JECH Online First, published on August 4, 2015 as 10.1136/jech-2015-205620

Associations between individual socioeconomic position, neighbourhood disadvantage and transport mode: baseline results from the HABITAT multilevel study

Jerome N Rachele,[1] Anne M Kavanagh,[2] Hannah Badland,[3] Billie Giles-Corti,[3] Simon Washington,[4] Gavin Turrell[1]

For numbered affiliations see end of article.

Correspondence to
Dr Jerome N Rachele, School of Public Health and Social Work and Institute of Health and Biomedical Innovation, Queensland University of Technology, Brisbane, QLD 4059, Australia; j.rachele@qut.edu.au

Received 11 February 2015
Revised 18 May 2015
Accepted 13 July 2015

To cite: Rachele JN, Kavanagh AM, Badland H, *et al. J Epidemiol Community Health* Published Online First: [*please include* Day Month Year] doi:10.1136/jech-2015-205620

ABSTRACT

Background Understanding how different socioeconomic indicators are associated with transport modes provide insight into which interventions might contribute to reducing socioeconomic inequalities in health. The purpose of this study was to examine associations between neighbourhood-level socioeconomic disadvantage, individual-level socioeconomic position (SEP), and usual transport mode.

Methods This investigation included 11 036 residents from 200 neighbourhoods in Brisbane, Australia. Respondents self-reported their usual transport mode (car or motorbike, public transport, walking or cycling). Indicators for individual-level SEP were education, occupation and household income; and neighbourhood disadvantage was measured using a census-derived index. Data were analysed using multilevel multinomial logistic regression. High SEP respondents and residents of the most advantaged neighbourhoods who used a private motor vehicle as their usual form of transport was the reference category.

Results Compared with driving a motor vehicle, the odds of using public transport were higher for white collar employees (OR 1.68, 95% CrI 1.41–2.01), members of lower income households (OR 1.71 95% CrI 1.25–2.30) and residents of more disadvantaged neighbourhoods (OR 1.93, 95% CrI 1.46–2.54); and lower for respondents with a certificate-level education (OR 0.60, 95% CrI 0.49–0.74) and blue collar workers (OR 0.63, 95% CrI 0.50–0.81). The odds of walking for transport were higher for the least educated (OR 1.58, 95% CrI 1.18–2.11), those not in the labour force (OR 1.94, 95% CrI 1.38–2.72), members of lower income households (OR 2.10, 95% CrI 1.23–3.64) and residents of more disadvantaged neighbourhoods (OR 2.73, 95% CrI 1.46–5.24). The odds of cycling were lower among less educated groups (OR 0.31, 95% CrI 0.19–0.48).

Conclusions The relationships between socioeconomic characteristics and transport modes are complex, and provide challenges for those attempting to encourage active forms of transportation. Further work is required exploring the individual-level and neighbourhood-level mechanisms behind choice of transport mode, and what factors might influence individuals from different socioeconomic backgrounds to change to more active transport modes.

BACKGROUND

More socioeconomically disadvantaged individuals have higher rates of cardiovascular disease,[1] stroke,[2] type 2 diabetes mellitus[3] and several forms of cancer[4 5]; as well as increased risk factors, such as obesity,[6] compared with more advantaged individuals. Those living in socioeconomically disadvantaged neighbourhoods also exhibit less healthy behaviours and worse outcomes, independent of their individual-level socioeconomic position (SEP).[7 8]

One potential method for improving health outcomes is facilitating decreased use of private motorised transport, and increasing physical activity by encouraging the adoption of more active forms of transport (walking and cycling) and use of public transport (incidental physical activity).[9] This approach has been widely recommended to governments as a means of preventing non-communicable diseases,[10] while simultaneously addressing additional public concerns such as climate change, air pollution, fossil fuel dependency, greenhouse gas emissions and productivity, otherwise termed as 'co-benefits'.[11]

Given health inequities among socioeconomic groups, and the documented benefits of using public transport and forms of active transport[9]; policies and urban forms that support lower socioeconomic groups to use active forms of travel might help reduce health inequities.[12] However, previous research examining relationships between SEP and choice of transport mode have revealed mixed results, so strategies for policymakers to promote active travel as a way of addressing health inequities is unclear. At the individual level, some studies have found educational attainment to be negatively associated with walking for transport,[13] cycling for transport,[14] and combined active transport,[15 16] contrary to others which have observed opposite trends.[17–20] Studies investigating transport mode with both individual-level occupation[16 19 20] and income,[16 21] have found inverse associations with active transport. Of the two studies investigating neighbourhood-level disadvantage and transport mode, one found that residents living in more advantaged neighbourhoods, compared with those in less advantaged neighbourhoods were less likely to walk for transport,[20] while another found trends in the opposite direction for active transport.[22]

