Full title: **Current issues in the impacts of transport on health**

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Structured Abstract

- **Introduction or background**: Transport affects health in many ways. Benefits include access to education, employment, goods, services and leisure, and opportunities for incorporating physical activity into daily living. There are major inequalities: benefits generally accrue to wealthier people and harms to the more deprived, nationally and globally.
- **Sources of data**: *Health on the Move 2*; *Journal of Transport and Health*
- **Areas of agreement**: Benefits of travel for access and physical activity. Harms include: health impacts of air and noise pollution; injuries and fatalities from falls or collisions; sedentary behaviour with motorised transport; community severance (barrier effect of busy roads and transport infrastructure); global climate change; impacts on inequalities; transport's role in facilitating spread of communicable diseases.
- **Areas of controversy include**: biofuels; cycle safety; driving by older people.
- **Growing points and areas for research include**: effects of default 20mph speed limits; impacts of autonomous vehicles on health and inequalities.

Key words

Transport, Health, Inequalities

Introduction or background

Globally, transport is a fundamental part of modern living. There is substantial variation in the transport polices adopted and systems available both within and between countries. For example, cities around the world differ in the extent of their provision of public transport, infrastructure for walking and cycling, and car dominance. Similarly, the existence and contents of policies related to speed and blood alcohol concentration limits, for example, and their enforcement differ markedly. These examples can have profound impacts on the health of citizens and on inequalities between different groups and demonstrate the implications of transport policy decisions irrespective of setting, that is, high, middle or low-income countries and urban versus rural. Here we give an introductory overview of the relationship between transport and health drawing upon relevant literature and using primarily a UK perspective.

Early work on the health impacts of transport focussed either on injuries or, later, on air pollution. Indeed, the first legislation controlling cars was due to concerns about injuries. In 1991, a coalition of public health organisations published *Health on the Move,*[1] the first report to consider a wide range of effects of transport on health. Subsequent reports by the British Medical Association, and others, updated this. The more recent second edition of *Health on the Move*[2] expanded the scope considerably, setting out the evidence base for both the underlying impacts of transport policies and travel behaviours on health and inequalities and the implications for policy. While these reports were ground-breaking at the time, most of the health impacts of transport are now well-accepted, and are described under 'areas of agreement' below.

Sources of data

The main sources of information for this introductory article are: *Health on the Move 2*[2]; articles in the *Journal of Transport and Health* updating some chapters; papers in *Journal of Transport and Health*; and the authors' own reading on the topic.

Areas of agreement

The freedom and opportunities promised by modern transport systems epitomise some of humanity's greatest achievements. Well-designed, safe and equitable transport systems have the potential to optimise access to employment opportunities, to services, including health and education, to social and family networks, and impact positively on health and wellbeing. However, at present, the opposite is often observed, with many planning and transport designs demonstrating the negative impacts of adopting certain ways of moving about. The health implications of transport have been summarised (Tables 1 & 2).[3, 4]

Benefits

Active travel

Walking and cycling for travel can provide sufficient physical activity to meet current recommendations for adults (e.g. 150 minutes per week of moderate intensity activity, and 10 minutes' weight-bearing activity twice a week). Some researchers also classify public transport as active travel, as people often walk (or cycle) a non-negligible amount at one or both ends of such journeys.[5, 6]

Table 1: Summary of the potential effects of transport modes and health. (The table is a summary of the content of Mindell et al 2014)[1].

Health issue / state	Table 1. Potential effects of transport on health			
	Any travel mode	**Predominant car use**	**Active travel (walking and cycing)**	**Public transport use**
Physical activity		Contributes to rise in physical inactivity and sedentary behaviour which in turn increases risk of ill-health.	Physical activity as part of daily routine, with subsequent positive health outcomes.	Opportunity to build physical activity into daily routine with subsequent positive health outcomes.
Mental Health	Isolation can be due to lack of transport options.	Noise caused by motorised vehicles can cause stress and anxiety and is a risk factor for CVD. Diving can be associated with stress, anxiety and road rage. Community severance causing loneliness and isolation.	Physical activity is effective in reducing clinical symptoms in those diagnosed with severe, moderate or mild depression and has been shown to be as effective as or even more effective than traditional treatments.	Walking has been shown to have significant benefits to mental health.
External causes of ill health		Health impacts of air pollution for which traffic is a dominant source: levels generally highest inside vehicles.	Exposure to air pollution. Exposed to lower levels than when inside vehicles, but dose may be higher if requires exertion. Note, in the UK, this is out-weighted by the health benefits of physical activity Pedestrian falls	Exposure to air pollution: inside buses is intermediate between cars/taxis and walking/cycling. High levels of iron particles inside trains.
	Impacts of traffic collisions. Jumping from bridges as a method of suicide.	Use of cars in violent attacks. Road rage, now deemed a psychiatric phenomenon. Single-vehicle collision and carbon monoxide poisoning from vehicle exhaust as a method of suicide.		Non-collision injuries, particularly among older people Jumping in front of trains as a form of suicide or being pushed by another individual.

