766 (95%CI 250 -1271) [1]). Walkability can be objectively assessed and takes into account a combination of features e.g., accessible and connected sidewalks, urban density and land use mix. Furthermore, proximity to destinations such as shops, services, work, and school are reported to be positively associated with walking as a choice of transportation. Similarly, cycling practice is positively associated with the presence of cycle-paths, the separation of cycling from other traffic modalities and the proximity to greenspaces, while it is negatively associated to objective and perceived traffic danger. Environments dominated by the presence of cars are detrimental to the perception of a safe and play-adapted neighbourhood.

Numerous cross-sectional studies report a significant association between physical activity, more specifically related to active transportation, and good physical condition. The protective effect conferred by increased active transportation covers a broad range of domains such as cardiovascular (for example for myocardial infarction OR: 1.77, 95%CI 1.05-2.99 for passive commuter compared to active commuters, evaluated in a Swedish study [2]) and respiratory health, obesity, musculoskeletal health, and general quality of life. The most pronounced protective effect against cardiovascular and respiratory diseases is attributed to cycling, with e-cycling being also effective. Obesity is negatively correlated with active travel, but interventions enabling a reduction of obesity via the sole promotion of active commuting

are scarce. Leisure-time walking and cycling are reported to reduce risks of fracture (risk ratio of 0.87 95%CI 0.82-0.92 [3]), and cycling as well as e-cycling were positively correlated with fitness outcomes. In addition, mental health was globally better in children walking to school and in adults engaged in active travel. In the end, a noticeable positive outcome of active transportation related to built infrastructures is that it seems to promote physical activity more broadly during life (percentage point increase in MVPA : 0.38, 95% CI 0.18-0.58 [4]), which could further strengthen the health benefits.

Overall, mobility infrastructure completed by social and educational incentives are effective in promoting active travel. While the detrimental health effects that active travellers are exposed to, such as increased pollution and traffic accidents, are largely compensated by the health benefits (benefit-cost ratio range from -2 to 360 (median =9) according to a systematic review [5]). The built environment can here again play a role in protecting active travellers by providing safe infrastructure and distancing motor-vehicles from cyclists and pedestrians. On a broader scale, modal shift driven by infrastructure and educational changes is an effective way to increase individual and community health, while decreasing greenhouse gas (GHG) emissions, and is documented as financially not only viable advantageous for communities.

Résumé Français

Les environnements favorables au mouvement, en particulier les infrastructures qui favorisent la mobilité active, sont des leviers importants pour promouvoir l'activité physique et favoriser des modes de vie sains. Cette revue de littérature vise à identifier les données actuelles sur les liens entre les infrastructures de mobilité et les changements de comportement, les effets en matière de santé, et les bienfaits environnementaux. L'analyse documentaire a permis d'identifier un total de 150 articles scientifiques et de publication de littérature grise. Les articles examinent la relation entre les interventions sur les infrastructures de mobilité et les trois résultats d'intérêt. Parmi les 150 références, 21 sont issues de citations et de recherches complémentaires dans la littérature grise.

Parmi les caractéristiques de l'environnement bâti, la marchabilité apparait comme un atout majeur pour promouvoir les déplacements actifs pour toutes les tranches d'âge de la population (augmentation du nombre de pas quotidiens de 766 pas (95%CI 250 -1271) [1]). La marchabilité peut être évaluée de manière objective et tient alors compte d'une combinaison de caractéristiques telles que des trottoirs accessibles et continus, la densité urbaine et l'occupation des sols. En outre, la proximité de destinations telles que les magasins, les fournisseurs de services, le travail et l'école est positivement associée à la marche comme choix de transport. De même, la pratique du vélo est positivement associée à la présence de pistes cyclables, à la séparation des vélos des autres modes de circulation et à la proximité d'espaces verts, tandis qu'elle est négativement associée au danger de la circulation objectif et perçu. Les environnements dominés par la présence de voitures nuisent à la perception d'un quartier sûr et adapté aux jeux.

De nombreuses études transversales font état d'une relation significative entre l'activité physique, liée à un transport actif, et une bonne condition physique. L'effet protecteur conféré par une augmentation de la mobilité active couvre un large éventail de domaines tels que la santé cardiovasculaire (par exemple, ratio de risque d'infarctus du myocarde: 1.77, 95%CI 1.05-2.99 pour les pendulaires passifs comparés à ceux adoptant une mobilité active d'après une étude suédoise [2]) et respiratoire, l'obésité, la santé musculo-squelettique et la qualité de vie en général. L'effet protecteur le plus prononcé contre les maladies cardiovasculaires et respiratoires est attribué au vélo, l'e-cyclisme

étant également efficace. Il existe une corrélation négative entre l'obésité et les déplacements actifs, mais les interventions permettant une réduction de l'obésité par la seule promotion des déplacements actifs sont rares. Marcher et faire du vélo comme loisir réduit les risques de fracture (ratio de risque : 0.87 95%CI 0.82-0.92 [3]), et la pratique du vélo mécanique ainsi qu'électrique est corrélée avec une bonne condition physique. En outre, les enfants qui se rendent à l'école à pied et les adultes qui pratiquent des déplacements actifs présentent une meilleure santé mentale. En fin de compte, un résultat notable de la pratique de la mobilité active est qu'elle semble promouvoir d'autres types d'activités physiques (augmentation de la MVPA en point de pourcentage: 0.38, 95% CI 0.18-0.58 [4]), ce qui pourrait d'avantage renforcer les bienfaits pour la santé.

Dans l'ensemble, les infrastructures de mobilité, complétées par des mesures incitatives sociales et éducatives, sont efficaces pour promouvoir les déplacements actifs. Les effets néfastes sur la santé auxquels les personnes actives sont sujettes, tels qu'une exposition accrue à la pollution et aux accidents de la circulation, sont largement compensés par les avantages pour la santé (rapport avantages-coûts de -2 to 360 (médiane =9) d'après une revue systématique [5]). L'environnement bâti peut ici aussi jouer un rôle dans la protection des personnes actives en fournissant des infrastructures sûres et en éloignant les véhicules à moteur des cyclistes et des piétons. À plus grande échelle, le transfert modal induit par des changements d'infrastructures et des mesures éducatives est un moyen efficace pour améliorer la santé des individus et des communautés, pour réduire les émissions de gaz à effet de serre (GES), et est documenté par des études européennes comme étant un projet financièrement viable et rentable.

