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Cycling behaviour and socioeconomic disadvantage: an investigation based on the English National Travel Survey

Eugeni Vidal Tortosa* Robin Lovelace† Eva Heinen‡ Richard P Mann§

Abstract

One of the main challenges for policymakers aiming to promote cycling in car-oriented transport systems is how to increase social diversity among its users. The under-representation of certain groups makes it difficult to normalise cycling and distribute its benefits throughout society. Many studies have explored cycling levels in relation to age and gender, and to a lesser extent disability and ethnicity. Less attention has been paid to bicycle use related to income and other socioeconomic factors associated with disadvantage. This study aims to better understand the relationship between income and other factors of socioeconomic disadvantage and cycling behaviour. We analysed data from the English National Travel Survey to estimate the likelihood of cycling participation (if individuals cycle at all), cycling frequency ('how often' they cycle), and cycling distance ('how far' they cycle) using regression models. We found that people in lower-income households cycle less for transport than people in higher-income households. However, no income inequalities were found for leisure cycling. In addition, low-income leisure cyclists were found to cycle more often, but higher-income leisure cyclists further. Our findings may have important policy implications. Favouring a broader focus on leisure and non-commuting utility cycling, and subsidised cycle access and maintenance, could help to diversify cycling.

keywords: cycling, cycling frequency, cycling distance, cycling inequalities, social disadvantage, health inequalities.

1 Introduction

The benefits of cycling are increasingly recognised. Cycling is healthy for body and mind, and as a mode of transport (utility cycling) is convenient, affordable, and environmentally friendly (Garrard et al., 2012; Heinen et al., 2010; Oja et al., 2011; Pucher et al., 2010). Consequently, cycling promotion has been gradually more prominent in high-income car-oriented countries during the last two decades (Pucher and Buehler, 2012).

One of the main challenges for policymakers aiming to promote cycling in car-oriented transport systems is how to increase social diversity among its users. The under-representation of certain groups makes it difficult to normalise cycling and distribute its benefits throughout society. Cycling diversity is important to increase overall cycling levels, with health and environmental benefits for the whole of society, but it can also help to reduce inequalities of certain social groups in terms of transport and health (Iacono et al., 2010; Lee et al., 2017). Cycling can improve the mobility and increase access opportunities to better jobs, education, recreation, and social interaction for social groups with difficulties to afford other modes of transport (particularly cars, but also public transport) (Golub, 2016). Moreover, it can increase physical activity of less active groups and, consequently, improve their health and wellbeing (Garrard et al., 2012; Oja et al., 2011).

*Corresponding author, Leeds Institute for Data Analytics (University of Leeds), ts16evt@leeds.ac.uk
†Institute for Transport Studies (University of Leeds), R.Lovelace@leeds.ac.uk
‡Institute for Transport Studies (University of Leeds), E.Heinen@leeds.ac.uk
§Department of Statistics, School of Mathematics (University of Leeds) and The Alan Turing Institute, R.P.Mann@leeds.ac.uk

Cycling inequalities in age and gender have been extensively studied. In car-oriented countries, female and the elderly populations seem to cycle considerably less (particularly for transport) than male, and young/middle-aged populations (e.g. Heesch et al., 2012; Heinen et al., 2010). These disparities are less present or non-existent in places where cycling is more common (Aldred et al., 2016; Goodman and Aldred, 2018).

The relationship between disability and ethnicity have also received some scientific attention. In England, people with disabilities were found half as likely to have cycled in the past four weeks as people without disabilities (Goodman and Aldred, 2018). Enacting more policies focused on inclusive infrastructure seems key to increase cycling uptake among these populations (Andrews et al., 2018; Clayton et al., 2017). Cycling levels also vary by ethnic groups (Goodman and Aldred, 2018; Harms, 2007). Unlike age, gender, and disability, these differences are observed in countries with low as well as high cycling levels. In the Netherlands and Denmark, where overall cycling levels are high, ethnic minorities tend to cycle less frequently (Harms, 2007; Heinen et al., 2010). Similarly, in England, where cycling is marginal, non-white individuals were found around half as likely as white people to have cycled in the past four weeks (Goodman and Aldred, 2018). Cultural differences, financial barriers to car use, as well as the place where these populations live may explain these differences (Harms, 2007).

More complex and less well understood are cycling inequalities related to income and other socioeconomic factors associated with disadvantage. In North America, an study in Canadian cities with population greater than 50,000 (Winters et al., 2007) and another in the Metro Vacouver Region (Winters et al., 2010) found a negative association between income and cycling. Also the National Household Travel Survey in the US reported a higher bike share among the lowest-income households (Pucher et al., 2011). However, another study from the US using data from 42 large cities (Dill and Carr, 2003) found no association between income and cycling. In the UK, by contrast, studies in England and Wales (Parkin et al., 2008) and in London (Green et al., 2010) found that low-income populations cycle less than higher-income groups. Also in Australia, specifically in the Sydney Greater Metropolitan Area (Merom et al., 2010), Brisbane (Heesch et al., 2015, 2014), and Queensland state (Sahlqvist and Heesch, 2012) low-income populations were found to cycle less.

Since cycling has been connected to the presence of cycling infrastructure (Dill and Carr, 2003; Mölenberg et al., 2019), one hypothesis to explain, at least in part, the inequalities in cycling levels by socioeconomic groups is that these may depend on the socio-spatial distribution of cycling infrastructure. However, there does not seem to be a clear relationship between socioeconomic inequalities in access to cycling infrastructure and socioeconomic inequalities in cycling levels. For example, in the US where disadvantaged groups have significantly lower access to bike lanes (Braun et al., 2019), low-income populations tend to cycle more (Pucher et al., 2011); while in the UK and Australia where access to cycling infrastructure is more equitable (Pistoll and Goodman, 2014; Vidal Tortosa et al., 2021)], low-income populations cycle less (Green et al., 2010; Heesch et al., 2015, 2014; Merom et al., 2010; Parkin et al., 2008; Sahlqvist and Heesch, 2012). Beyond infrastructural factors, other barriers to cycling found particularly important for socioeconomically disadvantaged populations include not having a bicycle or associated equipment, lack of secure storage at work and home (McNeil et al., 2017), and cultural aspects such as self-image and social norms (Bird, 2010; Steinbach et al., 2011).

The few studies that have investigated the association between income and cycling have tended to use cycling participation, i.e. a binary dependent variable based on whether individuals cycled during a specific period of time, as the only measure of analysis. By contrast, other measures of cycling behaviour such as how often or how far population cycle have been rarely explored. Green et al. (2010), who found that men from higher-income households in London cycled longer distances, is an exception. Another common absence in most studies that have examined the association between income and cycling is the distinction between utility cycling and leisure cycling. Heesch et al. (2014) and Heesch et al. (2015) conducted in Brisbane (Australia) are exceptions in this case. These studies found that people from low-income households cycled less for both purposes leisure and utility.

