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Longitudinal associations between bicycling and having dependent children, in middle-aged men and women

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ABSTRACT

Bicycling has multiple health benefits. Child-rearing may influence bicycling, but little is known about the impact of this between men's and women's bicycling, or of number and ages of children on bicycling. This study examined the longitudinal associations between having dependent children and bicycling for transportation and recreation over 4 years among mid-aged men and women. Data were from the HABITAT study (Australia). We analysed data from three survey waves (2007, 2009, 2011) using multilevel logistic regression stratified by gender (n = 7758). Findings indicate that having dependent children was associated with bicycling for transportation and recreation in contrasting ways for men and women. The odds of bicycling were higher in men with ≥2 children aged under 18y than men without children (transportation: OR = 1.93, 95% CI: 1.26, 2.98; recreation: OR = 2.37, 95% CI: 1.67, 3.37). Over time, the odds of recreational bicycling were lower in women with ≥2 children than women without children (OR = 0.83, 95% CI: 0.73, 0.93). However, for both men and women, the odds of recreational bicycling were higher in those with children aged 6–12y than those with younger or older children (men: OR = 1.86, 95% CI: 1.39, 2.49; women: OR = 1.79, 95% CI: 1.31, 2.46). Interventions to promote bicycling must therefore consider gendered differences in bicycling for travel and active leisure, and family circumstances. An opportunity to promote bicycling might be to target parents with children aged 6–12y.

1. Introduction

Bicycling has multiple health and environmental benefits (Götschi et al., 2016; Zahabi et al., 2016). For these reasons, increasing the use of bicycles, especially for transportation, has become a public health and sustainability goal, and cities around the world are increasingly promoting bicycle use (Buehler and Pucher, 2012). However, in countries with overall low levels of bicycling, there is a persistent gender disparity in bicycling for active transportation or leisure. Notably, women bicycle approximately one-third as often as men in low-bicycling countries like Australia, New Zealand, Britain, the US, and Canada (Heesch et al., 2012; Garrard et al., 2012; LeVine et al., 2014). In countries with high levels of bicycling, there is no gender disparity (Fishman et al., 2015; van der Kloof and Cox, 2015). It is important to understand factors contributing to differences in men's and women's bicycling.

The complexity of factors associated with bicycling can be understood within an ecological model of physical activity (Bauman et al., 2012). This model suggests multiple levels of influence, which include individual, interpersonal, environmental (physical and social), policy, and global factors. Consistent with this approach, a review of influences on bicycling for transportation showed it to be associated with: individual-level factors such as demographic characteristics (e.g., gender) and perceptions (e.g., comfort with bicycling); interpersonal factors (e.g., social support); and aspects of the social, built, and natural environments, including social norms, infrastructure, and hilliness, respectively (Muñoz et al., 2016).

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Focusing on the interpersonal level of the ecological model, studies have suggested that men's and women's differential involvement in child-rearing shapes their active transportation and active leisure. However, few studies have examined the intersection of gender, child-rearing, and parent bicycling (we use "parent" to include guardians and non-traditional child-rearing roles). Child-rearing can contribute to women's greater safety concerns (a well-cited barrier to women's bicycling in places with low-quality bicycling infrastructure) and their complex travel patterns, which are hypothesized to underpin gender disparities in bicycling (Ravensbergen et al., 2019). Gender differences in travel patterns are largest when there are children in the household, and reflect the traditional gender division of labour where women spend more time engaged in household-serving travel, typically characterized by carrying goods, carrying passengers, and having multiple destinations (Taylor et al., 2015; Yavorsky et al., 2015). Having children tends to reduce active travel for both men and women (Menai et al., 2015; Chakrabarti and Joh, 2019). However, only one study has examined bicycling separately from walking, with results showing that mothers reduce bicycling more so than fathers (Scheiner, 2014).

Child-rearing is also associated with changes in physically active leisure (Popham, 2006; Pot and Keizer, 2016; Rhodes and Quinlan, 2015; Bellows-Riecken and Rhodes, 2008). Much of the literature in this area focuses on the transition to parenthood and suggests that having children is associated with greater reductions in active leisure in women than men. Fathers tend to reduce their active leisure only when children are very young, whereas mothers reduce active leisure over much longer time periods (Popham, 2006; Rhodes and Quinlan, 2015). One reason for reduced active leisure is that child-rearing can contribute to time constraints (Popham, 2006; Pot and Keizer, 2016; Miller and Brown, 2005). Mid-aged adults are likely to have multiple time demands due to childcare, workforce participation, and possibly care of other family members. However, as children become older and more independent, parents may have more time available for active leisure, including bicycling.

