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Socioeconomic inequalities in cycling safety: An analysis of cycling injury risk by residential deprivation level in England

Abstract

Introduction: Previous studies have found a positive association between cycling injury risk and residential deprivation. However, most of these studies focused on serious and fatal injuries, children, and a specific point in time. This study explores i) inequalities in cycling injury risk by residential deprivation for all recorded casualties (slight, serious, and fatal) in England, ii) whether these inequalities vary by sex and age, and iii) how they have changed over time.
Methods: Using the STATS19 database of road traffic casualties in Britain, the English National Travel Survey, and population estimates for England over the six-year period 2014-2019, we estimated the ratio of slight, serious, and fatal cycling casualties per billion kilometres cycled by residential Index of Multiple Deprivation (IMD) quintile; by residential IMD quintile and sex and age group; and by residential IMD quintile and year.
Results: We found that the higher the level of residential deprivation, the higher the slight and serious cycling injury risk. The fatal cycling injury risk was also higher in individuals from the most deprived areas. Inequalities were particularly large for children, with slight and serious rates three times higher for children from the most deprived areas than for children from the least deprived areas. We also found that the linear trend lines of the slight and serious injury rates between 2014 and 2019 declined in the least deprived quintiles but not in the most deprived quintiles, which suggests that inequalities in slight and serious cycling injuries may have grown over the last years.
Conclusion: This study found that people from deprived areas are at higher risk of cycling injury for all types of severity; that children from deprived areas are most at risk; and that these inequalities may have recently increased.

Keywords: Cycling; Road traffic injury; Deprivation; Inequalities; Trends.

1. Introduction

Cycling has important health benefits (Oja et al., 2011), but it also involves injury risks. Although in Western countries such as the UK, the Netherlands, and Denmark it has been shown that benefits outweighed the risks (Hartog et al., 2010; Andersen et al., 2018), safety concerns are still one of the main barriers to cycle (Jacobsen et al., 2009; Horton, 2007; Pooley et al., 2013). Neither the benefits nor the risks of cycling are evenly distributed (Mackett and Thoreau, 2015; Rebentisch et al., 2019). People living in the most deprived areas in the UK have been found to cycle less than people living in less deprived areas (Steinbach, Green, et al., 2011; Parkin et al., 2008; Vidal Tortosa et al., 2021b; Vidal Tortosa et al., 2021a). Research also suggests that people living in the most deprived areas are at a higher risk of injury while cycling (and also while travelling by other modes) (Edwards et al., 2008; Feleke et al., 2018; O'Toole and Christie, 2018).

Most studies that have explored the association between residential level of deprivation and cycling injury risk focus on serious and/or fatal injuries, children, and a specific point in time. For example, Edwards et al. (2008) analysed serious road traffic injuries in children (aged 0 to 15) using Hospital Episode Statistics (HES) data. They found a higher risk of being seriously injured in child cyclists from deprived areas (child cyclists seriously injured/100.000 children) than in child cyclists from less deprived areas in England. O'Toole and Christie (2018) compared fatal and serious road traffic injuries between children aged 4 to 10 and children aged 11 to 15 using the STATS19 database. This study found that child cyclists aged 4 to 10 from the most deprived areas in England were particularly at high risk of being killed or seriously injured (child cyclist KSI/100.000 children). It also found that this risk was much higher in male than in female child cyclists, particularly in the most deprived areas. Feleke et al. (2018), who analysed inequalities in fatal road traffic injuries not only in children but also in adults using Office for National Statistics (ONS) data, found that child cyclists from the most deprived areas in England had higher risk of being fatally injured adjusting for both distance and time (child cyclist fatalities/billion km cycled and child cyclist fatalities/million hours cycling). They did not find, however, significant differences between adult cyclists of any age group.

Nonetheless, several questions remain unanswered. First, there has been little research into socioeconomic inequalities in minor cycling injuries. Previous studies focused on serious and/or fatal casualties. This is mostly because these studies compared the injury risk among different modes of transport and given that minor cycling injuries are exceptionally under-reported (Mindell et al., 2012; DfT, 2018), they are not directly comparable. Second, little is known on whether there are socioeconomic inequalities in serious cycling injuries in adults. Feleke et al. (2018) found no significant differences in the risk of dying while cycling in adults, however, the number of cycling fatalities might be too small to show whether cycling is overall more dangerous for a specific socioeconomic group of adults. Third, it is also unknown whether potential socioeconomic inequalities in

cycling injury risk in adults vary by sex and age, as it does in children (O'Toole and Christie, 2018). Finally, no prior study has explored, to the best of our knowledge, trends of socioeconomic inequalities in cycling injury risk.