Devising appropriate strategies to increase active forms of transport in lower socioeconomic groups requires an understanding of where, when and how to intervene. For example, as demonstrated previously,[23] individual-level (eg, education, occupation and income) and area-level (eg, neighbourhood disadvantage) socioeconomic markers are not interchangeable,[24] as each captures a different dimension of the socioeconomic construct and may require a different intervention strategy. Notably, individual-level socioeconomic indicators are likely to be temporally ordered; education is likely to precede occupation which is likely to precede household income. These, individual-level and area-level socioeconomic attributes likely signify discrete aetiological pathways that determine an individual's choice of usual transport mode. For example, level of education reflects attainment of human capital via formal education, accreditation and lived experience.[25] This may influence the acquisition of health literacy and knowledge about the importance of physical activity (which can be accumulated through active transport),[9] or the environmental implications (such as climate change) of particular transport mode choices. 'White collar' occupations are frequently located within the central business district or activity centres, with better access to public transport networks, and reduced availability of low-cost car parking.[26 27] However, 'blue collar' occupations such as trades and manufacturing may require employees to travel to industrial-zoned destinations, or outer-city suburban locations, with poorer coverage of public transport,[26] or may require transportation of heavy tools or specialised equipment best suited to motorised vehicles. Blue collar workers may also undertake shift work at times when public transport services are not operational, or work at multiple locations. Household income is likely to represent the availability of economic resources, increasing the likelihood of motor vehicle or bicycle ownership.[28] Area-level advantage, on the other hand, may determine the local infrastructure or services available to use different modes of transport. For example, disadvantaged neighbourhoods are often residentially denser, on average, and therefore may be more walkable (eg, more destinations within walking distance), and closer to public transport hubs.[12] Nevertheless, irrespective of area-level disadvantage, low density development on the urban fringe tends to be less walkable, and poorly served by shops, services and public transport.

Understanding how different socioeconomic measures are associated with usual transport mode will provide insight into which travel interventions might contribute to reducing socioeconomic inequities in health. The aim of this study was to examine associations between individual-level socioeconomic indicators (educational attainment, occupation and household income), neighbourhood-level socioeconomic disadvantage, and usual transport mode (car or motorbike, public transport, walking and cycling).

METHODS

Sample design and neighbourhood-level unit of analysis

This study used data from the How Areas in Brisbane Influence healTh And acTivity (HABITAT) project. HABITAT is a multilevel longitudinal (2007–2018) study of middle-aged adults (40–65 years in 2007) living in Brisbane, Australia. The primary aim of HABITAT is to examine patterns of change in physical activity, sedentary behaviour and health over the period 2007–2018, and to assess the relative contributions of environmental, social, psychological and sociodemographic factors to these changes. In this paper, we present findings from the HABITAT baseline survey data which were collected in May 2007. Details about HABITAT's sampling design have been published elsewhere.[29] Briefly, a multistage probability sampling design was used to select a stratified random sample (n=200) of Census Collector's Districts (CCD) from the Australian Bureau of Statistics (ABS), and from within each CCD, a random sample of people aged 40–65 years (n=17 000). A total of 11 036 questionnaires with useable data were returned (response rate of 68.9%). This sample was broadly representative of the Brisbane population.[7] CCDs are embedded within a larger suburb, hence, the area corresponding to, and immediately surrounding, a CCD is likely to have meaning and significance for their residents. For this reason, we hereafter use the term 'neighbourhood' to refer to CCDs. The HABITAT study was approved by the Human Research Ethics Committee of the Queensland University of Technology (Ref. no. 3967H).

Individual-level socioeconomic measures

Education: participants were asked to provide information about their highest educational qualification attained. A participant's education was subsequently coded as: (1) bachelor degree or higher (including postgraduate diploma, master's degree or doctorate); (2) diploma (associate or undergraduate); (3) vocational (trade or business certificate or apprenticeship) and (4) no postsecondary school qualifications.

Occupation: participants who were employed at the time of completing the survey were asked to indicate their job title and then to describe the main tasks or duties they performed. This information was subsequently coded to the Australian Standard Classification of Occupations (ASCO).[30] The original nine-level ASCO classification was recoded into five categories: (1) managers/professionals (managers and administrators, professionals and paraprofessionals); (2) white collar employees (clerks, salespersons and personal service workers); (3) blue collar employees (tradespersons, plant and machine operators and drivers, and labourers and related workers); (4) not in the labour force (not employed, home duties, students, retired, permanently unable to work or other (not easily classifiable)) and (5) missing.

Household income: participants were asked to estimate the total pre-tax annual household income using a single question comprising 13 income categories. For analysis, these were recoded into six categories: (1) ≥\$A130 000; (2) \$A129 999–\$A72 800; (3) \$A72 799–\$A52 000; (4) \$A51 999–\$A26 000; (5) ≤\$A25 999 and (6) missing (ie, left the income question blank, ticked 'Don't know' or 'Don't want to answer this').

Transport mode: participants were asked which type of transport they mainly used to get to and from places on most weekdays (Monday–Friday). Response options included (1) public transport; (2) car or motorcycle; (3) walk; (4) bicycle and (5) other. The 'other' category was excluded from analyses due to small cell sizes.

