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Associations between changes in crime and changes in walking for transport with effect measure modification by gender: A fixed-effects analysis of the multilevel longitudinal HABITAT study (2007–2016)

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ABSTRACT

Walking for transport is a potential solution to increasing physical activity in mid to older aged adults however neighbourhood crime may be a barrier. Using data from the How Areas in Brisbane Influence HealTh and ACTivity (HABITAT) study 2007–2016, this study examined associations between changes in crime (perceived crime and objectively measured crime) and changes in transport walking, and whether this association differed by gender. Fixed effects regression modelled associations between changes in crime and changes in transport walking, with interaction terms examining effect modification by gender. Positive associations were found between crimes against person and walking for transport. There was no evidence of effect modification by gender. Understanding the relationship between crime and walking for transport can inform policies aimed at promoting transport walking.

1. Background

Walking for transport, that is travelling to work, services, from place to place, or recreation destinations by foot, is a readily available option to incorporate physical activity (PA) into daily routines (Audrey et al., 2014). When considering the high level of physical inactivity globally (World Health Organization) a shift from heavy reliance on personal vehicles to more active modes of transport can have positive health outcomes. In addition to being a potential solution to a major public health challenge, it is more sustainable and economical, and can create more liveable cities (Giles-Corti et al., 2010). The benefits of increased transport walking are far reaching as underscored by the World Health Organization who advocate for the promotion of transport walking to support multiple Sustainable Development Goals (World Health Organization, 2022).

It is widely understood that physical inactivity increases the risk of developing non-communicable disease and premature mortality (World Health Organization). Despite this, 25% of the adult population globally do not meet the World Health Organization guidelines for PA (World Health Organization). To devise appropriate policies for the promotion of transport walking, barriers must first be understood. Previous studies have suggested that a likely deterrent to transport walking is crime.

Crime can be measured objectively, that is police recorded offenses, or subjectively. Subjectively measured crime can be conceptualised broadly as either perceptions about crime or a fear of crime. The two distinct concepts can influence walking for transport differently. For example, residents may recognise and perceive crime in the neighbourhood however, if it does not create fear or inhibit feeling safe than it may not discourage walking (Foster et al., 2016; Foster and Giles-Corti, 2008). Existing research examining the associations between crime and transport walking have presented mixed results. For example, longitudinal evidence of a relationship between fear of crime and a decrease in walking was identified in a study of residents in Perth, Western Australia (Foster et al., 2014a). A cross-sectional analysis of residents from the same sample also concluded that fear of crime was a deterrent to walking for transport (Foster et al., 2014b). Conversely, when using objective crime data, studies such as one in Glasgow, found no association between property crime and walking (Mason et al., 2013). Similar findings were observed in a longitudinal study of residents in Chicago, the only exception noted was locations with an increased rate of murder

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(Kerr et al., 2015). These locations experienced a decrease in walking, suggesting that only the most serious crimes are likely to affect decisions about walking. However, the relationship between crime and walking is complex and can be counterintuitive: one study in Brisbane, Australia, found high levels of objective crime were associated with increased odds of walking for transport (Foster et al., 2021). Likewise, burglary and personal crime were positively associated with walking in a study of neighbourhoods in Perth Australia (Foster et al., 2014c).

Adding further complexity is the likelihood that men and women experience crime differently. There is evidence to suggest that the time of day, more specifically after dark, is more likely to affect walking behaviour among females. For example, females have been shown to be less inclined to walk from a public transport stop to home of an evening compared to males, and are more reliant on family or friends to pick them up in a vehicle (Kim et al., 2007). With Australian women 55 years and over less physically active than their male counterparts (Australian Institute of Health and Welfarea) it is important to identify opportunities to reduce this disparity.

The aim of this study is to examine the association between changes in crime, measured both as perceptions and objectively (i.e., police-recorded), and changes in walking for transport, and to further examine whether this association differs by gender. It is hypothesized that the presence of crime, real or perceived, is likely to be negatively associated with walking for transport. However, existing literature has presented varied results.

