Active transport and obesity prevention – a transportation sector obesity impact scoping review and assessment for Melbourne, Australia.

Brown, V.[a,b], Moodie, M.[a,b], Mantilla Herrera, A.M.[a,c], Veerman, J.L.[a,c], Carter, R.[a,b]

[a] Centre for Research Excellence in Obesity Policy and Food Systems, Centre for Population Health Research, Faculty of Health, Deakin University, Geelong Victoria 3220 Australia.

[b] Deakin Health Economics, School of Health and Social Development, Deakin University, Geelong Victoria 3220 Australia.

[c] School of Public Health, The University of Queensland, Brisbane, Australia

Corresponding author: V. Brown, vbr@deakin.edu.au

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Abstract

Given the alarming prevalence of obesity worldwide and the need for interventions to halt the growing epidemic, more evidence on the role and impact of transport interventions for obesity prevention is required. This study conducts a scoping review of the current evidence of association between modes of transport (motor vehicle, walking, cycling and public transport) and obesity-related outcomes. Eleven reviews and thirty-three primary studies exploring associations between transport behaviours and obesity were identified. Cohort simulation Markov modelling was used to estimate the effects of body mass index (BMI) change on health outcomes and health care costs of diseases causally related to obesity in the Melbourne, Australia population.

Results suggest that evidence for an obesity effect of transport behaviours is inconclusive (29% of published studies reported expected associations, 33% mixed associations), and any potential BMI effect is likely to be relatively small. Hypothetical scenario analyses suggest that active transport interventions may contribute small but significant obesity-related health benefits across populations (approximately 65 health adjusted life years gained per year). Therefore active transport interventions that are low cost and targeted to those most amenable to modal switch are the most likely to be effective and cost-effective from an obesity prevention perspective. The uncertain but potentially significant opportunity for health benefits warrants the collection of more and better quality evidence to fully understand the potential relationships between transport behaviours and obesity. Such evidence would contribute to the obesity prevention dialogue and inform policy across the transportation, health and environmental sectors.

Highlights

- First comprehensive health impact scoping review of transportation focused on obesity
- AT may mediate population levels of obesity, but BMI effect likely to be small

- Available evidence of association between transport and obesity is inconclusive
- Low cost, targeted interventions may deliver small but significant obesity benefits
- Better information on obesity-related benefits of transport useful for planners

Keywords: Obesity, prevention, environment, health impact scoping review

1. Introduction

Approximately 52% of the world's adults are considered overweight or obese (1). The transportation sector has been identified for both its contribution to obesogenic environments through rapid motorisation, and for its potential to attenuate or moderate the effects of obesity on populations (2). Transport systems that encourage the incorporation of more incidental physical activity into daily life may offer potential as population level interventions for obesity prevention. Yet surprisingly little research has been conducted into potential obesity-related health effects of transportation behaviours.

Traditionally, health impacts considered during the transport policy process have been limited to the effects of injuries and emissions. Whilst a growing focus on the impact of environmental factors on health has resulted in an increasing number of health impact assessments (HIAs) quantifying the physical activity (PA), injury and emissions related health impacts of transport behaviours internationally over the last decade (3-7), limited studies have been undertaken for Australia (8). Whilst the mortality-related benefits of more walking and cycling for transport are now relatively well-established in the literature (9), the impact of and mechanisms for morbidity-related health effects are less understood (10).

Recent studies have suggested an association between 'automobility', defined as the use of and dependence on private motor vehicles as the primary form of transportation, and prevalence of obesity (11, 12). Recent systematic reviews have also investigated the association between active transport (walking, cycling and use of public transport) and obesity (13, 14). This study aims to collate and update this information to provide a current overview of the evidence for the potential obesity impacts of transport behaviour across all modes (i.e. walking, cycling, public and private transport). To the best of our knowledge, this represents the first scoping review considering the potential obesity impact of both motorised and non-motorised transport behaviours, and serves as a transport sector specific 'obesity impact assessment' (15).

Evidence for associations between mode of transport (walking, cycling, public and private transport) and obesity will be examined through a scoping "review of systematic reviews" and recently published literature. Obesity-related mortality and morbidity impacts of transport modes will then be modelled using the recent evidence from the literature in hypothetical scenario analyses for the Melbourne, Australia metropolitan area. Synthesis of the evidence and quantification of potential health impacts will highlight possible societal costs of automobile dependence not routinely captured in transport decision making. A better understanding of the potential obesity-related health effects of transport behaviours will provide valuable information for transportation, health and environmental planners.

2. Methods

2.1 Review of the evidence

Whilst it has been established that transport behaviours can have an impact on physical activity (PA) with resultant health benefits (16-18), the causal pathway between transport and obesity is less clear. The significant challenges of collecting rigorous evidence on the health effects of transport behaviours have been well-documented (19-21). Evidence for an obesity effect of transport modal choice relies on a logic framework as presented in Figure 1. The choice of mode of transport results in differing energy costs (metabolic equivalent task (MET) values) between modes. A shift to AT results in a change in energy expenditure, assuming that PA-related behavioural substitution does not occur (for instance, a person who usually goes to the gym cycles to work instead). Changes in energy expenditure may then lead to changes in BMI, assuming that there is no increase in energy intake (for instance, a cyclist consumes more calories as a consequence of higher energy expenditure).

Figure 1: Logic pathway between choice of mode of transport & obesity effect

Figure Notes: [1]Metabolic equivalent tasks (22). METs are defined as the ratio of the work metabolic rate to the resting metabolic rate. One MET is roughly equivalent to the energy cost of sitting quietly. BMI=body mass index.

A scoping review was undertaken to summarise the state of the evidence for an obesity effect across all modes and to inform the parameters for health impact modelling. The scoping review consisted of two parts:

(1) A scoping "review of systematic reviews". To be eligible for inclusion, systematic reviews needed to be published at any time in a peer-reviewed journal and to examine the association between mode of transport (walking, cycling, private or public transport) and an obesity-related effect; and

(2) A scoping review of new primary studies published from 2014 (the date of the most comprehensive and recently published systematic review). To be eligible for inclusion, primary studies had to be published in a peer-reviewed journal post January 2014 and to examine the association between mode of transport (walking, cycling, private or public transport) and an obesity-related effect.

Obesity effect was defined as a change in an adiposity-related outcome and reviews reporting solely on PA effect were excluded. A more generic health search term was also included so that studies where the obesity effect may not have been a primary outcome but was reported were captured. Reviews of associations between built environment characteristics (for example, composite indices such as walkability or public transport accessibility) and obesity were excluded. Academic databases searched included Scopus and EBSCOHost (all databases, including Business Source Complete, CINAHL, MedLine, SportDiscus and EconLit). The reference lists of included studies were also searched, and experts in the field were invited to recommend study inclusions. Full search strategies are given in Appendix A.

Data were extracted by one reviewer (VB) and verified by a second reviewer (RC). Associations were summed using the 'vote count method' (23) to report the number of expected, opposite, mixed or non-significant associations in each review (Table 1). Where unadjusted and adjusted results were presented, we report the final adjusted associations here.

Table 1 – Definition of associations reported

The quality of systematic reviews was assessed using the Preferred Reporting Items for Systematic Reviews Meta-Analyses (PRISMA) Statement (20). A score of 1 for each PRISMA item reported was summed to give an overall summary of the quality of reporting (PRISMA score). Criteria and PRISMA score for each review are given in Appendix B. Strength of evidence for primary studies published since 2014 was assessed using quality criteria based on the Strengthening of Reporting of Observational Studies in Epidemiology (STROBE) guidelines (24) and criteria adapted from previous studies (14, 25)(Appendix C).

2.2 Health impact modelling

Obesity-related health impact modelling was undertaken, using recent evidence of effect from the literature on changes in BMI associated with transport modal choice. Whilst estimates of effect from the literature may not be directly transferable, hypothetical scenario modelling using best available evidence provides useful exploratory analysis of the potential obesity effect of transport behaviours. Obesity effect estimates associated with transport behaviours were selected using the following selection criteria, together with expert guidance:

- relevance to the Australian transportation setting;
- relevance to the population of Melbourne, Australia;
- recency and strength of evidence;
- quality assessment score; and/or
- amenity to health impact modelling.

Cohort simulation Markov modelling was conducted to estimate the effect of changes in body mass index (BMI) on health outcomes and health care costs of nine diseases causally related to obesity (osteoarthritis of the knee and hip, breast cancer, colon cancer, endometrial cancer, kidney cancer, ischaemic heart disease, hypertensive heart disease, stroke and type 2 diabetes) for the 2010 population of Australia. The demographic profile of the Melbourne population was assumed to proportionally reflect that of the Australian population. Because our study estimates changes in health outcomes and health care costs based on a change in BMI (and not modal shift modelled to physical activity) the costs and consequences of a change to AT in terms of injuries or pollution effect are not included in our analysis. Recent studies have however demonstrated that the health benefits of a shift from motor vehicle travel to AT outweigh potentially negative effects of an increased risk of injury or exposure to emissions (26).

