Key health benefits associated with public transport: a rapid review

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An **Evidence Check** review brokered by the Sax Institute for the NSW Ministry of Health

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This rapid review was brokered by the Sax Institute.

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EXECUTIVE SUMMARY

The Centre for Health Advancement of the New South Wales (NSW) Ministry of Health commissioned a review to identify selected potential health benefits associated with the provision of public transport. Of 1733 articles, 27 met the search criteria, and reported on absolute measures of physical activity associated with public transport (n=9) where physical activity was reliably measured. A further 18 papers reported on factors associated with physical activity as part of public transport use (relative data). Additional grey literature was examined on an ad hoc basis.

A range of 8–33 additional minutes of walking was identified for public transport users. A significant proportion of public transport users (30%) met all their recommended levels of physical activity just from their transport walking, and public transport users were 3.5 times more likely to be sufficiently active compared with car drivers.

Lower weight was a major health benefit associated with additional minutes of walking associated with public transport use. Greater use of public transport was associated with better access or proximity to transport modes.

Using NSW Health Survey data and 'bootstrapping' statistical modelling, we examined the effect on the proportion of adults sufficiently physically active in NSW if inactive adults increased their walking by 8,16, 24 or 32 minutes a day for five days a week. For example, a 20% increase in currently inactive adults walking 24 minutes a day would lead to a significant population increase of sufficiently active people of 11.88%. There was a dose response relationship, with greater improvements at a population level resulting from more minutes being walked per day.

Collaboration between health and transport sectors to increase walking and cycling in conjunction with public transport has been recommended by many public health advocates because of the substantial health benefits associated with active travel. There are a number of international examples of successful inter-sectoral collaborations between the transport and health sectors. Agreement of the cost value of health benefits associated with active travel, and incorporation of these criteria into Treasury funding criteria would make active transport projects more competitive in relation to road projects and significantly enhance investment in active travel infrastructure, policies and programs.

BACKGROUND AND INTRODUCTION

The context of this paper is that the Centre for Health Advancement of the NSW Ministry of Health commissioned a review to identify selected potential health benefits associated with the provision of public transport. The review is undertaken to inform the development of the Long Term Transport Master Plan for NSW by the Transport for NSW agency. The findings of this proposed review will inform the Centre for Health Advancement's response to the Transport Master Plan.

The purpose of the review is to establish the current level of evidence regarding the relationship between public transport and public health benefits. Specifically the review questions are:

i. What is the ***nature*** and ***strength*** of the association between the use of public transport and incidental physical activity in adults, such as walking to and from stops or stations?

   - The specific hypothesis is that using public transport is associated with increased incidental physical activity
   - The ***nature*** of the association describes the type of physical activity that is associated with use of public transport
   - The ***strength*** of the association refers to the methodological quality of the studies on which the evidence is based and the size of the effect. Methodological quality includes the type of evaluation design and controlling for confounders.

ii. Are there any examples or case studies (internationally or nationally) of collaboration between health and transport agencies to determine the health impact of planned or implemented public transport options? What was the nature of these collaborations (e.g. formal health impact assessments)?

METHOD

A comprehensive rapid literature review was conducted, examining the published English language peer reviewed literature in the last 10 years. All modes of public transport were included (e.g. trams, trains, light rail, ferries, buses), with the exceptions of single mode walking, cycling, freight transport and taxi trips. Walking and cycling to and from public transport stations were included.

Grey literature (including government and agency reports) was included where it was frequently cited by other papers, or was readily identified through a Google search. This literature was primarily used to describe examples of collaboration between health and transport agencies (see Appendix 1).

Excluded from the review were papers focused on land use planning and changes to the built environment aimed at facilitating physical activity, as well as NSW Health or health agency funded transport schemes (e.g. isolated patients travel and the accommodation assistance scheme).

The search focused on three key elements:

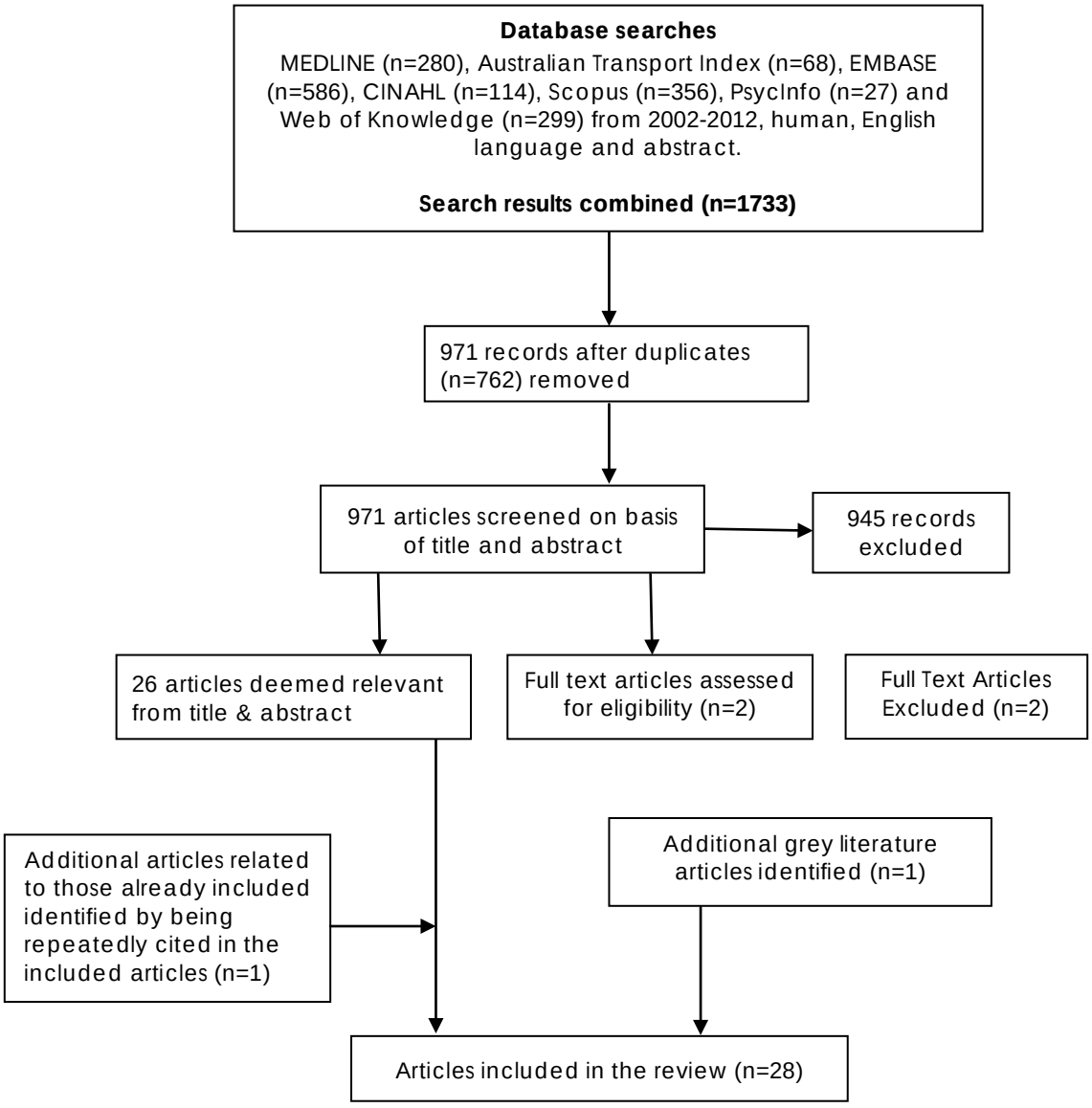
1. Population (adults)
2. Physical activity
3. Public transport