This study will extend on existing literature in several ways. First, previous studies have largely relied on cross-sectional data which are limited in their ability to infer causality. Second, this study will use a fixed-effects model to examine within-individual comparisons and will automatically adjust for all time-invariant confounders, further strengthening causal assertions. And third, this study will determine if these associations differ by gender. Few longitudinal studies have simultaneously examined crime measured both as perceptions and objective (Foster et al., 2016, 2021; Kerr et al., 2015). This study will examine both measures among a cohort across nine years and go further by examining gender differences. A further limitation of previous studies is their inability to account for neighbourhood self-selection (McCormack and Shiell, 2011). People who are more likely to walk for transport may choose to live in neighbourhoods that support walking. Failing to adjust for location preference can confound associations. This limitation has been addressed by including participant's preference for living in a particular neighbourhood. At baseline or upon moving participants were asked about their preference for choosing their current address.

2. Methods

2.1. Population and data

This study uses data from the How Areas in Brisbane Influence HealTh and AcTivity (HABITAT) study. The purpose of the HABITAT study was to examine changes in PA and sedentary behaviour in older adults and how social, environmental, sociodemographic, and psychological factors, influenced these changes (Turrell et al., 2021). The cohort of men and women, between 40 and 65 years old at baseline, broadly represent the population of Brisbane, Australia (Turrell et al., 2010). In addition to a self-report survey, a geospatial study of neighbourhood characteristics such as traffic, crime, safety, green spaces, and other surroundings was also developed as part of the HABITAT study (Turrell et al., 2021).

2.2. Procedure

Details about HABITAT's sampling design have been published elsewhere (Burton et al., 2009). Briefly, participants were selected via stratified random sampling from Census Collection Districts, (CCDs) in Brisbane. CCDs (n = 1625) were allocated an index of relative socioeconomic disadvantage score, ranked by their score then apportioned into deciles. From the deciles 20 CCDs were randomly selected to generate 200 areas. The area encompassing a CCD and the nearby surroundings are likely to hold meaning for the people living there. Therefore, hereafter CCDs are referred to as neighbourhoods (Australian Bureau of Statistics, 2016). The first wave of the study in 2007, received 11,035 responses (68.5% response rate) by eligible participants (Burton et al., 2009). Individual level data was collected for the HABITAT study through structured self-administered questionnaires. The questionnaires were mailed to eligible participants using the mail survey method developed by Dillman (2011) over five waves starting in 2007 with follow-up in 2009 (n = 7,866, 72.6% response rate), 2011 (n = 6,900, 67.6%), 2013 (n = 6,520, 67.6%) and 2016 (n = 5,187, 58.8%) (Turrell et al., 2021). In addition to individual questionnaires, at each of the time-points, a suite of objective environmental measures was generated using geographical information systems (Turrell et al., 2021). HABITAT received ethical clearance from the Queensland University of Technology Human Research Ethics Committee (Ref. Nos. 3967H & 1300000161).

2.3. Variables

2.3.1. Outcomes

Walking for transport: Participants were asked how many total minutes they spent walking in the previous week, specifically "What do you estimate was the total time that you spent walking for transport in the LAST WEEK?" at every wave. The question was derived from a question in the Active Australia Survey, which has demonstrated reliability (Brown et al., 2004). Participants were directed to only include time spent walking to work or completing necessary travel but not time walking for recreation. Responses exceeding 840 min per week (2 h per day) were excluded from analysis. Due to the zero-inflated negative binomial distribution, walking for transport was examined as both a dichotomous outcome (no transport walking vs any transport walking), and a continuous outcome (measured as minutes of walking for transport in the previous week), as has been the approach in previous studies of this nature (Bentley et al., 2018).