This study explores: i) inequalities in cycling injury risk by residential deprivation for all recorded casualties (slight, serious, and fatal) in England, ii) whether these inequalities vary by sex and age, and iii) how they have changed over time. Better understanding socioeconomic inequalities in cycling safety can support evidence-based policies to make cycling safer for all, and given the importance that safety concerns have on the choice of people to cycle, it could also be critical in addressing existing inequalities in cycling levels. Effective interventions to make cycling safer among people living in deprived areas could, therefore, have a double positive impact on the health of these groups: reducing their disproportionately high risk of being injured in traffic collisions and increasing their physical activity through greater participation in transport and leisure cycling.

2. Data and methods

2.1. Data

Three datasets for the six-year period 2014-2019 were used for this study: the STATS19 database of road traffic casualties in Britain, the National Travel Survey Special Licence Access (NTS), and Population estimates for England from the Office of National Statistics (ONS).

To prepare the casualty data, we transformed two variables of the STATS19 database: residential Index of Multiple Deprivation (IMD) decile[1] into residential IMD quintile (Q1 [most], Q2, Q3, Q4, Q5 [least]), and age into age group (<16, 16-29, 30-64, >64). This was done to increase sample size. Next, we removed all casualty records with no residential IMD decile, sex, and age group; and due to a change in the systems for severity reporting in 2016, we performed an adjustment on the slight and serious casualties. For this, we used a method developed by the ONS (ONS, 2019). Then, we aggregated the slight, serious, and fatal cycling casualties[2] by residential IMD quintile, sex/residential IMD quintile, age group/residential IMD quintile, and year/residential IMD quintile.

[1]Residential IMD decile refers to the level of deprivation of small administrative areas (Lower-layer Super Output Areas) of England where casualties lived at the time of the incident. IMD scores are based on seven domains of deprivation: Income Deprivation, Employment Deprivation, Education, Skills and Training Deprivation, Health Deprivation and Disability, Crime, Barriers to Housing and Services, and Living Environment Deprivation (DfCLG, 2015).

[2]Slight casualties are individuals involved in a road collision who as a consequence had an injury not requiring medical treatment. Seriously casualties are individuals involved in a road collision who as a consequence were detained in hospital as an "in-patient", or had any of the following injuries whether or not they were detained in hospital: fractures, concussion, internal injuries, crushings, burns (excluding friction burns), severe cuts, severe general shock requiring medical treatment and injuries causing death 30 or more days after the accident. Fatal casualties are individuals involved in a road collision who sustained injuries from the collision which caused death less than 30 days after the incident (DfT, 2017).

To prepare the exposure data (billion kilometre [Bkm] cycled), we calculated the weekly miles cycled per individual (weighted for drop-off in recording observed). For this, we used the file 'Stage' from the NTS. Next, we aggregated this variable by residential IMD quintile, sex/residential IMD quintile, age group/residential IMD quintile, and year/residential IMD quintile (weighted to adjust for non-response). Then, we divided each of these figures by the number of individuals in the NTS sample for each of these groups, and multiply them by the population estimates for England. To scale the weekly miles cycled to the full year and covert it into kilometres, we multiplied these figures by 52.14 and 1.61. Finally, we divided them by 1 billion.

There is a debate in the literature about which unit of exposure is the most appropriate for calculating road traffic injury rates. Distance travelled and time spent travelling are the most common (Vanparijs et al., 2015). Time spent travelling seems the most appropriate to compare the injury risk of different modes of transport. This is because distance travelled does not capture the substantial differences in average speed by modes of transport (for example, between drivers, cyclists, and pedestrians), and its use may lead to misleading comparisons (Mindell et al., 2012). We considered, however, distance travelled (Bkm cycled) the most appropriate measure of exposure for this study for three reasons. First, we do not compare the injury risk of different modes of transport. Second, distance travelled can be directly obtained from the NTS. Third, distance travelled is the most commonly used denominator in official documents (e.g. DfT, 2020; ETSC, 2020), which makes our findings more comparable.

