Abstract

Background: In most countries women cycle less than men. This is despite the clear environmental and health benefits of active commuting. Feminist critiques suggest this gender gap reflects societal roles and values, yet there has been little empirical research on the differences in men's and women's cycling in the context of total travel.

Methods: Regression analyses were used to explore the travel mode and distance travelled of 49,965 participants in the nationally representative, continuous, cross-sectional New Zealand Household Travel Survey (2002 to 2014). Regular cyclists were people who cycled at least 10 days in the preceding month. We reported results by gender and cyclist status.

Results: Car was the dominant mode of travel for all groups. While fewer women regularly cycled (2%) compared to men (5%), women travelled less each day (12-17% less distance) and were more likely to use public transport and walk than men. These gender patterns were broadly replicated in people who were regular cyclists. Women made 17-47% more motorised trips of less than 5km than men each day. Overall half of regular cyclists achieved 600 METS or above per week through travel related physical activity, compared to 11-15% of non-regular cyclists. Even after full model adjustment men had more than twice the odds (OR 2.58 (95%CI:2.29 - 2.92)) of cycling compared to women.

Conclusions: Men are more likely to cycle than women in NZ and cyclists get more physical activity. Nonetheless, analysis across all travel (irrespective of regularity of cycling status) suggests that women use more diverse travel modes and generate lower greenhouse gas emissions than men. Better consideration of the social processes shaping travel is needed to create policy, institutions, programmes and infrastructure that achieve the long term goals of the transport system, such as increasing cycling and reducing greenhouse gas emissions.

1. Introduction

There are a myriad of health, environmental and city liveability reasons to increase cycling for urban transport (Giles-Corti et al., 2016; Stevenson et al., 2016; Watts et al., 2017). Globally, many cities are investing in infrastructure, programmes and policies to increase cycling, with modest levels of success in some cases (Crane et al., 2017; Dill et al., 2014; Goodman et al., 2014; Heinen et al., 2015; Keall et al., 2015). In jurisdictions with a low overall prevalence of cycling, including New Zealand, one of the universal findings is a disproportionately low number of women cycling, with usually only 20-30% of cyclists being female (Garrard et al., 2012; Shaw et al., 2016). Low levels of cycling amongst women are not inevitable: in countries with higher levels of cycling, such as the Netherlands, women comprise about half of cyclists (Garrard et al., 2012; Pucher and Buehler, 2008). However in these low prevalence locations, pro-cycling policies, infrastructure and programmes appear to have had limited success to date in increasing the proportion of women cyclists (Aldred et al., 2016; Goodman and Cheshire, 2014; Ogilvie and Goodman, 2012; Pucher et al., 2011).

One body of research examining these variations in cycling focuses on how gender differences in factors such as risk perception, infrastructure preferences, cultural identities and trip purpose impact on the desire and ability of women to cycle (Aldred et al., 2017; Garrard et al., 2012; Heesch et al., 2012; Ravensbergen et al., 2019; Steinbach et al., 2011; Sullivan and O'Fallon, 2006). For example systematic reviews show that, compared to men, women report greater safety concerns related to cycling and stronger preferences for separated cycle infrastructure (Aldred et al., 2017; Ravensbergen et al., 2019). This approach tends to focus on cycling and cyclists, in particular underrepresented cyclists, and quantitatively or qualitatively examine the factors that impact on cycling (or lack thereof). One criticism of this approach is that it doesn't offer an obvious rationale for why many of these factors do not affect women in high cycling prevalence jurisdictions, not what the reasons underpinning the female/male differences are (Garrard et al., 2012; Ravensbergen et al., 2019).

Feminist explanations suggest a slightly different perspective with which to view gender differences in cycling (Connell, 2012; Heise et al., 2019). Law argued that gender is integral to understanding the social relations and structures that influence daily mobility through gendered patterns of activity and differential access to time, money and resources. These forces ultimately produce a range of observable variations in gender-related travel perceptions, experiences and behaviour (Law, 1999). In support of this hypothesis a range of gender differences in overall travel (not just cycling) have

been reported in a number of countries, for example women take fewer trips, travel less distances and for a shorter time as well as having different reasons for trips and use of travel modes (Hanson, 2010; Kronsell et al., 2016; Lee et al., 2018; Miralles-Guasch et al., 2016; Taylor et al., 2015).