2.3.2. Exposures

Perceived crime: Our measure of perceived crime is best conceptualised as a judgement or cognitive assessment of safety from crime, rather than an emotional reaction to crime (e.g., fear or anxiety about crime) (Foster et al., 2016; Foster and Giles-Corti, 2008). Participants were presented with the following statements and asked to respond on a 5-point Likert-type scale, ranging from 'strongly disagree' to 'strongly agree': there is a lot of crime in my suburb, there are unsecured dogs in my suburb, children are safe walking around the suburb during the day, the crime in my suburb makes it unsafe to walk streets at night, rowdy youth on streets or hanging around in parks in my suburb, the crime in my suburb makes it unsafe to walk streets daytime, I would feel safe walking home from bus stop/train station at night. These statements were adapted for the Australian population from the Neighbourhood Environment Walkability Scale questionnaire, which has acceptable validity, generalizability and reliability for measuring perceived neighbourhood walkability (Cerin et al., 2009). The perceptions of crime items were subjected to a principal components analysis with varimax rotation, combined to form a weighted linear (standardised) scale with a mean of 0 and a standard deviation of 1. Therefore, each additional increase in perceptions of crime in models represents a 1 standard deviation unit increase.

Objectively measured crime: Objective crime was measured using Queensland Police Service data. Data on reported crimes in Brisbane from 2007 to 2016 were provided. The total number of reported crimes from the previous two years were calculated from a 1 km network buffer around participants' location using geographic information systems. A network buffer was selected as it uses road networks which aligns with

transport walking. A distance of 1 km has been commonly identified as a reasonable walking distance and considers physical barriers such as rivers or lakes (Mavoa et al., 2019). Crime was allocated to three categories: crimes against person (homicide, assault, sexual offenses, robbery, and other offenses against the person), unlawful entry (unlawful entry without violence—dwelling, unlawful entry with intent—shop, unlawful entry with intent—other), and social incivilities (drug offenses, prostitution offenses, trespassing and vagrancy, and good order offenses) (Foster et al., 2021). The total counts of crime were rescaled by a factor of 100. Therefore, a one unit increase in each actual crime category in analysis represents 100 additional crimes in the previous two years.

Gender: Participants responded to a question asking 'are you male or female'. The working of the question was in line with Australian population health surveys at the time (i.e. the first wave was 2007), whereby respondents are likely to provide a gender response to a sex question. (Australian Institute of Health and Welfareb).

2.3.3. Covariates

Preference for living location: e.g. closeness to schools, greenspace etc.

Age: ascertained from reported year of birth and entered into models as years of age.

Education: classified as the highest qualification obtained from bachelor degree or higher, diploma, certificate, or high school only.

Employment: coded according to the Australian and New Zealand Standard Classification of Occupations (ANZSCO) and classified into five categories – professional, white collar, blue collar, home duties, retired or missing/not easily classifiable.

Household Income: participants were asked to provide information on their household annual income by selecting from five income range categories $130,000+, $72,800-129,999, $52,000–72,799, $26,000–51,999, Less than $25,999, 'don't know' or 'don't want to answer.'

Neighbourhood disadvantage used a census-derived index. The IRSD score collates data regarding the social and economic indicators, such as household income, unemployment rate, one parent families and educational attainment of residents of the area. A low score indicates a greater level of disadvantage whilst a high score indicates a relative lack of disadvantage. (Australian Bureau of Statisticsa).

Built Environment included street connectivity, land mix use and density data derived from information supplied by Brisbane City Council and MapInfo with each characteristic defined within a 1 km road network buffer around the participants residence. Street connectivity was determined by the number of four-way intersections within the buffer. Land use mix refers to the portion of land used for residential, commercial, industrial, and recreational purposes. Density was measured as the number of dwellings per hectare within the buffer.

2.4. Statistical analysis

From the original sample, 352 participants were omitted after it was revealed that they were not the same participants at each wave. Of the remaining 41,868 observations, 1547 observations were omitted because participants had moved out of the study area and were therefore missing environment data (i.e., crime and the built environment), leaving 40,321 in-scope observations. From those observations, 1947 were missing on residential preferences, 6016 on household income, 513 on occupation and 612 on walking for transport, leaving a final analytic sample of 31,234 observations (78% of the in-scope sample).

The analysis was informed by postulated relationships between the exposures and outcomes of interests, and other potential confounders. It was posited that age, socioeconomic indicators (e.g. education, occupation, household income), residential preferences, and the neighbourhood built environment were confounders, and these were adjusted for in all models. Objectively measured crime was also adjusted for when examining associations between perceived crime and transport walking, as we also posited that objectively measured crime was a confounder of the association between perceived crime and transport walking.

