An investigation into the relationships between ethnicity and child pedestrian injury in London

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ABSTRACT

Background: Previous research has identified higher pedestrian injury rates in London among 'Black' children and lower rates among 'Asian' children, compared to 'White' children. Whilst area affluence protects 'White' and 'Asian' from pedestrian injury, this is not true for 'Black' children. The mechanisms linking ethnicity, disadvantage and child pedestrian injury risk remain poorly understood.

Aims: To investigate a series of hypotheses about how ethnicity is related to pedestrian injury risk in London

Methods: Five studies analysed quantitative data sources to: (i) identify any ethnic differences in the quality of the road environment where children live; (ii) estimate the quantity of travel-time that children spend exposed to road traffic; (iii) examine whether night-time exposure is more hazardous for minority ethnic children; (iv) explore the relationship between ethnicity, deprivation and injury risk controlling for the quantity and quality of pedestrian exposure; and (v) examine whether 'group density' effects can shed light on the relationship between ethnicity, deprivation and injury risk.

Results: There was little evidence of differences in the quality of the road environment where 'White', 'Black' and 'Asian' children live. There was no evidence of a difference in the quantity of travel-time pedestrian exposure between 'White' and 'Black' children and some evidence that 'Asian' children walk less than their counterparts. There was no evidence that night-time exposure is more hazardous for minority ethnic children. Controlling for the quantity and quality of exposure changed the relationship between ethnicity, deprivation, and injury risk such that rates among 'Black' children were highest in the most affluent areas. 'Group density' effects may explain these findings.

Conclusions: The quantity and quality of exposure are important mediators of child pedestrian injury risk, although there was little evidence that they explain ethnic inequalities. The findings from this thesis suggest that that the meaning of pedestrian exposure plays a crucial role in complex pathways linking ethnicity to injury risk. Further investigation of individual causal explanations may have diminishing returns, given the evidence from this study that ethnic differences result from inter-related mechanisms.

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1 INTRODUCTION

1.1 CHILD PEDESTRIAN INJURY

Pedestrian injury is a leading cause of death and disability among children in Great Britain and internationally. Worldwide, road traffic crashes (many involving pedestrians) are the 8th leading cause of death among people under 20, killing more children per year than conditions such as malnutrition and tuberculosis (Peden, Oyegbite et al. 2008). In Britain alone, 1,545 young people under 16 were killed or seriously injured as pedestrians in 2012 (Department for Transport 2013).

Strong evidence from the epidemiological literature indicates that the risks of child pedestrian injury are not shared equally across populations. For example, many studies at the individual level have identified age as a risk marker for child pedestrian injury. Because these analyses tend to define age using different intervals, the literature is difficult to summarize. However, results do suggest that children aged between roughly 4 and 10 years are at higher risk of pedestrian injury compared to younger and older children (Howarth, Routledge et al. 1974, Jonah and Engel 1983, Rivara and Barber 1985, Dissanayake, Aryaija et al. 2009, Oxley, Jamaludin et al. 2012). Gender has also emerged as a salient risk factor for pedestrian injury in a number of individual level studies. There is clear consensus that boys face higher risks than girls (Howarth, Routledge et al. 1974, Rivara and Barber 1985, Joly, Foggin et al. 1991, Stevenson, Jamrozik et al. 1996).

Socio-economic differences in road traffic injury risks to child pedestrians are well reported in the literature in both individual (Mueller, Rivara et al. 1990, King and Palmisano 1992, Roberts 1997, Hasselberg, Laflamme et al. 2001, Edwards, Roberts et al. 2006) and ecological level studies (Rivara and Barber 1985, Braddock, Lapidus et al. 1991, Joly, Foggin et al. 1991, Bagley 1992, Kendrick 1993, Petch and Henson 2000, Hippisley-Cox, Groom et al. 2002, Graham and Glaister 2003, LaScala, Gruenewald et al. 2004, Graham, Glaister et al. 2005, Haynes, Jones et al. 2007, Edwards, Green et al. 2008, Graham and Stephens 2008, Wier, Weintraub et al. 2009).