In light of these different perspectives, in this analysis we sought to understand differences in cycling by gender in New Zealand in the context of wider differences in mobility by gender. Specifically, we aimed to answer the questions:

- How do the individual and household characteristics of women who currently cycle for transport differ from women who do not cycle? How do these findings differ for men?
- What are the patterns of travel for female cyclists and non-cyclists? How do these findings differ for men?
- Do any personal, sociodemographic and household factors explain the difference in cycling between women and men?
- What are the socio-demographic and household predictors of female cycling? How do these differ for men?

2. Methods

2.1 Study context

New Zealand is a car dominated society, with the highest levels of per capita car ownership in the OECD (OECD, 2017). Transport planning has traditionally been car-centric, and this has led to a decline in travel by all modes other than private cars (Imran and Pearce, 2015; Shaw et al., 2016). New Zealand has comparatively high levels of gender equality; at the end of the data period used in this study it ranked 13th in the Global Gender Gap Index. However economic equality remains an area of concern, e.g. in 2014 New Zealand women earned an estimated 61% of the male wage (World Economic Forum, 2014). These comparatively high levels of gender equality in combination with a highly car dominated transport system make New Zealand an interesting setting to examine gender differences in travel patterns.

2.2 Study design and population

We obtained anonymised data for this secondary analysis of the New Zealand Household Travel Survey (NZHTS) from the Ministry of Transport under their data sharing protocols. The NZHTS is a

continuous, nationally representative cross-sectional survey undertaken to provide ongoing surveillance of household travel patterns.

The NZHTS survey stratifies the country into geographic regions. A random sample of meshblocks from within these geographic units is then selected, roughly proportional to the population in the geographic area. Meshblocks are the smallest geographic unit for which statistical data are collected and processed in New Zealand, each one contains between 60 and 110 people. Within each meshblock all addresses are listed randomly and then every seventh address selected for participation. Each household is sent a letter and visited up to four times to maximise participation. Over a seven to eight-year period all addresses within a specific meshblock are invited to participate. When all addresses in a specific meshblock have been exhausted, another meshblock within the region is selected. The survey doubled in size between 2007/2008 and 2008/2009 from 2200 to 4600 households being invited to participate. All eligible household members (household members or visitors present during the survey period) are invited to participate in the survey. Participation in the survey is estimated at 70% by the Ministry of Transport. Further details on the NZHTS sampling and protocols for the 2003-2014 time period is available from the Ministry of Transport (Ministry of Transport, 2018).

All participants of the NZHTS between 2003 and 2014 who were eligible to be in the survey, had complete responses and were over the age of 18 were included in the population for this analysis. The survey methodology changed substantially in 2015 and again in 2018, so to ensure consistency only the earlier time period (2003-2014) was used in this analysis.

2.3 Data and variables

Data were collected through face-to-face interviews with participants. Between 2002-2014 each participant was randomly assigned two contiguous days of the week in which travel information was recorded in a travel diary- an even spread of days of the week was maintained. Subsequent to the travel diary days a follow-up interview occurred to elicit further personal and household information and to ensure the travel diary was complete (using a memory jogger).

The survey collected information on cycling in two different ways. Firstly, participants were asked about cycling participation in the last year and, if they had cycled in the last month for any reason, frequency (1-4 days, 5-9 days, 10-19 days or 20+ days). Secondly, all trips undertaken during the

two-day travel diary had a mode (e.g. car, bus, walking etc) coded, so people who took trips by bike were identified. In this analysis, we defined a regular cyclist as anyone who cycled ten or more days in the preceding month, in order to capture individuals who regularly cycle but happened not to during their two-day travel diary.