Key search terms, mapped to appropriate subject headings in each database and searched as a key word in title and abstract. *MeSH: Medical subject heading (Medline medical index term); the dollar sign ($) stands for any character(s).* All searches limited to English, humans, abstract and 2002-2012. Full definition of terms used is provided in Appendix 2.

RESULTS

Using the search strategy described above, 1,733 articles were generated (see Figure 1). After removal of duplicates (n=762), 971 article titles and abstracts were screened for relevance. A final number of 28 articles were retained that reported data related to extent of physical activity associated with public transport.

Figure 1: Summary of search strategy and identification of articles included in the review



The primary determinant of whether an article was retained was whether it reported any data on the extent of physical activity associated with public transport use. Articles generally discussing the issue or tangentially related topics were discarded.

Table 2 summarises nine studies where physical activity in relation to public transport was measured and reported. Five were from the USA, three from the UK and one from Australia. None addressed cycling. While not using the same measurement units, it appears that there are **at least**

8 minutes of **additional** physical activity associated with public transport use a day, and several studies reported a range up to 12–15 minutes a day. One study found public transport users accumulated up to about 24 minutes of walking a day, but did not examine walking related to car use. The Australian study[1] was consistent with the USA and UK studies (and was in the 12–15 minutes of walking range), strengthening the likelihood that the overseas data is relevant to the Australian context.

In the US, 29 percent of those who use transit were physically active for 30 minutes or more each day, solely by walking to and from public transit stops[2]. A similar result was found in the Australian context, with public transport users 3.5 times more likely to meet the recommended step target of 10,000 steps compared with car drivers[1]. Similarly in the US, transit users took 30 percent more steps per day and spent 8.3 more minutes walking per day than did people who relied on cars[3].

The Australian Government recommends that adults should get at least 30 minutes of moderate intensity physical activity on most, preferably all, days of the week[4]. The generally accepted cut-point for adequate physical activity is 150 minutes of moderate intensity physical activity per week[5].

For seniors, each public transport trip in the US was associated with an extra 412 steps, equivalent to about 8 minutes of walking (allowing for a slower speed).

An Australian report (using Victorian Travel Survey data) reported that people who used public transport on a particular day also spent an average 41 minutes walking and/or cycling as part of their travel. This is five times more physical activity than those who only use private transport, who on average only spend 8 minutes walking or cycling for transport, and representing an additional 33 minutes of physical activity[6].

Table 1: Average daily minutes of walking and cycling to transport

Transport modes used	Average daily minutes of walking and cycling for transport
Public transport (all users)	41 minutes
Public transport, no private transport	47 minutes
Private transport (cars, taxis and/or motorcycle) but no public transport	8 minutes
Overall Melbourne average	15 minutes

Source: Victorian Integrated Survey of Travel and Activity (VISTA)[6]

Overall, the findings are reasonably robust, with minutes of walking typically calculated from accelerometers, pedometers or travel diaries, rather than self-report. Those papers reporting absolute measures of walking time, energy expenditure or distance covered provide the best data in terms of additional physical activity gained from public transport use.

People who used public transport (i.e. subways, light or heavy rail, buses, trolleys, ferries etc.) for any reason were less likely to be sedentary or obese than adults who did not use public transport[7]. Conversely, reliance on the automobile for travel was associated with higher obesity rates at both the county and individual level[7-9]. There are a range of benefits associated with public transport use, and the papers reporting these findings are summarised in Table 3.

Table 2: Absolute measures of the association between the use of public transport and physical activity in adults

Study characteristics		Methodological				Outcome	
Author, year, country, study design, sample size/demographic	**Research Question**	**Public transport measure**	**Physical activity measure**	**Occupational/ leisure-time physical activity separated in final analyses**	**Confounders measured**	**Relative/ absolute outcome**	**Result**
Lachapelle, U. et al. 2011[10] USA Cross-sectional n=1,237 20–65yr olds working outside home	Relationship between commuting by public transport and objectively measured moderate intensity physical activity.	Reported % of all work commute trips taken by public transport. 3 groups: – non public transport user – infrequent public transport user(<50% commutes by public transport) – frequent public transport user(≥50% commutes by public transport).	Mean daily minutes of accelerometer measured moderate intensity physical activity.	Self report measures of occupational/ leisure-time physical activity did not confound results.	1) Neighbourhood walkability, enjoyment of physical activity, demographics.	absolute	1) Frequent public transport users accumulated significantly more (+8min) moderate-intensity physical activity daily compared with non-public transport users.
Besser, L.M. et al. 2005[2] USA Cross-sectional n=3,312 18+yrs who walked to/from transit on day of measurement	Estimate the daily level of physical activity obtained by Americans solely by walking to/from transit.	Only measured walking in transit users so no public transport measure.	Minutes spent walking to/from transit in a 24hr period.	Only walking to/from transit measured.	1) Uncontrolled 2) Stratified for transit type, demographics, population density, car ownership.	absolute	1) People who walk to/from transit accumulate 24.3 min of mean walking time/day 2) 29% of transit users achieve ≥30min walking to/from transit daily.
Edwards, R. et al. 2008[3] USA Cross-sectional n=28,771 18+ yr olds from National Household travel survey	Is the additional walking associated with mass transit use large enough to reduce obesity & health care costs? (by estimating additional walking associated with public transport use).	"Public transit user"=anyone who reports using public transport for any reason on assigned travel day.	Time spent walking on assigned travel day for any purpose.	No.	1) Demographics, number of household vehicles, own home, census region fixed effects.	absolute	1) Public transport use associated with significantly more (8–10min) additional walking per day.
Evans, A. et al. 2009[11] UK Cross-sectional n=5749 rail journeys Data from British National Travel survey 1999–2001	Focus is on rail and road safety.	Only examined walking in rail users so no public transport measure.	Self report distance walked to surface railway stations over 7 consecutive reporting days.	Only measured walking to train stations.	No.	absolute	Brits walk an average of 0.905km per journey on journeys with surface rail as the main mode. [equivalent to 10–12 minutes per trip]