Few studies have examined the effect of dependent children on men's and women's bicycling. Cross-sectional evidence suggests that children are a greater constraint on women's bicycling than men's (Heesch et al., 2012; LeVine et al., 2014; Grudgings et al., 2018; Shaw et al., 2020), but little research has also considered children's age. The relationship between child-rearing and bicycling may also differ by bicycling purpose (i.e., transportation or recreational bicycling). Differentiating bicycling purpose is important because correlates of bicycling differ by trip purpose (Menai et al., 2015; Heesch et al., 2014; Nehme et al., 2016). As many cities have active transportation goals, there is growing interest in examining correlates of transportation bicycling separate from bicycling for other purposes. The gender disparity may be greater for transportation bicycling than for recreational bicycling (Goodman and Aldred, 2018). More longitudinal research is needed therefore to understand gender differences in the relationships between having dependent children and bicycling, and to determine whether bicycling changes over time as children age, for both transportation and recreational bicycling.

This study examined associations between having dependent children aged under 18 years in the household with each of bicycling for transportation and bicycling for recreation among mid-aged men and women over a four year period. Within this aim were three research questions: 1) what is the association between the number of dependent children aged under 18 years in the household and bicycling, 2) what is the association between the ages of children in the household and parent bicycling, and 3) do these associations change over time?

2. Methods

2.1. Context and setting

Our data come from the longitudinal HABITAT study, a large population study which aimed to understand physical activity among mid-age adults living in Brisbane, Australia (Turrell et al., 2010). HABITAT used a socio-ecological framework to consider individual, social, and environmental influences on physical activity. Previous analyses from this study have shown that individual-level factors (household income and psychological attributes) were associated with bicycling for any purpose (Heesch et al., 2014). Perceived (safety, accessibility) and observed (distances, cycleway length) environmental factors, as well as social factors (neighbourhood disadvantage), were associated with transportation bicycling (Heesch et al., 2015). Previous analyses of HABITAT data furthermore showed that 18% of the sample were recreational bicyclists in 2007; 4% were transportation bicyclists; and almost all transportation bicyclists were also recreational bicyclists (Heesch et al., 2014). This is consistent with other Australian work showing that most bicycling is for recreation, and most adults who bicycle for transportation ride relatively long distances to work for the expressed aim of fitness training (Heesch et al., 2012; Garrard et al., 2021).

Brisbane is a subtropical city characterized by a relatively dense urban core surrounded by low-density car-oriented suburban development. Brisbane City Council and the Queensland State Government have heavily invested in bicycling promotion and infrastructure since 2006, with a focus on expanding an active school travel program as well as the region's principal routes (routes from suburbs into cities) (State of Queensland (Department of Transport and Main Roads), 2011; Brisbane City Council, 2012). However, the Brisbane bicycle network is not entirely connected, and off the principal routes much of it entails sharing roads with cars (Chataway et al., 2014; Osborne and Grant-Smith, 2017). Bicycling for any purpose in Brisbane has declined in recent years, from 26.3% in 2011 to 23.0% in 2019, which reflects an Australian-wide trend (Munro, 2019).

2.2. Sample design and data collection

We used HABITAT data from the first, second, and third waves (2007, 2009, 2011) because the survey item used to measure recreational bicycling was discontinued after the third wave, and participants were more likely to have young children in 2007–2011 than at later stages of the study. HABITAT's sampling design has been described elsewhere (Burton et al., 2009). In short, the investigators used a 2-stage probability sampling strategy to select a stratified random sample (n = 200) of Brisbane neighbourhoods across the range of area-level disadvantage, and from within each neighbourhood, a random sample of people aged 40–65 years. People (n = 17,000) were mailed a self-report questionnaire in 2007, and 11,035 valid questionnaires were returned (response rate 68.3%). Participants completed follow up questionnaires in 2009 (n = 7866) and 2011 (n = 6900). HABITAT received ethical clearance from the Queensland University of Technology Human Research Ethics Committee (Ref. No. 3967H & 1300000161).

2.3. Variables

2.3.1. Outcome variable: bicycling

Participants reported total time spent bicycling for transportation in the previous week. For analysis, we dichotomized responses into weekly bicycling or not bicycling (>0 min or 0 min) as previously done (Heesch et al., 2014). Participants also reported (from a list of recreational activities) frequency of bicycling in the past 12 months using a set of six response options. For analysis, we collapsed these into monthly bicycling ("more than once a week", "once a week", "once every 2 weeks", "once a month") or not-monthly bicycling ("once every 6 months", or "never").

2.3.2. Independent variables: dependent children in the household

The primary independent variable was the number of dependent children aged <18 years in the participant's care, at each wave, which

we categorised as 0, 1, and 2+ children. Participants with children in their care reported the ages of the children from a set of four response options (0–12 months, 1–5y, 6–12y, and 13–17y), which we collapsed to 0–5, 6–12, and 13–17 years.