According to a recent review, 23 out of 24 studies investigating the relationship between socio-economic disadvantage and child pedestrian injury risk found relatively disadvantaged children to be at higher risk than their more advantaged counterparts (Laflamme, Hasselberg et al. 2010). These findings were consistent across locations in Europe, Australia, North America and South America. Within the UK, studies have documented inequalities in child pedestrian injury risk by employment status at an individual level (Edwards, Roberts et al. 2006) and area deprivation at an ecological level (Grayling 2003, Edwards, Green et al. 2008). In London, evidence suggests that the pedestrian injury rate for children living in the most deprived areas of London was more than twice that of children living in the least deprived areas.(Edwards, Green et al. 2007)

Ethnic differences in injury risk have recently become the focus of a growing number of studies at both the individual level (Lawson and Edwards 1991, King and Palmisano 1992, Roberts, Norton et al. 1995, Campos-Outcalt, Bay et al. 2002, Stirbu 2006, Savitsky 2007, Abdel-Rahman, Siman-Tov et al. 2013) and at the ecological level (Braddock, Lapidus et al. 1991, Harrop, Brant et al. 2007). Table 1.1 highlights the results from 15 studies conducted in seven countries, including the UK and USA. Most studies suggest that children from minority ethnic groups have higher pedestrian injury risks than their majority ethnic counterparts(Rivara and Barber 1985, Braddock, Lapidus et al. 1991, Abdalla 2002, Campos-Outcalt, Bay et al. 2002, Stirbu 2006, Harrop, Brant et al. 2007, Savitsky 2007). Other research, however, has found that some minority ethnic groups have lower injury risk (Al-Madani and Al-Janahi 2006). Within the UK, 'non-white' children in various parts of the country (Christie 1995) and 'Asian' children in Birmingham (Lawson and Edwards 1991) have been found to be at greater risk of pedestrian injury compared to white children.

Studies have also explored interactions between age, gender and, socio-economic status and ethnicity in assessing the correlates of child pedestrian injury. Hasselberg and colleagues (2001), for instance, examined whether socio-economic differences in child pedestrian injury risk differed by gender in Sweden; they found socio-economic inequalities in risk among both boys and girls of a relatively similar magnitude. A study from Greece, by contrast, suggested that boys living in less wealthy towns are disproportionately disadvantaged compared to girls living in similar circumstances (Moustaki, Petridou et al. 2001).

1.2 The policy context of health inequalities in the UK

Policy makers with in the UK and worldwide have sought many different types of interventions (such as education, enforcement and engineering measures) to reduce both injuries overall and inequalities in injuries. While the literature suggests numerous predictors of injury risk, some differences in injury risk tend to be normalised within policy discourse while other are highlighted for intervention. This phenomenon is not unique to child pedestrian injury. The UK has a long-standing interest in inequalities in health outcomes. There are a number of national and regional policy incentives to examine evidence for inequalities in health, and a number of statutory agencies charged with working with communities to develop appropriate services to reduce inequalities (Department of Health 2003, Mayor of London 2008).

Table 1.1: Studies identifying ethnic differences in pedestrian injury risk

Country and Area	Authors, date	Study design	Outcome measure	Findings
Bahrain				
	(Al-Madani and Al-Janahi 2006)	Retrospective population study	Pedestrian injuries (all ages)	Bahrainis are more likely to be involved in pedestrian collisions than non-Bahrainis (p<.001)
Canada				
Alberta	(Harrop, Brant et al. 2007)	Retrospective population study	Child pedestrian fatality rates (aged 0-18)	Native children (Indians) had a much higher risk of pedestrian injury compared to non-Native children (rate ratio 6.9, 95% CI 4.1-11.2)
British Columbia	(Desapriya 2011)	Retrospective population study	Child pedestrian fatalities (aged 0-18)	Aboriginal children were overrepresented in fatality data (p=0.06)
Israel				
	(Savitsky 2007)	Retrospective population study	Child pedestrian hospitalisations (aged 0-17)	51% of non-Jewish child hospitalisations were for pedestrian injuries compared to 37% of Jewish child hospitalisations (chi-squared p<0.0001)
	(Abdel-Rahman 2013)	Retrospective population study	Child pedestrian hospitalisations (aged 0-17)	41.8% of Arab child hospitalisations were for pedestrian injuries compared to 33.4% of Jewish child hospitalisations (chi-squared p<0.0001).
Netherlands				
	(Stirbu 2006)	Retrospective population study	Pedestrian fatalities (aged 0-14)	Turkish, Moroccans and Surinamese had higher (but not statistically significant) pedestrian fatality risks compared to the native Dutch population (rate ratio 1.20, 95% CI 0.56-2.57)