The consequences of a change in BMI across age-sex groups were estimated by applying potential impact fraction calculations with continuous exposure and risk functions to the incidence of obesity-related diseases. Changes in incidence resulted in changes in future prevalence and disease-specific mortality for the cohort. Health adjusted life years (HALYs) gained and health care cost savings per year were reported. HALYs are summary measures of population health, incorporating both morbidity and mortality, and provide evidence of differences in duration and quality of life that are useful in resource allocation decision-making (27). Future health care cost savings were discounted at 3%. Modelling was undertaken using Excel 2010, with uncertainty analysis around the effect estimate and relative risk of incident disease using the Excel add-in Ersatz (28).

3. Results

3.1 Results from the scoping review of the evidence

A total of 44 studies were included in our evidence review (11 systematic reviews, 33 primary studies)(Figure 2).

Figure 2: PRISMA flowcharts for included studies

The evidence for an obesity effect of transport behaviours from published reviews to date is considered relatively weak (Table 2). Although most reviews scored generally well in terms of quality of reporting (mean PRISMA score of 20 out of a possible score of 26)(Appendix B), findings are generally inconclusive given the mixed findings and comparative weakness of study designs. Narrative summary of the strength of evidence for an obesity effect across the included reviews ranged from weak (29) or insufficient (30, 31) to moderate (32).

Overall, five reviews looked exclusively at associations between mobility and obesity in children or youth (13, 25, 30, 31, 33), with a further two reviews (32, 34) including active transport to school (ATS) as part of reviews of all age groups. In total, the reviews reported 124 associations (28 (23%) in the expected direction, 27 (22%) mixed associations, 4 (3%) opposite and 65 (52%) non-significant associations). It should be noted that several papers were reported across multiple reviews. Exclusion of duplicates across multiple reviews resulted in similar proportions of expected, mixed and non-significant associations (20%, 24% and 56% respectively).

Six reviews reported associations between transport behaviours and obesity in adults (14, 32, 34-37). In total, the reviews reported 55 associations (18 (33%) in the expected direction, 29 (53%) mixed and 8 (14%) non-significant associations). Again, several papers were reported across multiple reviews. Exclusion of duplicates across multiple reviews resulted in similar proportions of expected, mixed and non-significant associations (34%, 53% and 13% respectively).

Table 2 – Systematic reviews from the peer-reviewed literature on associations between mobility and obesity

Table notes: Q.A= Was quality assessment undertaken within the paper? Y=yes, N=no. BMI – body mass index. Body comp= body composition. WC=waist circumference. Dual energy=dual energy x-ray absorption. Bioimp.= bioimpedence. Air displace= air displacement plethysmography. (O=no.)= Number of studies using objectively measured exposure or obesity outcomes. (S=no.)= number of studies using subjectively measured (self-report, proxy) exposure or obesity outcomes. NR = not reported. PRISMA score=number of items met on the PRISMA checklist. PA = physical activity. ATS = active transport to school. TRIS=Transportation Research Information Services Database. [*]= mixed association including an association in the opposite direction.

Thirty-three primary studies reporting associations between mode of transport and obesity have been published since 2014 (Table 3). Sixteen studies (49%) reported associations in the expected direction, 14 (42%) reported mixed associations and 3 studies (9%) reported non-significant associations. Nineteen (58%) of these studies reported associations in adults or college students, with 1 study reporting specifically in pregnant women (3%) and 13 studies (39%) in children or adolescents.

The mean score for strength of evidence assessment across primary studies was 7 out of a possible 13 points (range 4 to 9)(Appendix D). Twenty-seven studies published since 2014 used a cross-sectional study design (82%)(38-64), with only 6 undertaking a longitudinal study (18%)(65-70). Over half of all studies (54%) reported on combined modes of transport (AT or private transport) (38-41, 43, 46, 49-51, 53, 54, 56, 62, 65, 66, 68, 70, 71), rather than reporting by mode despite growing awareness of the potential differences in health benefits of cycling compared to walking (10). Twenty-four studies (73%) used self-reported data on transport behaviours (38, 40, 41, 43, 45, 46, 50, 54-63, 65-68, 70, 71), with seven studies (21%) reporting use of validated self-report instruments (39, 42, 47, 49, 51, 52, 69) and only two studies (6%) reporting use of objectively measured data (48, 53). Obesity-related outcomes were also self-reported in twelve (36%) studies (40-42, 52, 55-57, 60, 63, 64, 66, 69). Given the large number of potential confounders in the association between transport behaviours and obesity, most studies (91%) controlled for age, gender, socioeconomic position and at least one other potential confounder (38-42, 45, 47-52, 54-68, 70, 71). Interestingly though, only thirteen studies (39%) controlled for diet in some way (38-40, 43, 45, 49, 51, 55, 57, 59, 61, 70, 71) and 20 (61%) controlled for PA in a domain other than transportation (45-52, 55, 57-64, 67, 70, 71).

Table 3: Primary studies published since 2014 reporting associations between mode of transport and obesity

Table notes: CI=confidence interval. PA= Physical activity. BMI= body mass index. [O]= Objectively measured. [S]= Self-reported. AT=active transport. WC= waist circumference. %=per cent. ARR= adjusted rate ratio. OR=odds ratio. AOR=adjusted odds ratio. PR=prevalence ratio. Mins=minutes. Freq=frequency. Long=longitudinal. Kgs= kilograms. SD = standard deviation. NSW=New South Wales. ATS=active transport to school. BPAR=blood pressure and adiposity risk.

Table 4 summarises the overall published associations between transport behaviours and obesity outcomes included in our scoping review.

Table 4 – Overview of associations reported in published reviews and papers published since 2014

3.2 Health impact modelling using scoping review results

Given the inconclusive nature of the evidence (Table 4), modelling of the potential obesity related health impacts of transport behaviours is problematic and needs to be interpreted carefully. The application of effect estimates from the best available literature is still reliant on assumptions around causation, transferability and generalisability of results. Information on the potential magnitude of the health impact of transport policies and interventions for obesity prevention are however useful to public health researchers, policy makers and stakeholders within the transport, health and environmental fields, providing they are not over-interpreted.

Estimates of statistically significant BMI association of transport behaviours in studies published since 2014 varied. Direct comparison or meta-analysis of results was not possible due to the methodological differences between studies. The majority of studies reporting statistically significant regression coefficients however found an effect of less than 1 BMI point associated with the relevant transport behaviour (Figure 3).

Figure 3: Studies published since 2014 reporting statistically significant associations between transport and BMI[a]

Figure Notes: [a] Direct comparison of results is not recommended due to methodological differences between studies. BMI=body mass index. AT=active transport. ATS=active transport to school. Pu=public transport. P=private transport. W=walking. C=cycling

The effect estimate as presented in the study by Martin et al. (66) was therefore selected for health impact modelling, due to the comparative strength of the study's longitudinal design. Whilst the study had some limitations, Martin et al. (66) present the first estimates of individual level impact on BMI of modal switch using cohort data from the nationally representative British Household Panel Survey (BHPS). The association with BMI is also relatively conservative in comparison to the results of some other studies (Figure 3). Martin et al. (66) found that modal switch from private transport to active or public transport for work journeys was associated with a significant reduction in BMI compared to continued private vehicle use (-0.32kg/m^2, 95% CI -0.60 to -0.05)(66). Assuming the transferability of this effect, this equates to a hypothetical reduction in weight of approximately 0.99 and 0.85 kilograms on average in Australian men and women of working age (defined here as 20 to 64 years of age) respectively.

Modal share of active or public transport to work amongst people living in metropolitan Melbourne, Australia is approximately 24% (72). Our "what-if" analysis assumes a hypothetical 5% increase in the Melbourne working population (aged 20 to 64 years, in the workforce) using public or active transport (assumed former private transport commuters) and estimates potential obesity-related health impacts. An improvement of 5% modal shift was selected for modelling as it was considered to be relatively conservative and feasible given current social and demographic profiles for Melbourne. It should be noted however that the current body of literature on cost-effectiveness of AT interventions incorporating PA-related health benefits relies heavily on relatively weak evidence of effect (18). Modelling parameters and data sources are given in Table 5.

Table 5 – Modelling parameters and data sources for hypothetical scenario analyses

Table notes: [a] based on 2,000 simulations drawn from parameter specific distributions. 95% UI=95% uncertainty interval. BMI=body mass index. s.d= standard deviation. VISTA= Victorian Integrated Survey of Travel and Activity. ABS=Australian Bureau of Statistics.