Gender was self-assigned either male or female (between 2002-2014 no other gender option was permitted). Information was collected during the interviews or derived on other relevant variables, including; age (grouped into 18-29, 30-44, 45-59, 60-74, 75+); personal income (collected in bins); NZDep (an area based deprivation measure); self-assigned total ethnicity (Māori, Pacific, Asian, NZ European, other - 4% of people self-identify with more than one ethnicity); employment status (full time, part time, looking for work, student, homemaker, beneficiary, retire and other); whether the person has multiple jobs; car driving license (yes/no); lifetime driving experience (self-reported kilometres driven – nil, less than 20000km, over 20000 km); household size (grouped into 1-2 people, 3-5 people and 6+); rurality; household car access (nil, 1 car, 2 or more cars); and working bikes in household (nil, 1 bike, 2 or more bikes).

Information was collected on the purpose (i.e. going to work, home, social visits etc), destination, mode, and duration of each trip taken during the travel diary. Trip distance was estimated by the Ministry of Transport by calculating the fastest route between the map coordinates of the origin and destination addresses provided by the respondents (via any intermediate address if relevant).

Transport related physical activity metabolic equivalents (METS) were calculated by multiplying the daily time spent in minutes for walking and cycling by 3.5 and 4.0 respectively, consistent with published values for walking for transport and cycling to and from work and analysis of the average speed of travel for those modes in the NZHTS (Ainsworth et al., 2011; Mizdrak et al., 2018). (One MET is considered equivalent to the resting metabolic rate, and MET values express intensity levels as multiples of the resting metabolic rate). A weekly MET value was then calculated and a binary variable of under or over 600METs/week was created; this is the approximate MET equivalent to the World Health Organization recommendations for minimum weekly physical activity for good health (Kyu et al., 2016; World Health Organization, 2010).

2.4 Analysis

We produced basic tabulations of person, household and travel characteristics of female cyclists and non-cyclists and male cyclists and non-cyclists. As interpreting travel patterns for each mode is quite complex we created a number of policy-relevant summary indicators. For example the proportion of trips under 5km taken by car (i.e. in theory able to be cycled), and proportion of people who achieved over 600METs from walking and cycling for transport. Analysis took into account how many days of the travel diary were completed (about 16% of the participants in the analysis only filled in one day of the two-day diary). We undertook logistic regression to identify sociodemographic and household associations between gender and cycling. Covariates that might plausibly act as confounders between the exposure (gender) and outcome (cycling) were examined. We then looked at the independent associations of sociodemographic and household factors separately by gender, hypothesising that given the different gender roles in society these associations might be different for women and men.

All analyses were undertaken using Stata 15.1. The data were weighted with survey weights calculated and provided by the Ministry of Transport to weight the sample to represent the entire New Zealand population. The confidence intervals and statistical tests will be slightly conservative (overstating the variance) because the software used did not account for post-stratification used in the travel survey estimates.(Ministry of Transport, 2017)

3. Results

Figure 1 shows the dataset for analysis and final participants. Overall two percent of women and five percent of men over the age of 18 were classified as regular cyclists using the definition of having cycled 10 more days in the preceding month. Over 94% of survey participants individuals took one or more trips by any mode during the two day travel diary period.

Figure 1 Participants of household travel survey 2003-2014 for analysis

Unweighted numbers reported in this figure (remainder of results use survey weights).

Table 1 shows the personal and household characteristics of the participants by cyclist status and gender (information about cycling during each survey year and frequency over the preceding year can be found in the supplementary information). Regular cyclists were more likely to be in the 30-44 age group and less likely to be in older age groups. Men overall were more likely to hold a drivers licence than women, but male regular cyclists were less likely (90.2%) to hold a drivers licence than

male non-regular cyclists (94.2%). For women this was reversed; women regular cyclists were more likely to hold a drivers licence (92%) than non-regular cyclists (86%).

Table 1 Personal and household characteristics by cyclist status and gender

Regular cyclist: cycled 10 or more days in the last month. *Individuals can identify with more than one category so no p values possible and only row percent.

Table 2 looks at the travel characteristics of regular cyclists and non-regular cyclists by gender. Men took overall fewer trips compared to women (e.g. non-regular cyclists mean daily trips 4.63 95%CI:4.57 - 4.70 for male cf. 4.90 95%CI:4.84-4.95 female) but travelled further (e.g. non-regular men cyclists 46 km/day 95%CI:45 – 47 cf. women 38 km/day 95%CI:37-39).