This paper analyses the relationship between income and other factors of socioeconomic disadvantage (i.e. education, economic status, parenting, single-parenting, driving licence holding, and car availability) and three cycling behaviours (cycling participation, cycling frequency, and cycling distance), distinguishing between utility cycling and leisure cycling. Better understanding socioeconomic inequalities in cycling behaviour and to what extent these inequalities occur per type of cycling can help in identifying policies best suited to meet the needs of disadvantaged populations to cycling, and in turn, diversify and make more equitable cycling uptake.

2 Data and methods

2.1 National Travel Survey

We used data from the National Travel Survey (NTS), the primary source of data on individual travel among residents of England. Individuals in sampled households were interviewed face-to-face to collect personal information, such as age, gender, economic status, driving licence holding, and car access. They were also asked to complete a seven-day travel diary and provide details of trips undertaken, including mode of travel, purpose, and trip length. The dataset used for this study is the End User Licence (EUL) version from 2017 (Department for Transport, 2017). In 2017, the number of households included in the diary sample (i.e. fully co-operating with completed individual interviews and travel diaries) was 6,135 and the number of individuals covered 14,541.

The NTS is organised in several files for Households, Vehicles, Individuals, Days, Journeys and Stages. For this study, we used the Journeys, Households, and Individuals files and carried out the following steps to prepare the data for analysis.

1) Using the Journeys file, we calculated for each individual a binary variable expressing whether they cycled or did not cycle at least once a week (cycling participation), a count variable specifying their number of weekly trips (cycling frequency), and a continuous variable specifying the weekly miles they travelled by bicycle (cycling distance). For the calculation of these variables, we applied weights provided by the NTS to adjust for the drop-off in the number of trips recorded by respondents during the course of the travel week. Each of these variables was calculated for utility cycling (including cycling for commuting, shopping, education/escort education, personal business, business, and other escort) and for leisure cycling (including cycling for visiting friends at private home, visiting friends elsewhere, entertainment / public activity, sport, holiday, and day trip). This information was added to the Individuals file.

2) From the Households file, we selected a range of variables by individual: area type, household income quintile, children in the household, and single-parent family. This information was also added to the Individuals file.

3) Finally, from the Individuals file, we considered the variables age, sex, ethnicity, mobility difficulties, educational qualifications, economic status, driving licence holding, car access, and own or use a bicycle.

Our analyses were restricted to adults (population 16 and over). Sixty seven participants were excluded with missing data (in the variables educational qualifications, driving licence holding, car access, area type, and ethnicity) and after adjusting for non-response bias (applying the non-response weights provided by the NTS), the total final diary sample was of 11,897.

2.2 Measurements

2.2.1 Dependent variables

As dependent variables, we used three measurements of cycling behaviour 1) cycling participation (a binary variable expressing whether individuals cycled or did not cycle at least once a week), 2) cycling frequency (a count variable specifying the number of weekly cycling trips of those who cycled at least once a week), and 3) cycling distance (a continuous variable specifying the weekly miles that those who cycled at least once a week travelled by bicycle), separately calculated for utility and leisure cycling.

2.2.2 Independent variables

The selection of the independent variables was based on the literature on transport disadvantage (Lucas et al., 2016; Social Exclusion Unit, 2003). As explanatory variables, we used seven socioeconomic disadvantage factors. Household income quintiles (1st (lowest 20%), 2nd, 3rd, 4th, 5th), which we used as a proxy for socioeconomic disadvantage, and six other specific variables associated with socioeconomic disadvantage: educational qualifications (any certificated educational qualifications: yes/no), economic status (full-time, part-time, unemployed, student, economically inactive), children in the household (yes, no), single-parent family (yes, no), driving licence (yes, no), and car access (yes, no). As control variables, we included socio-demographic characteristics previously associated with cycling levels (Fraser and Lock, 2011; Heinen et al., 2010; Wang et al., 2016; Winters et al., 2010). These were area type (inner London, other urban area - over 250k population, other urban area - 25k to 250k population, other urban area - 10k to 25k population, other urban area - 3k to 10k population, built-up areas, rural), age (16-29, 30-64, >64), sex (male, female), ethnicity (white, non-white), and mobility difficulties (yes, no).

2.3 Statistical analyses

To examine the extent to which income and other socioeconomic disadvantage factors are associated with cycling behaviour, we first evaluated descriptive statistics using bar graphs and contingency tables broken down by household income quintiles. Next, we estimated odds ratios (ORs) based on the set of independent variables using three regression models that followed a hierarchical structure. The first was a binomial regression model to predict the binary dependent variable ‘cycling participation’ which expresses whether individuals cycled or did not cycle at least once a week. And for those who cycled at least once a week, we used two other regression models: a zero-truncated negative binomial regression to predict the count dependent variable ‘cycling frequency’ (i.e. the number of weekly cycling trips of those who cycled at least once a week); and a gamma regression to predict the continuous dependent variable ‘cycling distance’ (i.e. the weekly miles that those who cycled at least once a week travelled by bicycle). We conducted these analyses for utility and leisure cycling separately. Correlations between the independent variables were calculated using the Generalized Variance-Inflation Factors (GVIF) (Fox and Monette, 1992). All values were lower than 2, except for a pair between 2 and 3, indicating no substantial multi-collinearity (James et al., 2013). Figure 1 illustrates the conceptual models.

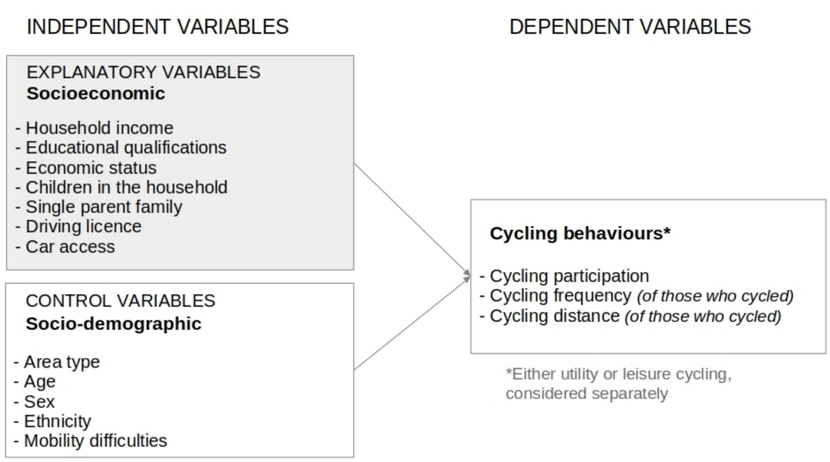

Figure 1: Conceptual models

Several independent variables were initially considered in the models but later discarded. Own or use a bicycle, which collects whether individuals own or have use of a household or a non-household bicycle, was discarded since we understood that owning or having use of a bicycle implies an intention to want to cycle. Therefore, the inclusion of this variable in the models would have been to some extent like considering the variable we were predicting. This would have hindered potential associations between other independent variables and cycling participation. Even so, this variable was considered in the descriptive statistics analysis. Type of household, walk time from household to the nearest bus stop, and health condition were discarded because we did not find any significant association ($p<0.05$) between them and cycling participation. To test for any geographical variation between London and the rest of England and to what extent this variation might affect the results for all England, we fitted the cycling participation model separately for London, the rest of England, and all England. This analysis was not performed for the frequency and distance models because the London sample size of those who participated in cycling was too small (less than 100) to get meaningful results.