Zusammenfassung Deutsch

Bewegungsfreundliche Umgebungen, insbesondere Infrastrukturen, die aktive Mobilität begünstigen, sind wichtige Hebel zur Förderung körperlicher Aktivität und gesunder Lebensstile. Diese Literaturrecherche zielt darauf ab, die aktuellen Belege für Zusammenhänge zwischen Mobilitätsinfrastrukturen und Verhaltensänderungen, Gesundheitsergebnissen sowie Umweltvorteilen zu ermitteln. Im Rahmen der Untersuchung wurden insgesamt 150 wissenschaftliche Artikel und Berichte aus der grauen Literatur identifiziert. Die durch die Suche ermittelten Artikel untersuchten den Zusammenhang zwischen Mobilitätsinfrastrukturmassnahmen und den drei interessierenden Themen. Von diesen Artikeln wurden 21 durch Zitate und zusätzliche Recherchen in grauer Literatur eingeschlossen.

Unter den Merkmalen der baulichen Umwelt scheint die Begehbarkeit ein wichtiger Faktor für die Förderung der aktiven Fortbewegung in allen Altersgruppen zu sein (Erhöhung der täglichen Schrittzahl von Erwachsenen um 766 Schritte (95%CI 250-1271) [1]). Fussgängerfreundlichkeit kann objektiv bewertet werden und berücksichtigt eine Kombination von Merkmalen, z. B. zugängliche und ununterbrochene Bürgersteige, städtische Dichte und Flächennutzung. Darüber hinaus wird berichtet, dass die Nähe zu Reisezielen wie Geschäften, Dienstleistern, Arbeit und Schule in einem positiven Zusammenhang mit dem Zu-Fuss-Gehen als Verkehrsmittelwahl steht. In ähnlicher Weise ist das Radfahren positiv mit dem Vorhandensein von Radwegen, der Trennung des Radfahrens von anderen Verkehrsarten und der Nähe zu Grünflächen in Verbindung gebracht, während ein negativer Zusammenhang mit objektiven und wahrgenommenen Verkehrsgefahren besteht. Eine von Autos dominierte Umgebung wirkt sich negativ auf die Wahrnehmung einer sicheren und spielfreundlichen Nachbarschaft aus.

Querschnittsstudien berichten über einen signifikanten Zusammenhang zwischen körperlicher Aktivität, insbesondere im Zusammenhang mit aktivem Verkehr, und guter körperlicher Verfassung. Die schützende Wirkung von aktiver Mobilität erstreckt sich auf ein breites Spektrum von Bereichen wie Herz-Kreislauf- und Atemwegserkrankungen (z.B für Myokardinfarkt, OR: 1.77 95%CI 1.05-2.99 für passive Pendler im Vergleich zu aktiven Pendlern, laut einer schwedischen Studie [2]), Fettleibigkeit, Gesundheit des Bewegungsapparats und allgemeine Lebensqualität. Die ausgeprägteste Schutzwirkung gegen Herz-Kreislauf- und Atemwegserkrankungen wird dem Radfahren zugeschrieben, wobei auch das Elektrofahrrad wirksam ist. Fettleibigkeit ist negativ mit aktiver Mobilität korreliert, aber es gibt nur wenige Massnahmen, die eine Verringerung der Fettleibigkeit allein durch die Förderung der aktiven Pendlermobilität ermöglichen. Freizeitspaziergänge und Radfahren verringern Frakturrisiko (Risikoverhältnis : 0.87 95%CI 0.82-0.92 [3]), und sowohl Radfahren als auch Radfahren mit elektrischer Unterstützung sind positiv mit der körperlichen Verfassung korreliert. Darüber hinaus weisen Kinder, die zu Fuss zur Schule gehen, und Erwachsene, die sich aktiv fortbewegen, eine bessere mentale Gesundheit auf. Letztendlich ist ein bemerkenswertes Ergebnis der aktiven Mobilität, dass sie andere Arten körperlicher Aktivität zu fördern scheint (prozentualer Anstieg der MVPA : 0.38, 95% CI 0.18-0.58 [4]), was die gesundheitlichen Vorteile noch weiter verstärken könnte.

Insgesamt sind Mobilitätsinfrastrukturen, die durch soziale und pädagogische Anreize ergänzt sein können, ein wirksames Mittel zur Förderung der aktiven Mobilität. Die nachteiligen gesundheitlichen Auswirkungen, denen aktive Reisende ausgesetzt sind, wie eine erhöhte Exposition gegenüber Umweltverschmutzung und Verkehrsunfällen, werden durch die gesundheitlichen Vorteile weitgehend kompensiert (Nutzen-Kosten-Verhältnis zwischen -2 und 360 (Median=9) gemäss einer systematischen Studie [5]). Auch hier kann die bebaute Umwelt eine Rolle beim Schutz von Aktivreisenden spielen, indem sie eine sichere Infrastruktur bereitstellt und Kraftfahrzeuge von Radfahrern und Fussgängern fernhält. Auf breiterer Ebene ist die Verkehrsverlagerung durch Infrastruktur- und Bildungsmassnahmen ein wirksames Mittel zur Verbesserung der Gesundheit des Einzelnen und der Gemeinschaft sowie zur Verringerung der Treibhausgasemissionen (THG) und wird in europäischen Studien als finanziell nicht nur tragfähiges, sondern auch vorteilhaftes Projekt dokumentiert.