Fixed effects models were used in analyses as they provide within-person comparisons over time and automatically adjust for all time-invariant confounders (Gunasekara et al., 2014), while other potential time-varying confounders, such as household income and occupation were also adjusted for. A three-stage analysis was undertaken in Stata SE version 16 (Stata Statistical Software, 2019). First, a logistic fixed effects model (using the 'xtlogit' command) estimated the association between changes in crime and changes in the odds of being a transport walker, that is any walking for transport versus none. Second, a linear fixed effects model (using the 'xtreg' command in Stata) was undertaken with walking for transport minutes measured as a continuous variable for each crime category. Third, to examine effect measure modification by gender, each of the models were extended by including an interaction term between each of the crime characteristics and gender. Effect measure modification was assessed by examining the interaction fixed effects and likelihood ratio tests.

3. Results

Descriptive statistics are presented in Table 1. The baseline sample consisted of 44.4% men (n = 4372) and 55.6 % women (n = 5464). Male representation declined as age category increased however women were more evenly disbursed over each age category (excluding 65–69 years old). There were more participants in the 'Professional' occupation category for both men and women (40.5% and 29.7% respectively). For neighbourhood disadvantage men and women were evenly disbursed in Q2, Q3 and Q4 with the highest representation in Q1 (the least disadvantaged neighbourhood) and the lowest representation in Q5 (the most disadvantaged neighbourhood). At baseline, 36.50% and 34.29% of men and women, respectively, reported walking for transport. For both men and women those living the most disadvantaged neighbourhoods (Q4 and Q5) were more likely to walk for transport than those in the least disadvantaged neighbourhoods (Q1 and Q2). Descriptive statistics for each of the crime exposures, including for baseline and changes in each exposure, are presented in Table 2. Mean perceived crime for both men and women increased between waves. For objectively measured crimes, crimes against person and unlawful entry, the mean decreased, and social incivilities increased for both men and women.

Regression results are presented in Table 3. Crimes against person had a positive association with the odds of being a transport walking and minutes of walking for transport. For every additional 100 crimes against person in the previous two years the odds of being a transport walker was 1.42 (OR 1.42, 95% CI 1.06,1.90) (p-value = 0.904). Minutes of walking for transport was also positively associated with every additional 100 crimes against person in the previous 2 years min of transport walking increased by almost 13 min (β 12.81, 95% CI 2.76,22.88) (p-value = 0.859). No association was found with perceived crime, unlawful entry, or social incivilities. There was no evidence for effect measure modification by gender by each of the crime exposures for either the odds of being a transport walker or walking for transport minutes.

4. Discussion

This study examined associations between changes in crime, perceived or police-recorded, and changes in transport walking, and further examined whether this association was different depending on gender. The results differed for perceived crime and objectively measured crime, highlighting the importance of examining both measures of crime. The findings of this study support some existing cross-sectional evidence (Mason et al., 2013; Foster et al., 2014c) that crimes against person have a positive association with walking for transport: that is, as crimes against person increased, transport walking

Table 1
Analytic sample and transport walking.