2.3.3. Covariates

We used previous research to hypothesize potential confounders (LeVine et al., 2014; Heesch et al., 2014; Singleton and Goddard, 2016). We then conducted exploratory analyses to examine the association between bicycling and each potential confounder in separate models adjusted for age and gender. We retained factors that were associated with either transportation or recreational bicycling ($p < 0.05$) as covariates in full models. These included: socioeconomic status, operationalized as education (highest qualification reported at Wave 1–10 categories collapsed into 3), employment status (10 categories collapsed into 3), and total pre-tax annual household income (13 categories collapsed into 5); living arrangements (6 categories collapsed into 4), and neighbourhood disadvantage. For neighbourhood disadvantage, the investigators used the Index of Relative Socioeconomic Disadvantage (IRSD), developed by the Australian Bureau of Statistics, for each of the 200 neighbourhoods (Burton et al., 2009). The IRSD is derived from 17 socioeconomic variables including education, occupation, income, unemployment, and household tenure. We grouped the 200 neighbourhoods into quintiles based on their IRSD: Q5 comprised the 20% most disadvantaged neighbourhoods and Q1 the 20% least disadvantaged neighbourhoods, relative to the whole of Brisbane. We treated three covariates as unchanging over time: age (centred at Wave 1), gender (reported at Wave 1), and education.

2.4. Data analysis

We used descriptive statistics to present demographic characteristics of the sample at Wave 1 and conducted a series of random-effects models to examine the association between having children and bicycling, separately for transportation and recreational bicycling. We stratified all models by gender, treated time as continuous (0, 2, 4), and fitted 3-level logistic models (observations nested in participants, and participants nested in neighbourhoods). To determine the association between number of dependent children and bicycling (research question 1), we computed 'base' models that included the number of children after controlling for age and time, and then computed 'full' models adjusting for all covariates. To determine the associations between ages of children and bicycling (research question 2), we repeated these models in subgroup analyses where the primary independent variable was ages of children and the analysis sample was limited to participants with at least one dependent child. To assess change over time (research question 3), we added an interaction term (time and children) to each full model. Data were analysed in Stata 15.1 (Stata Statistical Software, 2018) and figures were produced using R studio 1.1.447.

3. Results

3.1. Analytic sample

Of the 11,035 participants who returned a valid survey in 2007, we excluded those who did not complete the Wave 2 and Wave 3 surveys; were determined as different household members from those who completed the Wave 1 survey; moved from Brisbane after Wave 1; reported that they were restricted from doing physical activity "all the time", at all waves; did not provide required data for analysis (i.e., missing data on bicycling, children, or covariates). After exclusions, the analytic sample comprised 3338 men and 4420 women (Fig. 1). Of these, 2548 men and 3443 women returned surveys at all three waves.

There were few meaningful differences between participants included in the analytic sample and those excluded. Compared with participants who were excluded, a higher percentage of those included in the analytic sample were living with a partner. Among men, those included were older. Among women, those included had more years of education (Appendix A, supplementary material).