2.2. Analysis

To examine inequalities in cycling injury risk by residential deprivation, we estimated slight, serious, and fatal cycling injury rates as the ratio of slight, serious, and fatal cycling casualties per Bkm cycled by residential IMD quintile. To explore whether these inequalities vary by sex and age, we stratified these rates by sex and age group. Numerators and denominators of these rates combined the six-year period 2014-2019 to increase the accuracy of estimates. Finally, to analyse how inequalities in cycling injury risk by deprivation level changed over time, we calculated slight, serious, and fatal cycling injury rates by residential IMD quintile and year from 2014 to 2019.

Ninety-five percent confidence intervals (95% CIs) of each of these rates were computed using exact Poisson confidence limits based on the link between the Chi square and the Poisson distributions, in line with previous research (e.g. Bouaoun et al., 2015). The NTS sample of cyclists used for calculating the denominators (Bkm cycled) for each of the rates was in all cases 35 or over.

3. Results

3.1. Cycling injury rates by residential IMD quintile

Table 1 shows the number of slight, serious, and fatal cycling casualties as well as the Bkm cycled by residential IMD quintile for the entire period 2014-2019. Figure 1 depicts the resulting rates.

The slight cycling injury rate increases with deprivation, with almost twice the number of slight casualties per Bkm cycled in the most deprived quintile (Q1) than in the least deprived (Q5) (Figure 1A). The serious cycling injury rate also increases with deprivation, although, in this case, the gradient is slightly less pronounced (Figure 1B). The fatal cycling injury rate does not gradually increase with deprivation, although the highest is in people from the most deprived quintile (Q1) (Figure 1C). Note that the small number of fatal injuries makes the results of this rate less reliable, and, as we can see in Figure 1C, the 95% CIs overlap, indicating that the differences among quintiles are most likely not significant.

Table 1: Slight, serious, and fatal cycling casualties and Bkm cycled by residential IMD quintile, 2014-2019.

IMD quintile	Slight cycling casualties	%	Serious cycling casualties	%	Fatal cycling casualties	%	Bkm cycled	%
Q1 (most)	15242	23.1	4514	21.2	82	18.7	4.9	16.5
Q2	15823	24.0	4479	21.0	72	16.4	6.1	20.6
Q3	12536	19.0	4005	18.8	84	19.1	5.8	19.6
Q4	11408	17.3	4128	19.4	101	23.0	6.4	21.4
Q5 (least)	10978	16.6	4192	19.7	100	22.8	6.5	21.9

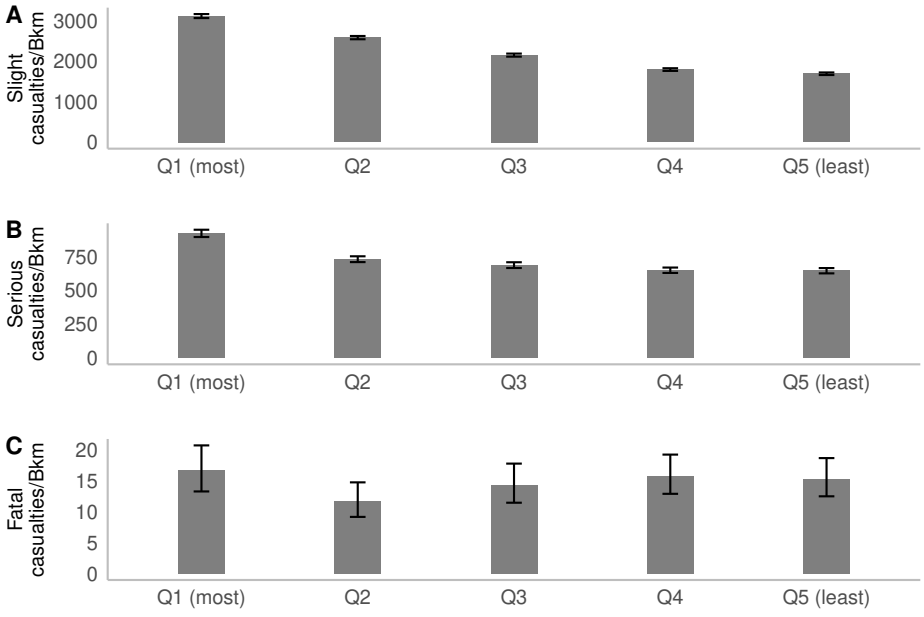

Figure 1: Slight, serious, and fatal cycling injury rates by residential IMD quintile, 2014-2019. The error bars show 95% confidence intervals.

3.2. Cycling injury rates by residential IMD quintile and sex and age groups

Tables 2 and 3 present the number of slight, serious, and fatal cycling casualties and the Bkm cycled by residential IMD quintile and sex, and by residential IMD quintile and age group for the entire period 2014-2019. Figures 2 and 3 show their associated cycling injury rates.