Overall	Men					
	2007 (baseline)			2007–2016		
	Total sample N	Transport walkers %	Mean (sd) transport walking	Mean (sd) change in transport walking mins	Mean % change in transport walking (decrease)	Mean % change in transport walking (increase)
	4372	36.5	38.5 (108.6)	−0.1 (74.8)	31.94	23.47
Age						
40–44	1191	40.4	42.4 (126.0)	−0.9 (78.4)	32.9	29.9
45–49	956	38.6	41.6 (93.75)	4.0 (88.4)	29.2	29.0
50–54	876	34.4	37.8 (127.2)	0.2 (80.8)	28.2	23.6
55–59	778	33.4	34.3 (76.0)	0.7 (44.2)	32.3	22.0
60–64	542	32.3	32.2 (100.2)	−6.7 (72.4)	34.0	23.2
65–69	29	34.5	32.9 (60.6)	−1.0 (19.3)	44.7	17.4
Education						
Bachelor degree or higher	1387	29.3	32.2 (113.7)	−1.3 (64.8)	37.2	19.0
Diploma/associate degree	939	28.8	28.9 (78.8)	−0.9 (43)	41.0	20.5
Certificate	541	36.6	37.8 (92.5)	2.4 (95.3)	35.9	26.0
No post-school qualification	1497	48.0	50.7 (123.4)	0.6 (89.9)	25.1	30.0
Occupation						
Professional	1770	41.9	42.3 (111.7)	2.1 (71.2)	26.3	28.1
White collar	604	37.3	34.0 (66.5)	3.2 (75.2)	31.2	23.9
Blue collar	1002	25.1	27.8 (105.4)	−1.0 (66.5)	42.9	18.9
Home duties	38	29.0	48.3 (148.6)	−14.6 (102.6)	30.0	11.1
Retired	289	32.9	37.3 (119.3)	−5.1 (78.2)	36.2	22.9
Missing/NEC	669	40.7	48.6 (125.7)	−5.0 (94.5)	26.4	17.1
Income						
$130,000+	915	40.7	40.0 (117.7)	−0.2 (82.7)	29.1	30.1
$72,800-129,999	1300	38.2	40.0 (98.2)	1.5 (60.2)	27.8	23.9
$52,000–72,799	684	36.1	39.5 (104.4)	−3.5 (83.5)	29.5	22.0
$26,000–51,999	728	31.0	34.7 (126.4)	2.4 (81.8)	38.1	21.3
Less than $25,999	315	41.6	46.5 (111.3)	−0.7 (72.9)	24.1	17.1
Don't know	62	33.9	28.7 (64.6)	4.1 (36.8)	30.8	18.8
Don't want to answer	368	28.5	30.4 (91.2)	−4.4 (82.3)	30.3	22.4
Neighbourhood disadvantage						
Q1 (most advantaged)	1314	35.7	35.3 (111.8)	1.6 (69.7)	32.0	24.9
Q2	842	36.2	38.5 (105.4)	0.5 (69.3)	31.0	24.1
Q3	867	34.3	35.4 (86.8)	1.0 (66.4)	32.1	22.2
Q4	819	39.3	40.91 (93.7)	−2.0 (72.4)	34.1	23.6
Q5 (most disadvantaged)	530	38.5	47.8 (150.5)	−4.5 (110.1)	31.7	18.0
Overall	Women					
	2007 (baseline)			2007–2016		
	Total sample N	Transport walkers %	Mean (sd) transport walking	Mean (sd) change in transport walking mins	Mean % change in transport walking (decrease)	Mean % change in transport walking (increase)
	5464	34.3	37.2 (169.2)	−2.4 (98.4)	36.1	22.8
Age						
40–44	1110	38.1	39.0 (129.6)	−0.7 (122.0)	29.7	22.1
45–49	1193	35.9	48.4 (288.0)	−4.7 (106.5)	32.9	24.2
50–54	1147	34.4	34.7 (98.1)	1.4 (4.0)	30.7	22.5
55–59	1079	32.6	33.7 (132.9)	−3.1 (73.9)	38.1	19.8
60–64	903	29.4	28.5 (96.8)	−5.8 (46.9)	42.5	22.0
65–69	32	31.3	26.1 (67.9)	−0.4 (38.4)	39.4	19.6
Education						
Bachelor degree or higher	2411	29.6	30.6 (122.1)	−3.3 (95.1)	39.9	20.0
Diploma/associate degree	784	34.2	36.5 (101.8)	−1.8 (71.2)	35.6	21.0
Certificate	614	37.5	40.3 (120.6)	−9.1 (91.2)	39.2	23.9
No post-school qualification	1639	40.0	46.4 (250.9)	0.7 (116.1)	31.9	27.1
Occupation						
Professional	1622	35.3	40.8 (255.1)	−0.4 (116.7)	32.1	24.3
White collar	1602	35.6	37.7 (122.4)	−2.5 (105.6)	32.5	20.8
Blue collar	377	30.8	36.5 (123.4)	−0.7 (67.5)	32.6	18.2
Home duties	509	28.7	21.6 (61.4)	4.0 (37.3)	41.1	18.8
Retired	535	30.0	23.3 (61.8)	−1.6 (28.1)	43.1	22.8
Missing/NEC	819	37.5	48.3 (143.8)	−13.0 (112.6)	36.3	26.1
Income						
$130,000+	820	30.6	38.3 (141.7)	−3.4 (86.7)	29.9	23.0