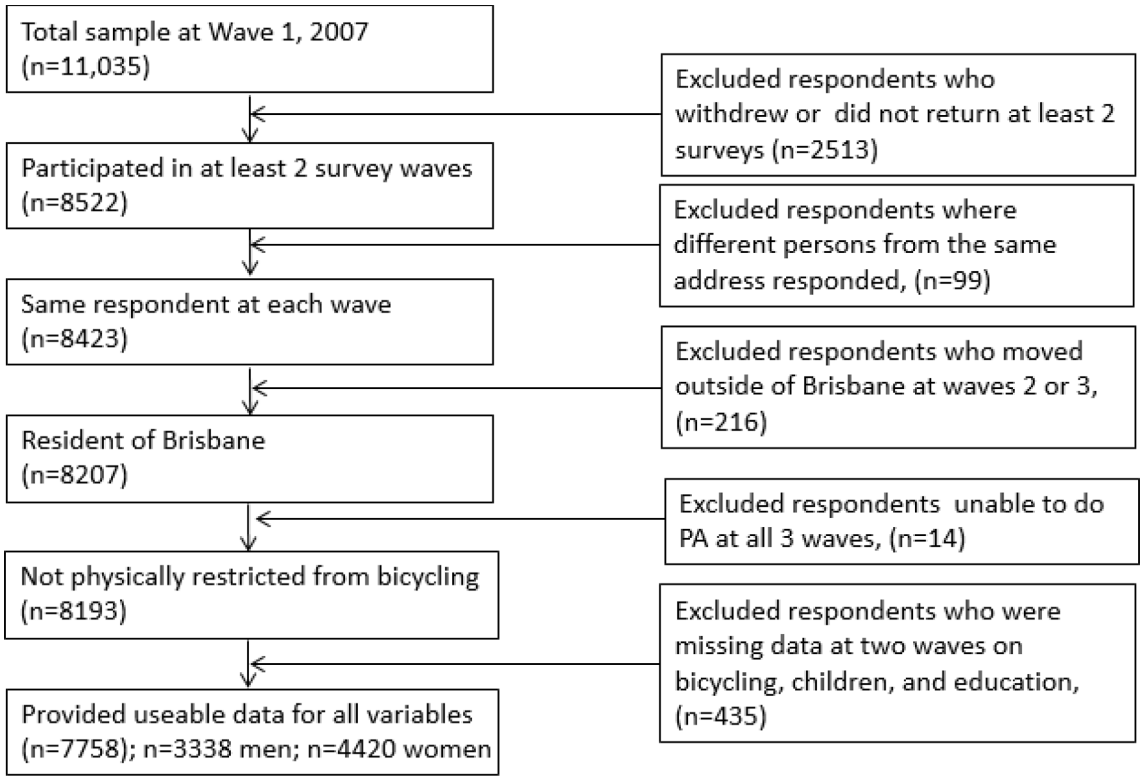

Fig. 1. Derivation of analytic sample for longitudinal analyses.

3.2. Sample characteristics, bicycling participation, and changes over time

As shown in Table 1, at baseline the percentage of men who bicycled for any purpose (29%) was greater than the percentage of women who bicycled (17%). Among men and women, bicyclists tended to be younger, university-educated, working full-time, and living with a partner. They also tended to have higher household incomes and live in advantaged neighbourhoods.

As shown in Table 2, a greater proportion of men than women participated in bicycling at each wave and at all waves. Change over time was assessed with lasagna plots (Appendix B, supplementary material) (Jones et al., 2014). For transportation, 10% of men and 3% of women stopped or started bicycling over the three waves, and 88% of men and 96% of women reported no transportation bicycling at any wave. For recreation, there was greater change: 30% of men and 22% of women stopped or started bicycling over the waves, whereas 59% of men and 74% of women reported no recreational bicycling at any wave.

3.3. Children and transportation bicycling

In base and full models, the odds of transportation bicycling were higher for men with two or more dependent children than for men without dependent children (Table 3). No association between dependent children and transportation bicycling was found for women. The age of dependent children was not associated with transportation bicycling for either men or women (Table 4). The odds of transportation bicycling did not change for men or women over time, nor were there any significant interactions between time and children in any models.

3.4. Children and recreational bicycling

In base and full models, the odds of recreational bicycling were higher in men with two or more dependent children than in men without dependent children (Table 3). Number of dependent children was not associated with women's recreational bicycling. For both men and women, the odds of recreational bicycling decreased over time. There was a significant interaction between time and children for women only: women with 2+ children were less likely to bicycle over time than women with no children. Among parents—both men and women—the odds of recreational bicycling were higher for those with children aged 6–12 years than those with younger or older children (Table 4). The odds of recreational bicycling were lower for men with children aged 13–17 years than men with younger children. No interactions between time and age of children were significant, indicating the relationship between recreational bicycling and ages of children did not vary over time.

4. Discussion

This paper examined longitudinal relationships between having dependent children in the household and bicycling in a low-bicycling country. The main finding was that men, but not women, with

Table 1
Demographic characteristics of the analytic sample (n = 7758) at baseline (2007) for men and women.

Characteristics	Men			Women		
	No bicycling[a]	Transportation	Recreation	No bicycling[a]	Transportation	Recreation
	n = 2345	n = 225	n = 940	n = 3626	n = 78	n = 722
Overall[b]	71.0%	6.7%	28.2%	83.0%	1.8%	16.3%
Age (years)[c]						
40–44	20.3%	38.7%	36.1%	17.1%	30.8%	32.0%
45–49	21.1%	21.3%	24.1%	20.5%	30.8%	24.5%
50–54	20.0%	23.6%	19.1%	21.4%	15.4%	18.7%
55–59	20.8%	8.0%	11.8%	21.2%	15.4%	14.8%
60–65	17.9%	8.4%	8.8%	19.9%	7.7%	10.0%
Education (highest level attained)						
Bachelor degree or higher	31.4%	52.0%	43.6%	29.3%	51.3%	42.2%
Diploma/certificate	34.3%	28.4%	31.9%	25.0%	25.6%	28.9%
School[d]	34.3%	19.6%	24.5%	45.7%	23.1%	28.8%
Employment status						
Full time	71.2%	72.4%	79.0%	36.7%	42.3%	42.4%
Part time	11.0%	12.4%	10.3%	32.0%	41.0%	35.6%
Not in paid work[e]	17.8%	15.1%	10.6%	31.2%	16.7%	22.0%
Household income ($AUD)						
130,000 per annum or more	18.4%	30.7%	28.2%	13.8%	17.9%	21.7%
72,800–129,999	29.4%	31.1%	31.4%	24.0%	28.2%	28.0%
41,600–72,799	23.5%	18.7%	20.9%	23.4%	23.1%	19.5%
0–41,599	17.9%	13.3%	11.8%	23.4%	17.9%	15.9%
Missing/Don't know/refuse[f]	10.8%	6.2%	7.8%	15.4%	12.8%	14.8%
Living arrangements						
Couple	71.8%	72.0%	76.0%	69.2%	75.6%	75.8%
Single living with children or with others	12.2%	13.8%	11.6%	15.8%	15.4%	13.3%
Single living alone	16.0%	14.2%	11.9%	14.7%	9.0%	10.0%
Other/Missing[f]	0.0%	0.0%	0.5%	0.4%	0.0%	1.0%
Neighbourhood disadvantage quartile						
Q1 (most disadvantaged)	12.5%	11.1%	10.2%	14.0%	11.5%	10.4%
Q2	19.3%	18.7%	17.2%	19.4%	19.2%	17.2%
Q3	20.0%	16.4%	19.0%	17.5%	17.9%	19.3%
Q4	19.3%	20.0%	18.3%	19.6%	9.0%	18.1%
Q5 (least disadvantaged)	29.0%	33.8%	35.2%	29.5%	42.3%	35.0%