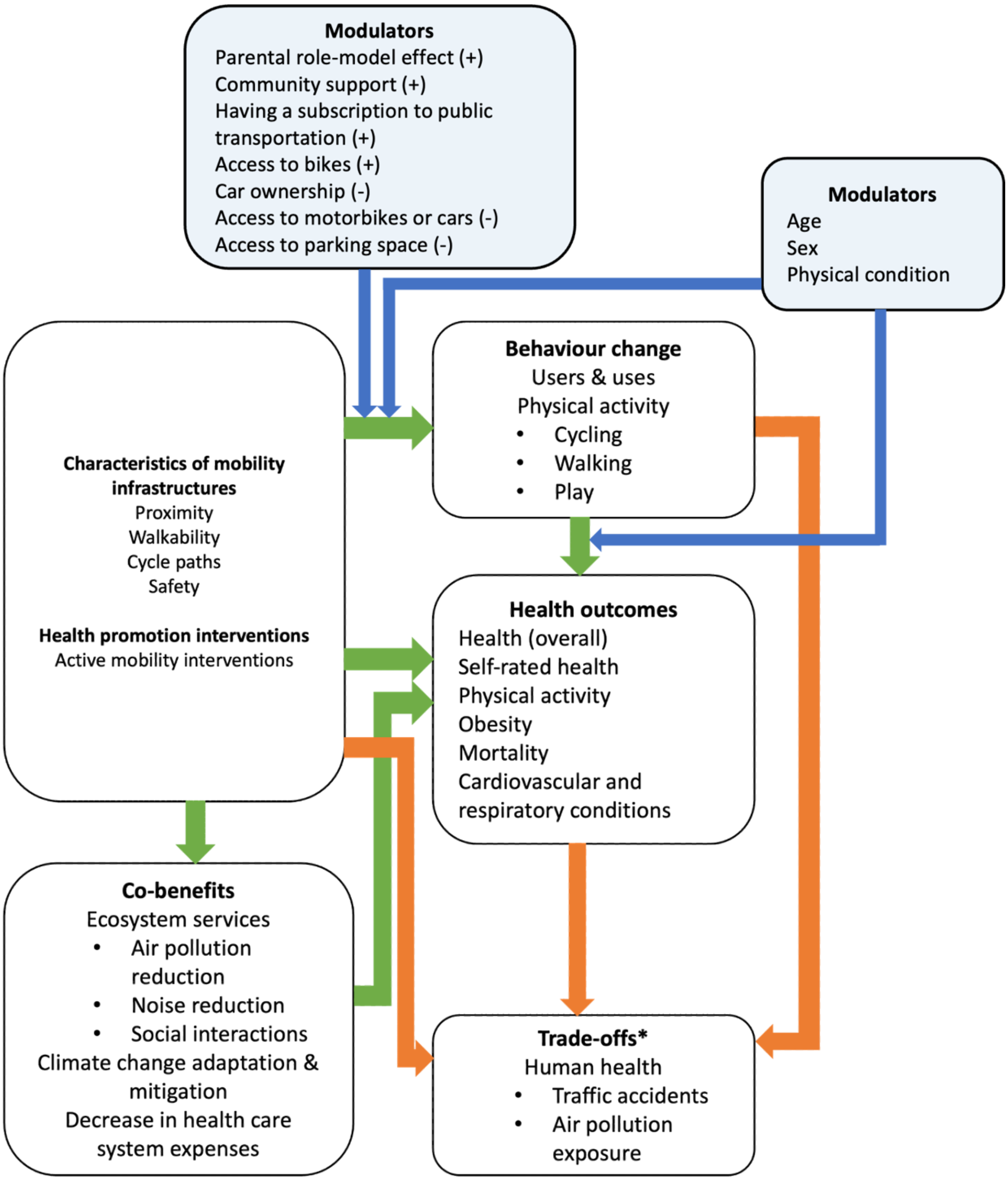

Figure 1 Main relationships between greenspaces, behaviour change, health outcomes and co-benefits

* Specifically for pedestrians and cyclists but not for the overall population

Content

Preamble

A large number of scientific publications become available on a daily basis, reflecting the rapid development of knowledge and progress of science on the link between mobility infrastructure and active mobility with human health and environmental co-benefits. Leading authorities should base decisions or policies on this knowledge; hence they need to master the actual state of this knowledge. Due to the large number of publications shared daily, decision makers heavily depend on accurate summaries of these publications, in the different public health domains. Therefore, the authors of this report were mandated by the Swiss School of Public Health plus (SSPH+), on request of the Federal Office of Public Health (FOPH), to inform the FOPH on recent findings from the literature.

Background

Movement-friendly environments, in particular infrastructure that favours active mobility are important leverages for promoting physical activity and subsequent health outcomes [6, 7]. The World Health Organization (WHO) guidelines on physical activity and sedentary behaviour recommend daily doses of moderate to vigorous physical activity, and vigorous activity to all age categories. However, the 2019 Switzerland physical activity fact sheet reported that about 60% of adolescents, and at least 25% of adults older than 35 years old were not meeting sufficient activity levels [8]. Because little activity is better than none, and that time constraints are commonly cited as an obstacle, replacing daily activities such as transportation by their more active counterpart is part of the strategies to fall within recommendation levels. Meanwhile, the transport sector accounts for 30% of the greenhouse gas (GHG) emissions of Switzerland, with the transport of people representing about 73% of it according to 2021 data [9]. A modal shift towards active mobility (walking and cycling) would allow for a win-win situation in terms of human health and environmental benefits. Such win-win interventions, here referred to as co-benefits, are both positive for human health, and the environment [10]. Actors involved in urban planning and infrastructure management have important roles in ensuring the future development of physical environments that are simultaneously supportive of human health and well-being, and more environmentally sustainable [7]. However, a better understanding of the effectiveness of such strategies, the identification of specific interventions and the exploration of potential barriers and facilitators is necessary to inform the design of policies and programs that promote good physical and mental health while also protecting the environment.

The first objective of this scoping review is to provide an overview of mobility infrastructure interventions, that took place in European countries to promote physical activity, notably in form of active transportation. In the second part, the relationship between an active mobility behaviour and specific health outcomes are analysed. Finally, this work touches upon the environmental and societal co-benefits of changes to the mobility infrastructures.

Definition of key concepts

Movement/exercise-friendly environment - Although no consensual definition of “a movement-friendly environment” exists, it can be described as natural or built (urban or rural) infrastructure that support and facilitate physical movement, exercise and activity. This can include features such as greenspaces, accessible paths for cycling, walking or other forms of active mobility; areas specifically designed for physical activity (for example, parks, playgrounds, exercise stations). Within this context, the literature makes important references to physical activity, which is defined by the World Health Organization (WHO) as "any bodily movement produced by skeletal muscles that requires energy expenditure including activities undertaken while working, playing, carrying out household chores, travelling, and engaging in recreational pursuits"[11].

Mobility infrastructure - In the context of a movement-friendly environment and this literature screening, mobility infrastructure is used to refer to infrastructure supporting active mobility. This refers specifically to modes of transportation that are non-motorised and environmentally friendly such as walking and biking. For trips of short distances, active mobility is seen as a sustainable and healthy alternative to using cars, which are a major source of air pollution and greenhouse gas emissions. In addition to being good for the environment, active mobility can also improve public health by providing opportunities for physical activity and can help to reduce traffic congestion and improve air quality in urban areas. Electrically assisted bikes, because they still require a certain level of physical efforts from the cyclists are also included under the term active mode of transportation.

Built environment - The built environment refers to the human-made features and physical infrastructure, including buildings, roads, bridges, parks, among other infrastructure in which people live, work and carry out recreational activities [12].

Walkability – The definition of walkability varies across the literature. It can be assessed both subjectively, the perception of walking-friendly environments depends on individual characteristics such as age, gender or socio-cultural background, and objectively via the use of audit tools [13]. In the latter case, it takes into account a combination of features to attribute a final score such as accessibility and connected sidewalks, density and land use mix which is the share of land occupied by residential, commercial buildings or offices for example.

Co-benefits - Sometimes called win-win strategies, co-benefits, refer to interventions that are simultaneously beneficial for maintaining, restoring or improving both human health and the environment [14]. Within the context of this literature screening, a specific focus is placed on co-benefits for biodiversity and climate change.

Questions addressed

- 1) What are the impacts of mobility infrastructure that support active mobility on behavioural change?
- 2) What are the impacts of active mobility on physical and mental health?
- 3) What are the co-benefits of active mobility?