5. Results from modelling potential health impact

Assuming generalisability and transferability of scenario effect estimates from the literature, we can see that potential obesity-related health gains may be achieved from transport interventions that encourage less time spent in cars and more time spent walking and cycling (Table 6). Whilst the evidence base for our modelling assumptions is not robust, we can surmise from published studies that any potential BMI effect attributable to transport behaviours would likely be relatively small on an individual level. Our modelling demonstrates that the potential health impact of small changes in BMI across populations may also have small but nonetheless significant population level effects.

Table 6 – Obesity related health impacts from scenario of association of transport behaviours and BMI, with 95% uncertainty intervals[a]

Table notes: [a] 95% UI=95% uncertainty intervals based on 2,000 simulations drawn from parameter specific distributions. BMI=body mass index. HALYs=health adjusted life years. AUD=Australian dollars.

Results from our hypothetical "what-if" analysis suggest that a 5% increase in active commuting of the Melbourne working age population would result in 65 health adjusted life years (HALYs) gained per year. If the intervention effect was maintained over the lifetime of the cohort this would result in 1,602 total lifetime HALYs gained. Total health care cost savings from diseases averted would total just over $750,000 per year. If the intervention effect was maintained over the lifetime this would result in an almost $20 million dollar saving to the Australian health system – a not inconsequential amount given the growing burden of obesity on health care systems. Even if we halved both the effect estimate (i.e. -0.16kg/m^2) and the population exposed (i.e. 2.5% modal switch) in a crude sensitivity analysis our modelling still suggests modest but worthwhile effects (16 HALYs gained per year (95% CI 12-21), health care cost savings approximately $190,616 per year (95% CI $137,814-$246,788)). This work fits into a broader body of work examining the cost-effectiveness of non-health sector interventions for obesity prevention. Whilst at this time a comparison of results across obesity prevention efforts is unable to be made, the potential cost-effectiveness of transport sector initiatives will be compared and contrasted with interventions from other sectors (*yet to be published*).

4. Discussion

This paper serves as an obesity impact assessment of the transportation sector given the current body of evidence. Despite growing interest in the health-related impacts of transport behaviours and the fact that the transport sector has been identified as a "piece of the puzzle" in mediating obesogenic environments (2), it is clear that our analysis raises more questions than can confidently be answered at this point in time. The link between active transport and obesity is controversial. Whilst a feasible logic pathway exists, our review demonstrates the current inconclusive nature of the evidence of an association between transport and obesity. Because obesity is a secondary outcome on the causal pathway and is influenced by dietary, PA and biological factors, the existing literature on the health impacts of transport behaviours currently focuses more broadly on PA, injuries and emissions effects (26). Only three transport-related health impact studies including obesity as a health endpoint have been published to date (74-76), and none of them have had a specific obesity focus.

Whilst the evidence is currently inconclusive, our analysis of published reviews found that differing methods for reporting associations may have resulted in potential overstatement of the strength of evidence at this point in time. Some published reviews report high proportions of expected associations between transport behaviours and obesity but do not readily distinguish between mixed and expected associations. For instance, the review by McCormack & Virk (36) cites 80% of studies as reporting expected associations between driving behaviours and obesity. The authors note that some mixed associations (including expected associations) were found. If the papers with mixed findings are separated from those with expected or non-significant findings as per our methods here, only 50% of studies included in that review reported expected associations. Similarly, the study by Schoeppe et al. (33) reported 50% of included studies relevant here as reporting expected associations, however if studies with mixed associations are separated that number falls to 30%. Our method here for reporting associations may therefore more accurately reflect the inconclusive nature of the evidence as it currently stands, but may be regarded as a more conservative approach to the reporting of the current body of evidence than in previous reviews.

Our review of studies published since 2014 demonstrates the growing interest in the obesity-related impacts of transport behaviour, with 33 new primary studies published in a relatively short period of time. There is increasing acceptance of the need to embrace both feasible and innovative approaches to the gathering of evidence in order to better understand potential health impacts of transportation systems (10, 26, 77, 78). Given the burden of obesity worldwide, it is important that obesity specific health impacts of transportation systems be addressed through more and better designed and funded research that:

- explores longitudinal associations between transport behaviours and health impacts, and obesity-related impacts specifically;
- objectively measures outcomes;
- accurately collects data on transport behaviours, ideally simultaneously across different transport domains (for instance leisure, commuting, occupational);
- examines potential differences in health benefits between modes;
- examines potential dose-response relationships;
- uses appropriate lengths of time to observe potential effects;
- is appropriately powered, representing another challenge given that in many places around the world cycling in women for instance has very low prevalence; and
- measures and controls for the many potential confounding factors that may influence the association between transport and obesity.

Obviously our health impact modelling is limited by the inconclusive nature of the evidence of an obesity effect of transport behaviours. Our modelling relies on a number of assumptions and is designed as a hypothetical “conversation starter” into how transportation choices might impact on future obesity-related health care costs, quality and quantity of life experienced by populations. The use of hypothetical assumptions for assessing the broader health and economic costs and benefits of transport behaviour is relatively common due to the lack of more reliable information and the inherent challenges in collecting this type of information (18). Limitations of our analysis include the assumption that effect estimates are generalisable and transferable to our population of interest. In the absence of better quality evidence, limitations also include the assumption that association equates to causation, which we know it may not. A number of the Bradford Hill criteria for causation (79) are however addressed to the best of our ability. Plausibility of mechanism for an obesity effect of AT is established and the use of an effect estimate from a longitudinal study design in our modelling minimises the effects of individual level confounding.

The exploratory results from our health impact scenario modelling therefore provide some tangible evidence of the potential value of devoting time, energy and resources to gaining a better understanding of obesity-related effects across populations. Our results for the Melbourne population suggest there may be small but worthwhile obesity specific impacts from improving rates of AT and reducing 'automobility', with the potential to contribute to broader policies to improve obesity-related outcomes across populations. Whilst AT will not be the sole panacea for obesity it may contribute as a mediator of body weight over time. Interventions that improve rates of AT support the shift in paradigm from the dichotomous framing of the central cause of obesity as personal choice versus environmental influence to the emerging perspective that the interaction between personal choice and the environment must be successfully tackled to halt the obesity epidemic (80). The incorporation of incidental PA through utilitarian transport in particular is regarded as a potentially feasible method for improving rates of PA, both in the healthy weight and overweight and obese populations. Yet given the relatively low prevalence of AT in many parts of the world, including in Australia, it is clear that effective and cost-effective interventions to promote and support AT are required.

Results from our review suggest that any potential BMI effect associated with transport behaviours is likely to be relatively small, but that small but significant population level health gains may be possible from interventions that are effective in achieving modal shift. Given this potentially small effect it is clear that the cost-effectiveness of active transport interventions from an obesity prevention perspective may rely on relatively low cost outlays. Careful design of potential interventions is also required because intervention effectiveness is most likely to be achieved in those most amenable to modal switch. Many factors influence modal choice including age, gender, topography, climate, perception of safety, distance, access, convenience and culture. In order to be both effective and cost-effective from an obesity prevention perspective, proposed interventions must successfully interpret and negotiate these and other influences in order to target those amenable to behavioural change. Those not currently amenable to modal switch may over time also become more accepting, through a combination of well-designed interventions to breakdown some of these barriers to AT behaviours, and through the normalisation of AT behaviours in those more readily amenable to modal switch.

Our study has several other limitations. Given the scoping nature of our literature, search relevant studies may have been inadvertently omitted, although we have taken steps to avoid the chance of this occurring (including using comprehensive academic databases within our search, and including key references from included studies and expert review). The vote count method employed to report associations is unable to capture Type II error within study inclusions; nor does it capture study quality or size of effect for individual studies reported in our 'review of reviews'. Results from a meta-analysis would also be preferable for use in our health impact modelling however, given the heterogeneity of the published literature at this time, this is not possible. In light of the limited evidence base for obesity effect, future studies examining broader health impacts of transport interventions with an obesity focus should also consider PA effect (modelled to obesity effect), although the purpose of this review was to examine evidence for obesity effect specifically.

5. Conclusion

Our review demonstrates the emerging body of evidence linking transport behaviours with health outcomes, and more specifically obesity-related health impacts. To the best of our knowledge this is the first health impact scoping review and modelling of transport behaviours with obesity as a specific focus. Whilst a credible logic pathway and growing evidence base supports the notional association between active transport and lower rates of obesity, more evidence is required using more rigorous study designs that control for potential confounding factors. Whilst our obesity impact scoping review and modelling was limited by assumptions around generalisability, transferability and causation and can therefore only provide hypothetical estimates of potential health impact of transport behaviours, the results demonstrate that there may be small but potentially significant obesity-specific benefits in committing time and resources to achieving environments and cultures that are more conducive to AT.

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Author contributions

VB formulated the major ideas for the paper and study inclusion criteria, and conducted the literature search and quality assessment. RC verified study inclusions. VB wrote the first draft of the main document and appendices. AM and LV provided the economic model, with VB undertaking the modelling. All authors reviewed and edited all sections. All authors read and approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.