[a] No bicycling was defined as no weekly transportation or monthly recreational bicycling.
[b] 84 participants (33 men and 51 women) did not respond to the bicycling item at baseline.
[c] Categorical age data are provided for descriptive purposes but a continuous measure was used in the analyses.
[d] School was defined as no post-secondary school qualification.
[e] Not in paid work included home duties, retired, unable to work, and unemployed.
[f] A missing category was included in all modelling for these variables.

Table 2
Bicycling participation (transportation, recreation) and household composition (number and ages of children) of men and women in the analytic sample, 2007–2011 (Waves 1–3).

	Men						Women					
	2007		2009		2011		2007		2009		2011	
	n	%	n	%	n	%	n	%	n	%	n	%
Overall[a]	3338		3126		2760		4420		4189		3674	
Transportation bicycling[b]												
Not bicycling	3108	93.1	2878	92.1	2562	92.1	4332	98.0	4050	96.7	3599	98.0
Bicycling	225	6.7	198	6.3	189	6.3	78	1.8	79	1.9	63	1.7
Recreation bicycling[b]												
Not bicycling	2367	70.9	2145	68.6	2048	74.2	3654	82.7	3439	82.1	3164	86.1
Bicycling	940	28.2	901	28.8	671	24.3	722	16.3	632	15.1	447	12.2
Number of children < 18 years[b]												
None	2072	62.1	2043	65.4	1574	57.0	2952	66.8	2994	71.5	2167	59.0
One	434	13.0	389	12.4	302	10.9	608	13.8	535	12.8	412	11.2
Two+	816	24.4	648	20.7	499	18.1	828	18.7	600	14.3	442	12.0
Children 0–5 years[c]												
None	864	69.1	778	75.0	626	78.2	1191	83.0	977	86.1	746	87.4
One or more	386	30.9	259	25.0	175	21.8	245	17.0	158	13.9	108	12.6
Children 6–12 years[c]												
None	605	48.4	520	50.1	389	48.6	692	48.2	609	53.7	487	57.0
One or more	645	51.6	517	49.9	412	51.4	744	51.8	526	46.3	367	43.0
Children 13–17 years[c]												
None	585	46.8	436	42.0	327	40.9	527	36.7	377	33.2	252	29.5
One or more	665	53.2	601	58.0	474	59.2	909	63.3	758	66.8	602	70.5

[a] Overall represents the number of participants who participated in the wave.
[b] Not all participants responded to this item at all waves. Percentage of missing data for bicycling varied between 0 and 3%. For number of children, percentage of missing data varied between 0 and 1% in 2007 and 2009, increasing to 14 and 18% in 2011.
[c] Variables representing children's ages were created only for participants who reported one or more children aged under 18 years at home.

Table 3
Association between number of children and participation in bicycling for transportation or recreation, separately for men and women, 2007–2011.