Study characteristics		Methodological				Outcome	
Author, year, country, study design, sample size/demographic	**Research Question**	**Public transport measure**	**Physical activity measure**	**Occupational/ leisure-time physical activity separated in final analyses**	**Confounders measured**	**Relative/ absolute outcome**	**Result**
Morabia, et al. 2010[12] USA Experimental n=18 Adults either working/studying at Queens College	Compare levels of physical activity between car & public transport commutes to work.	18 participants commuted by car to Queens College for 5 days then switched to commuting by public transport. (no public transport measure).	Activity diary +GPS system used to calculate the average metabolic equivalent value for car vs public transport.	N/a as experiment limited to walking for transport.	No.	absolute	Public transport commuters expended significantly more energy (+622kcal over 5 days) compared with travelling the same route by car. [approximately equivalent to 30 minutes walking]
Wener, R. et al. 2007[13] USA Cross-sectional n=177 Adults commuting from New Jersey to work in NY	Compare level of physical activity between car and transit users travelling to/from work.	If travelled to work by: public transport≥4×/wk =transit user car ≥4×/wk =car user.	Pedometer worn for 5 days and international physical activity questionnaire issued at start of measuring week.	No.	1) Income, gender & education 2) Income, gender, education & commuting time.	absolute relative	1) Train commuters walked significantly more steps (+30%) per day compared to car commuters 2) Train commuters 4× more likely to achieve 10,000steps/ day compared to car users.
Davis, M. et al. 2011[14] UK Cross-sectional n=214 Adults over 70yrs	Describe the frequency, purpose and travel mode of daily trips in older adults and their association with participant characteristics and objectively measured physical activity.	Determined by respondent noting 'mode of transport' in trip log.	Steps/day and minutes of moderate-intensity physical activity day assessed by accelerometer for 1wk + daily trip log noting purpose of trip/mode of trans-port .	Did not adjust for 'purpose of trip'.	1) Other trip types (car, walking, cycling), age, sex, physical function, use of a walking aid, education and car ownership 2) As per #1.	absolute	1) Each weekly trip made by public transport is significantly associated with extra 412.7steps/day in older adults. 2) Public transport trips made by older adults is significantly associated with minutes of moderate-intensity physical activity/day (ln=0.06).
Villanueva, K. et al. 2008[1] Australia (Perth) Cross-sectional n=103 University students	Compare pedometer-determined physical activity levels of university students using public transport compared to cars for travel to uni.	Categorised into 2 groups: 'mainly car user' or 'mainly public transport user' for travel to uni.	Time spent walking for transport estimated from pedometer and diaries.	Adjusted for self-report leisure-time physical activity in analysis #2.	1) Uncontrolled 2) Gender, age and leisure-time physical activity.	absolute	1) Public transport users took significantly greater steps (11,433 vs 10,242) compared with drivers. [1191 steps is equivalent to about 15 minutes of walking] 2) Public transport users significantly (3.55×) more likely

Study characteristics		Methodological				Outcome	
Author, year, country, study design, sample size/demographic	**Research Question**	**Public transport measure**	**Physical activity measure**	**Occupational/ leisure-time physical activity separated in final analyses**	**Confounders measured**	**Relative/ absolute outcome**	**Result**
						relative	to achieve 10,000 steps/ day compared with drivers.
Macdonald, J. et al. 2010[15] USA n= 498 Cross-sectional and pre/post intervention	Examine association between objective and perceived measures of the built environment, body mass index, obesity and meeting recommended physical activity (RPA) through walking and vigorous exercise. To assess effect of using light rail on weekly RPA.	Pre and post exposure to a new light rail transit line.	Categorised as either meeting the recommendations for physical activity through vigorous exercise or moderate-intensity physical activity (through walking) or not meeting recommendations.	No.	1) Age, gender, race, employment status, education, own residence, distance to work, perception of neighbourhood, access to parks, density of food/alcohol establishments, household density, use of public transport on weekly basis and propensity to use light rail 2) As per #1.	absolute	1) Light rail transit users decreased their body mass index by average of 1.18 compared with similarly situated non-LRT users over 12-15 month follow-up 2) Association between LRT use and meeting weekly recommended physical activity levels by walking was in a positive direction but not significant.

Table 3 illustrates the 18 studies which identified various associations with walking to and from public transport. These studies measured walking in some way, but did not always differentiate between single mode walking for transport (which was excluded from this review) or walking to public transport (multi-mode). Some of the papers reported total minutes walking for transport, and factors associated with it. Compared with motor vehicle use, there were clear health benefits for users of public transport, particularly lower weight.

A number of the papers compared energy expenditure of car users compared to public transport users, and all have concluded that there is significantly greater energy expenditure for public transport users.

There were higher levels of walking when public transport access points (stations and bus stops) were closer, and these associations were generally significant. Good access to public transport is significantly associated with walking sufficiently per week to meet physical activity recommendations.

Most of the papers reporting physical activity or energy expenditure outcomes relative to travel mode were cross-sectional, but adjusted for potential confounders

Of the two longitudinal papers one showed significant increases in physical activity associated with new public transport stops/stations[16], but the other did not, although it reported that limited public transport availability was associated with low transport walking[17].

Overall, the findings from the Australian papers are consistent with the overseas papers, suggesting that the results are relevant for NSW.

Table 3: Relative measures of the association between the use of public transport and physical activity in adults

Study characteristics		Methodological				Outcome	
Author, year, country, study design, sample size/demographic	**Research Question**	**Public transport measure**	**Physical activity measure**	**Occupational/ leisure-time physical activity separated in final analyses**	**Confounders measured**	**Relative/ absolute outcome**	**Result**
Morabia, A. et al. 2009[18] USA Experimental 3 arm study n=20 Adults either working /studying at Queens College	Assess the physical activity energy expenditure for transportation by car vs subway vs walking the same predetermined route.	Only the car vs subway arms are relevant to this report.	Activity diary+GPS system used to calculate the average metabolic equivalent value for each study arm.	N/a as experiment limited to walking for transport.	No.	relative	Physical activity energy expenditure (Kcal/min) was significantly greater in subway users (2.35) compared to car users (1.74) travelling the same pre-determined route.
Coogan, P. et al. 2009[19] USA Longitudinal n=20,354 Black females 21–69 yrs	Association between neighbourhood urban form and physical activity.	1) Shortest distance between each participant's address and public transport 2) Bus availability (measured by miles of bus routes within 0.5 miles of individual's address).	Hours/week spent in utilitarian walking (≥5hrs walking /wk vs <5hrs walking/wk).	Only measured utilitarian walking.	1) Demographics, caregiver responsibilities, smoking/alcohol status, number of moves in last 2yrs, energy intake, television viewing, %vacant housing units, neighbourhood SES, crime index 2) As for 1+ adjusted for all other urban form variables (housing density, sidewalks, parks etc).	relative	1) Distance to transit (OR: 2.63 for lowest quintile distance to transit) and bus (OR:3.23 for highest quintile bus routes) availability (when considered as only urban variable) is significantly positively associated with utilitarian walking 2) Bus availability is independently and significantly associated with utilitarian walking (OR 1.18–1.44 for lowest to highest quintile of bus route availability).
McCormack, G. et al. 2007[8] Australia (Perth) Cross-sectional n= 1803 18-59 yr olds	1) Association between walking for transport, leisure-time physical activity and vigorous physical activity and	1) Bus-stop within 400m or 1500m of home 2) Transit stop within 400m or 1500m of home.	Regular transport walker (transport walking reported at baseline and follow-up) vs irregular	Yes.	1) Demographics, number of dependents, BMI, neighbourhood socioeconomic status 2) As per #1.	relative	1) Residing within 400m of bus stop significantly associated (OR 1.66) with regular walking for transport