Appendix A – Search strategies

Scoping review of reviews:

Database	*Search strategy*	*Limiters*	*Hits*
Scopus	"active transport*" OR "active travel*" OR "active commut*" AND obesity OR "body mass index" OR "body weight" OR health	Article or review	40
EBSCOHost (all databases)	systematic review AND "active transport*" OR "active travel*" OR "active commut*" AND obesity OR "body mass index" OR "body weight" OR health	Scholarly (peer-reviewed) journals;	57
Search date			15 November 2015
Duplicates			40
After duplicates removed. Titles and abstracts searched.			57
Not relevant			48
Total from database search			9
Total from expert reference or from search of reference lists			2
Final inclusions for primary studies 2014-present			11

Scoping review of studies published 2014-present:

Database	*Search strategy*	*Limiters*	*Hits*
Scopus	"active transport*" OR "active travel*" OR "active commut*" AND obesity OR "body mass index" OR "body weight" OR health	2014-present	324
EBSCOHost (all databases)	"active transport*" OR "active travel*" OR "active commut*" AND obesity OR "body mass index" OR "body weight" OR health	Scholarly (peer-reviewed) journals; 2014-present	413
Total			737
Duplicates			234
After duplicates removed. Titles and abstracts searched.			503
Not relevant			473
Total from database search			30
Total from expert reference or from search of reference lists			3
Final inclusions primary studies 2014-present			33
Search date			16 May 2016

Appendix B – Criteria for quality of reporting assessment score based on PRISMA guidelines (systematic reviews)

PRISMA item	***Criteria description, based on PRISMA checklist(81)***	***Study reference number***										
		(30)	(13)	(31)	(25)	(35)	(36)	(37)	(34)	(33)	(14)	(32)
1.	Identifies the report as a systematic review, meta-analysis, or both	1	1	1	1	1	0	1	1	1	1	1
2.	Provides a structured summary, appropriate to the journal submission guidelines	1	1	1	1	1	1	1	1	1	1	1
3.	Describes the rationale for the review in the context of what is already known	1	1	1	1	1	1	1	1	1	1	1
4.	Provides an explicit statement of objectives for the study	1	1	1	1	1	1	1	1	1	1	1
5.	Indicates whether a review protocol exists	0	1	0	0	0	0	0	1	0	0	0
6.	Specifies study characteristics used as criteria for eligibility, giving rationale	1	1	1	1	1	1	1	1	1	1	1
7.	Describes all information sources in the search and date last searched	1	1	1	1	1	1	0	1	1	1	1
8.	Presents full electronic search strategy for at least one database, such that it could be repeated	0	1	1	0	1	1	1	1	0	0	1
9.	States the process for selecting studies	0	1	1	1	1	1	1	1	1	1	1
10.	Describes method for extracting data and any methods for obtaining and confirming data	0	1	1	0	1	1	1	1	0	1	0
11.	List and defines all variables for which data were sought and any assumptions or simplifications	1	1	1	1	1	1	1	1	1	1	0
12. and 15.	Describes methods for assessing risk of bias of individual studies and across studies	0	1	0	1	1	0	1	1	1	1	1
13.	States principal summary measures	1	1	1	1	1	1	1	1	1	1	0
14.	Describes synthesis of results or reasons why results cannot be synthesised (i.e. heterogeneity)	1	1	1	1	1	1	1	0	1	1	1
16.	Describes methods of additional analyses if applicable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
17.	Gives number of studies at each stage of the process, with flow diagram	0	1	0	1	1	1	1	1	1	1	1
18.	Presents data for each individual study. For our purposes, sample size and study duration must be presented as a minimum to receive a score=1	1	0	1	0	1	1	1	0	1	1	1
19.	Presents data on risk of bias if each study, with quality assessment score	0	1	0	1	1	0	1	1	1	1	0
20.	Presents data on results for each individual study	1	1	1	1	1	1	1	1	1	1	1
21.	Presents synthesis of results. N or =1 if further quantitative graph, table is presented.	N	N	1	1	N	N	N	1	1	1	N
22.	Presents results of any assessment of risk of bias. Must explicitly reference potential for bias to =1	0	1	1	1	1	1	0	1	0	1	1
23.	Results of additional analyses	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
24.	Summarises main findings including strength of evidence where applicable	1	1	1	1	1	1	1	1	1	1	1
25.	Discusses study limitations	1	1	1	1	1	1	1	1	1	1	1
26.	Provides general interpretation of results and implications for future research	1	1	1	1	1	1	1	1	1	1	1
27.	Describes funding source for study	1	1	1	0	1	1	1	1	1	1	1
	TOTAL	15	22	20	19	22	19	20	22	20	22	18

N/A= not applicable. N=narrative synthesis of results give

Appendix C – Strength of evidence assessment using STROBE statement

Quality criteria		*Specification of scores*	*Score*
1	Study type	Cross-sectional	0
		Longitudinal	1
2	Assessment of exposure, for reporting	Combined modes, binary or categoric	0
		Combined modes, continuous	1
		Mode specific, binary or categoric	1
		Mode specific, continuous	2
3	Exposure	Self-reported	0
		Self-reported, using validated instrument	1
		Objectively measured	2
4	Outcome	Self-reported	0
		Objectively measured (at least one timepoint where applicable)	1
5	Sample size	Small (n<500)	0
		500-10,000	1
		>10,000	2
6	Completeness of data	Data available for <80% of participants or not reported	0
		Data available for ≥80% of participants	1
7	Confounding	Not controlled for confounders	0
		Controlled for minimal confounders, did not control for age, gender, proxy for socioeconomic position (e.g. income, education)	1
		Controlled for at least age, gender, proxy for socioeconomic position (e.g. income, education)	2
		Controlled for above and other confounders	3
8	Clear presentation of results of associations of interest	No table listing results and significance	0
		Table listing results and significance	1
Total (highest possible)			*13*

Appendix D – Results of quality assessment of studies published since 2014

Study	***Quality assessment criteria***								***QA score***
	1	***2***	***3***	***4***	***5***	***6***	***7***	***8***	
Berglund et al. 2016 (40)	0	0	0	0	1	0	3	1	5
Bopp et al. 2014 (41)	0	0	0	0	1	0	3	0	4
Dabrowska et al. 2015 (42)	0	0	1	0	0	1	3	1	6
Ding et al. 2014 (64)	0	1	0	0	2	1	3	1	8
Falconer et al. 2015 (65)	1	0	0	1	1	0	3	1	7
Fernandez et al. 2015 (43)	0	0	0	1	1	0	1	1	4
Flint et al. 2014 (71)	0	0	0	1	1	0	3	1	6
Flint & Cummins 2016 (45) (Flint & Cummins 2015 (44))	0	2	0	1	2	0	3	1	9
Gutierrez-Zornoza et al. 2015 (46)	0	0	0	1	1	0	1	1	4
Jauregui et al. 2015 (47)	0	1	1	1	1	0	3	0	7
LaRouche et al. 2014 (48)	0	1	2	1	1	0	3	1	9
Laverty et al. 2015 (49)	0	0	1	1	2	1	3	1	9
Machado-Rodrigues et al. 2014 (50)	0	0	0	1	1	0	3	1	6
Martin et al. 2015 (66)	1	0	0	0	1	1	3	1	7
Martinez-Gomez et al. 2014 (67)	1	1	0	1	1	0	3	1	8
McKay et al. 2015 (51)	0	0	1	1	1	1	3	1	8
Menai et al. 2015 (52)	0	1	1	0	2	1	3	1	9
Mendoza & Liu 2014 (68)	1	0	0	1	1	0	3	1	7
Molina-Garcia et al. 2014 (69)	1	2	1	0	0	1	1	0	6
Muthuri et al. 2014 (53)	0	0	2	1	1	1	0	1	6
Mwaikambo et al. 2015 (54)	0	0	0	1	1	1	3	1	7
Olabarria et al. 2014 (55)	0	1	0	0	1	1	3	1	7
Pearson et al. 2014 (56)	0	0	0	0	2	0	3	1	6
Rissel et al. 2014 (57)	0	1	0	0	2	0	3	1	7
Sarmiento et al. 2015 (58)	0	0	0	1	1	1	3	1	7
Schauder & Foley 2015 (59)	0	1	0	1	2	0	3	1	8
Scheepers et al. 2015 (60)	0	1	0	0	1	1	3	1	7
Skreden et al. 2016 (70)	1	0	0	1	0	0	3	0	5
Sugiyama et al. 2016 (61)	0	1	0	1	1	1	3	1	8
Sun et al. 2015 (62)	0	0	0	1	2	1	3	1	8
Wanner et al. 2016 (39)	0	0	1	1	1	0	3	0	6
Wijtzes et al. 2014 (38)	0	0	0	1	1	1	3	1	7
Wojan & Hamrick et al. 2015 (63)	0	1	0	0	2	1	3	1	8