Neighbourhood disadvantage

Each of the 200 neighbourhoods was assigned a socioeconomic score using the ABS' Index of Relative Socioeconomic Disadvantage (IRSD).[31] The IRSD scores were calculated using 2006 census data and derived by the ABS using principle components analysis. A neighbourhood's IRSD score reflects each area's overall level of disadvantage measure on the basis of 17 variables that capture a wide range of socioeconomic attributes, including: education, occupation, income, unemployment, household structure and household tenure (among others). For analysis, the 200 neighbourhoods were grouped into quintiles based on their IRSD scores with Q5 denoting the 20% (n=40) most disadvantaged areas relative to the whole of Brisbane, and Q1 the least disadvantaged 20% (n=40).

Potential confounders

All models were adjusted for age, sex, country of birth (Australia or 'other'), disability and living arrangements.

Table 1 Frequencies of transport mode by individual-level socioeconomic characteristics and neighbourhood disadvantage: persons aged 40–65 years in the How Areas in Brisbane Influence healTh And acTivity (HABITAT) analytic sample (n=10 360)

	Car or motorbike		Public transport		Walking		Cycling		Total sample	
	N	Percent	N	Percent	N	Percent	N	Percent	N	Percent
Age (years)										
40–44	1780	84.7	215	10.2	57	2.7	50	2.4	2102	20.4
45–49	1875	82.0	310	13.6	67	2.9	36	1.6	2288	22.2
50–54	1791	83.2	266	12.4	63	2.9	34	1.6	2154	20.9
55–59	1627	83.0	238	12.1	79	4.0	16	0.8	1960	19.0
60–65	1567	86.1	182	10.0	63	4.5	8	0.4	1820	17.6
Sex										
Male	3879	82.9	545	11.7	130	2.8	123	2.6	4677	45.3
Female	4791	84.3	666	11.8	199	3.5	21	0.4	5647	54.7
Country of birth										
Australia	6538	83.9	899	11.5	242	3.1	110	1.4	7789	75.5
Other	2102	82.9	312	12.3	87	3.4	34	1.3	2535	24.6
Disability barrier										
Yes	7626	84.1	1043	11.5	276	3.0	127	1.4	9072	87.9
No	1014	81.0	168	13.4	53	4.2	17	1.4	1252	12.1
Living arrangements										
Alone with no children	1107	73.7	288	19.2	83	5.5	24	1.6	1502	14.6
Single parent, one or more children	721	79.3	146	16.1	35	3.9	7	0.8	909	8.8
Single and living with friends or relatives	488	74.6	123	18.8	31	4.7	12	1.8	654	6.3
Couple living with no children	2368	85.3	280	10.1	99	3.6	28	1.0	2775	26.9
Couple living with one or more children	3956	88.2	374	8.3	81	1.8	73	1.6	4484	43.4
Education										
Bachelor+	2686	83.4	420	12.8	83	2.5	82	2.5	3271	31.7
Diploma/associate degree	1008	87.1	146	12.1	34	2.8	15	1.3	1203	11.7
Certificate (trade/business)	1593	83.8	159	8.7	56	3.1	21	1.2	1829	17.7
None beyond school	3353	82.1	486	12.1	156	3.9	26	0.7	4021	39.0
Occupation										
Manager/professional	2987	84.3	394	11.1	82	2.3	81	2.3	3544	34.3
White collar	1865	81.0	364	15.8	61	2.7	12	0.5	2302	22.3
Blue collar	1308	88.6	108	7.3	38	2.6	23	1.6	1477	14.3
Not in labour force	2168	83.2	288	11.1	126	4.8	23	0.9	2605	25.2
Missing	312	78.8	57	14.4	22	5.6	5	1.3	396	3.8
Household income										
$A130 000+	1610	88.3	133	7.3	35	1.9	45	2.5	1823	17.7
$A72 800–$A129 999	2260	83.1	347	12.8	67	4.5	45	1.7	2719	26.3
$A52 000–$A72 799	1284	83.2	199	12.9	39	2.5	22	1.4	1544	15.0
$A26 000–$A51 599	1557	82.8	232	12.3	78	4.2	14	0.7	1881	18.2
Less than $A25 999	688	75.9	146	16.1	63	7.0	9	1.0	906	8.8
Missing	1241	85.5	154	10.6	47	3.2	9	0.6	1451	14.1
Neighbourhood disadvantage										
Q1 (least disadvantaged	2827	88.1	277	8.6	51	1.6	55	1.7	3210	31.1
Q2	1845	85.3	221	10.2	61	2.8	36	1.7	2163	21.0
Q3	1427	82.1	222	12.8	68	3.9	21	1.2	1738	16.8
Q4	1573	80.3	282	14.4	82	4.2	21	1.1	1958	19.0
Q5 (most disadvantaged)	968	77.1	209	16.7	67	5.3	11	0.9	1255	12.2
Total	8640	83.7	1211	11.7	329	3.2	144	1.4	10 324	

Disability information was provided via self-reported measures. Participants were asked to respond to the statement ‘I have a disability’ on a five-point Likert scale from (1) strongly disagree to (5) strongly agree. For analysis, this item was recoded into (1) not disabled (strongly disagree, disagree and unsure) and (2) disabled (agree and strongly agree). Participants were also asked to respond to a statement that best described their living arrangements. Response options were (1) living alone with no children; (2) single parent living with one or more children; (3) single and living with friends or relatives; (4) couple (married or de facto) living with no children; (5) couple (married or de facto) living with one of more children and (6) other.