Study characteristics		Methodological				Outcome	
Author, year, country, study design, sample size/demographic	**Research Question**	**Public transport measure**	**Physical activity measure**	**Occupational/ leisure-time physical activity separated in final analyses**	**Confounders measured**	**Relative/ absolute outcome**	**Result**
	presence of specific destinations within 400 and 1500m of respondent's home.		transport walker (reported at 1 survey) vs non transport walker (no transport walking reported at both surveys).				2) Residing within 400m or 1500m transit station significantly associated with walking for transport (OR: 5 and 2.38 respectively).
Lindstrom, M. 2008[7] Sweden Cross-sectional n=16,705 18–80 yr old employed people	Association between means of transport to work and overweight/ obesity.	Means of transportation to work measured as options: walking, biking, car, bus train, other (could tick multiple).	Not measured.	N/a as physical activity not measured.	1) Age, country of origin, education and time to travel to work.	relative	1) Odds of overweight + obesity(0.61–0.86) and obesity (0.51–0.95) in men who use public transport to travel to work are significantly lower compared with men who use a car to get to work.
Cerin, A. (Adelaide) Cross-sectional n=2650 20–65 yr olds recruited from 32 neighbourhoods in Adelaide	Examine the association of objective and perceived measures of access to destinations with self-reported walking for transport.	– Proximity of public transport – Monthly frequency of walking to public transport.	Weekly minutes of transport-related walking.	N/a as only measured transport-related walking.	1) Sociodemographics + neighbourhood selection (residents chose to live in area because of accessibility of certain destinations) 2) Sociodemographics and walking to specific types of destinations.	relative	1) No relationship between transport walking and proximity to public transport stops 2) Monthly frequencies of walking to public transport stop independently significantly associated with weekly minutes of walking for transport (b=3.7).
Brown, B. et al. 2007[16] USA Pre/post test design n=51 Adults living within ½ mile of new rail stop	Does a new light rail stop increase number of light rail users and does light rail ridership relate to moderate activity bouts?	Pre-post building of new light rail stop.	Moderate intensity physical activity (MPA) measured with accelerometers and respondents indicated whether they were	Respondents indicated whether the moderate intensity physical activity registered on accelerometers was	1) Gender, household size and home ownership 2) #1 variables + moderate-intensity physical activity pre new rail stop.	relative	1) Pre and post new stop rail rides were significantly related to more moderate intensity physical activity (MPA) bouts 2) Longitudinal analysis

Study characteristics		Methodological				Outcome	
Author, year, country, study design, sample size/demographic	**Research Question**	**Public transport measure**	**Physical activity measure**	**Occupational/ leisure-time physical activity separated in final analyses**	**Confounders measured**	**Relative/ absolute outcome**	**Result**
			related to walking to/from light rail stop.	associated with walking to/from light rail.			showed walks to transit contributed to MPA above prior activity levels (before construction of new stop).
Cleland, V. et al. 2008[17] Australia (Melbourne) Cross-sectional+ prospective n=357 Melbourne mothers	Examine whether mother's perceptions of the social and physical environment were associated with walking for leisure and transport.	"Public transport is limited in my area"-measured by extent of agreement using Likert Scale.	Self report time spent "walking for transport" Low=<30min/wk High=≥30min/wk.	Yes.	1) Not controlled 2) Highest level of schooling 3) Highest level of schooling and baseline walking variables.	relative	1) Baseline: limited public transport inversely related to high walking for transport (PR: 0.56–0.98) 2) Follow-up: public transport not significantly associated with high walking for transport (RR:0.68–1.08) 3) Longitudinal analysis=Limited public transport inversely associated with 'persistently high transport walking' (RR: 0.19–0.75).
de Bourdeaudhuij, I. et al. 2003[21] Belgium Cross-sectional n=521 18–65 yr olds from Ghent	Examine the variance in sitting, walking and moderate- vigorous physical activity explained by a wide range of community design and recreational environmental variables above and beyond the variance accounted for by individual and group demographic variables.	Ease of access to public transport stop.	International physical activity questionnaire: minutes spent walking AND minutes spent in moderate-intensity physical activity (not walking) in last week.	No.	1) Sex, age, education, living situation, working situation, height, weight, body mass index.	relative	1) 3% of the variance in walking (all purposes) was explained by greater ease of walk to public transport (correlate=0.16) and to land use mix.
Frank, L. et al. 2010[22]	Examine the relationship	– Distance to nearest public	Average distance	No.	1) Age, gender, ethnicity,	relative	1) As shortest distance to

Table 3: Relative measure of association between use of public transport and physical activity in adults

Study characteristics		Methodological				Outcome	
Author, year, country, study design, sample size/demographic	**Research Question**	**Public transport measure**	**Physical activity measure**	**Occupational/ leisure-time physical activity separated in final analyses**	**Confounders measured**	**Relative/ absolute outcome**	**Result**
USA Cross-sectional n=10,148 >16yr old residents of Atlanta	between energy used for active and motorised forms of transport and evaluate how modifiable features of the built environment are associated with the ratio between energy used for active vs motorised travel.	transport stop – 'Transit accessibility' (i.e.: whether respondent could access all the regions 5 major activity centres by walking to transit).	spent walking over 2 days (than converted to average kilocalories spent walking).		drivers' license status, income, #household members, vehicles in household 2) As per #1 3) As per #1.		nearest rail stop increased energy expended from walking decreased significantly 2) As shortest distance to nearest bus-stop increased, energy expended from walking increased significantly 3) Those that had access to all 5 of the major city centres via transit burned significantly more kilocalories from walking.
Kamada, M. et al. 2009[23] Japan Cross-sectional n=434 40–64 yr old rural Japanese women	Describe environmental correlates (focus on public transport) of physical activity among rural Japanese women.	– Self report 'access to public transport' – GPS measured distance to train station – Bus service convenience (combination of GPS measured distance to – bus-stop+bus frequency).	International physical activity questionnaire used to assess time spent in occupational, leisure-time physical activity and transportation related walking over a typical 7-day week and divided into: 1) sufficiently active (meeting recommendations) 2) insufficiently active (not meeting recommendations) 3) inactive (no moderate-vigorous	No.	1) Age, body mass index, gender, general health state, household economy, employment, engagement in farming, parenting/care-giving status, driving status 2) As per #1.	relative	1) 'Sufficiently active' women significantly more likely (OR=1.57) to report good access to public transport compared with inactive women 2) Non-drivers in an area where bus services were moderately convenient were more likely (OR:3.23) to be sufficiently active than those where it was less convenient.