The slight cycling injury rate is very similar for males and females across all the quintiles (Figure 2A). The serious cycling injury rate is higher for males across all the quintiles, being the difference significant in Q1, Q4, and Q5 (Figure 2B). The fatal cycling injury rate is higher for males in most quintiles, although, as the 95% CIs indicate, the differences among quintiles may not be significant (Figure 2C).

Table 2: Slight, serious, and fatal cycling casualties and Bkm cycled by residential IMD quintile and sex, 2014-2019.

IMD quintile	Sex	Slight cycling casualties	%	Serious cycling casualties	%	Fatal cycling casualties	%	Bkm cycled	%
Q1 (most)	Female	2920	19.2	697	15.4	12	14.6	0.9	19.0
	Male	12322	80.8	3817	84.6	70	85.4	4.0	81.0
Q2	Female	3334	21.1	858	19.2	14	19.4	1.2	20.0
	Male	12489	78.9	3621	80.8	58	80.6	4.9	80.0
Q3	Female	2709	21.6	764	19.1	17	20.2	1.2	20.4
	Male	9827	78.4	3241	80.9	67	79.8	4.7	79.6
Q4	Female	2384	20.9	761	18.4	19	18.8	1.5	22.9
	Male	9024	79.1	3367	81.6	82	81.2	4.9	77.1
Q5 (least)	Female	2103	19.2	695	16.6	10	10.0	1.3	19.8
	Male	8875	80.8	3497	83.4	90	90.0	5.2	80.2

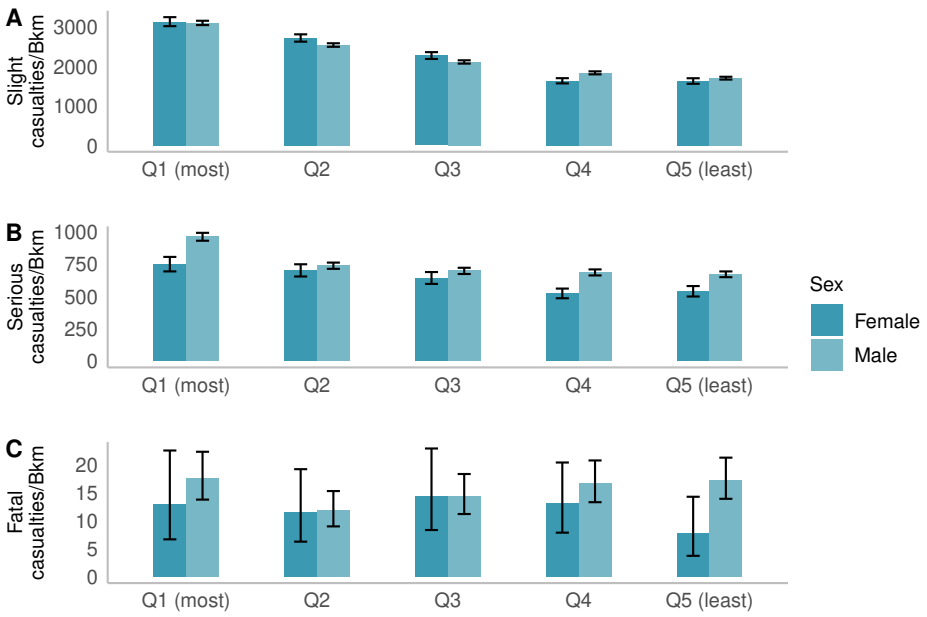

Figure 2: Slight, serious, and fatal cycling injury rates by residential IMD quintile and sex, 2014-2019. The error bars show 95% confidence intervals.

The slight cycling injury rate is higher in younger age groups and especially in those living in the most deprived areas. This rate is more than three times higher in children (aged <16) from the most deprived quintile (Q1) than in children from the least (Q5) (Figure 3A). The serious cycling injury risk seems more similar by age group, although it is still three times higher in children from the most deprived quintile (Q1) than in children from the least (Q5) (Figure 3B). The fatal cycling injury risk increases with age: the older the individuals, the higher the risk to die while cycling. Although, interestingly, this does not seem to be the case in the most deprived quintile (Q1), where all age groups have a quite similar fatality rate (Figure 3C). Notice also that the fatal injury rate in older people from the most deprived quintile (Q1) is lower than in older people from the rest of quintiles.