Disability		Poor planning and transport infrastructure can make the public realm unsafe for those with impairments, increasing their risk of traffic injuries.	Walking and cycling infrastructure need to accommodate those with impairments such as impaired hearing, vision, mobility, bladder/bowel control for example, to make this a viable option.	Public transport needs to accommodate those with impairments due to impaired hearing, vision, mobility, bladder/bowel control for example, to make this a viable option.
Specific diseases	Rapid regional, national and/or international spread of infectious diseases	Road traffic is the main sources of air pollution in urban areas in the UK. Exposure to air pollution, a risk for CVD, lung cancer and other respiratory diseases, is highest for drivers. Physical inactivity and a sedentary lifestyle, more likely to occur in car-dependent societies, are known risk factors for osteoporosis. Physical inactivity and obesity, more likely to occur in car-dependent societies, are known risk factors for certain cancers.	Walking and/or cycling along quiet streets can potentially reduce exposure to air pollution, thereby reducing the risk of associated health impacts of air pollution. Being physically active reduces the risk of osteoporosis and hip fractures. Physical activity reduces the risk of certain cancers.	Use of public transport can potentially reduce exposure to air pollution compared with using a private motorised vehicle Potential for spread of infectious diseases, such as influenza, through crowding on public transport. Physical activity reduces the risk of certain cancers.

However, the extent to which increased active travel impacts on body mass index (BMI), blood pressure, or other cardiovascular risk factors is less certain, as most studies have been cross-sectional. Longitudinal studies have shown a relationship between change in commute travel mode and change in BMI,[7] but the benefits of more environmental changes to create more walkable areas are less certain due to residential self-selection in most existing studies.[8]

Harms

Countering the potential for transport to positively impact on health and wellbeing are the numerous negative impacts that continue to be observed globally. Transport systems that prioritise private car use and other motorised vehicles impose a greater burden of related harms such as air pollution, noise pollution, road traffic casualties, community severance, poor mental health and reduced social interaction and cohesion. Transport policies centred on private vehicle use also limit the opportunities for, and likelihood of, daily physical activity and the associated health benefits. In western countries, the health benefits of active travel greatly outweigh the harms from injuries and air pollution.[9] The mortality and morbidity impacts of specific transport policies have been summarised.[10]

Inequalities

The positive and negative health impacts of transport are distributed unequally across populations.[11, 12] The greatest burden of the harms imposed by a car-dependent society falls on the most disadvantaged.[13, 14] For example, poorer people in cities are more likely to live in areas affected by traffic, noise, higher injury and fatality rates, and community severance imposed by major infrastructure or traffic volume.[15] In rural areas, the absence of adequate public transport and infrastructure for walking and cycling results in car-dependency even in low income households, for whom transport poverty (analogous to 'fuel poverty') impinges on their ability to fund other necessities.[16] The benefits of car ownership, such as access to services and employment opportunities, are similarly unevenly experienced, thereby exacerbating social inequalities.[13]

Medical considerations

There are specific considerations for most medical specialties, including how transport issues can affect patients' health and quality of life and can contribute to disease, and the effects of specific diseases or symptoms on patients' ability to travel, including impairments that restrict walking and diagnoses preventing driving (Table 2).[17] An American study found a higher risk of motor vehicle crashes for drivers with untreated cataracts, concluding that earlier surgery would be cost-effective.[18] Visual field loss in patients with glaucoma is also associated with higher involvement in at-fault vehicle collisions.[19] The environment may be disabling, for example, insufficient opportunities to sit en route for those with impaired walking; no public toilets available for those with impaired bladder control; street clutter or other trip hazards may prevent patients from walking. Communicable diseases can now spread further and faster. Truck drivers and those working on road construction are at increased risk of HIV infection.[20]