Statistical analysis

Participants who had missing data for transport mode, education, country of birth, disability and living arrangements were excluded (n=674), and two participants were excluded who were beyond 65 years of age when they responded to the survey.

This reduced the final sample to n=10 360 (94.1% of the total sample—table 1). Although it is anticipated that each socioeconomic indicator will have a unique contribution to usual transport mode, shared variances may arise due to the contextual and/or temporal relationships between these indicators. The analysis was informed by postulated relationships between the socioeconomic indicators, and other potential confounders (age, sex, country of birth, disability and living arrangements) and is represented in the form of a directed acyclic graph (figure 1). Education was conceptualised as a common prior cause (confounder) of occupation, income and neighbourhood disadvantage; occupation as a confounder of income and neighbourhood disadvantage, and income as a confounder of neighbourhood disadvantage.

To address the aim of the study, multilevel multinomial logistic regression was used. All models used transport mode as an unordered, categorical, dependent variable (car or motorbike as the reference category), and adjusted for age, sex, country of birth, disability and living arrangements. The models undertaken for analysis were: model 1, transport mode and education (bachelor degree or higher as the reference category); model 2, model 1 and occupation (managers and professionals as the reference category); model 3, model 2 and household income (≥$A130 000 as the reference category); and model 4, model 3 and neighbourhood disadvantage (most advantaged neighbourhoods as the reference category). Each regression used marginal quasi-likelihood iterative generalised least squares methods as the base estimates for Markov chain Monte Carlo (burn in=500, chain=50 000). All results are reported as odds ratios and their 95% credible intervals. Data were prepared in Stata SE V.13,[32] and all analyses were completed in MLwIN V.2.30.[33]

RESULTS

Descriptive statistics for individual and neighbourhood-level socioeconomic measures and usual transport mode are presented in table 1. 'Car or motorbike' was the most frequently (86.7%) reported transport mode ranging from 75.7% (household income <$A25 999) to 88.5% ('blue collar' occupations). Cycling was the least frequently reported usual transport mode (1.4%), ranging from 0.4% (females and those aged 60–65 years) to 2.6% (males).

Individual-level measures

Associations between individual-level socioeconomic measures and usual transport mode are presented in table 2.

Education: compared with residents with a bachelor degree or higher, those with a certificate level of education were less likely to use public transport than a motor vehicle, while those with no postsecondary school qualification were more likely to walk for transport. There was an inverse linear association for cycling, with residents holding a diploma or associate degree, certificate and no postsecondary school qualification, being less likely to cycle for transport than their counterparts with a bachelor degree or higher.

Occupation: compared with managers or professionals, residents working in 'white collar' occupations were more likely, and 'blue collar' workers significantly less likely, to use public transport than a private motor vehicle. Those not in the labour force were less likely than professionals or managers to walk as their usual transport mode. No evidence of associations for any of the occupation groups existed for the likelihood of cycling compared with motor vehicle use as the usual transport mode.

Household income: compared with residents living in the highest income households of ≥$A130 000, those living in households with all other income categories, $A72 800–$A129 999, $A52 000–$A72 799, $A26 000–$A51 599 and ≤$A25 999, were more likely to use public transport as their usual transport mode. Residents in the lowest household income category ≤$A25 999, were more likely than residents of higher income households to walk as their usual transport mode during weekdays than those earning ≥$A130 000. No evidence of associations were observed for cycling among any of the income categories.

Neighbourhood-level measures

Associations between neighbourhood-level disadvantage and usual transport mode are presented in table 3.