We found regular cyclists, irrespective of gender, took more trips and travelled for a longer time but about the same distance as non-regular cyclists. For example, female regular cyclists took a mean 5.66 (95%CI:5.38 - 5.94) trips daily by all modes and travelled 39km (95%CI: 35-44) compared to non-regular cyclists who took 4.90 (95%CI:4.84 - 4.95) trips for 38km (95%CI:37 - 39).

Regular cyclists (male and female) walked more than non-regular cyclists (trips, time and distance in these modes are all greater for regular cyclists). The number of PT trips was low for both men and women. Male regular cyclists and non-regular cyclists took the same number of PT trips (0.08 trips/day) however women non-regular cyclists took more PT trips than regular cyclists (0.10 95%CI:0.09-0.11 cf. 0.06 95%CI:0.03-0.08). Further information on public transport use in the previous month and year by cyclist status and gender is available in the supplementary information. Finally, the majority of trips taken, time spent travelling and distance travelled by both genders irrespective of cyclist status, was in a private motor vehicle. Proportionately fewer of the total km travelled by regular cyclists was in private motor vehicle (e.g. 33 out of 39km/day (85%) for women regular cyclists compared to 36 out of 38 km/day (95%) for non-regular cyclists)

Table 2 Daily travel characteristics by cyclist status and gender

These mean figures include people who did not travel during the two day travel diary.

Figures 2 and 3 show the six most common trip purposes by cyclist status (relevant table in the supplementary information). Overall these showed similar levels of trips with the purpose of accompanying people, shopping and social visits irrespective of cyclist status. Regular cyclists were more likely to take trips with the purpose of recreation (0.68 95%CI: 0.56-0.80) than non-regular

cyclists (0.26 95%CI 0.25-0.27). In general men took fewer trips accompanying other people and fewer shopping trips, irrespective of cyclist status.

Figure 2 Daily trips by trip purpose taken by women by cyclist status (six most common purposes)

Mean number of trips and 95% confidence intervals

Figure 3 Daily trips by trip purpose taken by men by cyclist status (six most common purposes)

Mean number of trips and 95% confidence intervals

Figures 4 and 5 show some summary indicators of travel by gender (relevant table in the supplementary information). Figure 4 shows that among non-regular cyclists 11% of women and 15% of men achieved 600 METs/week from transport related walking and cycling. For regular cyclists this increased to around half. Figure 5 shows mean trips taken per person, and, irrespective of gender, regular cyclists took over double the number of trips by walking, cycling or PT compared to non-regular cyclists. However women took more 'replaceable' trips of 5km or less in a private vehicle (mean of 2.4/day irrespective of cyclists status) than men. Men took less of these replaceable trips overall, and male regular cyclists took 21% less than non-regular cyclists.

Figure 4 Percentage of people taking any trips by sustainable modes and achieving 600METs transport related physical activity per week, by gender and cyclist status.

All differences between regular cyclists and non-regular cyclists significant at <0.0001. Any cycling and walking trips indicator = any trip taken by any of those modes within the travel diary period. Over 600 METs/week indicator = achieved over 600 METs/week from cycling and walking trips.

Figure 5 Mean daily potentially replaceable trips and trips by sustainable modes, by gender and cyclist status.

PT: public transport. Means and 95% confidence intervals presented.

Table 3 shows the results of regression analysis looking at the association between gender and cycling. Men had an odds ratio of 2.51 (95%CI: 2.24 - 2.81) of being a regular cyclist compared to women. This association was unchanged even after progressive adjustment for the sociodemographic, household and transport access factors that were theorised to potentially act as confounders in the association.

Table 3 Modelling of association between gender and cyclist status

* All models adjusted for survey year. Reference group: women.