(*continued on next page*)

Table 1 (*continued*)

Overall	Women					
	2007 (baseline)			2007–2016		
	Total sample N	Transport walkers %	Mean (sd) transport walking	Mean (sd) change in transport walking mins	Mean % change in transport walking (decrease)	Mean % change in transport walking (increase)
	5464	34.3	37.2 (169.2)	−2.4 (98.4)	36.1	22.8
$72,800-129,999	1320	35.7	42.4 (276.3)	−3.5 (157.9)	34.5	24.2
$52,000–72,799	814	37.0	33.3 (91.2)	1.1 (52.4)	37.0	27.5
$26,000–51,999	1098	36.2	37.5 (87.3)	−2.3 (54.3)	33.0	20.5
Less than $25,999	598	34.6	43.8 (179.2)	−9.0 (97.7)	37.2	21.8
Don't know	168	28.6	23.5 (54.3)	−0.3 (36.8)	50.0	18.0
Don't want to answer	646	30.5	27.1 (82.1)	1.7 (55.6)	44.2	23.4
Neighbourhood disadvantage						
Q1 (most advantaged)	1662	30.1	36.5 (249.5)	−4.3 (116.5)	38.0	22.2
Q2	1059	32.8	32.2 (106.0)	0.6 (118.1)	36.4	21.0
Q3	979	35.7	34.5 (86.8)	−1.6 (59.6)	33.7	23.8
Q4	1024	38.5	39.5 (105.1)	−1.7 (75.2)	26.1	26.6
Q5 (most disadvantaged)	737	38.1	46.5 (173.8)	−5.0 (94.8)	35.3	21.6

Table 2
Mean change in crime exposure 2007–2016 among participants of the HABITAT study, Brisbane, Australia.[a]

	Men				Women			
	Perceived crime	Crimes against person	Social incivilities	Unlawful Entry	Perceived crime	Crimes against person	Social incivilities	Unlawful Entry
Baseline (2007)								
Mean (SD)	−0.19 (0.95)	26.18 (47.77)	79.49 (255.34)	64.61 (50.92	0.13 (1.01)	24.78 (40.88)	73.35 (227.68)	61.76 (47.43)
Minimum	−2.3	0	0	0	−2.3	0	0	0
25th percentile	−0.71	9	25	28	−0.6	9	24	27
50th percentile	−0.37	18	44	55	0.02	18	44	55
75th percentile	0.32	31	79	88	0.77	30	77	82
Maximum	4.06	874	4754	446	4.06	874	4754	446
Changes between waves								
Mean (SD)	0.05 (0.47)	−0.71 (11.13)	3.51 (64.96)	−4.86 (15.36)	0.03 (0.48)	−0.29 (13.26)	5.31 (79.47)	−4.24 (14.94)
Minimum	−4.23	−242	−1514	−131	−3.04	−388	−2372	−192.5
25th percentile	−0.14	−2.75	−4.5	−9.75	−0.16	−2.5	−3	−9
50th percentile	0.06	−0.5	0.5	−3.25	0.04	−0.5	1	−2.75
75th percentile	0.22	1	7.33	1.5	0.22	1	8	2
Maximum	4.06	185.25	1300	114	4.54	323	2171.5	77.5

[a] The total counts of crime were rescaled by a factor of 100. Therefore, a one unit increase in each actual crime category in analysis represents 100 additional crimes in the previous two years.

also increased. However, no significant difference was observed by gender. Furthermore, no association was identified with any other category of crime.

Intuitively, an inverse relationship between crime and walking might be expected: that is, as crime increases, walking decreases. Cross-sectional studies have found that perceived crime was associated with reduced odds of walking for transport, even more so than walking for recreation, (Foster et al., 2021) and that higher incidents of objectively measured crime were associated with decreased walking. However, previous literature has also identified positive associations (Mason et al., 2013).