	Men						Women					
	Base[a]		Full[b]		Full, interaction		Base[a]		Full[b]		Full, interaction	
	OR	95%CI	OR	95%CI	OR	95%CI	OR	95%CI	OR	95%CI	OR	95%CI
Transportation bicycling												
Time	1.01	0.94,1.09	1.03	0.95,1.11	1.01	0.91,1.11	1.01	0.90,1.12	1.01	0.90,1.13	1.04	0.90,1.21
Number of children < 18 years												
None (REF)	1.00		1.00		1.00		1.00		1.00		1.00	
One	1.36	0.81,2.27	1.46	0.85,2.49	1.23	0.66,2.29	1.17	0.58,2.32	1.14	0.56,2.34	1.16	0.50,2.74
Two+	**1.84**	**1.19,2.84**	**1.93**	**1.26,2.98**	**1.91**	**1.18,3.07**	0.82	0.40,1.67	0.75	0.37,1.54	0.91	0.40,2.09
Interactions (time × number of children)												
Time × None (REF)					1.00						1.00	
Time × One					1.10	0.88,1.37					0.99	0.76,1.30
Time × Two+					1.02	0.87,1.20					0.88	0.68,1.14
Recreation bicycling												
Time	**0.93**	**0.89,0.98**	**0.93**	**0.89,0.93**	**0.92**	**0.87,0.97**	**0.86**	**0.82,0.90**	**0.85**	**0.81,0.89**	**0.89**	**0.83,0.95**
Number of children < 18 years												
None (REF)	1.00		1.00		1.00		1.00		1.00		1.00	
One	1.24	0.92,1.68	1.19	0.87,1.63	1.15	0.76,1.74	0.82	0.63,1.06	0.78	0.60,1.00	0.80	0.58,1.12
Two+	**2.60**	**1.88,3.60**	**2.37**	**1.67,3.37**	**2.22**	**1.46,3.37**	0.98	0.74,1.28	0.83	0.62,1.10	1.08	0.79,1.49
Interactions (time × number of children)												
Time × none (REF)					1.00						1.00	
Time × One					1.02	0.88,1.19					0.99	0.87,1.12
Time × Two+					1.05	0.94,1.16					**0.83**	**0.73,0.93**

[a] Base models adjusted for time and age.
[b] Full models adjusted for time, age, education, employment status, income, living arrangements, and neighbourhood disadvantage.

dependent children were more likely to bicycle for transportation and recreation than their counterparts without dependent children, and for men, this association did not change over time. Moreover, men and women with children aged 6–12 years were more likely to bicycle for recreation than parents with younger or older children.

4.1. Transportation bicycling

The evidence from previous research on the relationship between having children and transportation bicycling is mixed, with some cross-sectional studies finding a positive association for bicycling for transportation (Goodman and Aldred, 2018; Singleton and Goddard, 2016), and others finding the reverse (Grudgings et al., 2018; Brainard et al., 2019). We add to the literature by providing longitudinal evidence that men with two or more dependent children were more likely to bicycle for transportation than men without children. Given the sparse literature examining the impact of children on fathers' bicycling, this is a promising area for further investigation. Men with children perhaps have increased riding opportunities, such as accompanying children to school by bicycle (Janke and Handy, 2019). Working men with two or more

Table 4
Association between ages of children (0–5, 6–12, and 13–17 years) and participation in bicycling (transportation, recreation), separately for men and women with children aged under 18 years at home, 2007–2011.

	Men						Women					
	Base[a]		Full[b]		Full, interaction		Base[a]		Full[b]		Full, interaction	
	OR	95%CI	OR	95%CI	OR	95%CI	OR	95%CI	OR	95%CI	OR	95%CI
Transportation bicycling												
Time	1.02	0.90,1.16	1.03	0.91,1.16	0.95	0.65,1.40	1.02	0.87,1.19	1.04	0.89,1.21	1.4	0.77,2.54
Children aged 0–5 years[c]												
One or more	1.15	0.67,1.95	1.17	0.68,2.01	1.42	0.64,3.16	1.53	0.58,4.02	1.47	0.55,3.94	1.77	0.55,5.66
Children aged 6–12 years[d]												
One or more	1.27	0.72,2.22	1.2	0.68,2.13	1.13	0.49,2.59	1.66	0.84,3.30	1.58	0.80,3.12	2.57	0.97,6.80
Children aged 13–17 years[e]												
One or more	1.67	0.95,2.92	1.62	0.91,2.89	1.3	0.57,2.98	1.01	0.45,2.28	1.08	0.47,2.47	1.40	0.46,4.24
Interactions (time × age of children)												
Time × 0–5 years[f]					0.87	0.62,1.21					0.85	0.51,1.42
Time × 6–12 years[g]					1.1	0.81,1.48					0.74	0.46,1.2
Time × 13–17 years[h]					1.12	0.81,1.56					0.84	0.49,1.42
Recreation bicycling												
Time	0.95	0.88,1.03	0.97	0.90,1.04	1.10	0.87,1.39	**0.85**	**0.80,0.90**	**0.83**	**0.78,0.89**	1.04	0.84,1.29
Children aged 0–5 years[c]												
One or more	0.68	0.44,1.04	0.73	0.47,1.11	0.87	0.49,1.56	0.91	0.61,1.36	0.97	0.64,1.47	1.12	0.67,1.87
Children aged 6–12 years[d]												
One or more	**1.89**	**1.42,2.52**	**1.86**	**1.39,2.49**	**2.01**	**1.31,3.07**	**1.83**	**1.33,2.51**	**1.79**	**1.31,2.46**	**2.30**	**1.45,3.63**
Children aged 13–17 years[e]												
One or more	**0.60**	**0.43,0.83**	**0.61**	**0.43,0.85**	0.76	0.44,1.30	0.81	0.58,1.12	0.84	0.61,1.17	1.10	0.72,1.66
Interactions (time × age of children)												
Time × 0–5 years[f]					0.90	0.72,1.13					0.9	0.71,1.13
Time × 6–12 years[g]					0.95	0.80,1.13					0.84	0.70,1.02
Time × 13–17 years[f]					0.88	0.70,1.09					0.84	0.69,1.02