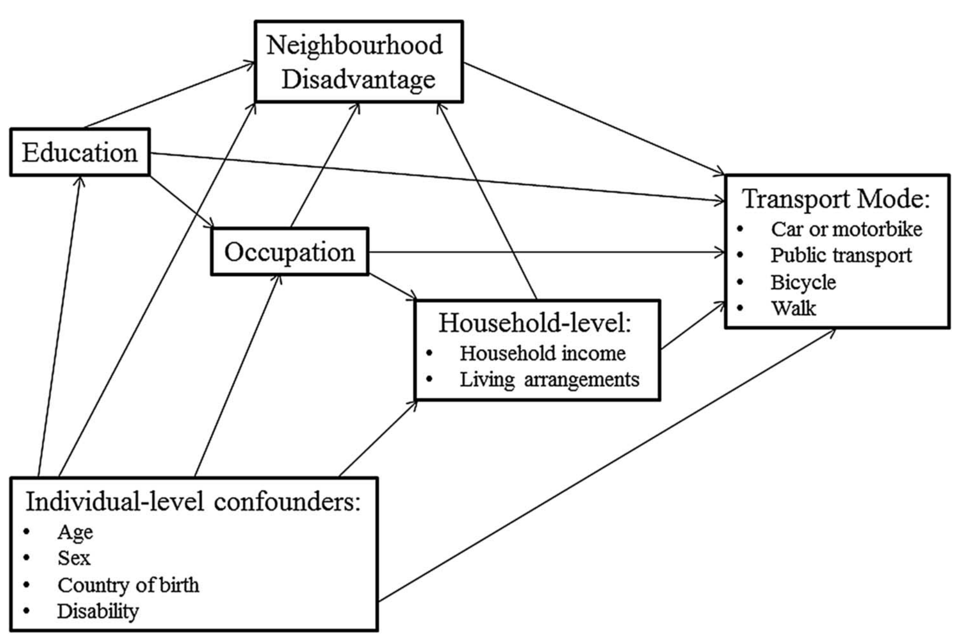

Figure 1 Directed acyclic graph conceptualising the relationships between neighbourhood disadvantage, individual-level socioeconomic characteristics and transport mode.

Table 2 Multilevel multinomial regression results of individual-level socioeconomic characteristics and transport mode

Fixed effects	Reference group	OR*	95% CrI
Education (reference group=bachelor degree+)			
Public transport			
Diploma or associate degree	1.00	0.94	0.76, 1.15
Certificate	1.00	**0.60**	**0.49, 0.74**
None beyond secondary school	1.00	0.90	0.77, 1.04
Walking			
Diploma or associate degree	1.00	1.20	0.77, 1.83
Certificate	1.00	1.28	0.89, 1.84
None beyond secondary school	1.00	**1.58**	**1.18, 2.11**
Cycling			
Diploma or associate degree	1.00	**0.52**	**0.28, 0.90**
Certificate	1.00	**0.39**	**0.23, 0.63**
None beyond secondary school	1.00	**0.31**	**0.19, 0.48**
Occupation† (reference group=manager/professional)			
Public transport			
White collar	1.00	**1.68**	**1.41, 2.01**
Blue collar	1.00	**0.63**	**0.50, 0.81**
Not in labour force	1.00	1.11	0.93, 1.34
Walking			
White collar	1.00	1.04	0.71, 1.53
Blue collar	1.00	0.89	0.57, 1.38
Not in labour force	1.00	**1.94**	**1.38, 2.72**
Cycling			
White collar	1.00	0.57	0.29, 1.05
Blue collar	1.00	0.87	0.50, 1.51
Not in labour force	1.00	0.84	0.49, 1.39
Household income‡ (reference group=$A130 000 +)			
Public transport			
$A72 800–$A129 999	1.00	**1.76**	**1.42, 2.19**
$A52 000–$A72 799	1.00	**1.51**	**1.17, 1.93**
$A26 000–$A51 599	1.00	**1.30**	**1.01, 1.69**
<$A25 999	1.00	**1.71**	**1.25, 2.30**
Walking			
$A72 800–$A129 999	1.00	1.34	0.87, 2.10
$A52 000–$A72 799	1.00	1.07	0.64, 1.79
$A26 000–$A51 599	1.00	1.56	0.97, 2.55
<$A25 999	1.00	**2.10**	**1.23, 3.64**
Cycling			
$A72 800–$A129 999	1.00	0.95	0.61, 1.48
$A52 000–$A72 799	1.00	0.89	0.50, 1.56
$A26 000–$A51 599	1.00	0.59	0.23, 1.16
<$A25 999	1.00	0.92	0.37, 2.17

*Occupation is adjusted for education and household income; household income is adjusted for education and occupation. All models adjusted for age, sex, country of birth, disability and living arrangements.
†The missing occupation category was retained in the analysis but the results are not presented in the table.
‡The missing income category was retained in the analysis but the results are not presented in the table.
95% CrI=95% credible interval.
Bolded text indicates significant associations existed.

Table 3 Multilevel multinomial regression results of neighbourhood disadvantage and transport mode

Fixed effects	Reference group	OR*	95% CrI
Neighbourhood disadvantage (reference group=most advantaged)			
Public transport			
Q2	1.00	1.15	0.89, 1.49
Q3	1.00	**1.42**	**1.10, 1.85**
Q4	1.00	**1.62**	**1.23, 2.07**
Q5 (most disadvantaged)	1.00	**1.93**	**1.46, 2.54**
Walking			
Q2	1.00	1.72	0.92, 3.36
Q3	1.00	**2.17**	**1.15, 4.18**
Q4	1.00	**2.17**	**1.19, 4.03**
Q5 (most disadvantaged)	1.00	**2.73**	**1.46, 5.24**
Cycling			
Q2	1.00	1.01	0.59, 1.71
Q3	1.00	0.74	0.40, 1.35
Q4	1.00	0.70	0.37, 1.28
Q5 (most disadvantaged)	1.00	0.68	0.30, 1.46

*Neighbourhood disadvantage with adjustment for age, sex, country of birth, disability, living arrangements, education, occupation and household income.
95% CrI=95% credible interval.
Bolded text indicates significant associations existed.