There are several potential explanations for finding a positive association between crime and walking for transport. Firstly, characteristics that shape neighbourhood walkability are also associated with an increased opportunity for crime. Residential density, high street connectivity, mixed land use and proximity to services, advocate for a walkable environment as well as creating opportunities for criminal activity (Foster et al., 2014c) A higher concentration of intersections can increase vulnerability to property crime due to easier accessibility in and out of the neighbourhood (Sohn, 2016). But it is this accessibility that also encourages transport walking by providing residents with shorter, direct routes to train stations, bus stops, shops and services.

Land use diversity (distribution of land for residential, commercial, industrial, leisure/recreation), a characteristic of walkability, is associated with higher crime. Neighbourhoods with high diversity of land uses can increase walking due to destination options but may also encourage criminal activity (Foster et al., 2014c; Gao et al., 2020). In contrast, green space has been shown to reduce the odds of walking for transport, possibly due to lower security, feelings of isolation and lack of natural surveillance (Gao et al., 2020).

It is conceivable that more walking increases the awareness of attributes associated with crime (e.g., graffiti, litter, loitering) and therefore the perception of crime. Residents may perceive crime but may not be deterred due to the presence of others and natural surveillance. The concept of natural surveillance, 'eyes on the street', can provide a sense of safety through physical characteristics, such as lighting and window placement, or through gatherings of people (Sohn, 2016). Easily observable areas can deter crimes such as homicide or assault but conversely higher density neighbourhoods can encourage opportunistic crimes such as burglary and drug offenses (Sohn, 2016). Neighbourhood

Table 3
Fixed effects regression models examining changes level of crime with changes in walking for transport, 2007–2016 among HABITAT study participants, Brisbane, Australia.[b]

Logistic Fixed Effects Regression		Linear Fixed Effects Regression	
	OR (95% CI)		β (95% CI)
Perception of Crime	0.95 (0.89, 1.01)	Perception of Crime	−1.63 (−4.37, 1.11)
Perception of Crime*gender	1.05 (0.92, 1.19)	Perception of Crime*gender	1.46 (−4.09, 7.01)
Likelihood ratio test	p = 0.490	Likelihood ratio test	p = 0.530
Crimes against person	1.42 (1.06, 1.90)	Crimes against person	12.81 (2.76, 22.88)
Crimes against person*gender	−0.03 (−0.54, 0.48)	Crimes against person*gender	1.15 (−14.29, 16.60)
Likelihood ratio test	p = 0.904	Likelihood ratio test	p = 0.859
Unlawful entry	1.06 (0.86, 1.32)	Unlawful entry	5.64 (−3.66, 14.94)
Unlawful entry*gender	1.21 (0.83, 1.77)	Unlawful entry*gender	8.85 (−7.21, 24.91)
Likelihood ratio test	p = 0.307	Likelihood ratio test	p = 0.190
Social incivilities	1.02 (0.97, 1.06)	Social incivilities	1.51 (−0.18, 3.21)
Social incivilities*gender	1.04 (0.96, 1.12)	Social incivilities*gender	0.11 (−2.61, 2.85)
Likelihood ratio test	p = 0.343	Likelihood ratio test	p = 0.919

[b] Coefficients for linear models are interpreted as the difference in transport walking minutes, while logistic models represent the odds of being a transport walker. Perceptions of crime are standard deviation unit increases, while objectively measured crime data have been rescaled to represent an additional 100 crimes in the previous two years.

disadvantage plays a part in walking for transport as well as crime. Residents of more disadvantaged neighbourhoods are more likely to engage in transport walking (Turrell et al., 2013) and are more likely to experience crime (Hale, 1996). Furthermore, vehicle ownership is lower when compared to residents in less disadvantaged neighbourhoods, potentially making transport walking a necessity (Turrell et al., 2013).