Methodology

The literature search focused on mobility infrastructure and three specific outcomes of interest, including a) impacts on behavioural change, b) impact on physical and mental health, and c) environmental co-benefits relating to climate change. This review has been conducted in accordance with the PRISMA guidelines for reporting literature reviews [15]. The full search strategies were developed in collaborations with librarians specialised in health literature searches of Unisanté (University of Lausanne). Combinations of key search terms such as ‘built environment’, ‘city planning’, ‘environment design’, ‘urbanization’, ‘active commuting’, ‘transportation, ‘bicycling’, ‘pedestrians’, ‘health behaviour change’, ‘healthy behaviour’, ‘physical activity’, ‘exercise’, among others were used to identify relevant literature (List available in Appendix 1). Databases which were used for the search include PubMed and EMBASE. Relevant articles were then selected according to the established criteria (Appendix 2), including geographic focus on Europe, and in particular Switzerland.

Programs promoting active mobility were considered as complementary to mobility infrastructure interventions, and therefore included in this review. Furthermore, for outcome *c) environmental impact and co-benefits relating to climate change*, the research team also drew on pre-existing literature review previously conducted by members of the research team [7]. In addition to the scientific literature, grey literature from reputable international organisations in relevant domains were also used to identify additional pertinent case studies that can serve as good practice examples illustrating pertinent interventions.

The scoping review identified a total of 150 combined scientific articles and grey literature reports. The articles that were included through the search examined the relationship between mobility infrastructure interventions and the three outcomes of interest. Among those, 21 were included through citations and grey literature searches. Figure 2 provides an overview of the number of articles and grey literature included at each step of the review.

The most prevalent article type gathered via the initial search strategy were reviews (n = 48) (notably systematic reviews n = 24, scoping reviews n= 9, narrative reviews n=5, umbrella reviews n=2, rapid reviews n=2 and reviews of miscellaneous types n=6) and cross-sectional studies n= 42. The other article types were randomised control trials n= 17, modelling studies n= 9, cohort studies n=5, controlled studies n=4, longitudinal studies n=4, prospective studies n=4, case studies n=2, and guidelines n=1. While this review’s main focus was on interventions in European countries, some of the selected articles include data from further located countries, mainly north America or Asia, as part of reviews or comparison studies.

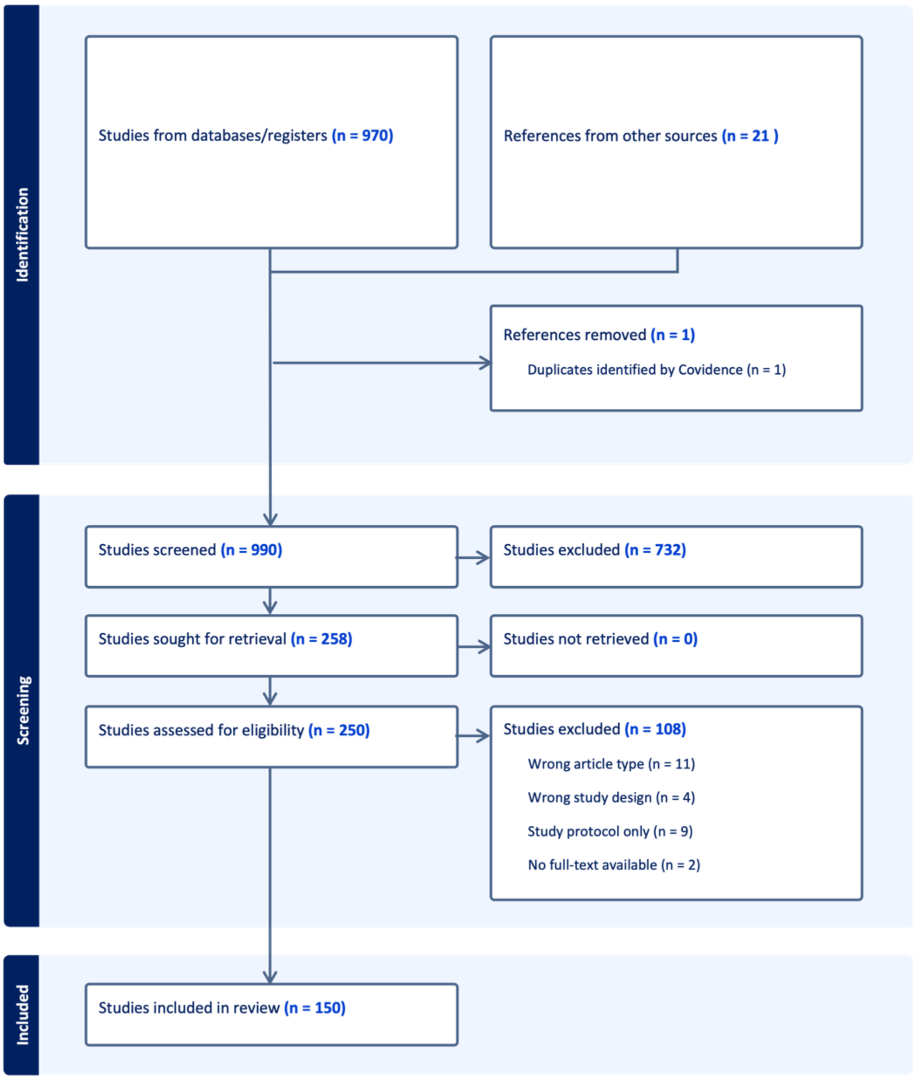

Figure 2. Flow diagram of the scoping review process indicating the number of scientific articles processed.

Results and Findings

1) What are the impacts of mobility infrastructure that support active mobility on behavioural change?

Summary:

Walkability is a composite term covering features such as urban density, land use mix diversity, and street connectivity. The literature reports strong evidence that walkable areas are positively associated with active transportation. Cycling in particular, was favoured by the presence of dedicated cycle routes, and low traffic danger. Infrastructure interventions such as the construction of dedicated cycling routes have been proven successful in recruiting more people to cycling. By reducing objective and perceived traffic danger, they tackled a major barrier to active transportation. Consequently, an increasing number of cyclists, and especially female cyclists, was observed on these specific infrastructures compared to streets without. Although the adaptation of well-chosen single road trunks supported noticeable changes in cycling counts, continuous networks should be favoured. In addition, the development of a bike and electric bike sharing system on an existing cycling network would convince additional people to the use of these modes of transportation. Despite quality of active mobility infrastructures, distance to destination remains a major barrier which is why urban planning policies should ensure that shops of first necessities or offices for example are at reasonable distance from one's home or at least, that these locations are made accessible using multimodal transportation. Educating the population about the benefits of active transportations and giving people the opportunity and skills to use bikes allowed to recruit more people to active transportation. However, the state of active mobility infrastructures remains a limiting factor. Furthermore, possessing a car and car prevalence is negatively associated with active transportation and affects children's perception of the environment. Last, mobility infrastructure interventions were seen to be more effective in populations and individuals with low social and economic support. Overall, the implementation of these infrastructures would make the public space more attractive to a greater diversity of people.