Neighbourhood disadvantage: compared with residents living in more advantaged neighbourhoods (Q1), a graded association existed for public transport, with those living in the most advantaged neighbourhoods (Q3, Q4 and Q5—most disadvantaged) all more likely to use public transport as their usual transport mode. Those living in more disadvantaged neighbourhoods were more likely to walk for transport as their usual transport mode (Q3, Q4 and Q5). No significant associations for cycling as the usual transport mode compared with motor vehicle use during weekdays existed by neighbourhood disadvantage groups.

DISCUSSION

This study revealed that the associations for each usual transport mode during weekdays were notably different across these individual-level socioeconomic measures; supporting the notion that discrete pathways between each socioeconomic measure with usual transport mode exist. Those living in disadvantaged neighbourhoods and those with lower incomes were more likely to use public transport and walk for transport, although no such relationship was found for cycling. Other socioeconomic measures were inconsistently associated with travel mode choices. Consistency of this study's findings with previous research was mixed, and may be explained by the different transport measures that were used. For example, several studies found educational attainment to be negatively associated with both walking[13] and cycling,[14] or a combined active transport[16]; while results from the FINRISK[17 18] and UK Time Use Survey[19] reported positive trends with active transport as the outcome. However, previous studies investigating 'active transport' or 'total transport physical activity' have typically combined walking and cycling for transport into one measure. Our results suggest that this should be avoided, as we found opposite associations between education and walking and cycling for transport (table 2). Hence, studies that combine walking and cycling for transport are likely to produce associations that attenuate to the null.

Of studies investigating individual-level occupation[16 19 20 34] and income,[16 21 34] most have found inverse trends with active transport. We found no significant associations between cycling and household income or occupation; however, this study lacked statistical power because of the low number of cyclists. The negative associations between transport, walking and public transport use and household income were consistent with previous literature (table 2).[35] Of the few studies investigating neighbourhood-level disadvantage and transport mode, only one found significant associations: those in more advantaged neighbourhoods were less likely to engage in active transport,[22] which concurs with this study's findings.

There are several factors that may limit the generalisability of this study's findings. First, survey non-response in the HABITAT baseline study was 31.5%, and slightly higher among residents from lower individual socioeconomic profiles, living in more disadvantaged neighbourhoods. Lower response rates from individuals of lower socioeconomic backgrounds are common in epidemiological studies.[36] This is only a problem if the associations between SEP and transport are different among respondents and non-respondents. However, if the usual transport mode of these non-responding residents of low socioeconomic background was walking, for example, then our findings (tables 2 and 3) may underestimate the 'true' magnitude of socioeconomic differences in walking in the Brisbane population. Second, the cross-sectional nature of the study design means that claims about causality must be made cautiously. However, reverse causation is unlikely as it seems improbable that transport use might determine SEP. Examining the relationship between socioeconomic measures and transport mode longitudinally may identify groups that are more susceptible to changing their transport behaviours. Third, our measure of transport mode was limited because it only captured the most frequent mode of transport, and it is possible that many respondents used a mixture of modes. Fourth, the findings of this study may also be confounded by unobserved individual, household and neighbourhood-level socioeconomic factors, or biased from the misclassification of self-reported responses. For example, we have not examined attributes of choice of transport mode that may have influenced the selection of usual mode by participants, and thus, these omitted factors may serve to confound with some of the measured neighbourhood level attributes.

While promoting active forms of transport, such as walking or cycling, or those that encourage incidental physical activity such as public transport, decision-makers need to consider both the socioeconomic profiles of the target individuals and area, as well as the complex relationships as demonstrated in this study, and recognise that a 'one-size-fits-all' approach is unsuitable. For example, if reliance on motor vehicles is to be reduced, adequate and appropriate alternative transport infrastructure to access places of employment need to be provided. Findings from Badland *et al*[37] highlight the importance of accessible public transport near both home and work, and the importance of ensuring employment hubs have access to high-quality public transport options. The results of this study also suggest that those living in more disadvantaged neighbourhoods are more likely to walk and use public transport. Ensuring that these areas have walkable neighbourhoods and access to public transport may indeed contribute to reducing health inequities. Despite growing interest in cycling, irrespective of the measures of SEP, we found no evidence that participants from more disadvantaged neighbourhoods were more likely to cycle for transport, in contrast with walking and public transport. Given that cycling is a low-cost form of transport, this warrants further investigation.

The present study has documented associations between individual-level SEP, neighbourhood disadvantage and transport mode. Future research should be directed at understanding why these associations exist; such as whether there is inequitable access to infrastructure for each transport mode (eg, footpaths, bikeways, public transport access) for residents with varying individual-level socioeconomic characteristics, or by neighbourhood disadvantage. This can be achieved via first, examining the individual-level characteristics of these groups (eg, access to and capacity to maintain a motor vehicle or bicycle); and second, investigating the built and social characteristics of advantaged and disadvantaged neighbourhoods (eg, access to bus stops and railway stations, local bikeways and land use mix).