Table 3: Slight, serious, and fatal cycling casualties and Bkm cycled by residential IMD quintile and age groups, 2014-2019.

IMD quintile	Age	Slight cycling casualties	%	Serious cycling casualties	%	Fatal cycling casualties	%	Bkm cycled	%
Q1 (most)	<16	2343	15.4	662	14.7	9	11.0	0.4	7.5
	16-29	5384	35.3	1403	31.1	18	22.0	1.5	30.4
	30-64	7283	47.8	2311	51.2	49	59.8	2.8	56.4
	>64	232	1.5	138	3.1	6	7.3	0.3	5.6
Q2	<16	1699	10.7	437	9.8	2	2.8	0.5	8.1
	16-29	5304	33.5	1210	27.0	9	12.5	1.6	26.3
	30-64	8489	53.6	2609	58.3	43	59.7	3.7	60.9
	>64	332	2.1	222	5.0	18	25.0	0.3	4.6
Q3	<16	1197	9.6	318	7.9	3	3.6	0.4	7.4
	16-29	3697	29.5	977	24.4	11	13.1	1.0	17.5
	30-64	7229	57.7	2442	61.0	46	54.8	3.9	66.6
	>64	413	3.3	268	6.7	24	28.6	0.5	8.5
Q4	<16	1022	9.0	306	7.4	6	5.9	0.4	6.0
	16-29	2993	26.2	794	19.2	13	12.9	1.0	16.3
	30-64	6876	60.3	2707	65.6	54	53.5	4.3	67.7
	>64	517	4.5	321	7.8	28	27.7	0.6	10.1
Q5 (least)	<16	996	9.1	263	6.3	7	7.0	0.5	7.5
	16-29	2407	21.9	673	16.1	7	7.0	1.0	14.6
	30-64	7010	63.9	2850	68.0	58	58.0	4.2	65.3
	>64	566	5.2	405	9.7	28	28.0	0.8	12.6

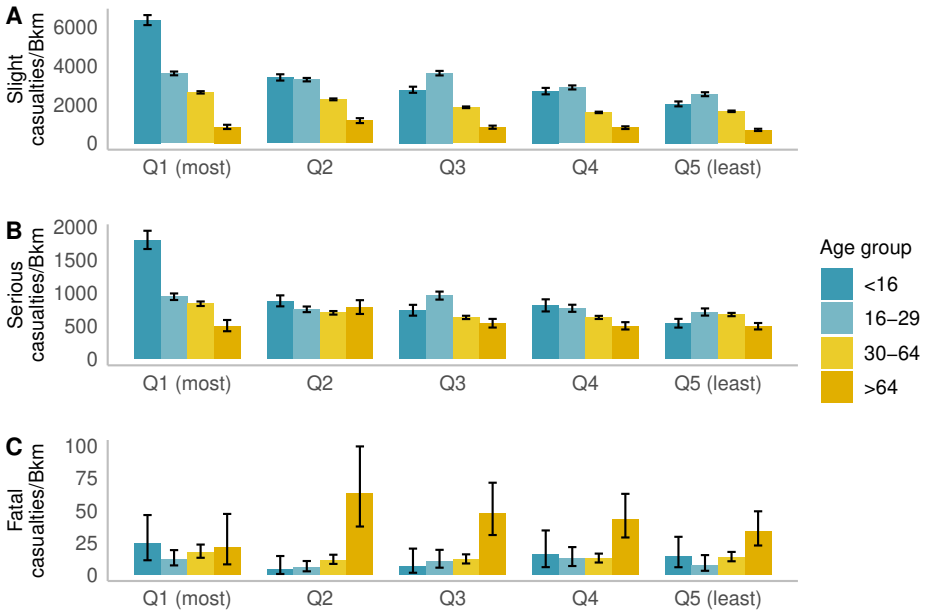

Figure 3: Slight, serious, and fatal cycling injury rates by residential IMD quintile and age group, 2014-2019. The error bars show 95% confidence intervals.

3.3. Time trend of cycling injury rates by residential IMD quintile

Table 4 shows the number of slight, serious, and fatal cycling casualties and the Bkm cycled by residential IMD quintile and year from 2014 to 2019. Figure 4 reveals the trends of their associated rates.

The linear trend lines of the slight injury rate decline in all the quintiles, except in the two most deprived (dots and triangles in blue) that remain flat (Figure 4A). Similarly, the serious injury rate declines in most of the quintiles, but less in the second most deprived (Q2) and it slightly increases in the most deprived (Q1) (Figure 4B). The number of fatal cycling casualties broken down by IMD quintile and year is very small, and therefore it is impossible to draw any conclusions about their relative trends over time in different quintiles (Figure 4C).