Results:

In the literature, the link between mobility infrastructure and behaviour change was most often analysed within cross-sectional studies. A few longitudinal studies reported on the implementation of heavy infrastructural changes such as bike lane construction or reallocation of road space. In addition, the promotion of active travel and educational programs aiming at active travel behaviour were reported. Active travel was thus reported either as a result of specific physical environment or social incentives. The features that were most often associated with an active behaviour were built environment interventions, proximity, promotion and education, the socio-economic environment, and a weak car-culture.

1.1 Effect of built environment interventions on active travel

The presence of certain features of the built environment and their correlations with active travel patterns has been extensively studied in the literature. Thereby, walkability was found to be positively associated with active transportation across all age groups within the population [1, 16-19]. An example of an audit tool to measure walkability is shown in Figure 3. In a systematic review and meta-analysis, the difference in the number of steps per day among adults living in high vs low walkable areas was reported to be 766 (95% C.I.: 250 to 1271) which is said to represent about 8% of the daily step recommendations [1]. When taken individually, the characteristics that compose “walkability” have less clear relations with active travel patterns and mixed findings are reported in the literature. For example, it has been found that density, land use mix diversity, street connectivity, walk/cycle facilities, aesthetics, general safety and traffic safety did not influence active transportation to school (walking and cycling) in Europe [17]. Another example is given by a systematic review focusing on 18 to 65 year old adults which reported that a better access to recreational facilities, better aesthetics, and traffic- and crime-related safety were not related to active transportation in Europe, whereas the characteristics: better access to shops, services, or work showed a positive association [18]. This suggests that isolated features of the environment have little effect on the overall behaviour and that cumulation of the features would be the most effective intervention. Lessons can be learnt from a cross-sectional study conducted on older people in Belgium in which an environmental index was calculated based on the following environmental factors: absence of high curbs, presence of different shops and services, presence of benches, presence of crossings, presence of bus stops and street lighting, and crime safety [20]. For perceived short distances, the more of these features, the higher the probability of older people to walk daily: probability of walking of 0.41 (95% C.I.: 0.39 to 0.43) in presence of all seven environmental factors. For perceived medium distances, combinations of four of these factors showed a significant change in the walking probability compared to if none of the feature was present: probability of 0.31 (95% C.I.: 0.29 to 0.33) vs 0.22 (95% C.I. 0.16 to 0.28). For perceived higher distances, the features were not anymore correlated with increase in walking.

Stepping away from the quantitative or binary assessment of walking (to walk or not to walk), walking should also be considered from a qualitative approach. In a meta-analysis, adults reported a better walking experience when exposed to picturesque sights, detail-rich environment, sufficient legibility and order, trees, natural light and fresh air. [21].

Separation of cycling from other traffic, high population density, and proximity of a cycle path or greenspace were characteristics reported to be positively associated with cycling behaviour in the overall population [22]. The same review communicates that perceived and objective traffic danger, and distance to cycle path were negatively related to cycling.

The following studies illustrate these aspects. In 2021, a 1-kilometre-long cycling route was implemented in the centre of the city of Fribourg (Switzerland) in substitution of the existing parking places. At the one year follow-up, a 20% increase in cycling counts was reported on weekdays [23]. In Cambridge, after implementation of a 22-kilometer-long traffic-free walking and cycling route, the people living closest to the new infrastructure were the ones most likely to increase their weekly commuting time [24]. In average, the increase in cycling time per week amounted to about 1h30. Both the presence of a cycling infrastructure and the proximity of the users to this infrastructure are important. In the centre of Lisbon, following a city-wide cycling network expansion, the cycling counts augmented by a factor 3.5 within one year [25]. Subsequent deployment of 1,400 bikes in a bike sharing system triggered further growth (by a factor 2.5) of the number of people cycling. However, bike sharing stations alone were insufficient at increasing cycling levels in locations where no other cycling infrastructures were present.

Time plays another role in changing mobility behaviours. In a randomised control trial in 11 Finnish workplaces walking and cycle path were improved (improvements included increased pavement smoothness and separation of cycling path from a mixed path) but no changes in actual behaviour of the employee, despite increased willingness to cycle, were observed [26]. A reported limitation of the study was the delay of the construction work that reduced the exposure to the new walking/cycling infrastructure to a maximum of 2 months.

An example of a broad-scale and long-term intervention are the cycling interventions hosted in 18 towns in England between the years 2005 and 2011. Interventions were both in term of infrastructure changes (including cycling lanes and paths and bike parking) and educational incentives at the expense of 14£ or 17£ per inhabitant and per year over a period of 6 years (6 towns) or 3 years (12 towns) [27]. The prevalence of cycling to work was reported to raise from 5.8% to 6.8% between 2001 and 2011 and to be significantly higher from the cycling-to-work increase in comparison towns. The percentage point increase in cycling was greatest among the most deprived areas (0.77, 95% C.I.: 0.60 to 0.94) compared to lesser deprived areas (0.39, 95% C.I.: 0.19 to 0.59).

When implementing changes to the infrastructure, the aim can be two-fold: Recruiting new active commuters (e.g. motorists shifting to bicycle use) and making the habit of cycling for transportation a permanent one [28]. Improving the cycling experience can especially help achieving this second goal. Cycling must not only be made possible, but it must be made desirable and attractive [29]. As reported by an Austrian cohort-study, most cyclists indeed favour routes displaying bicycle pathways/lanes, flat roads, and attractive areas instead of the shortest way available [30]. In average, the detour represented 7.6% of the shortest distance, which corresponded to 277 additional meters travelled.

To best address the needs and concerns of road users, Barrero et al. encourage urban planners to survey local populations [31]. Surveys for example highlight that while bike lanes are a first step towards safer cycling, cycle paths fully separated from other road users (notably pedestrians) grant the highest safety perception. In Zürich, implementation of cycling boxes (road marking for left-turning bicycle) allowed to increase the perceived safety at the crossing [32]. Objectively measured, the vehicles passing the cyclist indeed respected greater minimal distance after the intervention. Taking action for improving effective and subjective safety is important also for diversifying the profile of the cycling population. For the same trip, women's safety perception tend to be lower than men's [23]. In London, a study by Aldred et al. compared a road having separated cycle track with two parallel roads without traffic separation [33]. They observed a ten-percentage point difference in the number of female cyclists. Fully separated cycling infrastructure would appear safe to women but also to vulnerable populations such as children and elderlies. Aldred et al. also emphasise that the safe road invites more people wearing normal clothing (as opposed to sports clothing) than the other streets. This image is relevant in communicating that cycling is for everyone.