This study provides a basis from which to build a clearer understanding of the causal pathways between socioeconomic characteristics and usual transport mode. Further work is required exploring the individual and neighbourhood-level mechanisms behind the choice of transport mode, the propensity of individuals from different socioeconomic backgrounds to change their transport mode, and the subsequent implications for population health in the long term. This will require the collection of comprehensive longitudinal data in order to identify the relative influence of individual, social and built environment characteristics in order to better understand where to intervene.

What is already known on this subject

Facilitating more active forms of transport is seen as a practical means of increasing physical activity and reducing non-communicable diseases. Previous research examining relationships between socioeconomic position and transport mode have revealed mixed results; and often collapsed measures of walking and cycling into an 'active transport' category are used.

What this study adds

Different measures of socioeconomic status were associated with walking and cycling for transport; suggesting that studies should therefore avoid combining walking and cycling into a single 'active transport' measure as this is likely to produce associations that attenuate to the null. We showed that complex patterns of association between neighbourhood disadvantage, individual socioeconomic position and transport mode exist, and at times display contrary effects depending on the socioeconomic marker applied. The results suggest that different underlying factors predict differences at the various socioeconomic levels, and a one-size-fits-all approach to policies that promote active transport should be avoided.

Author affiliations
[1]School of Public Health and Social Work and Institute of Health and Biomedical Innovation, Queensland University of Technology, Brisbane, Queensland, Australia
[2]Gender and Women's Health Unit, Centre for Health Equity, Melbourne School of Population and Global Health, The University of Melbourne, Carlton, Victoria, Australia
[3]McCaughey VicHealth Community Wellbeing Unit, Melbourne School of Population and Global Health, The University of Melbourne, Carlton, Victoria, Australia
[4]Civil Engineering and Built Environment School, Science and Engineering Faculty, Centre for Accident Research and Road Safety, Health Faculty and Institute of Health and Biomedical Innovation, Queensland University of Technology, Brisbane, Queensland, Australia

Contributors JNR contributed to conception, analysis and interpretation of the data, drafting and revising of the article. AK contributed to the analysis and interpretation of the data. GT contributed to conception, analysis and interpretation of the data. All authors revised the article for important intellectual content, and approved the final manuscript as submitted.

Funding The HABITAT study is funded by the National Health and Medical Research Council (NHMRC) (ID 497236, 339718, 1047453). JNR is supported by the NHMRC Centre for Research Excellence in Healthy Liveable Communities (ID 1061404) and The Australian Prevention Partnership Centre (ID 9100001). HB is supported by the NHMRC Centre of Research Excellence in Healthy Liveability Communities (ID 1061404), The Australian Prevention Partnership Centre (ID 9100001) and VicHealth. BG-C is supported by an NHMRC Principal Research Fellow Award (ID 1004900). SW holds the Queensland Academic and Strategic Transport Chair funded by Transport and Main Roads and the Motor Accident Insurance Commission. GT is supported by an NHMRC Senior Research Fellowship (ID 1003710).

Competing interests None declared.

Ethics approval Human Research Ethics Committee of the Queensland University of Technology.

Provenance and peer review Not commissioned; externally peer reviewed.