Table 2: Summary of the potential effects of health issues on access to and/or use of transport modes. (The table is a summary of the content of Mindell et al 2014).[1]

Health issue / state	Table 2. Potential effects of health issues on transport mode use and /or access			
	Any travel mode	**Predominant car use**	**Active travel**	**Public transport use**
Cardiovascular disease (CVD)		Individuals who have an acute coronary event or stroke can have restrictions placed on their licence to drive ranging from 1 month post the event to permanent loss. This can lead to loss of livelihood (e.g. lorry or public service vehicle drivers).	Physical deficits following a stroke or significant angina that limits walking can limit mobility and the ability to walk and cycle. Individuals may develop visual field deficits or seizures because of a stroke and may therefore be unsafe as pedestrians or cyclists, because of a lack of awareness of traffic, obstructions, and other dangers.	Physical deficits following a stroke or significant angina that limits walking can limit mobility and the ability to use public transport.
Respiratory disease			The ability to walk and/or cycle and the pace and distance travelled can be limited by severe respiratory disease.	
Neurological disease		Dementia and seizures disorders, for example, may lead to inability to drive safely and subsequent loss of licence.	Individuals with dementia may get lost when walking.	Individuals with dementia may get lost when attempting to use public transport.
Musculoskeletal disease	Musculoskeletal diseases that cause reduced and/or painful mobility that affects all modes of transport:	Marked arthritis of the hands or hips, for example, may limit an individual's ability to drive.	Cycling may be a suitable transport option for people with arthritis of weight-bearing joints, such as the knee, hip or ankle, in whom both speed and distance for walking are often limited by pain.	Marked arthritis of the hands may be limit an individual's ability to hold onto handrails for support on public transport.

Mental Health	Mental illnesses may prevent travel either through fear or restrictions on use of vehicles. Evidence suggests that motor vehicle collision rates were higher among certain driver sub-groups including those having the most severe degree of mental illness and those using specific psychotropic medications such as benzodiazepines.	Mental illnesses may prevent travel through fear.	Mental illnesses may prevent travel through fear.
Disability	Loss of independence and access to services and social contact due to an inability to drive.	Impaired hearing, vision, mobility, bladder/bowel control for example, can impede the ability to walk and/or cycle, particularly where the environment does not provide the required facilities.	Inability to use public transport with subsequent loss of independence and access to services and social contact. Impaired hearing, vision, mobility, bladder/bowel control for example, can impede the ability to use public transport.
Age	Many acute and chronic medical conditions that become more common with advancing age, in addition to the drugs used to treat them, can adversely affect driving skills resulting in an inability to drive with loss of mobility and independence.	Acute and chronic medical conditions, which become more common with advancing age, can affect ability to walk and/or cycle.	Acute and chronic medical conditions, which become more common with advancing age, can affect ability to use public transport.

Areas of controversy

Biofuels

Although there are many synergies between healthy and sustainable transport policies, there are some differences.[4] Recently, UK concerns about air pollution have highlighted divergent policy aims, whereby diesel-engine vehicles were encouraged by previous governments, because of the lower CO_2 emissions compared with petrol engines. However, diesel engines emit more fine particles, with deleterious effects on cardiorespiratory diseases, including exacerbations and premature death. The UK government has recently proposed banning the sale of diesel and petrol engine vehicles from 2040, which will do nothing to improve air quality in the next two decades. In the meantime, the use of biofuels to replace fossil fuels to help address global climate change is controversial, as growing these crops can lead to deforestation or replacement of food crops. Micro-algae can avoid this, and have lower particulate emissions, but higher NO_x emissions.[21]

Is cycling dangerous?