Study characteristics		Methodological				Outcome	
Author, year, country, study design, sample size/demographic	**Research Question**	**Public transport measure**	**Physical activity measure**	**Occupational/ leisure-time physical activity separated in final analyses**	**Confounders measured**	**Relative/ absolute outcome**	**Result**
			intensity physical activity).				
Lachapelle, U. et al. 2009[24] USA Cross-sectional n=4156 16–70 yr old Atlanta residents	1) Assess the relationship between using public transport and meeting recommended levels of physical activity while controlling for neighbourhood built environment and demographic factors 2) Relationship between employer-sponsored public transport passes and walking.	– Distance to nearest transit stop/station – If respondent received and used free/subsidized transit pass.	Average self-report distance walked for transportation over the 2 reporting days. 3 groups: – sufficient walking (meets recommendation) – moderate walking (less than sufficient but more than no walking) – no walking (no walking for transport).	Only measured walking for transport.	1) Demographics, neighbourhood density, presence of services near work, distance from home to transit, car availability 2) As per #1 3) As per #1.	relative	1) Only trips with public transport are significantly associated with being sufficiently active (OR:3.35) compared to driving or being a car passenger 2) Having and making use of an employer-sponsored transit card positively and significantly associated with being sufficiently active (OR=4.96) compared with not having access to a card 3) Transit users living 450–1000m of transit were significantly more likely to be moderate walkers (O=6.54).
Li, F. et al. 2008[25] USA Cross-sectional n=1221 50–75 yr olds from 120 different neighbourhoods	Examine relationship between built environment factors, the prevalence of overweight/ obesity and various forms of physical activity.	Density of public transport stations/stops.	– Walked for household errands/ transportation ≥30min/wk or not – Self-report moderate-vigorous intensity physical activity resulting in 3 categories:	Yes.	Age, gender, race/ethnicity, employment status, home ownership, income, health status, fruit and vegetable intake, fried food consumption, body mass index. Residential density, median household income	relative	1) Density of public transport stations significantly associated with more walking for transport and being 'sufficiently active'.

Table 3: Relative measure of association between use of public transport and physical activity in adults

Study characteristics		Methodological				Outcome	
Author, year, country, study design, sample size/demographic	**Research Question**	**Public transport measure**	**Physical activity measure**	**Occupational/ leisure-time physical activity separated in final analyses**	**Confounders measured**	**Relative/ absolute outcome**	**Result**
			1) met guidelines for moderate or vigorous physical activity 2) insufficiently active 3) inactive.		and% African American/Hispanic residents.		
Liao, Y. et al. 2011[26] Japan Cross-sectional N=1420 30–59 yr old Japanese men	Examine the perceived environmental correlates of physical activity among normal weight and overweight Japanese men.	Access to public transport.	Categorised as either meeting the recommendations for walking and or moderate-vigorous intensity physical activity (excluding walking) or not meeting recommendations.	No.	1) Age, marital status, education, household income, employment status 2) As per #1.	relative	1) Good access to public transport (OR=2.3) is significantly associated with walking sufficiently per week to meet physical activity recommendations in normal weight men. This did not apply to overweight men 2) Good access to public transport had no significant relationship with moderate-vigorous intensity physical activity in normal weight and overweight men.
McConville, M. et al. 2010[27] USA Cross-sectional n=260 Healthy adults from Montgomery County non-representative)	Association between accessibility/ intensity of non-residential land uses and walking for transport.	– Distance to bus-stop/ railway from person's home measured – # of bus-stops within ½ or ¼ mile.	Walking for transport 3 categories: 1) none 2) <150min/wk 3) ≥150min/wk.	Only measured walking for transport.	1) Demographics +residential population density and sidewalk density. 2) As per #1 3) As per #1 + neighbourhood type.	relative	1) 1Compared to not walking for transport the odds of walking for transport for <150min/wk were significantly lower with greater distance to bus stop (OR=0.91, CI: 0.85–

Study characteristics		Methodological				Outcome	
Author, year, country, study design, sample size/demographic	Research Question	Public transport measure	Physical activity measure	Occupational/ leisure-time physical activity separated in final analyses	Confounders measured	Relative/ absolute outcome	Result
							0.97) 2) Compared to not walking for transport odds for walking ≥150min/wk were significantly lower with greater distance to bus stop (OR=0.01, CI:0.001–0.11) and rail station (OR=0.9, CI:0.82–0.99) 3) # of bus-stops within a ½ (OR: 1.06) and ¼ (OR: 1.16) mile buffer associated with greater odds of walking ≥150min/wk for transport compared to not walking for transport.
Wilson, L. et al. 2011[28] Australia (Brisbane) Cross-sectional n=10,286 40-65 yr old Brisbane residents from 200 neighbourhoods	Examine how a range of objectively measured neighbourhood features are associated with likelihood of middle-aged adults walking in their local neighbourhoods.	Distance to bus-stop/ railway from person's home measured.	Walking for leisure-time physical activity+transport walking 5 levels: -<30min -≥30min-<90min ->90min -<150min -≥150min-<300min -≥300min.	No.	Demographics and neighbourhood level socioeconomic status and within neighbourhood variation in age, sex household type, education, occupation and household income.	relative	1) There was no relationship found between proximity to public transport and walking for any purpose (maybe because they didn't specifically measure transport walking).
Wen, L. et al. 2007[9] Australia (NSW) Cross-sectional n= 6810 16+yrs old working in NSW	Association between various modes of transport to work and overweight and obesity.	Whether public transport was usual method of commuting to work or not.	Not reported in terms of association with public transport (overweight/ obese was instead).	Adjusted for people who met recommended levels of physical activity (all purpose).	1) Age, marital status, education, language spoken at home, meeting recommendations for	relative	1) Men who used public transport to get to work are significantly less likely to be overweight and obese (OR=0.65; CI=0.53-0.81)

Table 3: Relative measure of association between use of public transport and physical activity in adults