REFERENCES

1 Clark AM, Duncan AS, Luo W, *et al*. Socioeconomic status and cardiovascular disease: risks and implications for care. *Nat Rev Cardiol* 2009;6:712–22.
2 Addo J, Ayerbe L, Mohan KM, *et al*. Socioeconomic status and stroke: an updated review. *Stroke* 2012;43:1186–91.
3 Saydah S, Lochner K. Socioeconomic status and risk of diabetes-related mortality in the US. *Public Health Rep* 2010;125:377.
4 Uthman OA, Jadidi E, Moradi T. Socioeconomic position and incidence of gastric cancer: a systematic review and meta-analysis. *J Epidemiol Community Health* 2013;67:854–60.
5 Sidorchuk A, Agardh EE, Aremu O, *et al*. Socioeconomic differences in lung cancer incidence: a systematic review and meta-analysis. *Cancer Causes Control* 2009;20:459–71.
6 El-Sayed AM, Scarborough P, Galea S. Unevenly distributed: a systematic review of the health literature about socioeconomic inequalities in adult obesity in the United Kingdom. *BMC Public Health* 2012;12:18.
7 Turrell G, Haynes M, Burton NW, *et al*. Neighborhood disadvantage and physical activity: baseline results from the HABITAT multilevel longitudinal study. *Ann Epidemiol* 2010;20:171–81.
8 Turrell G, Hewitt BA, Miller SA. The influence of neighbourhood disadvantage on smoking cessation and its contribution to inequalities in smoking status. *Drug Alcohol Rev* 2012;31:645–52.
9 Rabl A, de Nazelle A. Benefits of shift from car to active transport. *Trans Policy* 2012;19:121–31.
10 Woodcock J, Banister D, Edwards P, *et al*. Energy and transport. *Lancet* 2007;370:1078–88.
11 Giles-Corti B, Foster S, Shilton T, *et al*. The co-benefits for health of investing in active transportation. *N S W Public Health Bull* 2010;21:122–7.
12 Turrell G, Haynes M, Wilson L-A, *et al*. Can the built environment reduce health inequalities? A study of neighbourhood socioeconomic disadvantage and walking for transport. *Health Place* 2013;19:89–98.
13 Cerin E, Mellecker R, Macfarlane DJ, *et al*. Socioeconomic status, neighborhood characteristics, and walking within the neighborhood among older Hong Kong Chinese. *J Aging Health* 2013;25:1425–44.
14 Andersen LB, Schnohr P, Schroll M, *et al*. All-cause mortality associated with physical activity during leisure time, work, sports, and cycling to work. *Arch Intern Med* 2000;160:1621–8.
15 Jurakić D, Pedisić Z, Andrijasević M. Physical activity of Croatian population: cross-sectional study using International Physical Activity Questionnaire. *Croatian Med J* 2009;50:165–73.
16 Mäkinen T, Borodulin K, Laatikainen T, *et al*. Twenty-five year socioeconomic trends in leisure-time and commuting physical activity among employed Finns. *Scand J Med Sci Sports* 2009;19:188.
17 Wang Y, Tuomilehto J, Jousilahti P, *et al*. Occupational, commuting, and leisure-time physical activity in relation to heart failure among Finnish men and women. *J Am Coll Cardiol* 2010;56:1140–8.
18 Hu G, Qiao Q, Silventoinen K, *et al*. Occupational, commuting, and leisure-time physical activity in relation to risk for type 2 diabetes in middle-aged Finnish men and women. *Diabetologia* 2003;46:322–9.
19 Adams J. Prevalence and socio-demographic correlates of "active transport" in the UK: Analysis of the UK time use survey 2005. *Prev Med* 2010;50:199–203.
20 Van Dyck D, Cardon G, Deforche B, *et al*. Neighborhood SES and walkability are related to physical activity behavior in Belgian adults. *Prev Med* 2010;50:S74–9.
21 Wagner A, Simon C, Evans A, *et al*. Physical activity patterns in 50–59 year men in France and Northern Ireland. Associations with socio-economic status and health behaviour. *Eur J Epidemiol* 2003;18:321–9.
22 van Lenthe FJ, Brug J, Mackenbach JP. Neighbourhood inequalities in physical inactivity: the role of neighbourhood attractiveness, proximity to local facilities and safety in the Netherlands. *Soc Sci Med* 2005;60:763–75.
23 Turrell G, Kavanagh AM. Socio-economic pathways to diet: modelling the association between socio-economic position and food purchasing behaviour. *Public Health Nutr* 2006;9:375–83.
24 Geyer S, Hemström Ö, Peter R, *et al*. Education, income, and occupational class cannot be used interchangeably in social epidemiology. Empirical evidence against a common practice. *J Epidemiol Community Health* 2006;60:804–10.
25 Hatch SL, Feinstein L, Link BG, *et al*. The continuing benefits of education: adult education and midlife cognitive ability in the British 1946 birth cohort. *J Gerontol B Psychol Sci Soc Sci* 2007;62:S404–S14.
26 Murray AT. Strategic analysis of public transport coverage. *Socioecon Plann Sci* 2001;35:175–88.
27 Badland HM, Garrett N, Schofield GM. How does car parking availability and public transport accessibility influence work-related travel behaviors? *Sustainability* 2010;2:576–90.
28 Australia Bureau of Statistics. *Car nation*. Canberra: Australia Bureau of Statistics (ABS), 2014.
29 Burton NW, Haynes M, Wilson LAM, *et al*. HABITAT: a longitudinal multilevel study of physical activity change in mid-aged adults. *BMC Public Health* 2009;9:76.
30 Austalian Bureau of Statistics. *Australian standard classification of occupations*. 2nd edn. Canberra: ABS, 1997.
31 Australia Bureau of Statistics. *Information paper: an introduction to socioeconomic indexes for areas (SEIFA)*. Canberra: ABS, 2006.
32 StataCorp. *Stata Statistical Software: Release 13*. College Station, TX: StataCorp, 2013.
33 Rasbash J, Brown WJ, Healy M, *et al*. *MLwIN Version 2.30*: Centre for Multilevel Modelling: University of Bristol, 2014.
34 Kwaśniewska M, Kaczmarczyk-Chałas K, Pikala M, *et al*. Socio-demographic and lifestyle correlates of commuting activity in Poland. *Prev Med* 2010;50:257–61.
35 Paulley N, Balcombe R, Mackett R, *et al*. The demand for public transport: the effects of fares, quality of service, income and car ownership. *Trans Policy* 2006;13:295–306.
36 Galea S, Tracy M. Participation rates in epidemiologic studies. *Ann Epidemiol* 2007;17:643–53.
37 Badland H, Hickey S, Bull F, *et al*. Public transport access and availability in the RESIDE study: is it taking us where we want to go? *J Trans Health* 2014;1:45–9.