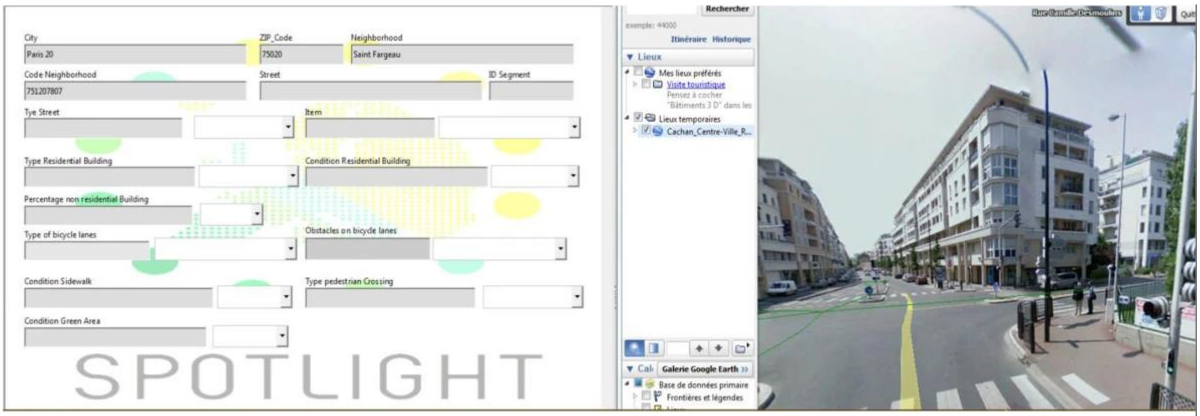

Figure 3. Figure from the study "The SPOTLIGHT virtual audit tool: a valid and reliable tool to assess obesogenic characteristics of the built environment" by J. Bethlehem et al. (2014)[34] representing a snapshot of the survey on features of the built environment next to the street portion under analysis.

1.2 Effect of proximity on active travel

Distance to destination is a major factor influencing the mode of transportation as revealed in systematic reviews, meta-analyses and other types of reviews [19, 22, 35, 36]. Living within a 20-minute walking distance from school is positively associated with walking to school [19]. In another study surveying adolescents, commuting to school by foot was considered by a majority of adolescent up to a maximal distance of 2.5km (about 30 min walk) [37]. In the same study, the maximal distance considered for biking to school was 4km (less than 10 min biking).

Therefore, across studies and for all age categories, the most decisive predictor of active travel thereby seems to be the distance to destination. The greater the distance, the lesser the efficiency of incentives due environmental factor such as presence of shops, services, benches, and crossings usually positively associated with walking [20].

Distance to the nearest bike-sharing station can also be seen as an obstacle. Following implementation of a bike-sharing system in Spain no behaviour change was observed if the closest station was further than 250m away from the student's home [38].

Urban planning must therefore carefully address these proximity issues, by ensuring dense walking and cycling networks and ensuring that one's home is at reasonable distance from essential services of daily-life (schools, food store…). Multimodality, between public and active transports should be considered for great distances.

1.3 Built environment interventions and physical activity

The same way that active travel is influenced by the built environment, the latter also modulates other forms of physical activity such as playing and sports participation. The effect can for example be mediated by the visual perception of the environment, with aesthetics being positively associated with physical activity [39]. Another review reports that school interventions such as colourful, playfields or sports-adapted playground and access to game equipment were associated with children engagement in moderate to vigorous physical activity (MVPA) [40]. In the meantime, greening of the school ground was subjectively reported to increase light physical activity (LPA). Differences in types of physical activities depending on the environment were further highlighted by a cross-sectional study in the UK: it measured that when children are in buildings or in environments dominated by road and pavements, they engage significantly more in LPA than in MVPA (the difference is around 15 minutes) [41]. On the opposite, the activity profile in parks and gardens was seen to be dominated by vigorous physical activity. So-called Play Street interventions (urban interventions consisting in reducing traffic of certain roads to provide safe spaces for children to play near home) have also been evaluated over summer vacations for their effectiveness in increasing children MVPA in Belgium [42]. Compared to children living in control neighbourhoods were Play Streets were not implemented, the children having access to Play Streets displayed one additional hour per week in MVPA and three hours and a half less sedentary time per week during the playtime week compared to the week before intervention. Regarding student's behaviour, a systematic review also reports that a low compactness index (which includes residential density) and number of sports facilities were both correlated with increased sport-participation [43]. Simple interventions which do not involve infrastructure changes, such as encouraging the use of stairs while traveling or shopping, has shown little impact on adult's health-enhancing physical activities in the past [44].

Importantly, the built environment is not the only factor conditioning one's engagement in physical activities. Age-specific behaviour must also be mentioned. In a Dutch modelling study, the authors expose that while walkability can explain the propensity of adults to engage in out-of-home activities, the same metric is not valid for the youth and elderly [45]. The authors of the study suspect that the proximity of parks could be better indictors of those activities (assumption not tested in the models).

1.4 Promotion of education interventions in active travel

Schools, and to some extent workplace environments, have been used as study environment for interventions related to the promotion of active travel. In a systematic review, "safe route to school" projects, which are developments or improvements of cycle and footpaths, were reported to be positively associated with cycling [22]. The later review reports the case of a study where a total of 10% more children were biking to school when their home to school path had been equipped following a “safe route to school” project compared to the children deprived of a safe route. However, as mentioned earlier, to grant the intervention’s success, the proximity issue should be addressed, notably for students living far from school [46]. Mitigated success of a recent randomised control trial in a Spanish school illustrated that sole promotional and educational measures were not sufficient for achieving a behaviour change. The study consisted in a 4-week long intervention divided in four different stages: theoretical courses on cycling, cycling practical trainings first on a circuit and then in an urban environment, and lastly knowledge sharing by teaching younger students what they had formerly learnt [47]. While post-intervention evaluation revealed better cycling knowledge, it indicated no change in the actual travel behaviour of the children. In addition, student increasingly considered the built environment as a barrier to walking for transportation. Features of the physical environment that represent a barrier to active commuting from children’s perspective were the focus of a systematic review published in 2014. It reports traffic safety as the most statistically significant barrier, followed by distance, presence of highway and absence of crosswalk, road safety, busy street, no direct route, lack of sidewalks and insufficient light or crossings [48].