3 Results

3.1 Descriptive statistics

Individuals of the 2017 NTS sample made 1.7% of their trips by bicycle: 1.2% for utility purposes (i.e., commuting, shopping, education, escort education, personal business, business, and other escort) and 0.6% for leisure (i.e., visiting friends at private home, visiting friends elsewhere, entertainment / public activity, sport, holiday, and day trip).

Commuting was the main purpose for cycling for individuals from all household income quintiles. However, people in the lower household income quintile make a quarter as many commuting cycling trips as people in the highest household income quintile. The differences concerning other cycling trip purposes were less pronounced, being in some cases, such as visiting friends at private home and education, greater among people in lower household income quintiles than among people in higher household income quintiles (Figure 2).

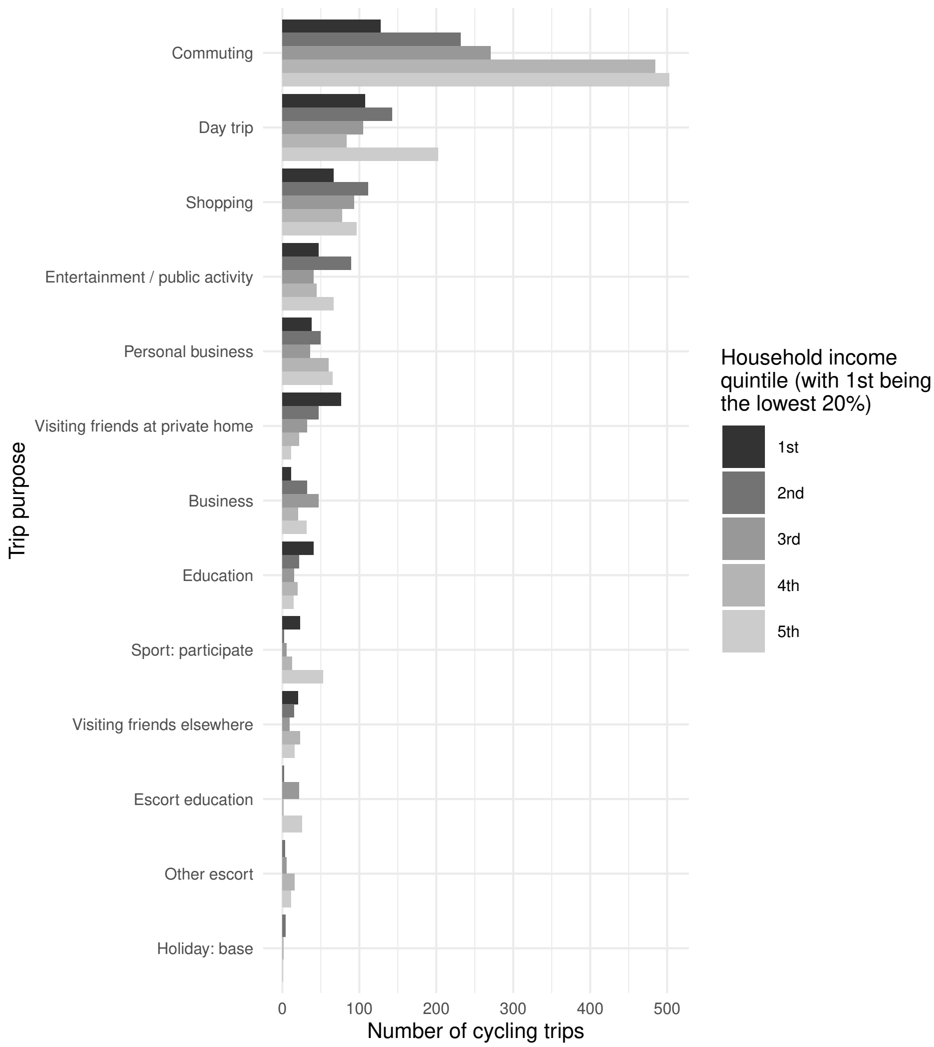

Figure 2: Cycling trips by trip purpose and household income quintiles

Five per cent of individuals participated in a cycling activity at least once a week: 3.3% for utility cycling and 3.0% for leisure cycling. There was a gradual positive association in utility cycling participation by income quintiles, i.e., the higher the income, the greater the number of individuals who cycled at least once a week for utility purposes. However, for leisure cycling, lower quintiles did not show an increase of cycling participation with higher income levels, although individuals in the highest quintile (5th) cycled more than the rest (Figure 3).

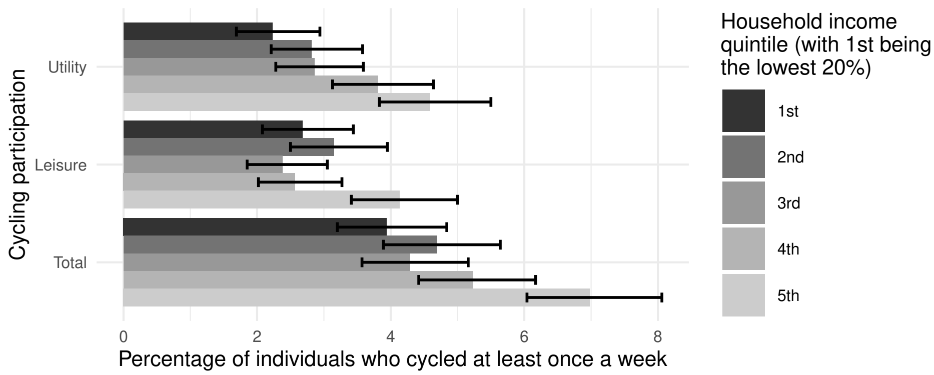

Figure 3: Cycling participation by type of cycling and household income quintiles. The error bars show 95% confidence intervals of the observed proportions

The mean weekly cycling trips of those who cycled at least once a week was 6.6: 6.8 for utility cycling and 3.7 for leisure cycling. The mean of utility cycling frequency across income quintiles was overall flat, although utility cyclists from the lower-income quintile (1st) cycled least frequently. By contrast, except for the 5th quintile, there was a gradual negative association between the mean of leisure cycling frequency and income quintiles, meaning that leisure cyclists with lower incomes cycled more frequently than leisure cyclists with higher incomes (Figure 4).