Country and Area	Authors, date	Study design	Outcome measure	Findings
New Zealand				
	(Roberts, Norton et al. 1995)	Case-control study	Child pedestrian injury risk	Risks of child pedestrian injury were greater for Maori children (Odds ratio 1.87, 95% CI 0.98-3.58) and Pacific Islander children (Odds ratio 1.63, 95% CI 0.83-3.20) compared to white children
	(Hosking et al 2013)	Retrospective population study	Child pedestrian hospitalisations and fatalities (aged 0-14)	Per 100,000 children, rates of hospitalisations and deaths were higher for Maori (34.4, 95% CI 29.3-40.4) and Pacific (40.4, 95% CI 35.1-46.7) children compared to Asian (12.8, 95% CI 9.7-17.1) and NZE (13.3, 95% CI 11.3-15.6) children.
United Arab Emirates				
Dubai	(Abdalla 2002)	Retrospective population study	Pedestrian fatalities among young people (<30 years old)	Per 100,000 population, pedestrian fatality rates among non-U.A.E. population (4.9) were more than double the pedestrian fatality rates of native U.A.E. population (2.7).
UK				
London	(Steinbach, Green et al. 2010)	Retrospective population study	Child pedestrian injury rates (aged 0-15)	Per 100,000 children, pedestrian injury rates were higher in 'Black' children (176, 95% CI 172-181), than in either 'White' children (118, 95% CI 116-121) or in 'Asian' children (91, 95% CI 88-95)
Birmingham	(Lawson and Edwards 1991)	Retrospective population study	Child pedestrian injury rates (aged 0-14)	Rates of pedestrian injury per 1,000 children among Asian children aged 0-4 (2.2) and aged 5-9 (7.4) were higher than rates among Non-Asian children aged 0-4 (1.0) and aged 5-9 (3.8). Rates among Asian children aged 10-14 (3.4) were lower than rates among Non-Asian children aged 10-14 (4.1)
Selected areas	(Christie 1995)	Case-control study	Child pedestrian injury risk	'Non-white' children had higher risks of injury compared to 'White' children (odds ratio 2.02)

Country and Area	Authors, date	Study design	Outcome measure	Findings
USA				
Arizona	(Campos-Outcalt, Bay et al. 2002)	Retrospective population study	Child pedestrian fatality rates	Rates per 100,000 children were significantly higher ($p<0.01$) in American Indian males (4.62) and females (5.50) aged under 5, American Indian males aged 5-14 (5.22), and Hispanic males aged under 5 (1.98) compared to non-Hispanic white children of a similar age and gender.
Memphis, Tennessee	(Rivara and Barber 1985)	Ecological analysis	Census tracts with child pedestrian injuries (aged 0-14)	Census tracts with child pedestrian injuries had a higher percentage on non-white residents (5.7%) compared to census tracts without injuries (2.1%) ($p<0.001$)
Hartford, Connecticut	(Braddock, Lapidus et al. 1991)	Ecological Analysis	Frequency of child pedestrian injuries (aged 0-15) in census tracts	Census tracts with a high frequency of child pedestrian injuries had greater proportions of 'non-white' residents (85%) compared to moderate- (64%) and low-(39%) frequency tracts
Orange County, California	(Agran, Winn et al. 1996)	Retrospective population study	Child pedestrian injury hospitalization rates (aged 0-15)	Hispanic children had higher pedestrian injury hospitalization rates compared to non-Hispanic white children (Incident rate ratio 2.05, 95% CI 1.20-3.48)

Inequalities that become framed as 'social problems', and therefore potentially amenable to political solutions, have tended to drive both the research and policy agendas (Vallgårda 2008). In terms of child pedestrian injury, for instance, the greater vulnerability of boys compared to girls has been normalised in policy discourse. Instead, academics and policy makers have focused on reducing socio-economic inequalities in risk (Laflamme and Diderichsen 2000, Ward 2005, Kendrick, Mulvaney et al. 2009, Steinbach, Grundy et al. 2011). While the most appropriate strategies are under debate, improving "health and healthcare of the most disadvantaged in our society" remains a primary emphasis of public health policy (Department of Health 2003: p1). Among academics, "intervention studies that address inequalities in health are a priority area for future public health research" (Bambra, Gibson et al. 2010: p284).