Table 4 shows the regression results examining the socio-demographic and household determinants of cycling compared to not cycling by gender. After adjusting for the other household and socio-demographic factors in the table most other ethnic groups were less likely to cycle than NZ European, although some of the confidence intervals include one (even with 12 years data there were few non NZ European female cyclists). There were no clear associations by income for women. Women who had larger household sizes and children in the households were much less likely to cycle than women who don't. For example women with any children in the household under 18 were 60% less likely to be regular cyclists compared to those without children (OR 0.43 95%CI: 0.31 - 0.58). There was a linear association between cycling and household car access; the more cars in the household the less likely cycling was. Most findings were similar for men; although while Pacific and Asian men were less likely to cycle than NZ European (e.g. Pacific men OR 0.42 (95% CI: 0.25 - 0.72)), Māori men had about the same chance of being regular cyclists after adjusting for other covariates (OR 0.97 (95%CI: 0.75 - 1.25).

Table 4 Socio-demographic and household determinants of cycling compared to not cycling by gender

*Adjusted for all other variables in table and survey year. **Bold results**: 95%CI exclude the null.

4. Discussion

4.1 Key findings

The majority of travel (trips taken, time spent and distance travelled) was by private vehicle for all groups, however, despite this, we found distinct and complex patterns in travel by gender and cyclist status in NZ adults. Women took more trips, but travelled 12-17% fewer kilometres per day, and were more likely to walk and use PT than men. Thus women overall had a more diverse and lower greenhouse gas emission travel profile than men. Women undertook more potentially replaceable trips per day (car trips less than 5km) than men (female regular cyclists and non-regular cyclists both took more replaceable trips than men). For both men and women regular cyclists were much more likely to achieve 600METs per week from transport-related cycling and walking than non-regular cyclists. Even after full model adjustment for household and sociodemographic factors men were still over twice as likely to cycle as women.

4.2 Strengths and Weaknesses

A strength of this study is the data, which comes from a nationally representative cross sectional survey of household travel in New Zealand with 12 years of standardised data collection.

This research was interested in utility/transport cycling rather than recreational cycling since the former is more likely to substitute for travel by car, with consequent social and environmental benefits. We initially explored three different definitions of a regular cyclist; one or more cycling trip in the two day travel diary, cycling for any reason 10 or more days in the last month (implying this is a regular activity) or any cycling for any reason in the last month. The three definitions resulted in an overall prevalence of regular cyclists amongst women of 1.7%, 2.2% and 9.1% and men 3.9%, 5.3%, and 17.2% respectively. We also examined a definition of cycling 5 or more days in the last month but there was some evidence that this may have lowered the specificity of the exposure measure by recruiting in more recreational only cyclists (see Table 6 in supplementary material). We chose the definition of cycling 10 or more days in the last month for this analysis. We felt this approach achieved a compromise between only using people who took a cycling trip in the two day travel diary (resulting in a selected group may not have represented the overall travel patterns of all cyclists) or using those who cycled less than 10 days a month (which may have inflated our exposure measure to include people who took infrequent recreational cycling trips). Our exposure group may include some people who exclusively cycle for recreational reasons, however these are likely to be relatively few – only 1% of individuals who cycled during the travel diary period (i.e. people who we know the purpose of every trip including cycle trips) did so exclusively for recreational reasons. We also acknowledge that the boundary between these activities is not always straight forward (Handy et al., 2014), and the focus on utility transport has limitations (Aldred, 2015). We conducted sensitivity analyses using these different definitions (data not presented). Defining a cyclists as someone who has done any cycling in the last month showed, unsurprisingly, that the cyclist group was identical to the non-cyclist group of the relevant gender (i.e. if a person only cycles once a month then the remainder of their trips will look the identical to the remainder of the same gendered population). Using the definition of a cyclist only being someone who took a cycling trip during the travel diary period resulted in findings largely similar to what we have presented but slightly more exaggerated in terms of the difference (i.e. even fewer kilometres travelled by car). Better elucidation of cycling patterns and reasons in national surveys would be helpful to construct analyses such as this.

As with all analyses using routinely collected data we were limited to the variables collected, which in some cases were not optimal (e.g. limited socioeconomic variables, family type was determined by 'interviewer observation' rather than directly asked). The cross-sectional nature of the survey also means that it is difficult to pinpoint cause and effect. For example, the association between increased car access and reduced cycling may mean either being without a car results in more cycling or being less likely to cycle leads to greater likelihood of buying a car.