Study characteristics		Methodological				Outcome	
Author, year, country, study design, sample size/demographic	**Research Question**	**Public transport measure**	**Physical activity measure**	**Occupational/ leisure-time physical activity separated in final analyses**	**Confounders measured**	**Relative/ absolute outcome**	**Result**
					physical activity.		compared with men who drive to work (not significant for women).
Pikora, T. et al. 2006[29] Australia (Perth) Cross-sectional n=1678 18–59 yr old Perth residents	Association between physical environmental factors and walking for recreation and transport near home.	Extent of presence of public transport within 400m of home (embedded in a 'destination score').	Walking for transport near home or not in last 2 weeks (no time specified).	Yes.	1) Demographics, socioeconomic status of area of residence + all other environmental variables (function, safety, aesthetic and destination).	relative	1) Presence of public transport 400m from home was not significantly associated with walking for transport (relationship was positive). However, the presence of destinations (including public transport) was significantly related to walking for transport near home (OR:1.8;CI: 1.33–2.44).
Lovasi, G. et al. 2009[30] USA Cross-sectional n=13,102 30+yrs old New York residents	Test whether association between walkable environments and lower body mass index was stronger within disadvantaged groups.	– #bus/subway stops within 1km radius of home. – Use public transport or not.	Not measured (body mass index used).	N/A.	1) Age, gender, race, individual education, % of Black/Hispanic residents in area, % below poverty line 2) As per #1.	relative	1) 'Advantaged people' who have subway access and use public transport are significantly more likely to have a lower body mass index compared with disadvantaged groups.

Modelling of NSW Health Survey data

Data were drawn from the NSW Health Survey conducted in 2010. The NSW Continuous Health Survey was conducted by telephone among a representative sample of residents aged 16 years or over in NSW, Australia. The variable of interest was minutes of physical activity per week. Sufficient physical activity was defined as a respondent having engaged in 150 or more minutes of exercise during the week. Almost half of women (49.8%) and 60.7 per cent of men were classified as sufficiently physically active[31].

All statistical analysis was done using the software package "R". All statistical analysis was weighted using the NSW Health Survey post-stratification weights. Minutes of physical activity per week was estimated using the weighted empirical distribution function. To calculate 95% confidence intervals, a survey bootstrapping technique was used with 1000 replicates and the 2.5% and 97.5% quantiles of the replicates were found.

The distribution of physical activity in the inactive population and total population was modelled based on scenarios where there was an increase in 8,16, or 24 minutes of physical activity per week (five days, to represent using public transport during a working week), and if 10,20 or 30% of the population added these additional minutes (see Table 4).

Table 4. Population increase in the proportion of NSW adults who are sufficiently physically active by increases in minutes of physical activity and the percent uptake by those currently inactive

		Minutes of physical activity added per weekday		
		8	16	24
Percent uptake of physical activity by insufficiently active	10%	1.96% (1.85%–2.09%)	3.48% (3.34%–3.71%)	5.94% (5.71%–6.08%)
	20%	3.93% (3.65%–4.12%)	6.97% (6.66%–7.19%)	11.88% (11.66%–12.13%)
	30%	5.89% (5.74%–6.45%)	10.45% (9.81%–10.94%)	17.82% (16.95%–18.27%)

There is a clear dose-response relationship between the proportion of the population achieving 150 minutes per week of physical activity (and considered 'sufficiently physically active') by the addition of either 8, 16 or 24 minutes of walking. Conservatively, if only 10% of those inactive people in NSW walked for 16 minutes more each week, state-wide there would be 3.5% more adults meeting public health recommendations for physical activity.

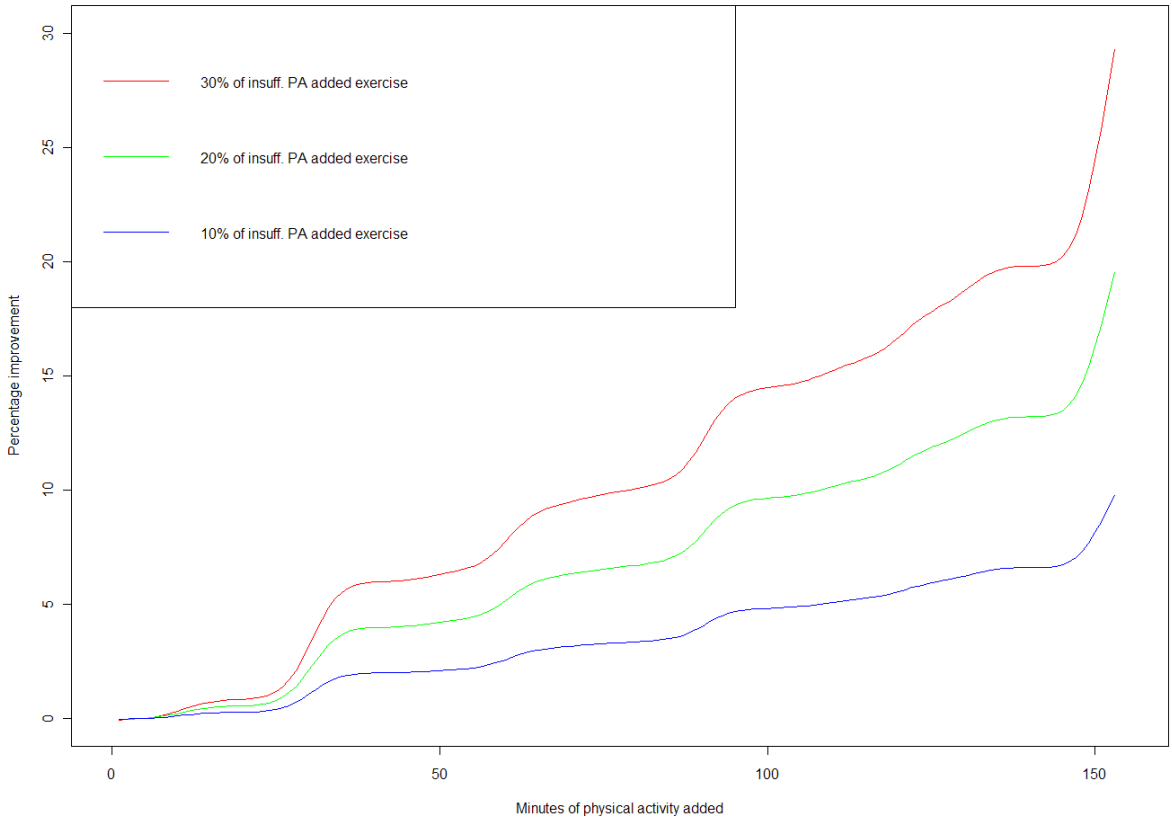


Figure 2. Smoothed improvement in physical activity in the insufficiently physically active, NSW Health Survey 2010

Figure 2 represents a graphical representation of the increase in sufficient physical activity in NSW if 10, 20 or 30% of the inactive population increased their minutes of physical activity.

DISCUSSION

There is relatively little data available on the extent of physical activity associated with public transport use, but it is clear that there is an additional amount ranging from 8 to 33 minutes of walking per day. For some people this transport related walking is sufficient to meet the recommended levels of physical activity. Increases in people walking for transport, by as little as 16 minutes a day, would lead to significant increases in physical activity and population health in NSW.