[a] Base models adjusted for time and age.
[b] Full models adjusted for time, age, education, employment status, income, living arrangements, and neighbourhood disadvantage.
[c] Reference is no children aged 0–5 years.
[d] Reference is no children aged 6–12 years.
[e] Reference is no children aged 13–17 years.
[f] Reference is no children aged 0–5 years at baseline.
[g] Reference is no children aged 6–12 years at baseline.
[h] Reference is no children aged 13–17 years at baseline.

children may use transportation bicycling as a means to accrue moderate or vigorous-intensity physical activity in response to having less discretionary time for exercise on workdays (Hamilton and White, 2010).

In our study, proportionately fewer women than men with dependent children rode a bicycle for transportation. This was expected, as studies from low-bicycling countries consistently report a gender disparity (Goel et al., 2021). Findings from a US study also suggest that among women, having children is negatively associated with walking and bicycling to work (Bopp et al., 2014). This may be due to reduced convenience pertaining to the need to conduct additional errands, which may also involve travel with children, before and after work. Studies from Britain and New Zealand also indicate that women with children are less likely to bicycle for transportation than women without (Grudgings et al., 2018; Shaw et al., 2020). However, in our study, among women we found no association between having dependent children and transportation bicycling. One possible reason could be that women who ride for transportation in a challenging environment like Brisbane (which is hilly, low-density, and car-oriented) are more experienced, confident, and committed bicyclists, and thus have found ways to ride regardless of whether or not they have children.

4.2. Recreational bicycling

Our findings advance current knowledge of the association between having dependent children and participation in recreational bicycling. Our study showed that having two or more dependent children is associated with increased likelihood of men bicycling for recreation at least monthly, and little impact on women's recreational bicycling. This reflects the broader literature on parenting and physical activity. A review on fathering and active leisure suggests that fathers want to set an example as role models or to engage in activities with their children (Pot and Keizer, 2016). In contrast, women with children are less likely to engage in leisure-time physical activity than women without children, possibly due to increased household chores coupled with time and childcare constraints (Popham, 2006; Bellows-Riecken and Rhodes, 2008). This gender difference in men's and women's recreational bicycling may also reflect women's concerns about motor traffic and lack of safe cycling routes (Heesch et al., 2012; Le et al., 2019). It is certainly likely that riding with children changes bicycling behaviour: whereas children provide social opportunities for women's bicycling (mothers value children learning to bicycle as an important life skill), traffic-safety concerns limit bicycling with children to low-traffic, primarily recreation spaces (e.g., parks) (Bonham and Wilson, 2012; Sersli et al., 2020). Gender differences in bicycling for recreation may also reflect motivations, with some studies suggesting that bicycling could provide an opportunity to engage in a shared family activity or, conversely, to escape the demands of parenting (Bonham and Wilson, 2012; Sherwin et al., 2014).

In the current study men and women with children aged 6–12 years were more likely to ride a bicycle for recreation than those with older or younger children. This supports the findings of previous cross-sectional studies (Menai et al., 2015; Goodman and Aldred, 2018). Explanations for why having children aged 6–12 years prompts bicycling among parents include that this is (1) the age range to teach children to ride a bicycle (Sherwin et al., 2014), and (2) children start to ride their own bicycles at these ages, and require supervision to keep them safe from car traffic (Schwanen, 2011; Eyer and Ferreira, 2015). Parents of

children in this age group may therefore be receptive to interventions that encourage bicycling. Children may facilitate leisure-time physical activity among mid-aged parents generally (Rattay and von der Lippe, 2020); recreational bicycling may be well-suited for family-oriented leisure-time physical activity.

4.3. Implications for research and practice

The implications of our results are threefold. First, as mid-aged men with dependent children were more likely to bicycle than men without, future research should examine relationships between fatherhood and bicycling, and the reasons why men with children choose to ride or not.