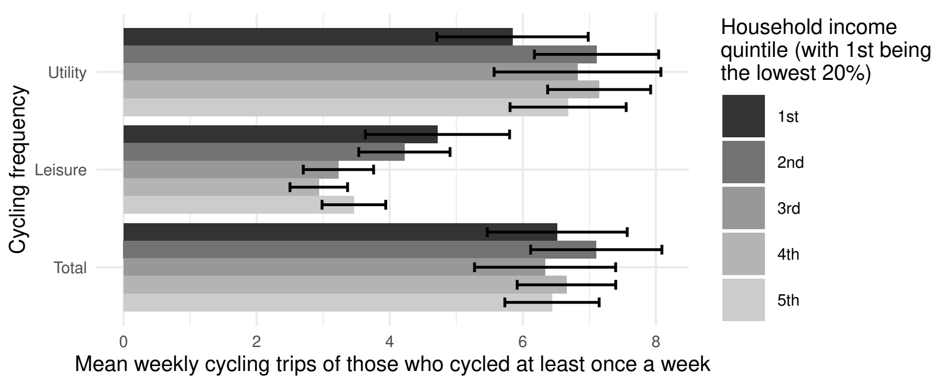

Figure 4: Cycling frequency by type of cycling and household income quintiles. The error bars show 95% confidence intervals of the observed means

The mean weekly miles cycled by those who cycled at least once a week was 24.5: 19.9 for utility cycling and 19.6 for leisure cycling. The mean of utility cycling distance was substantially higher among higher-income cyclists (4th and 5th) but this tendency did not apply for leisure cycling, although the 5th quintile showed the higher value (Figure 5). The total distance travelled by bicycle represented 0.9% of all distance travelled by all modes of transport.

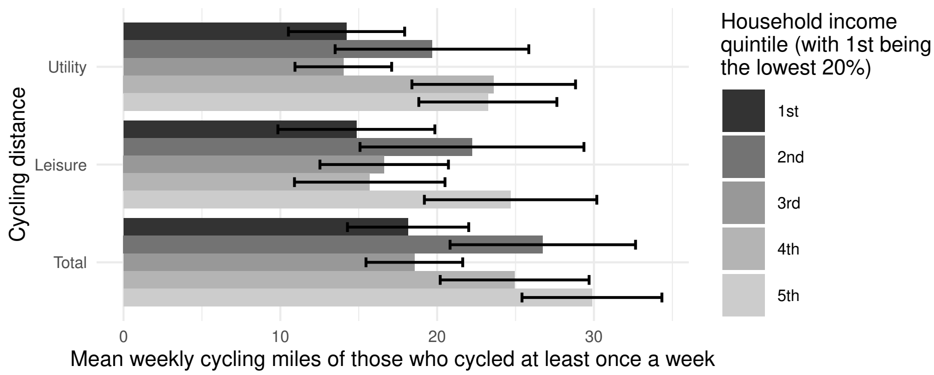

Figure 5: Cycling distance by type of cycling and household income quintiles. The error bars show 95% confidence intervals of the observed means

All the explanatory variables (educational qualifications, economic status, children in the household, single-parent family, driving licence, car access, and own or use a bicycle) were aligned with 'household income quintiles', with low-income linked to disadvantages of each of these factors (Table 1). This observation supports our use of 'household income quintiles' as the main explanatory variable and proxy for socioeconomic disadvantage in the study. The disparity of owning or having use of a bicycle should be noted, due to the great influence that this might have on cycling use. While some people might not have a bicycle simply because they are not keen on cycling, others might not cycle because they do not have access to a bicycle. Only two in ten in the 1st quintile own or have use of a bicycle, compared to almost five in ten in the 5th quintile.

3.2 Multivariate analyses

3.2.1 Utility cycling

We found that being in the highest household income quintile (5th) is significantly positively associated with the likelihood of utility cycling participation (Table 2, binomial model). Specifically, individuals in the 5th income quintile are 62% more likely to cycle for transport than people in the 1st quintile. Other socioeconomic factors significantly positively associated with engaging in utility cycling were being a part-time worker (Odds ratio 1.43, 95% CI 1.05-1.96) and lacking car access (OR 1.98, 95% CI 1.47-2.68). Among the control variables, utility cycling participation was significantly negatively associated with the area types urban from 10k to 25k population, built-up and rural, and with being a female, and non-white; and significantly positively associated with having no mobility difficulties.

No significant association was found between cyclists household income quintiles and the odds of cycling for transport more frequently (Table 2, zero-truncated negative binomial model). However, cycling for transport more frequently was significantly negatively associated with being a student (OR 0.68, 95% CI 0.48-0.97) and economically inactive (OR 0.57, 95% CI 0.43-0.76); and positively associated with lacking car access (OR 1.21, 95% CI 1.01-1.45). Regarding the control variables, a lower likelihood of utility cycling frequency in rural areas was found.

We also found no association between utility cyclists income and utility cycling distance (Table 2, gamma model). A significant negative association was found, however, between being a part-time worker (OR 0.71, 95% CI 0.51-0.98), unemployed (OR 0.33, 95% CI 0.12-0.91), a student (OR 0.58, 95% CI 0.34-0.99), economically inactive (OR 0.39, 95% CI 0.26-0.58), having no children (OR 0.74, 95% CI 0.59-0.98), and cycling further away for transport. Lacking car access was also positively associated with utility cycling distance (OR 1.38, 95% CI 1.04-1.84). Among the control variables, a significant negative association was found between being a female utilitarian cyclist and cycling distance.