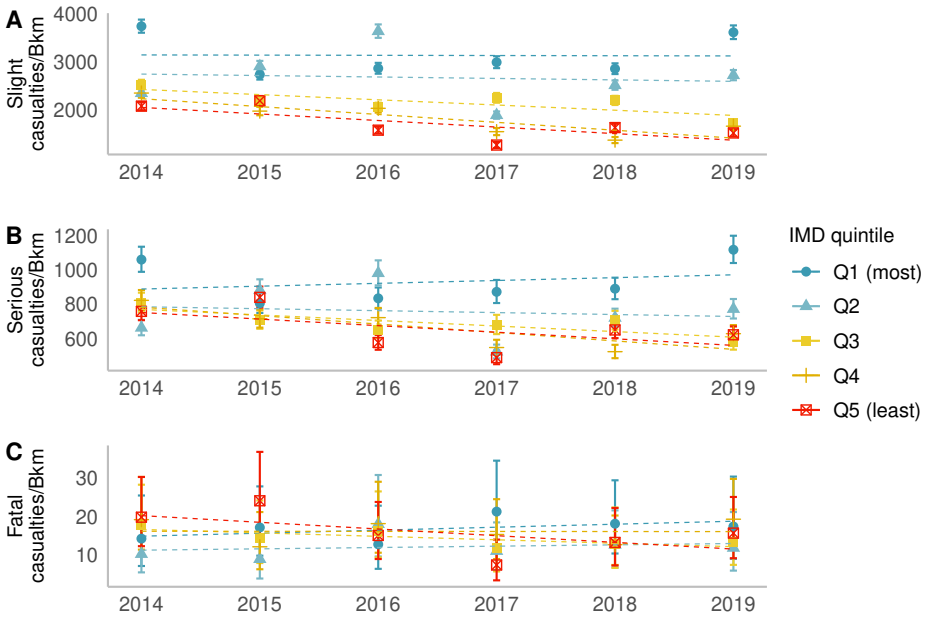

Figure 4: Slight, serious, and fatal cycling injury rates by residential IMD quintile and year, 2014-2019. The error bars show 95% confidence intervals. The lines show the linear trend.

4. Discussion

4.1. Summary of findings

The first aim of this study was to explore inequalities in cycling injury risk by residential deprivation for all recorded casualties (slight, serious, and fatal) in England. Substantial inequalities were found. The risk of slight and serious injuries while cycling increased gradually with the level of residential deprivation. The gradient was greater in slight injury rates than in serious injury rates. The risk of cycling fatality was also higher in individuals from the most deprived

Table 4: Slight, serious, and fatal cycling casualties and Bkm cycled by residential IMD quintile and year, 2014-2019.

IMD quintile	Year	Slight cycling casualties	%	Serious cycling casualties	%	Fatal cycling casualties	%	Bkm cycled	%
Q1 (most)	2014	2902	19.0	821	18.2	11	13.4	0.8	15.8
	2015	2565	16.8	753	16.7	16	19.5	0.9	19.1
	2016	2482	16.3	721	16.0	11	13.4	0.9	17.6
	2017	2259	14.8	658	14.6	16	19.5	0.8	15.4
	2018	2532	16.6	788	17.5	16	19.5	0.9	18.0
	2019	2502	16.4	773	17.1	12	14.6	0.7	14.1
Q2	2014	3001	19.0	845	18.9	13	18.1	1.3	20.8
	2015	2624	16.6	795	17.7	8	11.1	0.9	14.7
	2016	2635	16.7	709	15.8	13	18.1	0.7	11.8
	2017	2418	15.3	667	14.9	14	19.4	1.3	20.8
	2018	2601	16.4	743	16.6	13	18.1	1.0	16.8
	2019	2544	16.1	720	16.1	11	15.3	0.9	15.2
Q3	2014	2441	19.5	780	19.5	17	20.2	1.0	16.5
	2015	2132	17.0	690	17.2	14	16.7	1.0	16.7
	2016	2026	16.2	640	16.0	16	19.0	1.0	16.8
	2017	1905	15.2	574	14.3	10	11.9	0.8	14.5
	2018	2070	16.5	663	16.6	12	14.3	0.9	16.1
	2019	1963	15.7	657	16.4	15	17.9	1.1	19.5
Q4	2014	2216	19.4	774	18.7	18	17.8	0.9	14.8
	2015	1966	17.2	710	17.2	12	11.9	1.0	15.6
	2016	1914	16.8	678	16.4	17	16.8	0.9	14.7
	2017	1728	15.1	609	14.8	17	16.8	1.1	17.5
	2018	1853	16.2	704	17.1	17	16.8	1.3	21.1
	2019	1731	15.2	653	15.8	20	19.8	1.0	16.3
Q5 (least)	2014	2213	20.2	805	19.2	21	21.0	1.1	16.3
	2015	1916	17.5	734	17.5	21	21.0	0.9	13.4
	2016	1897	17.3	691	16.5	18	18.0	1.2	18.4
	2017	1559	14.2	598	14.3	9	9.0	1.2	18.8
	2018	1735	15.8	688	16.4	14	14.0	1.1	16.3
	2019	1658	15.1	676	16.1	17	17.0	1.1	16.7