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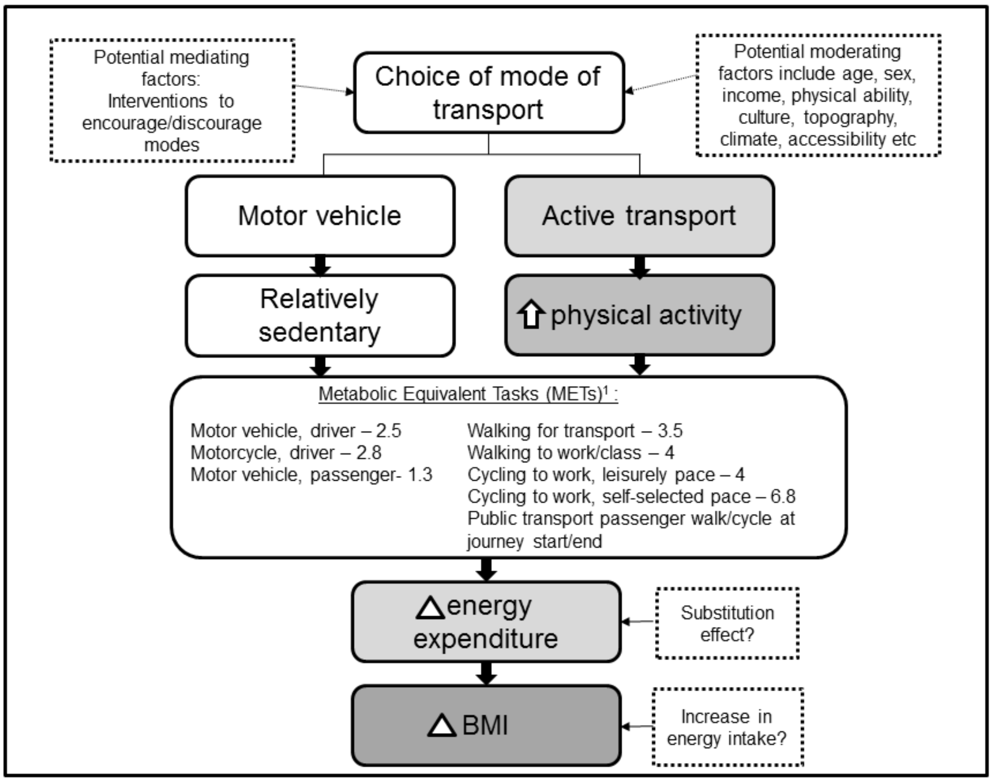
Potential mediating factors: Interventions to encourage/discourage modes
Choice of mode of transport
Potential moderating factors include age, sex, income, physical ability, culture, topography, climate, accessibility etc
Motor vehicle
Active transport
Relatively sedentary
⇧physical activity
Metabolic Equivalent Tasks (METs)¹ :
Motor vehicle, driver – 2.5
Motorcycle, driver – 2.8
Motor vehicle, passenger- 1.3
Walking for transport – 3.5
Walking to work/class – 4
Cycling to work, leisurely pace – 4
Cycling to work, self-selected pace – 6.8
Public transport passenger walk/cycle at journey start/end
△energy expenditure
Substitution effect?
△BMI
Increase in energy intake?

Fig. 1

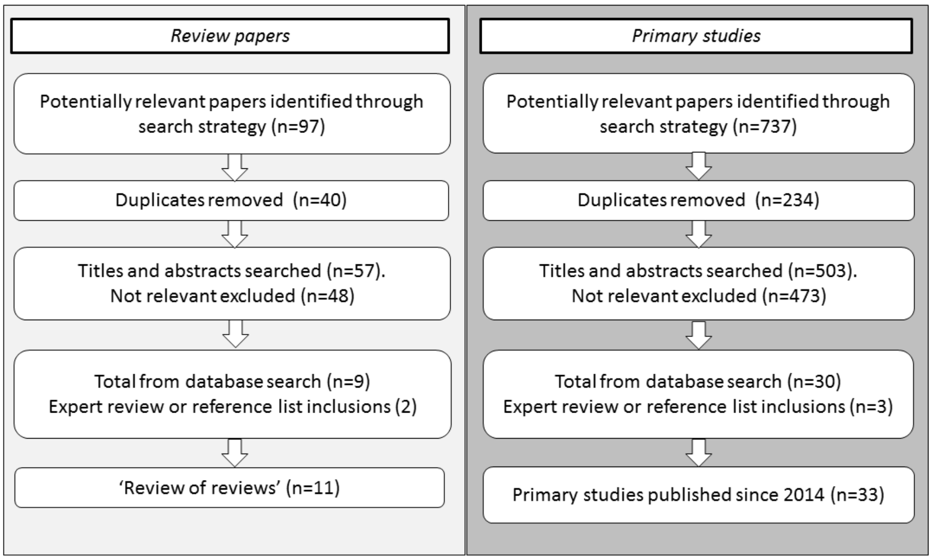
Review papers
Potentially relevant papers identified through search strategy (n=97)
Duplicates removed (n=40)
Titles and abstracts searched (n=57). Not relevant excluded (n=48)
Total from database search (n=9) Expert review or reference list inclusions (2)
'Review of reviews' (n=11)
Primary studies
Potentially relevant papers identified through search strategy (n=737)
Duplicates removed (n=234)
Titles and abstracts searched (n=503). Not relevant excluded (n=473)
Total from database search (n=30) Expert review or reference list inclusions (n=3)
Primary studies published since 2014 (n=33)

Fig. 2

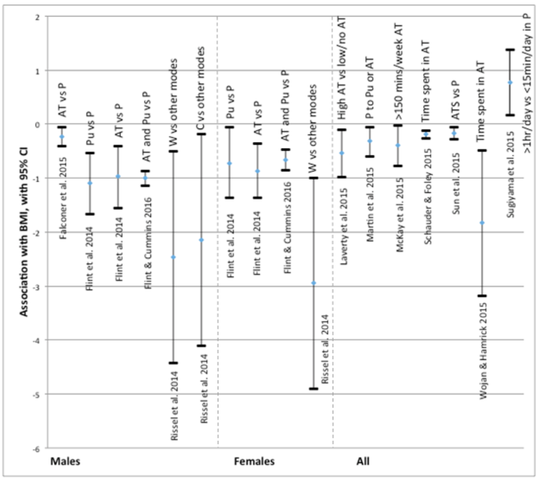
Association with BMI, with 95% CI
2
1
0
-1
-2
-3
-4
-5
-6
Males
Females
All
AT vs P
Falconer et al. 2015
Pu vs P
Flint et al. 2014
AT vs P
Flint et al. 2014
AT and Pu vs P
Flint & Cummins 2016
W vs other modes
Rissel et al. 2014
C vs other modes
Rissel et al. 2014
Pu vs P
Flint et al. 2014
AT vs P
Flint et al. 2014
AT and Pu vs P
Flint & Cummins 2016
W vs other modes
Rissel et al. 2014
High AT vs low/no AT
Laverty et al. 2015
P to Pu or AT
Martin et al. 2015
>150 mins/week AT
McKay et al. 2015
Time spent in AT
Schauder & Foley 2015
ATS vs P
Sun et al. 2015
Time spent in AT
Wojan & Hamrick 2015
>1hr/day vs <15min/day in P
Sugiyama et al. 2015

Fig. 3

Table 1 – Definition of associations reported

Association reported as	***Mode***	***Hypothesised association with obesity outcome***
Expected	Motor vehicle	Positive association
	Public transport (with active component at journey start/end)	Negative association
	Walking	Negative association
	Cycling	Negative association
Opposite	Motor vehicle	Negative association
	Public transport	Positive association
	Walking	Positive association
	Cycling	Positive association
Mixed	Varied associations within sub-group analyses, or using different techniques. Could be positive, negative or not statistically significant.	
Non-significant	No association, or no statistically significant association reported at the 5% level.	