Table 1: Independent variables by household income quintiles

	1st (lowest) (n=2185)	2nd (n=2264)	3rd (n=2516)	4th (n=2496)	5th (highest) (n=2436)	Overall (n=11897)
Educational qualifications: Yes (n, perc.)[a b]	1401 (64.09)	1612 (71.20)	2113 (83.99)	2204 (88.30)	2184 (89.64)	9513 (79.96)
Educational qualifications: No	785 (35.91)	652 (28.80)	403 (16.01)	292 (11.70)	252 (10.46)	2384 (20.04)
Economic status: Full Time	453 (20.71)	662 (29.25)	1216 (48.34)	1557 (62.39)	1737 (71.30)	5625 (47.28)
Economic status: Part Time	303 (13.88)	347 (15.33)	417 (16.60)	320 (12.83)	260 (10.68)	1648 (13.85)
Economic status: Unemployed	92 (4.22)	29 (1.30)	32 (1.29)	15 (0.62)	14 (0.56)	183 (1.54)
Economic status: Student	213 (9.77)	137 (6.05)	116 (4.61)	79 (3.16)	74 (3.02)	619 (5.20)
Economic status: Economically inactive	1124 (51.42)	1088 (48.08)	734 (29.17)	524 (21.01)	352 (14.44)	3822 (32.13)
Children in the household: Yes	750 (34.30)	624 (27.55)	834 (33.16)	652 (26.13)	716 (29.38)	3575 (30.05)
Children in the household: No	1436 (65.70)	1640 (72.45)	1681 (66.84)	1844 (73.87)	1721 (70.62)	8322 (69.95)
Single parent family: Yes	116 (5.31)	55 (2.43)	33 (1.31)	10 (0.40)	10 (0.42)	224 (1.88)
Single parent family: No	2069 (94.69)	2209 (97.57)	2483 (98.69)	2486 (99.60)	2426 (99.58)	11673 (98.12)
Driving licence: Yes	1449 (66.31)	1656 (73.14)	2066 (82.11)	2167 (86.81)	2213 (90.85)	9550 (80.28)
Driving licence: No	736 (33.69)	608 (26.86)	450 (17.89)	329 (13.19)	223 (9.15)	2347 (19.72)
Car access: Yes	1408 (64.42)	1737 (76.75)	2196 (87.29)	2220 (88.94)	2124 (87.20)	9685 (81.41)
Car access: No	778 (35.58)	526 (23.25)	320 (12.71)	276 (11.06)	312 (12.80)	2212 (18.59)
Own or use a bicycle: Yes[c]	510 (23.34)	682 (30.11)	960 (38.18)	1006 (40.30)	1180 (48.42)	4338 (36.46)
Own or use a bicycle: No	1675 (76.66)	1582 (69.89)	1555 (61.82)	1490 (59.70)	1257 (51.58)	7559 (63.54)
Area type: Inner London (n, prop.)	135 (6.16)	146 (6.46)	90 (3.58)	142 (5.69)	192 (7.90)	705 (5.93)
Area type: Built-up areas	277 (12.68)	322 (14.20)	339 (13.48)	325 (13.02)	233 (9.57)	1496 (12.57)
Area type: > 250k	571 (26.14)	587 (25.93)	716 (28.46)	655 (26.26)	548 (22.48)	3077 (25.87)
Area type: 25k to 250k	138 (6.33)	163 (7.19)	249 (9.91)	204 (8.19)	171 (7.04)	926 (7.79)
Area type: 10k to 25k	86 (3.93)	153 (6.76)	149 (5.94)	158 (6.32)	152 (6.25)	698 (5.87)
Area type: 3k to 10k	775 (35.45)	582 (25.72)	604 (24.01)	657 (26.30)	691 (28.34)	3308 (27.81)
Area type: Rural	203 (9.30)	311 (13.74)	368 (14.63)	355 (14.21)	449 (18.43)	1686 (14.17)
Age: 16-29	568 (26.00)	417 (18.43)	606 (24.09)	559 (22.40)	437 (17.93)	2587 (21.75)
Age: 30-64	1051 (48.10)	1056 (46.67)	1349 (53.64)	1517 (60.77)	1745 (71.64)	6719 (56.48)
Age: >64	566 (25.90)	790 (34.90)	560 (22.27)	420 (16.83)	254 (10.42)	2590 (21.77)
Sex: Male	1011 (46.25)	1033 (45.61)	1210 (48.09)	1282 (51.36)	1278 (52.46)	5813 (48.86)
Sex: Female	1175 (53.75)	1231 (54.39)	1306 (51.91)	1214 (48.64)	1158 (47.54)	6084 (51.14)
Ethnicity: White	1775 (81.24)	1992 (88.01)	2217 (88.14)	2245 (89.93)	2142 (87.92)	10371 (87.18)
Ethnicity: Non-white	410 (18.76)	271 (11.99)	298 (11.86)	251 (10.07)	294 (12.08)	1526 (12.82)
Mobility difficulties: Yes	309 (14.16)	296 (13.07)	196 (7.78)	123 (4.93)	95 (3.88)	1019 (8.56)
Mobility difficulties: No	1876 (85.84)	1968 (86.93)	2320 (92.22)	2373 (95.07)	2342 (96.12)	10878 (91.44)

[a] Number and percentage of individuals.
[b] For educational qualifications 'Yes' indicates any certificated educational qualifications.
[c] For own or use a bicycle 'Yes' includes 'Own a bicycle yourself', 'Have use of household bicycle', and 'Have use of non-household bicycle'.

3.2.2 Leisure cycling

No significant association was found between household income and the likelihood of engaging in leisure cycling (Table 3, binomial model). However, less educated people were significantly less likely to participate in leisure cycling (OR 0.54, 95% CI 0.37-0.78). Other explanatory variables found positively associated with leisure cycling participation were being a part-time worker (OR 1.82, 95% CI 1.31-2.52), a student (OR 2.99, 95% CI 1.86-4.80), and lacking car access (OR 1.90, 95% CI 1.39-2.59). Among the control variables, people between 30 and 64 years and having no mobility difficulties were found to be more likely to cycle for leisure; by contrast, females and particularly non-white populations were less likely.

A significant negative association between leisure cyclists from the 3rd (OR 0.70, 95% CI 0.52-0.95) and 4th (OR 0.63, 95% CI 0.45-0.86) household income quintile and leisure cycling frequency was found (Table 3,

Table 2: Associations with utility cycling participation, utility cycling frequency, and utility cycling distance