areas. These findings support previous studies in England (e.g. Edwards et al., 2008; O'Toole and Christie, 2018).

A combination of environmental, social, and economic factors may explain these inequalities. Although this is an analysis based on the residence of the casualties, there is evidence that a large proportion of cycling injuries occur close to home (e.g. Steinbach et al., 2013). More intersections, homes without a play area, population density, street parking, road density, traffic volume, and a lack of safe crossing sites have been previously associated with higher road risk in deprived areas (Alwash and McCarthy, 1988; Christie et al., 2010; Green et al., 2011; Morency et al., 2012). However, deprived areas in England have

been also found to have a higher density of traffic calming measures and cycle tracks (Rodgers et al., 2010; Vidal Tortosa et al., 2021b; Steinbach, Grundy, et al., 2011), previously linked to lower cycling injury risk (Aldred et al., 2018; Teschke et al, 2012).

Another element to consider is the driving behaviour of motorists in deprived areas. Much of the research in cycling safety focuses on the environment and the cyclist. However, research on how drivers' behaviour affects cyclists risk is often neglected, even though drivers are the ones who endanger cyclists. Some existing studies show that motorists from deprived areas drive in a more aggressive and antisocial way (Braver, 2003; Hasselberg et al., 2005). Further research is needed to examine the impact that urban environments and driving misbehaviour in deprived areas may have on the safety of cyclists from these areas.

Social and economic factors may play an important role too. People from deprived areas, most of them with low incomes, are possibly more likely to own bicycles of poorer quality (e.g. with worse brakes, tyres, and lights), which might make a difference when facing dangerous road traffic situations. Furthermore, cyclists living in deprived areas have been found to have less access to safety equipment such as helmets (Kendrick, 2003; Sullins et al., 2014), which could increase the severity of their injuries considerably (Thompson et al., 1999).

The second aim of the study was to explore whether these inequalities vary by sex and age. We did not find important variations by sex; however, we found substantial variations by age group, particularly in children. Children from the most deprived quintile were found three times at a higher risk of slight and serious injury while cycling than children from the least deprived quintile. This finding supports previous research on cycling injury risk in children (Edwards et al., 2008; Embree et al., 2016; Feleke et al., 2018; O'Toole and Christie, 2018). By contrast, we found that the differences in the slight and serious rates in young and middle-aged adults by level of deprivation are smaller; and that the fatal rate for older people in the most deprived quintile is, in fact, lower.

This raises a policy-relevant question: why are these inequalities greater in children than in adults? This could be because in deprived areas there are more environments especially dangerous for children (e.g., more intersections, street parking, and unsafe crossings sites). Also, children who grow up in deprived areas might have fewer opportunities to ride safely and learn how to ride safely (e.g. less ability to buy safety equipment, less access to green and off-road safe spaces, less parental supervision, etc.) (Towner et al., 2005), which might contribute to making them less skilled and confident when cycling, particularly in their initial years of riding. Previous research found higher cycling injury risk among younger than older children from deprived areas (O'Toole and Christie, 2018). Differences in the type of cycling could also partly explain these inequalities. Hagel et al. (2015) found that the odds of hospitalisation were lower for children and adolescents who cycled to school, work, or shopping (utilitarian cycling) than for children and adolescents who cycled for other purposes. Further research is needed to explain why children from deprived areas are particularly at high risk of injury while cycling.