Designating certain health inequalities as 'problematic' and others as 'normal' is not inevitable. Nor is this phenomenon consistent across place and time. For example, in her paper comparing policy discourse around social inequalities in health in Denmark, England, Norway and Sweden, Vallgårda (2008) argues that in England, the framing of social inequalities in health as a policy problem has recently shifted. Previously, such inequalities were examined in a gradient across the whole population, with health problems increasing with lower social class or lower education level. More recently, health inequalities are being viewed as a dichotomy, where one or another particular population is identified as being at a health disadvantage. This latter view provides the political context for much of today's academic and policy discourse surrounding ethnic inequalities in health.

1.3 BACKGROUND TO THE THESIS: RESEARCH ON ETHNIC INEQUALITIES IN CHILD PEDESTRIAN INJURY IN LONDON

Concerns about potential ethnic inequalities in road traffic injury permeated the policy agenda of Transport for London, the body responsible for delivering the Mayor of London's transport strategy (Mayor of London 2001) in 2006. In response, Transport for London commissioned the London School of Hygiene and Tropical Medicine to examine ethnic inequalities in road injury risk in London. A report on our findings was published in 2007 (Steinbach, Edwards et al. 2007). My role in this report was to prepare the data, conduct the statistical analysis and draft the report. The findings relating to child pedestrian injury from this report are the basis for the research questions addressed in my PhD.

Our report examined pedestrian injury rates for 'White', 'Black' and 'Asian' children in London from 1996-2006. Examining more than 19,000 pedestrian casualties involving children, we found that injury rates among 'Black' children were 50% higher than rates among 'White' children. Injury rates among 'Asian' children were substantially lower than that of children from other ethnic groups (Steinbach, Edwards et al. 2007).

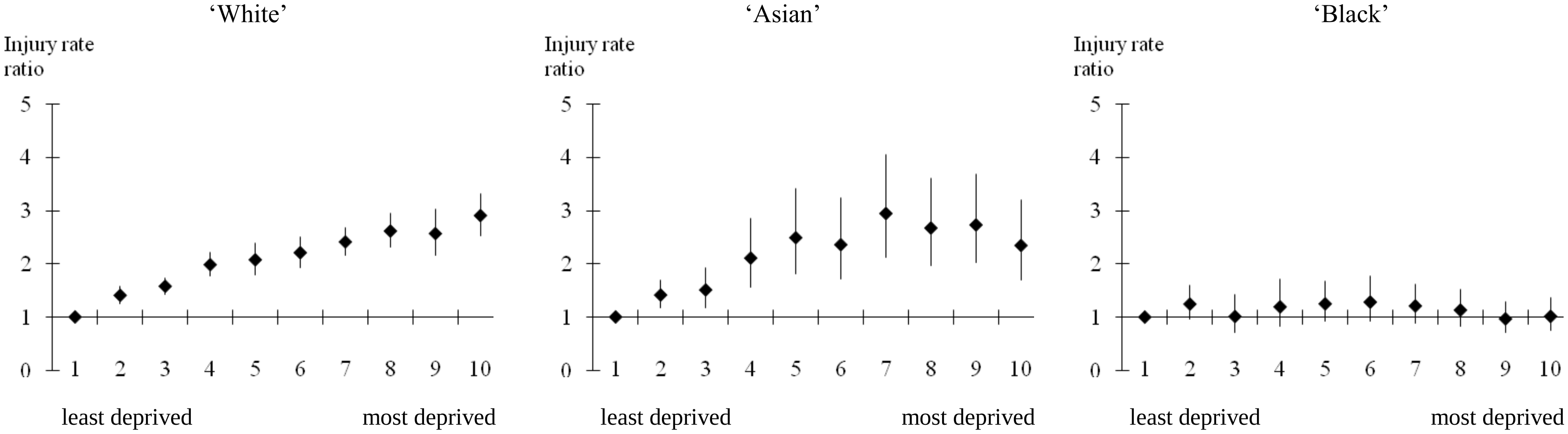
Our findings on 'Black' children in London concurred with most other research both internationally and in the UK. Ethnic minority children have been found to be at greater risk of pedestrian injury. Curiously though, there is no consensus about precisely *who* is at risk with evidence that different ethnic groups are at higher risk in different contexts (Table 1). Nor do we have specific understanding of what precisely drives those risks. Why are 'Black' children at higher risk of pedestrian injury in London? Why do 'Asian' children have lower risk?