	Cycling participation	Cycling frequency	Cycling distance
	Binomial model [a] OR (95% CI)[d]	Zero-truncated model [b] OR (95% CI)	Gamma model [c] OR (95% CI)
Household income quintile: 1st (lowest)	1	1	1
Household income quintile: 2nd	1.22 (0.82, 1.80)	1.19 (0.91, 1.56)	1.25 (0.83, 1.88)
Household income quintile: 3rd	1.12 (0.75, 1.66)	1.10 (0.84, 1.44)	0.92 (0.61, 1.38)
Household income quintile: 4th	1.35 (0.92, 1.99)	1.14 (0.87, 1.50)	1.47 (0.98, 2.22)
Household income quintile: 5th (highest)	1.62 (1.10, 2.38) *	1.11 (0.85, 1.45)	1.35 (0.90, 2.02)
Educational qualifications: Yes	1	1	1
Educational qualifications: No	0.72 (0.52, 1.01)	1.16 (0.91, 1.49)	1.36 (0.93, 1.99)
Economic status: Full Time	1	1	1
Economic status: Part Time	1.43 (1.05, 1.96) *	0.95 (0.77, 1.17)	0.71 (0.51, 0.98) *
Economic status: Unemployed	0.63 (0.24, 1.63)	0.51 (0.24, 1.07)	0.33 (0.12, 0.91) *
Economic status: Student	1.06 (0.64, 1.75)	0.68 (0.48, 0.97) *	0.58 (0.34, 0.99) *
Economic status: Economically inactive	0.72 (0.48, 1.06)	0.57 (0.43, 0.76) ***	0.39 (0.26, 0.58) ***
Children in the household: Yes	1	1	1
Children in the household: No	1.05 (0.83, 1.33)	0.92 (0.78, 1.08)	0.74 (0.59, 0.98) *
Single parent family: Yes	1	1	1
Single parent family: No	2.26 (0.64, 7.99)	2.08 (0.78, 5.56)	2.51 (0.66, 9.54)
Driving licence: Yes	1	1	1
Driving licence: No	1.06 (0.77, 1.45)	0.87 (0.71, 1.07)	0.82 (0.60, 1.13)
Car access: Yes	1	1	1
Car access: No	1.98 (1.47, 2.68) ***	1.21 (1.01, 1.45) *	1.38 (1.04, 1.84) *
Area type: Inner London	1	1	1
Area type: > 250k	1.02 (0.67, 1.55)	0.95 (0.72, 1.25)	1.01 (0.66, 1.55)
Area type: 25k to 250k	0.85 (0.57, 1.26)	1.17 (0.92, 1.50)	0.84 (0.57, 1.24)
Area type: 10k to 25k	0.58 (0.34, 0.97) *	0.92 (0.65, 1.31)	0.97 (0.57, 1.67)
Area type: 3k to 10k	0.57 (0.32, 1.02)	0.81 (0.55, 1.20)	0.88 (0.48, 1.59)
Area type: Built-up areas	0.41 (0.27, 0.62) ***	0.99 (0.75, 1.29)	0.96 (0.63, 1.46)
Area type: Rural	0.44 (0.27, 0.71) ***	0.66 (0.48, 0.93) *	0.65 (0.40, 1.06)
Age: 16-29	1	1	1
Age: 30-64	1.17 (0.90, 1.54)	0.95 (0.79, 1.14)	1.01 (0.75, 1.34)
Age: >64	0.67 (0.41, 1.10)	1.29 (0.90, 1.84)	0.86 (0.50, 1.48)
Sex: Male	1	1	1
Sex: Female	0.37 (0.29, 0.47) ***	1.04 (0.89, 1.22)	0.77 (0.60, 0.99) *
Ethnicity: White	1	1	1
Ethnicity: Non-white	0.34 (0.21, 0.53) ***	1.17 (0.86, 1.59)	0.82 (0.50, 1.35)
Mobility difficulties: Yes	1	1	1
Mobility difficulties: No	3.06 (1.47, 6.38) **	0.74 (0.46, 1.18)	0.72 (0.33, 1.56)
n	11581	363	363
Pseudo R-squared (Nagelkerke)	0.09	0.15	0.29

[a] The binomial model estimates the association between the independent variables and utility cycling participation (yes/no weekly utility cycling).
[b] The zero-truncated negative binomial model estimates the association between the independent variables and cycling frequency of those who participated in weekly utility cycling.
[c] The gamma model estimates the association between the independent variables and miles travelled by bicycle for those who participated in weekly utility cycling.
[d] OR (95%) = Odds ratio and 95% confidence intervals.
* p < 0.05, ** p < 0.01, *** p < 0.001

zero-truncated negative binomial model). Also being a student (OR 0.49, 95% CI 0.30-0.79) was significantly negatively associated with leisure cycling frequency. However, significant positive associations were found between being a part-time worker (OR 1.48, 95% CI 1.15-1.89), unemployed (OR 1.79, 95% CI 1.09-2.92), lacking car access (OR 1.39, 95% CI 1.10-1.77), and leisure cycling.

Finally, we found a positive association between cyclists from the 5th income quintile (OR 1.55, 95% CI 1.03-2.35), unemployed (OR 2.65, 95% CI 1.19-5.89), and leisure cycling distance (Table 3, gamma model). By contrast, cyclists with no 'educational qualifications' were found to be significantly associated with less leisure cycling distance (OR 0.60, 95% CI 0.39-0.91). Among the control variables, female and non-white cyclists were significantly negatively associated with leisure cycling distance.

3.3 Geographical variation

Some variations were found between the odds ratios of utility and leisure cycling participation by household income quintile in London and in the rest of England. However, the impact that London has on all England seems quite small, as we can deduce from the nearly unnoticeable differences between the results of the rest of England and England (Figure 6).

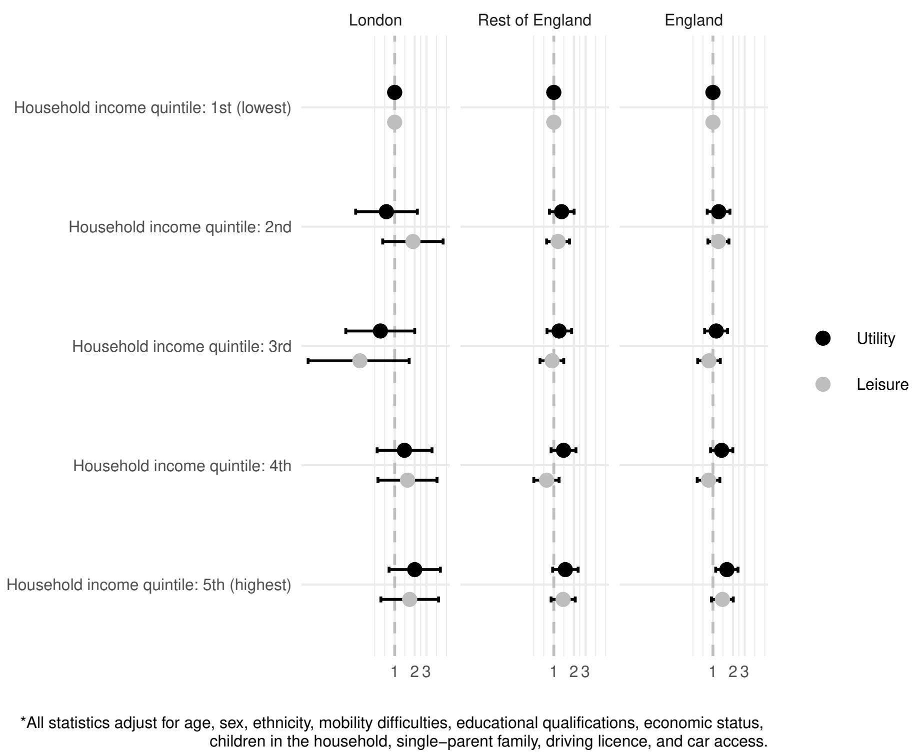

Figure 6: Forest plot displaying exponentiated ORs (95% CI) of utility and leisure cycling participation by household income quintile and by geographical area.

4 Discussion

This paper examined the extent to which income and other factors of socioeconomic disadvantage are related to cycling behaviour based on a large household travel survey in a wealthy country with a car-dominated transport system (England). Descriptive statistics and regression models enabled explorations of the associations between socioeconomic variables and three dependent variables (cycling participation, cycling frequency, and cycling distance) for both utility and leisure cycling.