Table 2 – Systematic reviews from the peer-reviewed literature on associations between mobility and obesity

Study (study type)	*Aim of study*	*Population*	*Inclusion criteria of included studies*	*Search dates*	*Sources searched*	*Exposure of interest here (O/S/NR)*	*Obesity outcome/s (O/S/NR)*	*No. papers w/-obesity outcome (total in review)*	*Study design of inclusions with obesity outcome*	*Associations reported*		*Q. A*	*Prisma score*
Faulkner et al. 2009 (30) (Systematic review)	To examine whether children who actively commute to school are (i) more physically active; and (ii) have a healthier body weight than children who are driven.	Children and youth, 5 to 18 years of age	Objectively measured BMI/ body weight; English language	Until 2007 - 2008	Sport Discus; Medline; Web of Science; Google Scholar; ProQuest Dissertations and Theses	ATS – walking, Cycling (O=10)	Body weight, BMI, body comp. (O=10)	10 (13)	9 cross-sectional 1 longitudinal	Expected	0/10	N	15
										Opposite	-		
										Mixed	1/10		
										Non-significant	9/10		
LaRouche et al. 2014 (13)	To examine differences in PA, body composition and	School aged children, aged 5.0 to 17.9 year	Report on at least one PA, body comp. or cardio fitnes	Until April 2012	Medline; PubMed; Embase; PsycInfo; ProQuest; ProQ	ATS – walking, cycling	BMI, skinfolds, WC, dual energy, bioimp., air	40 (68)	1 quasi-experiment, 10 longitudinal	Expected	11/40	Y	23
										Opposite	-		
										Mixed	8/40		

(Systematic review)	cardiovascular fitness between active and passive school commuters.	s old	s variable; English and French languages		uest Dissertations and Theses; Key informant	(NR=39)	displace. (O=12) (NR=27)		28 cross-sectional		[1*]		
										Non-significant	21/40		
Lee et al. 2008 (31) (Systematic review)	To examine associations of ATS with PA, weight and obesity.	School aged children (up to university age)	Report on association between ATS and PA or weight	Until Dec 2007	PubMed; Sport Discus; TRIS; Google; Google Scholar	ATS – walking, cycling (NR=18)	BMI, WC, % body fat, fat mass, overweight (O=15) (S=3)	18 (32)	2 longitudinal 16 cross-sectional.	Expected	3/18	N	20
										Opposite	1/18		
										Mixed	4/18		
										Non-significant	10/18		
Lubans et al. 2011 (25) (Systematic review)	To review associations between ATS and health. To review quality of studies exploring associations.	Children or youth, aged 5 to 18 years	Reports quantitative association; English language	1980 – Dec 2009	Embase; Ovid; MedLine; PsycInfo; PubMed; Scopus; Sport Discus; TRIS	ATS – walking, cycling (NR=25)	BMI, skinfolds, air displace. (O=22) (S=3)	25 (27)	24 cross-sectional 1 longitudinal	Expected	3/25	Y	20
										Opposite	-		
										Mixed	9/25		
										Non-significant	13/25		
Mayne et al. 2015 (35)	To examine the use of natural or quasi-experi	General population	Natural or quasi experiment effects on PA,	2005 - 2013	PubMed; MedLine	Public transport - light rail	Obesity, BMI, weight	1 (37)	1 longitudinal	Expected	1/1	Y	23
										Opposite	-		

(Systematic review)	ments to evaluate the efficacy of policy of built environment changes on obesity related outcomes.		diet or obesity;			(S=1)	(S=1)			Mixed	-		
										Non-significant	-		
McCormack & Virk 2014 (36) (Systematic review)	To review associations between motor vehicle travel distance and time and weight status.	Adults, 16 years of age and over	English language; Reports quantitative association	Until March 2014	PubMed; MedLine; TRIS; Web of Science	Motor vehicle (S=7) (O+S=1) (NR=2)	Obesity, WC, BMI, body comp. (O=2) (S=8)	10 (10)	7 cross-sectional 2 longitudinal (ecological) 1 prospective	Expected	5/10	N	19
										Opposite	-		
										Mixed	3/10		
										Non-significant	2/10		
Oja et al. 2011 (37) (Systematic	To review the evidence on the health benefits of cycling.	General population	English and German languages; Observational or intervention studies.	Not stated	BioMed Central; Google Scholar; PubMed; Scopus; SportDiscus; TRIS; Web of Science	Cycling (S=2)	Obesity, overweight, body mass, BMI (S=1) (NR=1)	2 (16)	1 cross-sectional 1 intervention	Expected	-	Y	21
										Opposite	-		
										Mixed	1/2		
										Non-significant	1/2		
						Walking and cycling	Weight	1 (16)	1 longitudinal	Expected	1/1		
										Opp	-		

review)						(S=1)	(S=1)			osite			
										Mixed	-		
										Non-significant	-		
Saunders et al. 2013 (34) (Systematic review)	To review the evidence for health benefits of active transport	General population	Controlled trials and prospective observational studies;	Until Nov 2012	Cochrane; CINAHL Plus; Embase; Global Health; Google Scholar; IBSS; MedLine; PsycInfo; Social Policy and Practice; TRIS; Web of Science	Walking and cycling (O+S=1) (NR=2)	BMI (NR=3)	3 (24)	3 intervention	Expected	-	Y	23
										Opposite	-		
										Mixed	-		
										Non-significant	3/3		
						ATS – walking and cycling (S=3)	BMI, weight, skinfolds (O=2) (S=2) (NR=1)	5 (24)	5 longitudinal	Expected	-		
										Opposite	-		
										Mixed	1/5		
										Non-significant	4/5		
Schoeppe et al. 2013 (33) (Systematic review)	To review the evidence for associations between independent mobility and PA, sedentary behaviour	Children aged 3-18 years	Report on associations; intervention studies excluded unless report on cross-sectional associations	Until Mar 2012	PubMed; Scopus; CINAHL; SportDiscus; PsycInfo; TRIS	ATS – walking and cycling (S=20)	BMI, WC, body comp., fat mass, skinfold thickness, overweight, obesity, adiposity	20 (52)	4 longitudinal 16 cross-sectional	Expected	7/20	Y	21
										Opposite	3/20		
										Mixed	3/20		
										Non-significant	7/20		

	and weight status.		; English language				(O=20)						
Wanner et al. 2012 (14) (Systematic review)	To summarise the evidence on associations between active transport, PA and body weight in adults.	Adults	Quantitative association between AT and PA or weight at individual level; English, French or German language.	Until Oct 2010	MedLine; Web of Science; Embase; SportDiscus; PsycInfo; CINAHL; TRIS; Cochrane	Walking and cycling (S=30)	Body weight (S=19) (O=9) (O+S=2)	38 (46)	38 cross-sectional	Expected	11/38	Y	22
										Opposite	-		
										Mixed	25/38		
										Non-significant	2/38		
Xu et al. 2013 (32) (Systematic review)	To summarise the evidence of relationships between AT to work or school and cardiovascular health and body weight.	School aged children and adults in the workforce	English language; RCTs, cohort, case-control or cross-sectional studies	Until Sep 2012	MedLine; CENTRAL; Cochrane	ATS – walking, cycling	BMI, WC, overweight, obesity	5 (19)	4 cross-sectional 1 longitudinal	Expected	4/5	Y	19
										Opposite	-		
										Mixed	-		
										Non-significant	1/5		
						Walking and cycling	BMI	1 (19)	1 cross-sectional	Expected	-		
										Opposite	-		
										Mixed	1/1		
										Non-significant	-		

Table notes: Q.A= Was quality assessment undertaken within the paper? Y=yes, N=no. BMI – body mass index. Body comp= body composition. WC=waist circumference. Dual energy=dual energy x-ray absorption. Bioimp.= bioimpedence.

Air displace= air displacement plethysmography. (O=no.)= Number of studies using objectively measured exposure or obesity outcomes. (S=no.)= number of studies using subjectively measured (self-report, proxy) exposure or obesity outcomes. NR = not reported. PRISMA score=number of items met on the PRISMA checklist. PA = physical activity. ATS = active transport to school. TRIS=Transportation Research Information Services Database. [*]= mixed association including an association in the opposite direction.

Table 3: Primary studies published since 2014 reporting associations between mode of transport and obesity

Publication	*Aim of study*	*Population*	*Study design*	*Exposure [O/S]*	*Outcome [O/S]*	*Results*	*Association*	*Strength of evidence*
Berglund et al. 2016 (40)	To explore associations between travel mode and health-related outcomes, including BMI.	Swedish adults, aged 45-75 years n=1,786	Cross-sectional	Regular mode of travel [S]	BMI, weight [S]	Odds for risk of obesity or being overweight were considerably higher in those who travelled inactively (AOR 1.42, 95% CI 1.13 – 1.80, p≤0.01).	Expected	5
Bopp et al. 2014 (41)	To examine associations between AT to campus and weight.	College students, Pennsylvania State University n=773	Cross-sectional	Prevalence of walking, cycling, driving to campus [S]	BMI [S]	Overweight students actively travelled less often compared to normal-weight students (8.63 trips per week compared to 11.29 trips per week, p=0.02).	Expected	4
Dabrowska et al. 2015 (42)	To evaluate associations between PA and BMI in menopausal women.	Polish women aged 45-55 n=400	Cross-sectional	Time in transport PA [S]	BMI [S]	Pearson correlation between transportation domain physical activity and obesity -0.2319, p<0.01.	Expected	6
Ding et al. 2014 (64)	To examine associations between driving time and health behaviours in middle-aged and older adults.	Adults aged 45 to 75 years and living in NSW n=35,183	Cross-sectional	Time spent driving each day [S]	BMI [S]	Longer driving time positively associated with obesity compared to driving between 1 to 30 minutes daily (driving time of between 31 and 60 mins daily AOR of obesity 1.3, 95% CI 1.21-1.40, p<0.001; 61-120 mins AOR 1.5, 95% CI 1.3-1.63, p<0.001; 121+ mins AOR 1.78, 95% CI 1.61-1.97, p<0.001).	Expected	8
Falconer et al. 2015 (65)	To evaluate AT through adolescence and associations with adiposity.	Children from the Avon Longitudinal Study of Parents and Children n=2,026	Long. Follow up at 12, 14, 16, 17.5 years	Usual travel mode to school [S]	BMI Fat mass [O]	Males consistently choosing AT reduced BMI score at age 17.5 years of -0.23 (95% CI -0.40 to -0.06) compared to consistently passive. No associations found in females. No difference in fat mass.	Mixed	7
Fernandez et al. 2015 (43)	To evaluate overweight and obesity prevalence and risk factors.	Barbadian school students in class 3 n=580	Cross-sectional	Mode of transport to school [S]	BMI [O]	AOR of overweight and obesity for boys commuting to school actively 0.38 (95% CI 0.2 – 0.73, p<0.01). Results for girls and all not statistically significant.	Mixed	4