There is much more data available on the health benefits of a modal shift away from motor vehicles to active travel (including public transport). In general, policy initiatives that favour active travel have many cobenefits[32], and even in the absence of complete data, there are many benefits from such a shift.

RECOMMENDATIONS

1. More research is needed to clearly identify the absolute amount of additional physical activity resulting from public transport us, and the factors associated with this physical activity.

2. Given the clear association of additional physical activity with public transport use and the high concordance of interest between health and transport sectors, encouraging public transport instead of motor vehicle travel should be a priority for health and transport sectors.

3. Increased public transport use by motor vehicle users would likely lead to reductions in weight by those people shifting their travel mode and increasing their physical activity.

4. Encouraging access (proximity) to public transport appears to be critical for increasing use.

5. Increased use of public transport by inactive adults in NSW would incrementally increase the proportion of people who meet recommended guidelines for physical activity.

6. Small percentage increases in the proportion of the NSW population who are sufficiently active through additional public transport use would lead to significant state-wide health benefits.

7. Internationally, there are clear examples of health and transport sectors working together to promote active travel (walking and cycling), and policy consistency and partnership between these sectors can help achieve mutual goals.

8. Health impact assessments may be one approach to partnership between health and transport sectors, but specific health outcomes have not been reported where transport has been the focus of a health impact assessment without the implementation of a funded project or plan.

9. Collaborative partnerships between health and transport sectors can be successful in changing travel behaviour to active travel if adequately resourced, and with supporting policies.

10. The development of criteria for assessing transport policies and infrastructure that includes health benefits need to be developed as a matter of urgency.

APPENDIX 1: Examples of collaboration between health and transport agencies to determine health impact of planned or implemented public transport options

Internationally there is general acknowledgement of the fundamental role that transport plays as a social determinant of health[33-35]. Transport can influence access to health services, as well as education and employment. Social inclusion and connectedness can be enhanced by easily accessed and affordable transport options. There are physical activity possibilities depending on the mode choice, as well as exposure to air pollutants and crash risks. Governments internationally, and in Australia, have identified a need to increase levels of active travel.

The Australian Government has identified that because more than three quarters of the population live in urban environments, enhancing the liveability of the urban environment is a priority. Improved opportunities for walking, cycling and public transport are all critical dimensions of improved urban liveability.

Below are some examples of where government and non-government health and transport agencies have worked together to determine the health impact of planned or implemented public transport options.

Australian Context

Queensland Health (2011)

The Queensland Health Department commissioned a team of transport consultants to review the literature on the health benefits of active travel, with a view towards costing the measurable health benefits associated with active travel. Fishman E, Garrard J, Ker I, Litman T. *Cost and Health Benefit of Active Transport in Queensland: Research and Review*, Stage One Report. Prepared by CATALYST for Health Promotion Queensland, 2011.

(Available from http://www.sensibletransport.org.au/sites/sensibletransport.org.au/files/u5/Executive%20Summary%2010.09.11%20V2.pdf)

Todd Litman, a transport economist, was a lead contributor to these reports, and has done considerable work in this area of evaluating the health benefits of public transport. www.vtpi.org – Evaluating Public Transportation Health Benefits.

The NSW Premier's Council for Active Living (PCAL)

PCAL has a unique role in NSW linking government and non-government agencies to collaborate on active transport projects. The recent NSW Bike Plan and the draft NSW Walking Strategy are good examples of significant policy directions which have brought together representatives of the health and transport sectors.

An important development in the preparation of the Walking Strategy, was the inclusion of financial values to various health benefits (and costs) resulting from walking[36]. Similar values have also been developed for cycling, and both walking and cycling values are summarised in a submission to the Australian Transport Council in 2011 by PCAL (below)[37].

Table 5: Financial values of various health benefits (and costs) resulting from walking and cycling per kilometre

Benefit	Walking ($/KM)	Cycling ($/KM)
Health $/KM	1.68	1.12
Decongestion		
Heavy $/KM	0.34	0.34
Medium $/KM	0.24	0.24
Light $/KM	0.06	0.06
Vehicle operating cost (car) $/KM	0.35	0.35
Vehicle operating cost (bicycle) $/KM	0.32	0.32
Injury costs $/KM	-0.37	-0.24
Noise reduction $/KM	0.09	0.09
Air quality $/KM	0.03	0.03
Greenhouse gas emissions $/KM	0.02	0.02
Infra.(roadway) provision $/KM	0.06	0.06
Parking cost savings $/KM	0.02	0.02

Source: TMR 2011, based on similar RTA and PCAL methodology used to generate NSW parameters

Cycling Connecting Communities

A health promotion demonstration project funded by NSW Health in the former Sydney South West Area Health Service (SSWAHS) aimed to increase levels of cycling and population physical activity. The project management included an Advisory Committee with representatives from the health, transport, local council, and local bicycle user groups. It achieved increases in use of local cycling infrastructure, but was not of sufficient scale to impact upon population level physical activity. Adequate resourcing in a more densely populated area would likely achieved greater impact[38].

Health Impact Assessment in Australia

Health Impact Assessment (HIA) is a tool for assessing the potential effects of a program or project on the health of a population. It identifies the potential positive and negative impacts of the program or project and develops recommendations that can improve or minimise harm to the health and wellbeing of the affected population.

A literature review conducted in 2009 highlighted a number of Australian projects and research studies and reported a range of benefits associated with active travel and public transport use, similar to what has been described in this report[39].

Oran Park and Turner Road (SSWAHS) HIA

SSWAHS has completed a Health Impact Assessment on the Oran Park/Turner Road precinct developments that are part of the South West Growth Centre. The aim of the HIA was to provide planners and decision makers with evidence about the possible impacts on health of certain decisions and to make recommendations to enhance the positive and mitigate any negative impacts.

The main issues within the scope of the HIA were identified as: public transport, active transport, social connectivity, physical activity, injury, and food access. The HIA was undertaken by

representatives from Population Health, and other representatives from SSWAHS, CHETRE, and Camden Council.

Monitoring of action against the recommendations of the HIA has been jointly undertaken by Population Health and Camden Council. Meetings with the developers and landowners of Oran Park/Turner Road to monitor progress and further develop the recommendations have also commenced. There is some evidence that some of the recommendations have been taken up, and there are positive actions being taken (see http://www.sswahs.nsw.gov.au/PopulationHealth/content/pdf/Final%20Oran%20Park%20Eval%20Report%20June%202011.pdf. The extent to which this will lead to increased physical activity is not known.

International Context

Health economic assessment tool for cycling (HEAT for cycling)

The tool conservatively estimates the maximum and the mean annual benefit and values (per cyclist, per trip, and total annual benefit) in terms of reduced mortality as a result of cycling. It was developed by a team of health and transport experts to better value the costs and benefits of cycling.