Relative to walking and driving

In general, there is disproportionate media coverage of rare events. Most of the time, the five deaths per day (on average) on British roads are not mentioned by national or regional media but cyclist deaths, which are infrequent, are given prominence. This distorts people's perception of risk. The difference in fatality rate by age and by sex are far larger than the differences by travel mode, when comparing car drivers, pedestrians, and cyclists.[22] Young males are safer cycling than driving, as are other road users when these males cycle rather than drive.[23] Mortality rates increase considerably in older people for drivers, cyclists and pedestrians. The lower rates for drivers at most ages is artificially reduced by the five- to nine-fold lower mortality rate for driving on motorways (where the longest and most time-consuming journeys occur) compared with general purpose roads, where cycling and walking can occur. Road travel mortality rates have fallen dramatically in this country over the past decade, by a similar proportion in all groups. Overall, fatality rates by distance travelled are higher for pedestrians than cyclists, when falls while travelling are included, but the picture is reversed when considering fatality rates by time spent travelling.[24]

Cycle helmets

One of the biggest controversies in the field relates to cycle helmets and mandatory use, much of the debate having not been peer-reviewed. Early research, based on case-control studies, showed that helmet-wearers were less likely to be injured, certainly for superficial injuries. However, these were conducted when 10-15% of cyclists wore helmets; they and their exposure to injury were not necessarily typical and the results may not have been generalizable. The results may indicate that helmets provide individual protection but there may have been unmeasured confounding, if people who were likely to wear helmets also had reduced head injury risk.

Those who believe helmets are effective and who see injured or killed individuals, and their families, advocate for mandatory helmet laws. However, if helmets do not provide protection, if they protect against superficial but not serious head (brain) injuries, or if they increase risk in other ways that negate these benefits, such laws are less useful. Even if they do provide net benefit to individuals, if they deter people from cycling (e.g. dislike or unavailability of helmets, or implying cycling is dangerous), the population health impacts of reduced physical activity are likely to be an order of

magnitude greater than the benefits of reducing serious head injuries. An overview by two well-respected epidemiologist/statisticians concluded that overall, there is no good evidence for cycle helmets being beneficial.[25]

Cycling infrastructure

Supporting the uptake of cycling for everyday travel can be a valuable opportunity to increase physical activity combined with social, economic and environmental co-benefits. Cycling, potentially one of the most effective ways to weave physical activity into daily living, delivers substantial health benefits that confer a reduction in mortality on a par with smoking cessation. Increasing levels of cycling is an opportunity to save considerable numbers of lives.[2,9]

Converting non-cyclists into active cyclists has greater potential to improve the health of people in the UK than increasing cycling among current cyclists. Segregated cycleways are often seen as means to attract those who have little, if any, previous experience in cycling,[2, 26] and are often proposed as the solution to achieving a cycling nation. However, poorly designed segregated infrastructure can render cycling inconvenient and more unsafe, particularly at traffic junctions where cyclists experience a loss of priority. What is needed to unleash the health benefits of a cycling cutlure is a comprehensive, multi-faceted package of policies and infrastruture, with the provision of separate cycleways serving to form just part of a complete, safe, and convenient cycle network. The UK's 'hierachy of provision' for guiding the development of cycle-friendly infrastructure places most emphasis on traffic and speed reduction, followed by junction treatment, hazard site treatment, and traffic management. The factors requested by novice cyclists (reallocation of carriageway space, including cycle lanes, and cycle tracks independent of the road network) are low on the evidenced-based recommended list, but may be important in encouraging them to try cycling for travel.

Definitions of road travel injuries - Pedestrian falls

Some countries, for example Russia, require involvement of a motor vehicle to define a death or injury when traveling as a road travel casualty. Most high income countries, including Great Britain, include travel-related casualties involving any form of vehicle, however powered. However, although falls off a bicycle on-highway and single vehicle crashes are included, pedestrian falls on a pavement are excluded from official road travel casualty data. Pedestrian non-fatal, travel-related injuries requiring hospital treatment are five times as frequent due to falls on the pavement as collision with a motor vehicle.[27] There are calls for pedestrian falls on a highway to be included in road travel statistics.[28, 29]

Older drivers

There is a widespread belief that older drivers are more likely to crash, but the evidence is sparse. Men and women aged 75+ do have higher fatality[24] and hospital admission rates[22] as drivers than middle-aged drivers, but the extent to which this is an increase in collisions not increased case-fatality rates associated with co-morbidity is unclear. Li and colleagues found that crash risk was higher for drivers aged 75+ but the increased case-fatality rate had greater effects.[30] The risk drivers impose on other road users is highest for young male drivers, not older drivers.[23, 31] They also have a far higher mortality and morbidity than other people when walking and cycling.