Flint et al. 2014 (71)	To determine whether AT is associated with obesity.	Participants from the UK Household Longitudinal Study (UKHLS) n=15,777	Cross-sectional	Commuting mode to work [S]	BMI, % body fat [O]	Commuting by AT significantly predictive of lower BMI and % body fat compared with using private transport (fully adjusted difference in males using public transport BMI score -1.10 (95% CI -1.67 to -0.53, p<0.001) and AT -0.97 (95% CI -1.55 to -0.40, p<0.05))(fully adjusted difference in females using public transport BMI score -0.72 (95% CI -1.37 to -0.06, p<0.05) and AT-0.87 (95% CI -1.37 to -0.36, p<0.05)).	Expected	6
Flint & Cummins 2016 (45) Also reported in Flint & Cummins 2015 (44)	To examine association between active commuting and obesity in mid-life.	UK participants aged 40 to 69 years n=264,341	Cross-sectional	Commuting mode to work [S]	BMI, % body fat [O]	Active commuting predictive of lower BMI and % body fat for both men and women, with a dose-response pattern across all modes. Active and public transport commuters had significantly lower BMI (men -1.0 BMI point, 95% CI -1.14 to -0.87; women -0.67, 95% CI -0.86 to -0.47) than private car commuters. Results were larger for cyclists (men -1.71 BMI point, 95% CI -1.86 to -1.56; women -1.65 BMI point, 95% CI -1.92 to -1.38).	Expected	9
Gutierrez-Zornoza et al. 2015 (46)	To determine the associations between ATS and health.	Spanish school children aged 10 to 12 years. n=956	Cross-sectional	Days within previous week walked or cycled to school [S]	BMI, WC, fat mass % [O]	No significant difference overall in BMI between children who actively commuted to school daily and those who did not.	Non significant	4
Jauregui et al. 2015 (47)	To examine correlates of ATS and associations with BMI.	Mexican adolescents 10-14 years n=2,952	Cross-sectional	Usual mode to school [S]	BMI, weight [O]	Unadjusted models found significant association between ATS and BMI z-score. Adjusted models found no significant association between ATS and BMI z-score. Significant negative association between being overweight or obese and ATS.	Mixed	7
LaRouche et al. 2014 (48)	To investigate differences in body composition, fitness and cardiovascular risk	Canadian adolescents aged 12-19 years. n=1,016	Cross-sectional	Time spent walking or cycling [O and S]	BMI, WC [O]	Adolescents who reported ≥1 hour/week of utilitarian cycling had lower BMI and WC than those who reported no cycling (BMI difference -1.2 (95% CI -2.2-0.3, p=0.014), WC difference	Mixed	9

	factors across levels of walking and cycling in adolescents.					-3.4 (95% CI -5.5 to -1.3, p=0.005). Associations between walking and BMI and WC were inconsistent or non-significant.		
Laverty et al. 2015 (49)	To examine associations of AT and to determine whether AT is associated with adiposity in low and middle income countries.	Residents of China, India, Mexico, Ghana, Russia and South Africa n=40,477	Cross-sectional	Time spent walking or cycling [S]	BMI, WC, waist-hip ratio [O]	High use of AT associated with lower risk of overweight (ARR 0.71, 0.59-0.86), lower BMI (-0.54kg/m^2, 95% CI -0.98 to -0.11), lower waist-hip ratio (ARR 0.71, 95% CI 0.61-0.84) and lower WC (-2.16cm, 95% CI -3.07 to -1.26). Moderate AT was associated with lower WC (-1.52cm, 95% CI -2.40 to -0.65) and lower waist-hip ratio (ARR 0.79, 95% CI 0.68-0.92) but BMI difference was non-significant.	Mixed	9
Machado-Rodrigues et al. 2014 (50)	To analyse associations between blood pressure and adiposity risk (BPAR) and ATS.	Portuguese school children aged 7-9 years. n=665	Cross-sectional	Mode and duration of ATS [S]	BPAR score [O]	Results suggest independent and inverse association between BPAR and ATS (adjusting for BMI β =-0.13 (95% CI -0.22 to -0.04), standardised β -0.07, p=0.01).	Expected	6
Martin et al. 2015 (66)	To estimate the impact of active commuting on BMI.	Adults Great Britain n=4,056	Long. Follow-up 2 years	Main mode of travel to work [S]	BMI [S]	Switching from private to AT associated with a significant reduction in BMI compared to continued private transport use (-0.32kg/m^2, 95% CI -0.60 to -0.05). Switching from AT to private transport associated with significant increase in BMI (0.34kg/m^2, 95% CI 0.05-0.64).	Mixed	7
Martinez-Gomez et al. 2014 (67)	To examine the associations of AT at 11, 15 and 18 years of age with central body fat at 18 years of age.	Brazilian children born in 1993 n=3,469	Long. Follow up 7 years	Time spent active commuting per week [S]	WC, trunk fat mass [O]	AT at 11 years of age not associated with central body fat. AT in boys at 15 and 18 years associated with central adiposity measures. Boys with consistently high rates of AT had lower levels of central body fat compared to those with low rates of AT (WC -2.92cm, 95% CI -4.75 to -1.10, p<0.05).	Mixed	8
McKay et al. 2015 (51)	To examine correlates of AT and associations with adiposity in rural India and Bangladesh.	Adults from rural sites in India and Bangladesh n=2,122	Cross-sectional	Time spent in AT per week [S]	BMI, WC, waist-hip ratio [O]	≥150 minutes/week AT associated with lower BMI (-0.39kg/m^2, 95% CI -0.77 to -0.02, p=0.037), lower likelihood of high WC (OR 0.77, 95% CI 0.63-0.95, p=0.018) and high waist-hip ratio (OR 0.72, 95% CI 0.58-0.89, p=0.002).	Mixed	8

Menai et al. 2015 (52)	To examine correlates of active transport in French adults and to determine associations with physical activity across domains.	French adults aged 18 years and over n=39,295	Cross-sectional	Travel time by commuting mode [S]	BMI [S]	BMI significantly negatively associated with all domains of walking and cycling (commuting, leisure and errands).	Expected	9
Mendoza & Liu 2014 (68)	To examine whether ATS in kindergarten was associated with adiposity in Grade 5 children.	Kindergarten aged children in the US in 1998-99 n=12,022	Long. Follow-up 6 years	Main mode of transport to school [S]	BMI [O]	Children who ATS in kindergarten had lower BMI z-scores in fifth grade than peers who were passive commuters to school, regardless of BMI z-score in kindergarten.	Expected	7
Molina-Garcia et al. 2014 (69)	To examine behavioural change, correlates of public bicycle share scheme and potential role in promotion of healthy weight.	Spanish university students, n=173	Long. Follow up 8 months	Frequency of modes per week [S]	BMI [S]	Increase in bicycle energy expenditure may suggest a positive role in promotion of healthy weight. BMI difference amongst bicycle share users between T1 and T2 was 0.3 BMI units.	Expected	6
Muthuri et al. 2014 (53)	To determine the prevalence and determinants of overweight and obesity in Kenyan children.	Kenyan children aged 9-11 years n=563	Cross-sectional	Mode of transport to school [S and O]	BMI, % body fat, WC [O]	A higher proportion of children using motorised transport were overweight or obese (25.8%) compared to those using AT (14.7%) to get to/from school (p=0.0019).	Expected	6
Mwaikambo et al. 2015 (54)	To determine the prevalence and factors associated with overweight and obesity in children in Dar es Salaam.	Children aged 7 to 14 years attending primary school in Dar es Salaam, n=1,722	Cross-sectional	Mode of transport to school [S]	BMI [O]	Children using private cars or school buses were more likely to be overweight or obese than those who used public transport (AOR=1.6, 95% CI 1.1-2.3, p<0.05).	Expected	7
Olabarria et al. 2014 (55)	To examine the relationship between mobility and overweight and obesity.	Spanish adults living in Barcelona n=2,312	Cross-sectional	Mobility (walking, public transport, private transport) [S]	BMI [S]	No significant associations between mode of mobility and obesity were observed in women. In men, lower risk of overweight/obesity found in those who walked (walking <30 minutes PR0.81, 95% CI 0.70-0.93 and walking ≥30 minutes PR=0.81, 95% CI 0.73-0.90) or travelled by public transport only (PR=0.75, 95% CI 0.64-0.90).	Mixed	7