To explore this issue, a useful starting point is, perhaps, to look at socio-economic status. Much work on ethnic inequalities in health more generally, attributes ethnic differences in health outcomes to differences in socio-economic status between minority and majority ethnic populations (Williams and Collins 1995, Hayward, Crimmins et al. 2000). Others argue that components of ethnicity apart from socio-economic status independently affect health (Nazroo 1998). Indeed, work by Smith and colleagues (2009) comparing general health between first and second generation migrants reported that improved socio-economic circumstances of the second generation did not lead to improved levels of health, which may highlight that other aspects of ethnicity do affect health. But there is a broad consensus that socio-economic disadvantage is likely, at the very least, to contribute to ethnic differences in health outcomes (Nazroo 1998).

It is therefore not surprising that guidelines on epidemiological research into ethnicity and health suggest that researchers consider an association with socio-economic status as an explanation for any found differences in health between ethnic groups (Bhopal 1997). Ethnic minorities in the UK tend to live in deprived areas (Prime Ministers Strategy Unit and The Office of the Deputy Prime Minister 2005), with particularly steep gradients in London (Edwards, Green et al. 2007). It therefore seems plausible that deprivation may explain the higher child pedestrian injury risks of ethnic minorities in London and the rest of the UK.

My co-authors and I therefore, followed up on the report commissioned by TfL by undertaking a study to investigate the relationship between ethnicity, deprivation and child pedestrian injury in London. Our study is available in Appendix 1 (Steinbach, Green et al. 2010). We found that the well-documented association of higher injury risk with increasing area deprivation was apparent for 'White' and 'Asian' children. But we also found an unanticipated result: for 'Black' children, living in an affluent area did not protect them from increased injury risk (Figure 1.1). Or put another way,

Figure 1.1: The relationship between deciles of area deprivation and pedestrian injury risk for ‘White’, ‘Asian’ and ‘Black’ children in London (Steinbach, Green et al. 2010)



unlike the other children we examined, child pedestrian injury rates for 'Black' children remained largely constant no matter whether they lived in wealthy or poor neighbourhoods.

This leaves an interesting epidemiological puzzle, with clear policy relevance in a country committed to reducing health inequalities. Why do ethnic minority children appear to be at increased risk of pedestrian injury? Specifically, why are 'Black' children at higher risk of pedestrian injury in London? And why does area affluence appear not to protect 'Black' children from higher pedestrian injury risk? What are the mechanisms driving the relationships between ethnicity, deprivation and injury risk?

The implications of these questions are important, and the answers could have impact beyond child pedestrian injury to other areas of health inequality. If the mechanisms driving ethnic inequalities in child pedestrian injury are more complex than we thought, how should policymakers respond to the overall differences in injury rates? What types of interventions are likely to have a positive impact? Until we have a better understanding of why ethnic inequalities exist, policy makers have limited abilities to address these inequalities. Taking London as a case study, my thesis focuses on identifying and understanding the various factors that drive ethnic inequalities in pedestrian injury rates.

1.3.1 Ethnicity as an epidemiological variable

Before exploring the factors that may underpin ethnic differences in child pedestrian risk, it is important to examine the notion of 'ethnicity' itself. As a variable, ethnicity is methodologically and practically challenging to use in epidemiological studies. Definition ambiguities and measurement difficulties threaten its value in health research. As a concept, ethnicity is socially constructed, multi-dimensional and fluid. Influenced by historical value systems as well as the current political and social context, meanings of ethnicity change over time (Bradby 2003). Definitions of ethnicity may involve dimensions of race, skin colour, language, religion, nationality, country of origin, and/or 'culture'. A major limitation of the concept of ethnicity in practice is that researchers often do not clearly define what they mean by 'ethnicity'(Comstock, Castillo et al. 2004).

Practically, the way 'ethnicity' is measured raises concerns about validity. Observer-defined ethnicity may differ from a person's self-defined ethnicity, and even self-defined ethnicities may depend on the availability of response categories. While fixed response categories facilitate comparisons over time, and potentially across data sources, mutually exclusive groups cannot reflect mixed ethnic identities. Further, fixed response categories such as 'Black', 'White', or 'Asian', commonly used in the U.K., may mask considerable within-group differences and emphasize between-group differences (Bradby 2003). These definition and measurement issues suggest that findings reporting ethnic differences in health outcomes may therefore be particularly vulnerable to artefactual explanations.