Second, in low-cycling contexts such as Brisbane, fewer women than men bicycle for transportation, regardless of whether or not they have children. Attracting women to bicycling will likely require high quality infrastructure, as evidence from Australia and elsewhere shows that women prefer bicycling when separated from traffic (Heesch et al., 2012; Le et al., 2019; Aldred et al., 2016). Improving safe access to destinations within neighbourhoods to support a greater diversity of trip purposes, including to shops, schools, and parks, may encourage more women to bicycle (Shaw et al., 2020; Sersli et al., 2020; Bourke et al., 2019; Heesch et al., 2016). Planners have tools to enable travel by bicycle quicker, easier, and as comfortable as travel by car (Winters et al., 2017), and these tools are used by cities with high bicycling modal share such as Amsterdam (Pucher and Buehler, 2008), where the accessibility of shops and schools by bicycle supports high bicycling levels among women before and after they have children (van der Kloof and Cox, 2015; Eyer and Ferreira, 2015). Wider availability of cargo, longtail, and electric-assist bicycles may also help people to manage the physical demands of carrying children or goods, as well as the challenges of longer distances and hills (Riggs and Schwartz, 2018; Bjørnarå et al., 2020; Dowling, 2020).

Broader measures will be needed to address the social processes and institutional structures that contribute to gendered inequalities in daily mobility that are reflected in bicycling (Shaw et al., 2020; Sersli et al., 2020; Craig and van Tienoven, 2019). For example, policies enabling greater temporal flexibility in work, onsite daycare, or initiatives to share responsibility for children's travel would ease the temporal demands of combining childcare and paid work (Thorhauge et al., 2020). These policies would support women, single parents, and families more generally. Changing physical and social environments to better accommodate prospective riders who do not see themselves reflected within dominant bicycling culture (i.e., "male, fast, and Lycra-clad") (Garrard et al., 2021: p210; Fuller et al., 2021) may also help to increase bicycling participation in both women and men.

Third, the finding that parents of children aged 6–12 years are more likely to bicycle for recreation, suggests that health promotion practitioners could consider interventions to encourage and sustain this interest. At the built environmental level, it is well-established that high quality infrastructure away from motorized traffic is vital when bicycling with children; therefore, expanding bicycle routes where parents and children aged 6–12 years feel safe riding is essential for participation (Goodman and Aldred, 2018; Janke and Handy, 2019; Sersli et al., 2020; Clayton and Musselwhite, 2013). This could be augmented at the individual level with bicycle skill training for parents and children (Sersli et al., 2020). At the community level, parental bicycling might also be sustained by policies making bicycling attractive and convenient for a wider variety of purposes, such as bicycling with children to extracurricular activities (Janke and Handy, 2019; Sersli et al., 2020). Further research should examine the constraints and facilitators of bicycling specific to men and women with children of different ages.

5. Strengths and limitations

This is the first study to examine the association between dependent children and bicycling, separately for transportation and recreational bicycling and for men and women. A major strength of this study was the use of a large, longitudinal dataset. Our results indicate that previous findings of no association between dependent children and bicycling could have been due to the use of models in which men's and women's data were pooled. One limitation is that there was no measurement of co-bicycling, so we do not know whether parents bicycled alone or with children. As the study was limited to mid-age adults only, we cannot generalize to younger parents. There was attrition across the waves, although we found few meaningful differences between those included and those lost-to-follow-up. A different recall period was used for assessment of transportation and recreational bicycling; thus, data may not be comparable across type of bicycling, or frequency of participation (e.g., weekly recreational bicycling). The data are from 2007 to 2011, but given minimal change in bicycling prevalence and gender patterns, the findings are still relevant to guide future work. Our findings may not be generalizable to other contexts where there are not gender disparities in bicycling, or where urban environments are designed to facilitate bicycling for all ages and all trip types, including household-serving trips.

6. Conclusion

In this study, having two or more dependent children was positively associated with both transportation and recreational bicycling in men, but not in women. Recreational bicycling was more common in both men and women with children aged 6–12 years than in those with younger or older children. Interventions to promote bicycling should therefore consider gender differences in travel and active leisure patterns and the barriers to bicycling faced by parents with dependent children. Policy-makers might consider developing social and physical environments and programs that support parents with children in this age range to take up and continue bicycling.

7. Contributors

GT, NB, and WB established the HABITAT study and collected the data. SS and KH conceptualized the analysis. SS conducted the analysis and drafted the manuscript. All authors participated in the interpretation of the data and revisions to the manuscript. All authors read and approved the final manuscript.

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CRediT authorship contribution statement

Stephanie Sersli: Conceptualization, Formal analysis, Writing – original draft preparation, Writing – review & editing, Funding acquisition. **Gavin Turrell:** Investigation, Writing – review & editing. **Nicola W. Burton:** Investigation, Writing – review & editing. **Wendy J. Brown:** Investigation, Writing – review & editing. **Kristiann C. Heesch:** Conceptualization, Writing – review & editing, Supervision.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.pmedr.2021.101479.

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