Drivers with mild dementia have an increased risk of collisions.[32] Because of age-related functional limitations, particularly deteriorating vision, hearing, and cognition,[33] some countries test older

drivers routinely, but a recent review found no benefits of this.[34] Screening of older drivers is associated with higher pedestrian fatalities among older people.[35] Driving cessation is most common among older adults with visual impairment or functional limitations.[33] However, many studies have found poorer wellbeing and less social interaction in older people who have stopped driving.

Growing points

20mph speed limits

In 2011, excessive speed was reported as a contributory factor in one-quarter of road fatalities in Britain.[36] The likelihood of death with increasing excess speed is not linear. At 20mph, 5% of pedestrians are killed in collisions between a cars and pedestrians, however, this increases to 50% at 30 mph and 95% at 40 mph. The World Health Organization endorses adopting a limit as low as 20 kph (12 mph) in school and shopping areas, for example, and on exclusively residential roads.[37]

Adopting a default 20mph speed limit has been proposed as a public health intervention that has both proven benefits for many health issues and little negative impact.[38] The introduction of city- or town-wide 20mph limits has been recommended by the National Institute for Health and Care Excellence[39] and the British Medical Association[40] to prevent unintentional injuries among children and young people. As well as reducing road danger, the use of 20mph limits may support improvements in air pollution, levels of active travel, social inclusion, community cohesion, local business viability, and reductions in noise pollution and inequalities.[38] The adoption of a national default limit on residential streets of 20mph instead of ad hoc localised implementation, using signs not engineering, is likely to cause less confusion and unfavourable driving styles; be more effective; and prevent displacement of traffic to other streets, thereby negatively impacting on air pollution emissions.[38]

Behaviour change

Kelly and Barker have written about the six common errors made by policy-makers in relation to behaviour change.[41] These misapprehensions are: 'it is just common sense'; 'it is about getting the message across'; 'knowledge and information drive behaviour'; 'people act rationally'; 'people act irrationally'; and 'it is possible to predict accurately'. They focus on the need to understand the preceding conditions that leads to people's behaviours, and what leads to those precursors. Interventions to change the behaviour of individuals, or of policy-makers, regarding transport behaviour need to be based on firm theoretical understanding of the considerable, and growing, scientific literature on behaviour change.[42, 43]

Areas timely for developing research

Autonomous vehicles have potential positive and negative impacts of on the public's health and a research agenda has been published.[44] Benefits include: being electric, so pollution is generated elsewhere, not on roads, (and if green energy, only from building that energy infrastructure); reduced injury (or so it is claimed); enabling people with impairments affecting their ability to drive safely, including older people, to be able to travel by private car for longer, with better access and reduced isolation. However, there are potential disadvantages if transport policies encouraging autonomous vehicles discourage a shift toward active travel, and to public transport for longer distances or for those unable to walk or cycle due to impairments or encumbrances, such as pushchairs or luggage.

Conclusions

Mobility and transport can allow us to thrive as communities and global nations. Although transport planning and access have not traditionally been viewed as the realm of the health profession, the transport sector has profound impacts on health and inequalities. A well-integrated and high quality transport system that prioritises walking, cycling and use of public transport can improve both physical and mental health by increasing levels of physical activity, social interaction and capital, promoting access to services and employment opportunities, while simultaneously reducing air and noise pollution, traffic injuries, community severance, and crime rates. Such a system, organised in tandem with spatial planning policies that encourage mixed-use developments so that common destinations are within easily accessible distances, also supports sustainability and climate change mitigation and the associated health impacts. Although such a view of transport may have once been considered radical, the health impacts of transport systems are now widely accepted.

However, knowledge of this potential to transform and shape the health of communities and nations has not been enough to lead to large scale adoption of a transport system centred on active travel and use of public transport in the UK nor many other locations globally.

Health professionals have a key role to play in disseminating the information discussed here and elsewhere. Transport and mobility are an integral part of people's lives and should be considered when addressing patients' health needs. Many patients have specific difficulties with travel, due to their specific diseases.[17]

Every interaction with a patient is an opportunity to raise awareness of the benefits of active travel (and public transport use) and to encourage positive behaviour change, where this is feasible. Using their collective voice, the health profession can advocate for safe, fair and healthy transport policies and designs in the communities in which they live and work and can lead by example.[40] Unleashing the positive health and environmental impacts of transport to improve lives and reduce the burden of ill-health, now and in the future, is an opportunity not to be missed.