Table 3: Associations with leisure cycling participation, leisure cycling frequency, and leisure cycling distance

	Cycling participation	Cycling frequency	Cycling distance
	Binomial model [a] OR (95% CI)[d]	Zero-truncated model [b] OR (95% CI)	Gamma model [c] OR (95% CI)
Household income quintile: 1st (lowest)	1	1	1
Household income quintile: 2nd	1.21 (0.84, 1.74)	0.90 (0.69, 1.18)	1.35 (0.91, 2.00)
Household income quintile: 3rd	0.87 (0.59, 1.29)	0.70 (0.52, 0.95) *	1.09 (0.71, 1.66)
Household income quintile: 4th	0.86 (0.58, 1.27)	0.63 (0.45, 0.86) **	0.95 (0.62, 1.47)
Household income quintile: 5th (highest)	1.39 (0.95, 2.02)	0.81 (0.60, 1.08)	1.55 (1.03, 2.35) *
Educational qualifications: Yes	1	1	1
Educational qualifications: No	0.54 (0.37, 0.78) **	1.00 (0.75, 1.34)	0.60 (0.39, 0.91) *
Economic status: Full Time	1	1	1
Economic status: Part Time	1.82 (1.31, 2.52) ***	1.48 (1.15, 1.89) **	0.93 (0.65, 1.33)
Economic status: Unemployed	2.02 (0.99, 4.13)	1.79 (1.09, 2.92) *	2.65 (1.19, 5.89) *
Economic status: Student	2.99 (1.86, 4.80) ***	0.49 (0.30, 0.79) **	1.29 (0.74, 2.25)
Economic status: Economically inactive	1.24 (0.86, 1.80)	1.20 (0.92, 1.58)	1.25 (0.85, 1.85)
Children in the household: Yes	1	1	1
Children in the household: No	1.20 (0.93, 1.55)	0.89 (0.72, 1.10)	0.89 (0.66, 1.19)
Single parent family: Yes	1	1	1
Single parent family: No	2.06 (0.60, 7.07)	1.48 (0.53, 4.12)	0.64 (0.16, 2.53)
Driving licence: Yes	1	1	1
Driving licence: No	0.72 (0.51, 1.01)	0.95 (0.72, 1.26)	0.93 (0.64, 1.37)
Car access: Yes	1	1	1
Car access: No	1.90 (1.39, 2.59) ***	1.39 (1.10, 1.77) **	1.07 (0.76, 1.50)
Area type: Inner London	1	1	1
Area type: > 250k	1.42 (0.88, 2.31)	1.08 (0.74, 1.58)	1.18 (0.71, 1.97)
Area type: 25k to 250k	0.97 (0.61, 1.54)	1.09 (0.75, 1.58)	0.81 (0.50, 1.33)
Area type: 10k to 25k	0.58 (0.31, 1.10)	1.18 (0.71, 1.97)	1.37 (0.69, 2.72)
Area type: 3k to 10k	1.27 (0.72, 2.26)	1.05 (0.66, 1.67)	1.36 (0.73, 2.53)
Area type: Built-up areas	0.82 (0.51, 1.30)	1.13 (0.78, 1.64)	1.35 (0.82, 2.22)
Area type: Rural	0.65 (0.38, 1.12)	1.25 (0.81, 1.91)	1.20 (0.67, 2.16)
Age: 16-29	1	1	1
Age: 30-64	1.53 (1.12, 2.09) **	1.06 (0.80, 1.39)	1.39 (0.94, 2.05)
Age: >64	0.72 (0.43, 1.18)	1.10 (0.74, 1.63)	1.08 (0.61, 1.92)
Sex: Male	1	1	1
Sex: Female	0.40 (0.31, 0.50) ***	0.85 (0.70, 1.03)	0.61 (0.47, 0.79) ***
Ethnicity: White	1	1	1
Ethnicity: Non-white	0.26 (0.16, 0.44) ***	1.19 (0.76, 1.87)	0.35 (0.19, 0.66) **
Mobility difficulties: Yes	1	1	1
Mobility difficulties: No	1.92 (1.07, 3.43) *	0.72 (0.47, 1.09)	0.86 (0.45, 1.66)
n	11581	332	332
Pseudo R-squared (Nagelkerke)	0.08	0.2	0.22

[a] The binomial model estimates the association between the independent variables and leisure cycling participation (yes/no weekly leisure cycling).

[b] The zero-truncated negative binomial model estimates the association between the independent variables and cycling frequency of those who participated in weekly leisure cycling.

[c] The gamma model estimates the association between the independent variables and miles travelled by bicycle for those who participated in weekly leisure cycling.

[d] OR (95%) = Odds ratio and 95% confidence intervals.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

4.1 Findings from the descriptive statistics

An interesting and unexpected finding from the descriptive statistics was that, people in the lowest household income quintile make a quarter as many commuting cycling trips as people in the highest household income quintile. This might be partly explained by the fact that low-income populations tend to be proportionally less economically active (see the gradient in the economic status rows by income quintile in Table 1). This finding may have important policy implications, given that urban cycling planning tend to focus on commuting, which might be reinforcing inequalities in cycling rather than providing diversity (Golub, 2016).

The descriptive analysis also highlights the importance of bicycle ownership and access, which increases uniformly with household income. Only two in ten individuals in the 1st income quintile own or have use of a bicycle, compared to five in ten in the 5th quintile. This corresponds with findings from the US (National Highway Traffic Safety Administration, 2008). In this sense, qualitative research on barriers to cycling among disadvantaged populations found that not having a bicycle or finding it too expensive is one of the main barrier to cycling among disadvantaged groups (McNeil et al., 2017). Moreover, bike share schemes (BSS), an increasingly widespread way of giving people access to bicycles, have been found to be geographically closer to higher socioeconomic areas (e.g. Ursaki and Aultman-Hall, 2015; Ricci, 2015). These findings suggest that measures to provide access to working bicycles such as via the implementation of BSS and funding for bicycle repair (e.g. Big Bike Revival) may contribute to reducing barriers to cycling, especially for low-income groups.

4.2 Findings from the multivariate analyses

4.2.1 Cycling and household income

Our model predicting utility cycling participation showed that individuals from the highest household income quintile were more likely to engage in utility cycling. This corresponds with previous findings from the UK and Australia (Green et al., 2010; Heesch et al., 2014). However, research from North American countries found no association (Dill and Carr, 2003; Xing et al., 2010) or a negative association between income and utility cycling (Pucher et al., 2011; Winters et al., 2010, 2007). Contrary to our expectations, we found no significant association between income and leisure cycling participation. This differs from a study in press based on the Active Travel Survey that found that people living in most deprived areas in England engage significantly less in leisure cycling than people living in non-deprived areas (blinded reference), and from international research that found that lower-income groups tend to cycle less for leisure (Heesch et al., 2015, 2014; Kamphuis et al., 2008). Finally, we also found that low-income leisure cyclists cycle more frequently than higher-income leisure cyclists, but higher-income leisure cyclists cycle further. This is consistent with previous research in London that found that higher-income cyclists cycle longer distances (Green et al., 2010) and with the growth of long-distance sport cycling among the higher classes (e.g. D.G., 2013; Dirs, 2014).