Rutter H et al. Health economic assessment tool for cycling (HEAT for cycling). Copenhagen, WHO Regional Office for Europe, 2007. (http://www.thepep.org/en/workplan/candw/documents/Cycling_HEAT_v1.0.xls, accessed 6 February 2012).

Sustainable travel towns in UK (2004-2009)

The Sustainable Travel Towns project was implemented in three pilot towns in the UK between 2004–2009. The main aim of the project was to achieve a significant shift from single occupancy car use to sustainable and active modes of travel. Increases in population level physical activity were a secondary aim. Each pilot town implemented a range of behaviour change intervention to promote walking and cycling and encourage the use of public transport. These strategies were applied over a 5-year period in a comprehensive and strategic way together with complementary infrastructure including improved public transport services. The project leader was the Department for Transport with input from the Department for Health collaborating with local council authorities in each town.

There has been good collaboration between the transport and health sectors from the outset of this project. Early collaboration in the form of a health impact assessment determined that evaluation of the project would be designed so it incorporates a social model of health and health indicators were established in order to be able to systematically evaluate the impact of the project on population health. Evaluation results are very positive[40].

HIA of Edinburgh's transport policy

In 1998 the City of Edinburgh Council was considering how to take their transportation policy forward and developed three possible scenarios for its future direction. To ensure the newly developed policy provided benefits for the population of Edinburgh and surrounding areas the local transport authorities engaged the health community to cooperate in performing a HIA of

the proposals. The HIA was prospective and built around a combination of evidence from a literature review, available data on relative impacts and insights from key informants with local knowledge of health and transport issues. The outcome of the HIA was a set of recommendations for ongoing transport policy which recognized the potential to address inequalities by giving priority to pedestrians, cyclists and public transport[41].

Cycling England

Cycling England was an independent body comprising representatives of transport, education, and local government agencies funded by the Department for Transport to promote cycling in England. It was founded in 2005 to replace the National Cycling Strategy Board. Following the 2010 Comprehensive Spending review it was earmarked for abolition, to be replaced by Local Sustainability Travel Funds and new ways of supporting cycling. Cycling England has helped establish a number of Cycling Demonstration Towns. Between 2005 to 2008 six towns across England receive European levels of funding to significantly increase their cycling levels Aylesbury, Brighton and Hove, Darlington, Derby, Exeter and 'Lancaster with Morecambe' collectively received over £7m from Cycling England across three years, plus local match-funding, to deliver a range of measures designed to get more people cycling. In January 2008, the Government provide an further £140m over three years for the program which was awarded to Bristol, Blackpool, Cambridge, Colchester, Chester, Leighton-Linslade, Shrewsbury, Southend, Southport, Stoke-on-Trent, Woking and York in June 2008. Evaluation of the initial six demonstration towns reported significant increases in cycling, and population level increases in physical activity[42].

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APPENDIX 2: Electronic search strategy

Key search terms, mapped to appropriate subject headings in each database and searched as a key word in title and abstract. *MeSH: Medical subject heading (Medline medical index term); the dollar sign ($) stands for any character(s).* All searches limited to English, humans, abstract and 2002–2012.

MEDLINE/PSYCINFO

1. Adult

MESH Term (Medline)	Key Word (phrase searching)
1. Adult	Adult$

2. Physical activity

MESH Term (Medline)	Key Word (phrase searching)
1. Exercise	Physic$ activ$, exercis$, physical training, fitness training
2. Physical fitness	Physical fitness
3. Physical exertion	Physical exertion
4. Walking	Walk$, active travel, active commut$, active transport$
5. Bicycling	Bicyc$, cyc$, biking
6. Leisure activities	Leisure activ$

3. Public transport

MESH Term (Medline)	Key Word (phrase searching)
1. Transportation	Public transport$, public transit$, rail$, tram, metro, bus, ferry, subway, mass transit.

AUSTRALIAN TRANSPORT INDEX

1. Adult

MESH Term	Key Word (phrase searching)
1. Adult	Adult$

2. Physical activity

MESH Term	Key Word (phrase searching)
1. No relevant subject term	Physic$ activ$, exercis$, physical training, fitness training
2. No relevant subject term	Physical fitness
3. No relevant subject term	Physical exertion
4. Walking	Walk$, active travel, active commut$, active transport$
5. Cycling	Bicyc$, cyc$, biking
6. No relevant subject term	Leisure activ$

3. Public transport

MESH Term (Medline)	Key Word (phrase searching)
1. Public transport	Public transport$, public transit$, rail$, tram, metro, bus, ferry, subway, mass transit

EMBASE

1. Adult

MESH Term	Key Word (phrase searching)
1. Adult	Adult$

2. Physical activity

MESH Term	Key Word (phrase searching)
1. Exercise	Physic$ activ$, exercis$, physical training, fitness training
2. Fitness	Physical fitness
3. No relevant subject term	Physical exertion
4. Walking	Walk$, active travel, active commut$, active transport$
5. Bicycle	Bicyc$, cycles, cycling, biking
6. No relevant subject term	Leisure activ$
7. Physical activity	Physic$ activ$

3. Public transport

MESH Term (Medline)	Key Word (phrase searching)
1. Traffic and transport	Public transport$, public transit$, rail$, tram, metro, bus, ferry, subway, mass transit

SCOPUS

1. Adult

Key Word (phrase searching)
Adult$

2. Physical activity

Key Word (phrase searching)
Physic$ activ$, exercis$, physical training, fitness training
Physical fitness
Physical exertion
Walk$, active travel, active commut$, active transport$
Bicyc$, cycle, cycling, biking
Leisure activ$

3. Public Transport

Key Word (phrase searching)
Public transport$, public transit$, rail$, tram, metro, bus, ferry, subway, mass transit

CINAHL

1. Adult

MESH Term	Key Word (phrase searching)
1. Adult	Adult$

2. Physical activity

MESH Term	Key Word (phrase searching
1. Exercise	Physic$ activ$, exercis$, physical training, fitness training
2. Physical fitness	Physical fitness
3. No relevant subject term	Physical exertion
4. Walking	Walk$, active travel, active commut$, active transport$
5. Cycling	Bicyc$, cycle, cycling, biking
6. Leisure activities	Leisure activ$
7. Physical activity	Physic$ activ$

3. Public transport

MESH Term (Medline)	Key Word (phrase searching)
1. Transportation	Public transport$, public transit$, rail$, tram, metro, bus, ferry, subway, mass transit

WEB OF KNOWLEDGE

1. Adult

Key Word (phrase searching)
Adult$

2. Physical activity

Key Word (phrase searching)
Physic$ activ$, exercis$, physical training, fitness training
Physical fitness
Physical exertion
Walk$, active travel, active commut$, active transport$
Bicyc$, cycle, cycling, biking
Leisure activ$

3. Public transport

Key Word (phrase searching)
Public transport$, public transit$, rail$, tram, metro, bus, ferry, subway, mass transit