Children’s perception of the built environment, and their travel behaviour is likely influenced by their parent’s travel behaviour. In hope of shaping that perception, targeting the mobility behaviour of parents of kindergarten children can be a promising intervention. Parents included in a Norwegian randomised control trial, who were previously cycling less than once a week, were given access to different bike types: e-bikes with trailer, cargo-bikes or traditional bikes with trailer, depending on the study group [49]. The intervention was successful in increasing the cycling frequency of the participant of the intervention group to kindergarten and to work (average cycling increase was around 1.5 days/week in autumn and spring) and a decreased car use was reported (car use decreased from around 1.5 days/week compared to baseline use). Cycling behaviour to the grocery store did not change with the car being prevalent in this situation. The participants shared that appearing as a role model to their toddlers contributed to making cycling a desirable behaviour [50].

In a medical context, personalised, targeted education to active travel can be an effective way to increase walking and cycling levels. Prescribing physical activity sessions and active commuting to abdominally obese women over an 18-months randomised clinical trial was successful in achieving a 34% reduction in car commuting [51].

1.5 Car culture and active travel.

Overall, motorised transportation (not including public transports) is negatively associated with active travel. A meta-analysis thereby specifies that: traffic noise and parking space for cars was inversely correlated with walking [21]. On the contrary, punctual public transportation and stations within walking distance were positively associated with walking. Furthermore, in cross-sectional studies, having a subscription to the public transport service correlated with walking or cycling for errands [52]. Public and active transports thereby appear as complementary to active modes of transportation.

When access and space to motorised transportation is granted, changing travel behaviour is not straightforward. Deployment of the Spanish bike sharing program previously mentioned did not reach the students who had access to motorbikes or cars [38]. Presence of a main road to school or having a park space at work are example of car-related adaptations of the built environment that are negatively associated to active travel behaviour [40, 52]. Similarly, a study performed on data on the Welsh youth reported that the presence of traffic or car parking near one's place negatively impacts the perception that the local place is a safe place for children to play outside or to walk alone after dark [53].

A timid attempt at questioning car mobility was made in a Belgian study: participants in the process of obtaining a driving licence received a one-hour lesson on active transportation at the end of their class [54]. While the intervention future drivers significantly more aware of car-sharing schemes it failed at increasing the intention to use active modes of transportation.

1.6 Socio-Economic environment and active travel

Consideration for the social and economic situation of the population or individuals is important for the understanding the additional mechanisms underlying the travel behaviour. Regarding social relations: crowded spaces, and a sense of abandonment were negatively correlated with active travel in adults[21]. Interestingly, a cross-sectional study reported that adults scoring poorly on psychosocial attributes, which they define as perceived social support, perceived barriers and self-efficacy, are the ones that respond most positively to mobility infrastructure interventions with increased walking for recreation and leisure-time physical activities [55].

Parents perceiving a social pressure to walk with their kids engaged more in active travel [21]. Reversely, when the children felt in their parents a negative perception of the environment, they showed a preference for car travel to school [36]. However, if parents displayed a physically active lifestyle and effective support to their children, the later were more likely to engage in physical activity [56, 57].

Regarding the effect of the wealth of the housing: possessing one or more vehicle was negatively related to active travel to school [58]. The same study reported that children living in deprived area of high-income countries showed a positive association with active travel to school, despite safety concerns. The authors report that this behaviour could be the result of a financial necessity rather than of a deliberate choice.

2) What are the impacts of active mobility on physical and mental health?

Summary:

Numerous cross-sectional studies report a significant association between active transportation and good physical condition. With increasing cycling levels, risks of diagnosed hypertension are reduced and so are risks of myocardial infarction. As an example, a Danish study reported that if all elderly would cycle, 7.4% coronary heart diseases would be avoided. On the other hand, while cycling confers a greater respiratory capacity, cyclists are more exposed to traffic pollution than their passive counterparts. Taking the case of Switzerland, transport related pollution is responsible for 14,000 years of life lost and 22,500 hospital days across the population. The benefits of a modal shift, from passive to active transportation, are seen at two different scales: for the individual themselves, active travel has a net positive health impact due to the protective effect of physical activity (notably a better musculoskeletal health); for society as a whole, the pollution avoided due to a part of the population making the modal shift would benefit everyone's health. Finally, studies report an increased self-rated health, emotional well-being, and quality of life among both children and adult active commuters.

Results:

Physical activity deriving from active travel and reduction of sedentary behaviour is highly correlated with positive health outcomes. The effects most often evaluated together with active mobility behaviour are cardio and respiratory health, obesity, musculoskeletal health, and mental health.

Briefly mentioned here is also that mobility-related physical activity was reported to increase overall physical activity.

2.1 Cardiovascular and respiratory health

Active travel and physical activity have been proven to have protective effects on various cardiovascular conditions. Among the adverse health effects less observed in people engaging in active travel and physical activity, literature reviews report on incident coronary heart disease, stroke, hypertension, cholesterol, and ultimately cardiovascular mortality [59-62]. Similarly, respiratory fitness is increased in people physically active or displaying active travel patterns, with greater value of maximal volume of oxygen [61].

Cross-sectional studies nevertheless highlight that the benefits of walking or cycling for transportation are not equivalent. Beneficial cardiorespiratory outcomes are found in ascending order for walking, e-cycling, and cycling without assistance [63-70]. The protection of cycling against hypertension is dose-dependent: a UK study on 6949 cyclists (ranging from commuters to racing cyclist) captured that the risk of diagnosed hypertension decreases from 0.98 (95%C.I.: 0.80–1.21) to 0.86 (0.70-1.06) and 0.67 (0.53-0.83) for cycling activity levels respectively in the range 23-40, 40-61 and >61 metabolic equivalent hours/week (MET-h/week) compared to cyclists in the range below 23 MET-h/week [71]. Meanwhile, motorised transportation displayed negative association with cardiorespiratory health [2, 63]. A Swedish study based on adult data evaluated that the odds ratio for myocardial infarction was 1.77 (95%C.I.: 1.05-2.99) for car commuters compared to active commuters [2]. In a prospective study on the effect of bicycling on the reduction of coronary heart disease (CDH) in an elderly Danish population cycling was associated with a 26% risk reduction [72]. It was also calculated that if all participants would have engaged in recreational or commuter cycling, a total of 7.4% of CHD cases could have been prevented. In another Swedish study evaluating the maximal oxygen consumption levels of children and adolescent, passive commuters had of 40.9 ml/min/kg vs 44.0 ml/min/kg for those who commuted by bike as assessed by a cycle ergometer test [63] .