4.2.2 Cycling and other socioeconomic factors associated with disadvantage

Educational qualifications were neither positively or negatively associated with utility cycling participation, but negatively associated with leisure cycling participation. A similar conclusion was drawn in a recent study conducted in England using the Active Travel Survey (Goodman and Aldred, 2018). According to that study, individuals with higher educational levels were found more likely to participate in leisure cycling, but within most English local authorities this association was absent for utility cycling. We also found a negative association between low education and cycling distance for leisure. By contrast, Xing et al. (2010), who also studied the associations between education and cycling distance, found education associated with cycling distance for transport but not for leisure.

Several categories of economic status were found associated with cycling behaviour for both utility and leisure cycling. It is worth highlighting the higher likelihood of utility cycling participation and frequency, and leisure cycling participation among part-time workers. These populations might tend to live closer to their work and have more spare time for recreational activities (Office for National Statistics, 2017). However, previous studies found that part-time employment was associated with utility cycling, but not with recreational cycling (Heesch et al., 2014). More spare time could also explain the higher likelihood of unemployed population to participate and cycle more frequently for leisure. Surprisingly, students were found significantly positively associated with leisure cycling participation, but not with utility cycling. In addition, students cyclists were found to cycle less frequently for both utility and leisure cycling, and shorter distances for utility. This supports previous research indicating that workers cyclists cycle longer distances than students cyclists (Larsen et al., 2010). Cyclists economically inactive were found to cycle less frequently and shorter distances for utility than cyclists working full-time. This might be because the former make no commuting trips.

Lacking car access was strongly positively associated with utility cycling participation, utility cycling frequency, and utility cycling distance. Contrary to previous research (e.g. Goodman and Aldred, 2018; Heesch et al., 2014), this variable was also positively associated with leisure cycling participation and leisure cycling frequency.

4.2.3 Cycling and other socio-demographic variables

The associations found regarding the control variables broadly supports prior findings. Built-up areas and urban areas between 10k to 25k inhabitants were associated with less utility cycling participation, and rural areas with less utility cycling participation and with less utility cycling frequency. Similarly, Harms et al. (2014) found that people living in rural areas in the Netherlands cycled less often, although this difference was not found for leisure cycling. Pucher et al. (2011) also reported lower levels of cycling to work in rural areas in the US, however, he found higher levels of recreational cycling in these areas. Age was only associated with cycling leisure participation, although previous studies found it also associated with utility and commuting cycling (Goodman and Aldred, 2018; Green et al., 2010; Heinen et al., 2010; Pucher et al., 2011; Winters et al., 2010). A strong negative association was found between females and both utility and leisure cycling participation. Negative associations of similar magnitude were found in previous studies (Goodman and Aldred, 2018; Handy and Xing, 2011; Heesch et al., 2012). Females were also significantly associated with cycling shorter distances. This supports Heesch et al. (2012) and Larsen et al. (2010). The even higher strong association between ethnicity and utility and leisure cycling participation also agrees with previous studies in the UK and the Netherlands (Goodman and Aldred, 2018; Harms, 2007; Parkin et al., 2008). Finally, no mobility difficulties were significantly positively associated with both utility and leisure cycling participation. This corroborates previous research as well (Andrews et al., 2018; Clayton et al., 2017; Goodman and Aldred, 2018).

4.3 Strengths and limitations

The strengths of this paper include the use of well-established national data set with a large representative sample, an in-depth focus on income and other socioeconomic inequalities on cycling, distinguishing between cycling participation, cycling frequency, and cycling distance as well as between leisure and utility cycling. Nevertheless, this paper has several limitations. First, despite the advantages of using the NTS, the sample size for the cycling frequency and distance models was relatively small. This may result in less reliable estimation and less likely identification of significant relationships. Second, the measurement of leisure cycling in the NTS is poor. The NTS only collects data on the public highway, excluding cycling leisure travel across open countryside on unsurfaced paths such as mountain biking. Consequently, the findings regarding leisure cycling should be interpreted cautiously. Third, since the dependent variable cycling participation refers to individuals who did or did not cycle in a specific week, the binary model might have considered as not cyclists a few regular cyclists that for any reason (e.g. illness, bad weather, bicycle in repair, etc.) did not cycle during that specific week. In the same way, the model could have considered as regular cyclists, occasional cyclists who for whatever reason cycled in that week. Fourth, the models presented may be omitting powerful explanatory variables not available in the NTS that might affect cycling behaviour and perhaps some of our explanatory variables. For example, cultural background or attitudes and social norms.

4.4 Further research

The results presented in this paper clearly show that there is no simple, universal, relationship between cycling and disadvantage. Our findings raise further questions and suggest directions for future research. The finding that people in low-income households cycle substantially more for non-commuting than for commuting purposes raises the question: why? The paper provides a motivation for qualitative research into the extent to which the perceptions of decision-makers about cycling and disadvantage reflect the evidence: we hypothesise that decision-makers under-estimate the importance of leisure and non-commuting cycling for people from low-income households. Further modelling work could explore interaction effects: do the impacts of explanatory variables depend on the state of a second variable? In particular, the interactions between income and car ownership, having children and gender, income and education, education and ethnicity and cycling could offer interesting additional insights. Two other interesting unanswered questions are how have the relationships between cycling and social disadvantage changed over time and why.

5 Conclusions

The research reported in this paper reveals that people in lower-income households participate less in utility cycling, particularly in commuting cycling, than people in higher-income households. Contrary to prior expectations, no income inequalities were found for leisure cycling participation. In addition, low-income leisure cyclists were found to cycle relatively more frequently, but higher-income leisure cyclists further. Other remarkable findings are that less educated people participate less in leisure cycling and cycle shorter distances for leisure; part-time workers participate more in utility and leisure cycling and cycle more frequently for utility; students participate more in leisure cycling but cycle less frequently and shorter distances for utility; and people with no car participate and cycle more often for utility and leisure cycling, and cycle further for utility. The study also shows a substantial disparity in bicycle ownership and access by income household quintile.

These findings may have important policy implications, given that much investment in cycling seems to be based on the premise that building infrastructure for utility cycling (commuting in particular) is the best way to get people cycling. Data from the National Travel Survey shows that commuter cycling participation rise continuously with household income, meaning that alternative interventions such as greenways and a dense, connected and permeable network created by 'low traffic neighbourhoods' may be more beneficial to low-income groups than major arterial routes (cycle-superhighways) aimed to commuter cyclists. Our findings also suggest that bicycle ownership and maintenance support could be key for cycling inclusion.

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