1.3.2 Are findings on ethnic differences in child pedestrian injury in London an artefact of the data?

Before attempting to solve the epidemiological puzzle of ethnic differences in child pedestrian injury risk in London, it is important to determine whether previous findings are robust, particularly given the operational difficulties of using ethnicity as a variable in epidemiological research. When assessing the strength of epidemiological relationships between exposures and outcomes, researchers must consider the roles of bias, chance and confounding.

Bias

Findings on ethnic differences in child pedestrian injury in London undoubtedly suffer from some methodological issues regarding the ethnicity variable and may be at risk of bias due to measurement. Briefly, previous work (Steinbach, Green et al. 2010), used data on road injuries from police records of road collisions (STATS19) 1996-2006 as numerators, and population data from the 2001 population census as denominators in injury rate calculations. To calculate injury rates, injuries were assigned to the population in the lower super output area in which the injury collision occurred. A major threat to the validity of study findings is the mapping of ethnicity categories between the STATS19 and census data (Table 1.2). The measure of ethnicity used in the STATS19 is the six-category Police National Computer 'Identity Code'(ACPO 2001), which relies on observer identification of physical attributes. Initially, these seem of limited value. Categories such as "Dark-skinned European" do not reflect how most people would define their own ethnicity and there are no population data that use these same categories. However, police data do offer a number of advantages such as good coverage of the ethnicity variable and may be less subject to selection biases inherent in other sources of data. For instance, hospital data which is often used in studies examining injury risk may be subject to bias due to differences in health seeking behaviour. Our previous work addressed whether police data could be used to estimate ethnic differences in injury rates. To estimate rates of childhood pedestrian injury by ethnic group, the study pragmatically mapped STATS19 ethnic categories to aggregated census groupings of ethnic categories. In the decennial census, respondents self-selected their ethnicity from a fixed set of response categories. We conducted sensitivity analyses to compare results from alternative mappings to assess potential measurement bias issues.

Table 1.2: Derivations of ethnic groups from mapping of STATS19 ethnicity categories to census ethnic group codes in Steinbach et al 2010

Steinbach 2010	STATS19	Census 2001
‘White’	White-skinned European	British
	Dark-skinned European	Irish
		Other White
‘Black’	Afro-Caribbean	Caribbean
		African
		Other Black
		Mixed-White & Black Caribbean
		Mixed-White & Black African
‘Asian’	Asian	Indian
		Pakistani
		Bangladeshi
		Other Asian
		Mixed-White & Asian
(excluded from main analysis)	Oriental	Chinese
	Arab	Other
		Mixed-Other

Results from initial mappings suggested that average annual pedestrian injury rates were higher in ‘Black’ children (176 per 100,000 children; 95% CI 172-181), than in either ‘White’ children (118 per 100,000 children; 95% CI 116-121) or in ‘Asian’ children (91 per 100,000 children; 95% CI 88-95). Sensitivity analyses examined other plausible mapping of ethnicity codes, for example, Mapping 1- excluded ‘Dark skinned Europeans’ from the ‘White’ group, Mapping 2- included ‘Arab’ and ‘Oriental’ in the ‘Asian’ group, Mapping 3- included ‘Dark skinned Europeans’ in the ‘Asian’ group, Mappings 4-6 included children with missing ethnicity codes in the ‘Black’, ‘White’ and ‘Asian’ groups in turn. Injury rates in the ‘Black’ group remained higher than other ethnic groupings in all except one mapping (when records with missing ethnicity codes were included in the ‘Asian’ group, rates in the ‘Asian’ group became equivalent to rates in the ‘Black’ group.) The relatively low injury rates of ‘Asian’ children compared to ‘White’ children should however be interpreted with care, as these findings changed based on alternative mappings. Alternative mappings did not substantively change the relationship between deprivation and injury in ‘White’, ‘Asian’ and ‘Black’ children (as shown in Figure 1.1).

There are other threats to the validity and reliability of these findings. These include numerator-denominator bias which arises, for example, from assigning casualties to the population in the area in which the traffic collision occurred (rather than to their area of residence), and data completeness (evidence suggests that 30% of road traffic injuries in the UK are unreported (Ward, Lyons et al. 2006)). However, there is evidence that child pedestrian injuries in London occur very close to home (Edwards, Green et al. 2007) and sensitivity analyses repeating the analysis assigning children to areas of residence revealed no substantive differences in the results. To address potential bias resulting from the under-reporting of injuries, a further sensitivity analysis used only serious and fatal injuries (which are more likely to be reported) and this found a similar pattern of results as analyses using all severities.