The final aim of the study was to explore how these inequalities have changed

over time. We found that between 2014 and 2019 the linear trend lines of the slight and serious injury rates slightly decreased in the least deprived quintiles, but not in the most deprived quintiles. This suggests that the inequalities in minor and serious cycling injuries may have increased in recent years. In other words, although since 2014 the risk of cycling injury in England seems to have overall declined (DfT, 2020), according to our data, it did decline among people from least deprived areas, but not among people from most deprived areas.

This finding may indicate that recent policies implemented to increase cycling safety have benefited more non-deprived than deprived populations. For instance, there may have been more investment in cycling infrastructure and traffic calming measures in less deprived areas in recent years. Steinbach, Grundy, et al. (2011) found that the implementation of 20 mph zones in London targeted at deprived areas, which led to a reduction in socioeconomic differences in road injury. However, they suggested that the potential of the implementation of these zones for further mitigation of inequality was limited. It is possible that later (during the years analysed in this study) these measures were implemented more in less deprived areas, which could have led to widening the disparities again.

Another explanation could be that cycle-friendly infrastructure implemented in recent years, regardless of its distribution, is more suitable for non-disadvantaged than for disadvantaged groups. A recent study (Vidal Tortosa et al., 2021a) found that low-income groups in England cycle far less for commuting, which suggests that commuting-centric cycling infrastructure, such as 'cycle superhighways', may be less convenient for low-income than for middle- and higher-income cyclists. Further research is needed to investigate whether the increase in inequalities in slight and serious injuries can be attributed to changes in the underlying probabilities of such injuries, and if so, why this increase may have occured. It would be also interesting to follow up on the trends in the coming years and, for example, analyse the impact that the 'emergency' Low Traffic Neighbourhoods, set up during Covid-19, have had on this regard.

4.2. Strengths and limitations

One strength of this paper is that it looked at four aspects not explored to date: socioeconomic inequalities in slight cycling injury risk; socioeconomic inequalities in serious cycling injury risk in adults; the variation of socioeconomic inequalities in cycling injury risk in adults by sex and age; and how socioeconomic inequalities in cycling injury risk have changed over time. Other strengths are that for the calculation of the cycling injury rates we adjusted for changes in the system for severity in 2016 and that we used Bkm cycled as a unit of exposure.

The paper has nevertheless several limitations. First, since cyclists have no obligation to inform the police about collisions (Mindell et al., 2012; DfT, 2018), the number of cycling incidents in the STATS19 database is particularly under-reported. If levels of reporting vary by deprivation level, this may have included a bias in our estimates of rates. Second, the variable postcode (and associated variable residential IMD quintile) was missing in 12% of the casualties, which were consequently removed from the analysis. If completion of this variable varies by deprivation levels, then this may have also introduced bias in

our results. Third, the variable residential IMD quintile refers to the level of deprivation of the area where individuals live, but not to the level of deprivation of individuals. Therefore, among the cycling casualties considered in each quintile there might be some from a different individual deprivation level (e.g. young high-income professionals living in gentrified deprived areas). Finally, although as we mentioned before, Bkm cycled seems the most adequate unit of exposure for the calculation of the rates of this study (because we do not compare different modes of transport, it is obtained directly from the NTS, and it is the most commonly used denominator in official documents), we should take into account that using this denominator we did not capture certain differences in the average speed by type of cyclist and trip.

5. Conclusions

This paper found substantial inequalities in cycling injury risk by residential deprivation level: the higher the level of residential deprivation, the higher the risk of slight and serious injuries while cycling. The risk of cycling fatality was higher in individuals from the most deprived areas too. The paper also reveals that these inequalities were particularly large for children, with slight and serious rates three times higher for children from the most deprived areas than for children from the least deprived areas. The differences in adults, however, were smaller, and older people from the most deprived areas presented a lower fatality rate than older people from less disadvantaged areas. Finally, we also found that the linear trend lines of the slight and serious injury rates between 2014 and 2019 declined in the least deprived quintiles but not in the most deprived quintiles, which suggests that inequalities in slight and serious cycling injuries may have grown over the last years.

The reasons for these inequalities are likely to be multifaceted and involve a combination of environmental, social, and economic factors. Further research is needed to investigate the impact that urban environments and driving misconduct have on the safety of cyclists from deprived areas, why children from deprived areas are particularly at high risk, whether the increase in inequalities in slight and serious injuries can be attributed to changes in the underlying probabilities of such injuries, and if so, why. Answers to these questions will help to find more effective policies to reduce the current safety gap between socioeconomic groups; and, in turn, make cycling more attractive among the disadvantaged.

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