References

1 Hannah J, Morton S, Watkins S. *Health on the move: policies for health promoting transport. The policy statement of the Transport and Health Study Group.* Birmingham: Public Health Alliance, 1991

2 Mindell JS, Watkins SJ, Cohen JM, eds. *Health on the Move 2: policies for health promoting transport. The policy statement of the Transport and Health Study Group: 2nd Edition.* Stockport: Transport and Health Study Group, 2011

3 Cohen JM, Boniface S, Watkins S. Health implications of transport planning, development and operations. *Journal of Transport & Health* 2014; 1: 63-72

4 Mindell JS, Cohen JM, Watkins SJ, Tyler S. Synergies between low-carbon and healthy transport policies. *Proceedings of the Institution of Civil Engineers - Transport* 2011; 164: 127-139

5 Sener IN, Lee RJ, Elgart Z. Potential health implications and health cost reductions of transit-induced physical activity. *Journal of Transport & Health* 2016; 3: 133-140

6 Besser LM, Dannenberg AL. Walking to Public Transit: Steps to Help Meet Physical Activity Recommendations. *American Journal of Preventive Medicine* 2005; 29: 273-280

7 Martin A, Panter J, Suhrcke M, Ogilvie D. Impact of changes in mode of travel to work on changes in body mass index: evidence from the British Household Panel Survey. *Journal of Epidemiology and Community Health* 2015; 69: 753

8 Braun LM, Rodriguez DA, Song Y, Meyer KA, Lewis CE, Reis JP, Gordon-Larsen P. Changes in walking, body mass index, and cardiometabolic risk factors following residential relocation: Longitudinal results from the CARDIA study. *Journal of Transport & Health* 2016; 3: 426-439

9 Whitfield GP, Meehan LA, Maizlish N, Wendel AM. The integrated transport and health impact modeling tool in Nashville, Tennessee, USA: Implementation steps and lessons learned. *Journal of Transport & Health* 2017; 5: 172-181

10 Khreis H, May AD, Nieuwenhuijsen MJ. Health impacts of urban transport policy measures: A guidance note for practice. *Journal of Transport & Health* 2017

11 Mackett RL. The health implications of inequalities in travel. *Journal of Transport & Health* 2014; 1: 202-209

12 Mackett RL, Thoreau R. Transport, social exclusion and health. *Journal of Transport & Health* 2015; 2: 610-617

13 Kay D. *Fairness in a car-dependent society.* London: Sustainable Development Commission, 2011

14 Gössling S. Urban transport justice. *Journal of Transport Geography* 2016; 54: 1-9

15 Mindell JS, Anciaes PR, Dhanani A, Stockton J, Jones P, Haklay M, Groce N, Scholes S, Vaughan L. Using triangulation to assess a suite of tools to measure community severance. *Journal of Transport Geography* 2017; 60: 119-129

16 Lucas K. Transport and social exclusion: Where are we now? *Transport Policy* 2012; 20: 105-113

17 Mindell JS, Cohen DL, Shelton NJ, Sutaria S, Hayward A, Watkins SJ. Transport and clinical practice. *Journal of Transport & Healt*h 2014; 1: 73-80

18 Mennemeyer ST, Owsley C, McGwin GJ. Reducing older driver motor vehicle collisions via earlier cataract surgery. *Accid Anal Prev* 2013; 61: 203-211

19 Kwon M, Huisingh C, Rhodes LA, McGwin GJ, Wood JM, Owsley C. Association between Glaucoma and At-fault Motor Vehicle Collision Involvement among Older Drivers: A Population-based Study. *Ophthalmology* 2016; 123: 109-116

20 Albrecht D, Zamora G, Banister D, Valentine N, Dora C. *Transport: shared interests in sustainable outcomes.* Social Determinant of Health (SDH) Sectoral Briefing Series. Geneva: World Health Organization, 2011

21 Mata TM, Martins AA, Caetano NS. Microalgae for biodiesel production and other applications: A review. *Renewable and Sustainable Energy Reviews* 2010; 14: 217-232

22 Mindell JS, Leslie D, Wardlaw M. Exposure-Based, 'Like-for-Like' Assessment of Road Safety by Travel Mode Using Routine Health Data. *PLoS ONE* 2012; 7: e50606