Pearson et al. 2014 (56)	To examine the influence of neighbourhood environments on weight outcomes and weight related behaviours.	Adults living in New Zealand aged 15 years and over. n=12,488	Cross-sectional	Prevalence of AT to work [S]	BMI [S]	Overweight and obesity status not significantly associated with AT to work in adjusted models.	Non-significant	6
Rissel et al. 2014 (57)	To examine the prevalence of walking and cycling, and associations with BMI.	Adults living in NSW aged 16 years or over. n=21,229	Cross-sectional (pooling)	Main mode of transport to work [S]	BMI [S]	Walking to work significantly associated with lower BMI (men β -2.47, 95% CI -4.43 to -0.51 women β -2.95, 95% CI -4.91 to -0.99). Cycling to work significantly associated with lower BMI in men (β-2.15, 95% CI -4.11 to -0.19) but not in women.	Mixed	7
Sarmiento et al. 2015 (58)	To assess associations between adiposity indicators and ATS in low, middle and high income countries	Children aged 9 to 11 years from 12 countries n=7,372	Cross-sectional	Mode of transport to school [S]	BMI, obesity, % body fat, WC [O]	Children reporting AST were less likely to be obese, had lower WC, and lower % body fat compared to children who used motorised transport to school. Negative associations found between BMIz and ATS (AOR -0.09, p=0.012) for both genders. Non-significant association for girls when stratified.	Mixed	7
Schauder & Foley 2015 (59)	To examine the extent to which the time spent walking or cycling for transport is associated with 10 health outcomes.	Adults living in the US n=10,498	Cross-sectional (pooling)	Daily minutes of active transport [S]	BMI [O and S]	BMI, overweight and obesity significantly associated with AT using OLS regression (BMI -0.188, p<0.01; overweight -0.0102, p<0.01; obese -0.01 p<0.01). Using instrumental variables, association of AT with BMI no longer statistically significant (overweight -0.0401, p<0.05; obese -0.0485, p<0.05).	Mixed	8
Scheepers et al. 2015 (60)	To examine associations between AT and perceived general health, wellbeing and body weight.	Adults living in the Netherlands n=3,663	Cross-sectional	Preferred mode [S]	BMI [S]	Cyclists more likely to have a health body weight than car users (OR=1.52, 95% CI 1.28-1.79). Walkers more likely to have a healthy body weight than car users (OR=1.35, 95% CI 1.09-1.69).	Expected	7
Skreden et al. 2016 (70)	To examine whether women who maintain active transport to work	Pregnant employed women in the Norwegian	Long. (Prospective trial data)	Mode of transport to work	Weight [S and O]	Weight gain through pregnancy was significantly different between women who switched from active transport to motorised	Expected	6

	throughout pregnancy will have a lower weight gain than women who change to less active modes of transport.	Fit For Delivery trial, using AT to work pre-pregnancy n=219	With follow up at 16, 30, 36 weeks and term delivery	[S]		transport ("active-less active") vs those who maintained active transport throughout pregnancy ("active-active")(2.2kg difference at term delivery, sig. at 1% level).		
Sugiyama et al. 2016 (61)	To examine associations of time spent sitting with markers of cardio-metabolic risk in Australian adults.	Australian adults aged 34 – 65 years n=2,800	Cross-sectional	Time spent in car in last week [S]	BMI, WC [O]	Overall, compared to spending <15 mins per day in cars, spending >1 hour per day in cars was significantly associated with higher BMI (0.77 higher BMI, 95% CI 0.16-1.38, p<0.05) and WC (1.5cm greater waist, 95% CI 0.02-2.98, p<0.05). When stratified by gender however time spent in cars only stat sig. for men (BMI higher by 1, 95% CI 0.23-1.77, p<0.05 in men driving >60 mins/day).	Mixed	8
Sun et al. 2015 (62)	To examines associations between ATS and physical and mental well-being in Chinese children.	Chinese school students in grades 1 to 12 n=21,596	Cross-sectional	Mode of transport to school [S]	BMI, skinfold, WC [O]	ATS was significantly associated with lower BMI, % body fat and WC. ATS was associated with lower odds of being obese (AOR 0.855, 95% CI 0.786 to 0.930) compared with children using motorised transport.	Expected	8
Wanner et al. 2016 (39)	To examine cross-sectional associations between domain specific PA and measures of obesity.	Adult participants aged 18 to 60 years in the Swiss Cohort Study on Air Pollution and Lung and Heart Disease in Adults n=3,042	Cross-sectional	Domain specific PA [S]	BMI, WC, waist to hip, waist to height, % body fat [O]	Cross-sectional results suggest an association between transport-related PA and obesity parameters in the lowest and highest tertiles, but not for per cent body fat.	Mixed	6
Wijtzes et al. 2014 (38)	To examine associations of children's sedentary and physical activity behaviours with indicators of body fat.	Dutch children aged 6 years n=5,913	Cross-sectional	Days per week of ATS [S]	BMI, fat mass [O]	No significant associations found between ATS and indicators of body fat.	Non-significant	7
Wojan & Hamrick et al. 2015 (63)	To examine association between compact development, AT and	Adults aged 20 years or over living in the US	Cross-sectional	Mode of transport to work	BMI [S]	Average treatment effect of -1.83 from AT on BMI (p=0.008, 95% CI -3.1764 to -0.484). This translates into 11 fewer pounds for the	Expected	8

	body composition.	n=12,405		[S]		average respondent who walks or cycles to work.		

Table notes: CI=confidence interval. PA= Physical activity. BMI= body mass index. [O]= Objectively measured. [S]= Self-reported. AT=active transport. WC= waist circumference. %=per cent. ARR= adjusted rate ratio. OR=odds ratio. AOR=adjusted odds ratio. PR=prevalence ratio. Mins=minutes. Freq=frequency. Long=longitudinal. Kgs= kilograms. SD = standard deviation. NSW=New South Wales. ATS=active transport to school. BPAR=blood pressure and adiposity risk.

Table 4 – Overview of associations reported in published reviews and papers published since 2014

	Children and adolescents		**Populations aged 18 years plus**		**Total (%)**
Status of association	**As reported in published reviews**	**Studies published since 2014**	**As reported in published reviews**	**Studies published since 2014**	
Expected association	28	5	18	11	62 (29%)
Opposite association	4	0	0	0	4 (2%)
Mixed association	27	6	29	8	70 (33%)
No association or association not significant at 5% level	65	2	8	1	76 (36%)

Table 5 – Modelling parameters and data sources for hypothetical scenario analyses

Parameter	*Mean value*[a]	*95% UI*[a]	*Source*	*Limitations and assumptions*
"What-if" scenario analysis				
BMI effect of modal switch from private transport to public or active transport	-0.31 kg/m^2	(-0.037 to -0.579 kg/m^2)	Samples drawn from a normal distribution (mean=-0.32kg/m^2, s.d. 0.1375) from one published source (66)	- Assumes generalisability and transferability of effect estimate to Australian population. - Sample size for exposed n=179, sample size for non-exposed n=3,090.
5% increase in the Melbourne working age population in the workforce using public or active transport			VISTA (72) and ABS (73)	Assumes accuracy of VISTA and ABS data.

Table notes: [a] based on 2,000 simulations drawn from parameter specific distributions. 95% UI=95% uncertainty interval. BMI=body mass index. s.d= standard deviation. VISTA= Victorian Integrated Survey of Travel and Activity. ABS=Australian Bureau of Statistics.

Table 6 – Obesity related health impacts from scenario of association of transport behaviours and BMI, with 95% uncertainty intervals[a]

"What-if" scenario analysis	*Results*
HALYs gained per year	65 (95% UI 48-85)
Total lifetime HALYs gained (assuming effect stability over time)	1,602 (95% UI 1,165-2,086)
Health care cost offsets per year (AUD2010)	$766,651 (95% UI $559,285 - $982,067]
Total lifetime health care cost offsets (AUD2010) (assuming effect stability over time)	$18,824,326 (95% UI $13,782,095 - $24,498,093)

Table notes: [a] 95% UI=95% uncertainty intervals based on 2,000 simulations drawn from parameter specific distributions. BMI=body mass index. HALYs=health adjusted life years. AUD=Australian dollars.

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V. Brown, M. Moodie, A.M. Mantilla Herrera, J.L. Veerman, R. Carter

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