It is noteworthy that neighbourhood disadvantage and the walkability were adjusted for in this study. Despite this, crimes against person were positively associated with walking for transport. It is possible that there is residual confounding from built environment measures, neighbourhood disadvantaged and individual socioeconomic position. It is also possible that the entropy based land use mix measure used in this study may not reflect the mix of destinations likely to affect walking for transport (Mavoa et al., 2018). For example, land previously used for industrial purposes may be replaced with retail land, but these changes may not be evident in the land use measure used in this study, itself an entropy measure. While the entropy land use mix measure is in common use in the literature (Cerin et al., 2017), future research should consider alternative approaches (Mavoa et al., 2018; Sugiyama et al., 2019). Last, no time-of-day data was collected. It is likely that walking for transport is largely undertaken during business hours. As previous studies have highlighted, concerns about walking and crime and safety are more prominent after dark (Kim et al., 2007; Bhowmick et al., 2021).

This study also examined if the association between crime and transport walking differed by gender. It was hypothesized that women would be more deterred by crime, however, no differences were identified between genders. Again, this may be a result of the neighbourhood built environment. Previous research has identified that transport walking is more prominent around services such as shops, particularly amongst women (Bird et al., 2010). This suggests that proximity to non-residential services may be sufficient to outweigh the presence of crime.

This study has a number of key strengths. First, there is limited longitudinal research examining the association between walking for transport and crime and the differences in gender, and this study has increased rigor to infer a causal association. Second, the data was obtained from the HABITAT study, a large, multilevel study following participants over nine years. Third, the cohort is from a broad range of socioeconomic neighbourhoods, increasing this study's generalizability. Fourth, limited studies have examined the association of subjectively and objectively measured crime jointly.

However, there are some limitations that need to be considered when interpreting this study's findings. Walking for transport data was self-reported and therefore may prone to recall bias (Althubaiti, 2016). Furthermore, participation in HABITAT decreased over each wave, potentially introducing further bias. The remaining cohort was over-represented by higher socioeconomic groups who may have less exposure to factors that influence perceptions of crime (Turrell et al., 2021). Last, although police-recorded crimes are recorded from official crime-reports, crime that may have occurred, but the offenses withdrawn, were excluded. This may have resulted in underreporting of objectively-measured crime. Crimes committed outside the 1 km network buffer and further afield, particularly serious offenses, may serve to increase residents' concerns about safety and constrain their walking. However, while crimes occurring outside the 1 km network buffer were not included in the objective measure, they could factor into whether participants in the sample felt safe from crime.

There are several priorities for future research. This study used data from residents in Brisbane, Australia. Whilst the crime rate in Brisbane is comparable to other Australian cities such as Melbourne and Sydney (Australian Bureau of Statisticsb) further research may be needed to examine more diverse areas where crime is experienced differently. Future studies may seek to measure transport walking objectively, for example by using accelerometers or GPS, to reduce the risk of bias from self-reporting.

Increasing participation in walking can have significant public health benefits. However, neighbourhood attributes that encourage walking may unintentionally create opportunities for crime. Building on current government policies, efforts should be made to improve neighbourhood walkability while simultaneously discouraging crime and creating a sense of safety. These approaches may include improved lighting along cycling/walking corridors, upgraded pedestrian crossings and infrastructure to move pedestrians and cyclists to off road paths (Queensland Government; Victorian Government). Effective urban planning with well-connected streets, access to services and transportation as well as safety features can increase and maintain participation in walking for transport.

5. Conclusion

Understanding the interaction between crime and walking for transport, in particular populations or locations, can inform policy makers to more effectively promote walking. This study identified a positive association between crimes against person and walking for transport, but no findings for other crime categories. Transport walking is a valuable form of incidental physical activity and can play a critical role in improving population health. Reducing car dependence through the promotion of safe, accessible, and affordable alternative forms of transport is imperative given the rising incidence of chronic illnesses and obesity and to provide a better quality of life. Furthermore, an increase in walking for transport can help to alleviate the associated negative impacts from traffic volume, such as poor air quality and road trauma. There is a need for a balance between encouraging walking through neighbourhood design and examining ways to promote safety.

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Declaration of competing interest

None declared.

Data availability

Data will be made available on request.

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