23 Scholes S, Wardlaw MJ, Heydecker B, **Mindell JS**. Risks in driving and cycling including third-party deaths in Great Britain 2005-2013: a population-based repeated cross-sectional study. *J Transp Health.* 2018; **8 B**:

24 Feleke R, Scholes S, Wardlaw M, Mindell JS. Comparative fatality risk for different travel modes by age, sex, and deprivation. *Journal of Transport and Healt*h 2017; 8 B: Accepted

25 Goldacre B, Spiegelhalter D. Bicycle helmets and the law. *BMJ 2*013; 346

26 Standen C, Crane M, Collins A, Greaves S, Rissel C. Determinants of mode and route change following the opening of a new cycleway in Sydney, Australia. *Journal of Transport & Health* 2017; 4: 255-266

27 Naumann RB, Dellinger AM, Haileyesus T, Ryan GW. Older adult pedestrian injuries in the United States: causes and contributing circumstances. *Int J Inj Contr Saf Promot* 2011; 18: 65-73

28 Noland RB, Sinclair JA, Klein NJ, Brown C. How good is pedestrian fatality data? *Journal of Transport & Health*

29 Methorst R, Schepers P, Christie N, Dijst M, Risser R, Sauter D, van Wee B. 'Pedestrian falls' as necessary addition to the current definition of traffic crashes for improved public health policies*. Journal of Transport & Health*

30 Li G, Braver ER, Chen LH. Fragility versus excessive crash involvement as determinants of high death rates per vehicle-mile of travel among older drivers. *Accid Anal Prev* 2006; 35: 227–235

31 Lafont S, Amoros E, Gadegbeku B, Chiron M, Laumon B. The impact of driver age on lost life years for other road users in France: A population based study of crash-involved road users. *Accid Anal Prev* 2008; 40: 289-294

32 Chee JN, Rapoport MJ, Molnar F, Herrmann N, O'Neill D, Marottoli R, Mitchell S, Tant M, Dow J, Ayotte D, Lanctôt KL, McFadden R, Taylor J-P, Donaghy PC, Olsen K, Classen S, Elzohairy Y, Carr DB. Update on the Risk of Motor Vehicle Collision or Driving Impairment with Dementia: a Collaborative International Systematic Review and Meta-Analysis. *The American Journal of Geriatric Psychiatry* 2017

33 MacLeod KE, Satariano WA, Ragland DR. The impact of health problems on driving status among older adults. *Journal of Transport & Health* 2014; 1: 86-94

34 Siren A, Haustein S. Driving licences and medical screening in old age: Review of literature and European licensing policies. *Journal of Transport & Health* 2015; 2: 68-78

35 O'Neill D. Towards an understanding of the full spectrum of travel-related injuries among older people. *Journal of Transport & Health* 2016; 3: 21-25

36 Department for Transport. *Reported road casualties Great Britain: 2011* Annual Report and Stats19 data. London, 2012

37 WHO Global Road Safety Partnership. *What are the tools for managing speed? Speed management: a road safety manual for decision-makers and practitioners.* Geneva: Global Road Safety Partnership, p. 53 (Chapter 3). 2008

38 Jones SJ, Brunt H. Twenty miles per hour speed limits: a sustainable solution to public health problems in Wales. *Journal of Epidemiology and Community Health* 2017; 71: 699

39 NICE. *Unintentional injuries on the road: interventions for under 15s* NICE Guidelines PH31. London: National Institute for Health and Care Excellence, 2010

40 BMA. *Healthy transport = Healthy lives.* London, 2012

41 Kelly MP, Barker M. Why is changing health-related behaviour so difficult? *Public Health* 2016; 136: 109-116

42 Michie S, van Stralen MM, West R. The behaviour change wheel: A new method for characterising and designing behaviour change interventions. *Implementation Science : IS* 2011; 6: 42-42

43 Nehme EK, Pérez A, Ranjit N, Amick BC, Kohl HW. Behavioral theory and transportation cycling research: Application of Diffusion of Innovations. *Journal of Transport & Health* 2016; 3: 346-356

44 Crayton TJ, Meier BM. Autonomous vehicles: Developing a public health research agenda to frame the future of transportation policy. *Journal of Transport & Health*