The downside of active physical activity and active commuting on cardiovascular health is the increased pollution to which the non-motorised commuters are exposed [73-76]. Exposure varies greatly with modalities of the measurements and external factors such as fuel-type, traffic density, distance to the road, and respiratory rate. Exposure during rush hours were for example greater than in the middle of the day or late in the evening. Pedestrians or cyclists travelling on a track further away from the road were less exposed to particulate matter concentrations. However, when taking the breathing rate due to the increased physical expenditure into account, cyclists are usually more affected by pollution than other road users (inhaled particulate matter of cyclist vs bus user differs by a factor greater than 4, pedestrians vs bus users by a factor greater than 3) as assessed by two Irish studies [73, 77]. Concerning the general population of Switzerland, as revealed by a 2010 cross-sectional study, transport related air pollution is responsible for 14,000 years of life lost and 22,500 hospital days [78]. Despite increased exposure to pollution, the cost-benefit ratio of a modal shift from motorised vehicle towards bicycle is still significantly in favour of change. Reviews compiled that the benefit of the resulting physical activity exceeds by far the health prejudice of pollution exposure and traffic accidents (“benefit-cost ratio range from -2 to 360 (median = 9)” according to a systematic review by Mueller et al.) [5, 79]. In England and Wales, the most conservative scenario of the effect of increased active travel transportation on the national health system (NHS) finances estimated savings of 6 billion dollars within a 20-year period [80].

2.2 Obesity

A negative correlation between active travel and BMI is extensively reported in the literature [52, 81-86]. Notably, a decrease in body fat or BMI is often the hoped-for outcome in school interventions [57, 87]. Observational studies quite systematically confirm the correlation between a low BMI and active travel, and especially cycling [62]. However, interventions consisting in the promotion of active travel and measuring a change in body size as an output have mitigated results [51, 66, 88-90]. Important limitations reported by the later studies were that physical activities other than the active commutes, and nutritional intake were not taken into consideration.

2.3 Musculoskeletal health

Levels of physical activity as low as less than 20 minutes of leisure-time walking or biking per day have protective effects on the risk of fracture. Compared to those who never engage in leisure-time walking or biking, the more active individuals present hazard ratios of 0.77 (C.I.: 95% 0.70-0.85) for hip fractures and of 0.87 (0.82-0.92) for any fracture [3].

Among the multiple health benefits of active transportation, fitness is reported to be improved by biking [61, 91]. In a systematic review, the maximal cycling power was reported to have increased between 4.9% and 11% post intervention across 3 studies [61]. Significant differences exist between the power output of individual cycling on bikes equipped with electrical assistance using the no support mode, the eco support mode, or the power support mode (power output of 118.2 W, 101.8 W and 94.2 W respectively) [69]. In an observational study focusing on Danish adolescents, muscle endurance and flexibility were seen to be higher among cyclists of respectively 10% and 6% than among passive commuters or walkers [91].

2.4 Mental health

Significant overall health benefits are attributed to an active lifestyle. In a recent scoping review, children engaging in active travel estimated to have a better health and reported higher happiness levels [35]. In line with this, a more recent Spanish cross-sectional study assessed that children who walk to school reported increased emotional well-being and health-related quality of life [68] .

Similarly, in a comparative study of Swedish adults, the self-rated health of participants engaged in active travel was significantly better than those of inactive travellers [82]. Besides, in a randomised control trial targeting hospital employees in Austria, the intervention group in which active transport or multi-modal active transport were promoted showed a significant increase in mental health and overall health than the inactive control group. A greater health-related quality of life was also reported by the intervention group that commuted by bike compared to the intervention group that used a combination of public transports and walk for commuting.

2.5 Additional physical activity

Contrary to the 'ActivityStat' hypothesis stating that an increase in physical activity in one domain will be compensated by a decrease in another one, there appears to be a positive feedback between active travel and physical activity [4]. The British study making this claim recorded that each percentage point increase in (non-school) active travel led to an additional 0.38 (95% CI 0.18-0.58) increase in MVPA. In other studies, aside from physical activity inherent to the travel itself, walking and or cycling were associated with high engagement in moderate, vigorous or overall physical activity. The exact combination of associations seemed to be sex-dependant in European children and adolescents [63, 92-94].

3) What are the co-benefits of active mobility?

Summary:

A modal shift, from passive to active transportation, would have a marked advantage both at the individual level of the person making the transition and at the broader society level. Indeed, noise reduction, particulate matter reduction and lower rate of traffic accidents are all for the benefit of human health, and of health-care costs. Estimated cost-savings forecasted in European studies are seen to be largely in favour of active transportation. For initial investment in the improvement and development of cycling infrastructures future savings are made in health care expenses. A decrease in car prevalence would also free the space necessary for social exchanges (for example in the form of Plays Streets) and provide higher sense of security within the neighbourhood. The latter would in turn favour the uptake of active mobilities. Development of e-bike sharing networks are interesting solutions to be considered to support this large-scale modal shift. Last, the GHG reduction induced by a higher share of walking and biking is a substantial aspect to be considered in urban development policies.

Results:

When looking at the contribution of the positive and negative health outcomes of active transports on the population, there is on one side: protective effect against cardiovascular and respiratory condition, type II diabetes, hypercholesterolemia, and reduced obesity; On the other side: traffic accidents and air pollution exposure. At the individual level, the person engaged in the active behaviour has been showed to face a significant net beneficial effect [5, 74]. A Dutch study evaluated that the gain in life-years due to adoption of daily cycling habits is 9 times greater than the years of life lost due to increased exposure to pollution [95]. The modal shift has also been reported to be clearly beneficial at the community level as well due to overall decrease in fuel-burning related pollution and noise reduction. European studies have forecast net avoided costs for the NHS amounting to 6 billion dollars within a 20-year period [80] and for the Stockholm county's health care budget (the net benefit amounted to 8.7% of the initial investments on infrastructures, which were of 900€ per year per person shifting from cars to bikes) [96].

Car prevalence in the overall urban space has been associated with detrimental perception of the environment, e.g., a lack of safety and community feeling. On the opposite, active modes of transportation have been seen to favour social interaction and the freed space could be allocated to other types of infrastructures supporting social gatherings such as Play Streets [42] or green spaces.

Last but not least, a modal shift from car driving to walking or biking would significantly reduce GHG emissions. In a modelisation of the deployment of a wide e-bike network for Switzerland, a GHG emission reduction up to 10% of national fossil fuel-based emissions was estimated [97]. At the scale of the city of Barcelona, the implementation of bike sharing stations was estimated to have avoided the emission of 9,000 tons of CO2 from fossil fuel-based vehicles [74]. Lowering GHG emissions is mandatory as part of both mitigation and prevention strategies against the warming climate as extensively underlined by the IPCC reports. Shifting away from cars and towards active modes of transportations would allow Switzerland to get a step closer to its reduction target (- 50% GHG by 2030 compared to the level of 1990 [98]). Last but not least, this modal shift would reduce at the source the microplastic pollution of water and soils originating from the friction of car tires with the brakes and road [99].

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