4.3 Policy and practice implications

This paper provides further evidence for gender differences in cycling being a social process which is just one illustration of a variety of gendered travel patterns and behaviours (Law, 1999). One of the most striking findings in this paper is that overall differences in travel between genders are largely maintained even when men and women are regular cyclists. That is, the 'travel profiles' of both men and women regular cyclists look more like their gender compatriots than each other (i.e. women regular cyclists take more trips but travel the same distance as women non-regular cyclists; the same applies to men). These similarities are only revealed because we framed the analysis around overall travel patterns by gender, rather than just looking at differences amongst men and women who cycle.

Commonly cited explanations for gender differences in (all) travel, including cycling, include women working closer to the family home, having more household responsibilities or having less access to the family vehicle (Hanson, 2010). However, international studies suggest that these explanations are not always supported by evidence (Hanson, 2010; Kavanagh and Bentley, 2008; Kronsell et al., 2016; Miralles-Guasch et al., 2016). For example, one Spanish study showed that even for the same trip purpose women and men will use different modes (Miralles-Guasch et al., 2016). In this study we also found differences in mode for trips for the same purpose by gender. For example shopping trips undertaken by men in NZ are much more likely to be done using a car than those by women (unpublished results). A US study by Taylor et al explored possible reasons for why women undertake more household serving trips than men (i.e. travel other than commuting). These included time-use related reasons (i.e. the perception that women have more time because they are more likely to have part-time paid work), microeconomic (i.e. women earn less than men) and gender socialisation (i.e. implicit gender beliefs about who should do specific tasks in the household). Gender socialisation that fitted best with these findings, as even in households where women were better educated, worked more and earned more than their male partners, they still

undertook about 50% more household serving trips (Taylor et al., 2015). We need to use the available NZHTS data to further examine differences by gender in overall travel.

What do these findings mean for policy to increase women's cycling? The combination of an existing propensity towards low greenhouse gas emission travel modes, evidence from countries with high overall cycling levels that women take half (or more) of the trips by bike *and* the number of trips women take in NZ that are potentially amendable to mode swapping suggests there is significant potential for supporting increased cycling among women, who already have more flexible and lower carbon travel. The travel patterns and reasons for travel that we observed in this study suggest specific changes in cycling infrastructure to women to undertake relatively short trips to their required destinations (home/shops) and to travel safely in the company of others. These would likely require whole street/suburb changes rather than a network approach of the provision of cycle lanes on busy streets leading into the central city. These are changes that require a much greater emphasis on what is local to where people live, to facilitate activities that can be regarded as mundane. These types of policies work to enable mode change within established variations in travel by gender; and implicitly normalise these gender variations in travel. An additional approach would be policies that aim to disrupt the processes that structure social relations and institutions that ultimately result in the observable gender differences in travel (Law, 1999).

While most of the discussion is centred on women, it is just as relevant to consider how gender processes play out in men's travel. Despite men cycling more than women, men travel further each day and take the majority of trips by car, meaning their travel profile is more greenhouse gas emission intensive. Even men who regularly cycle still travel further by private vehicle than female non-regular cyclists. In addition, there are other stark examples of gender inequities in transport outcomes e.g. New Zealand men are much more likely to be hospitalised or killed as a result of road traffic injury than women (Hosking et al., 2013). Men's travel is perceived as less complex than women's due to less unpaid work-related travel, hence, in theory, it should be more amenable to mode change. Policies need to focus on how to get more men, for example, using public transport for their routine commuting.

Finally, we need policies to challenge the social processes that underpin the gender differences in travel. Like other gender related social processes, gendered perceptions of travel start early in life (Baslington, 2008). Gender equity policies that aim to break down traditional roles and responsibilities of men and women may be useful to help ameliorate some of the current gender

differences in travel. However these need to be done in tandem with environmental transport policies as international literature suggests that as women moved into the labour force women's travel became more like men's, rather than vice versa, meaning car travel increased(Susilo et al., 2018).

5. Conclusion

Cycling provides just one example of wider differences in travel patterns by gender in NZ. To achieve a low greenhouse gas emission land transport system, of which cycling is an important part, more attention needs to be paid in transport research, policy, institutional structures, planning and programmes to understanding and modifying the social processes impacting on travel.

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