Role of chance

Chance is another possible explanation for these findings, as random variations in numbers of casualties may cause spurious results. However, it seems unlikely that this study’s findings are purely due to chance. The numbers of ‘White’, ‘Black’ and Asian injuries were aggregated over 11 years and were therefore sufficiently large (11,206 ‘White’, 5,400 ‘Black’, and 2,511 ‘Asian’ casualties) for reliable estimates. Confidence intervals around estimates of pedestrian injury rates in ‘Black’, ‘White’, and ‘Asian’ children did not overlap. In all sensitivity analyses (except when records with missing ethnicity codes were included in the ‘Asian’ group), confidence intervals around estimates of ‘Black’ child pedestrian injury rates did not overlap with confidence intervals of ‘White’ and ‘Asian’ estimates.

Confounding

Finally, there may be an alternative explanation for the study’s findings on ethnicity and road traffic injury in London if the relationship between ethnicity and injury is confounded by another variable. The analysis considered the role of the most likely confounder, socio-economic status, by estimating the relationships between deprivation and injury separately for each ethnic grouping. (Of course, rather than confound, socio-economic status could mediate the relationship between ethnicity and child pedestrian injury, depending on how ‘ethnicity’ is theorised.) One key limitation of the study was that while the analysis was able to adjust for area level deprivation, the analysis was not able to adjust for individual level socio-economic status. It is possible that the measure of area level deprivation used in the study more accurately reflects individual level deprivation in ‘White’ and ‘Asian’ children compared to ‘Black’ children. Qualitative evidence from studies of housing and social class in London suggests that the relationship between residence and affluence may operate differently across different ethnic groups (Butler and Robson 2003, Watt 2005). Individual level deprivation, then, remains a potential confounder.

The analysis also took into account some aspects of the road environment that are known to be associated with pedestrian injury risk: density of road junctions, A roads and minor roads, proportion of postcodes in an area characterized as business, and the total area (in square metres). Borough level information on vehicle speeds and traffic flows were included in a sensitivity analysis. The inclusion of these potential confounders in the model made little substantive difference to the findings, although many of the road environment factors were found to have a statistically significant relationship with pedestrian injury.

While the measures and data used in this study are far from perfect, the findings of ethnic differences in child pedestrian injury in London do appear relatively robust to various sensitivity analyses, suggesting that these results are not merely an artefact of the data, nor of the methods used to estimate risk. As Bhopal (1997) has cautioned, 'black-box epidemiology', the identification of ethnic differences in health without establishing causal mechanisms, can contribute to racist stereotyping of 'cultural difference'. Therefore, epidemiological research is necessary to unpick the mechanisms that link ethnicity, deprivation and child pedestrian injury.

1.4 A HYPOTHESIZED MODEL OF LINKS BETWEEN ETHNICITY, DEPRIVATION AND CHILD PEDESTRIAN INJURY RISK

While disparities in injury risk are well known, the mechanisms that link ethnicity, deprivation and injury risk are less developed in the literature, perhaps in some part due to the difficulties of studying 'ethnicity' in epidemiological research. Researchers investigating links between ethnicity and health more generally have argued that the many dimensions of ethnicity can usefully be grouped into two categories: structural elements and identity elements (Karlsen and Nazroo 2002).

There are two key structural elements of ethnicity - associations with (typically low) socio-economic factors and experiences of racism. In many countries around the world, including the UK, ethnic minorities are disproportionately from poor households (Palmer and Kenway 2007). There are well established links between low socio-economic status and poor health outcomes, and while the processes linking lower socio-economic status to poor health are not entirely understood, they are likely to include to both material disadvantage and increased psychosocial stress (Adler and Snibbe

2003). Experiences of racism or racial discrimination are another important structural element of ethnicity, which can have both direct and indirect effects of health (Priest, Paradies et al. 2013). Interpersonal experiences of racism can have both direct physical consequences and important psychological consequences which can damage health (Karlsen and Nazroo 2002). Indirect, also known as institutional, racism can further influence the health of ethnic minorities by restricting choices and opportunities and excluding minorities from society (Williams 1999).

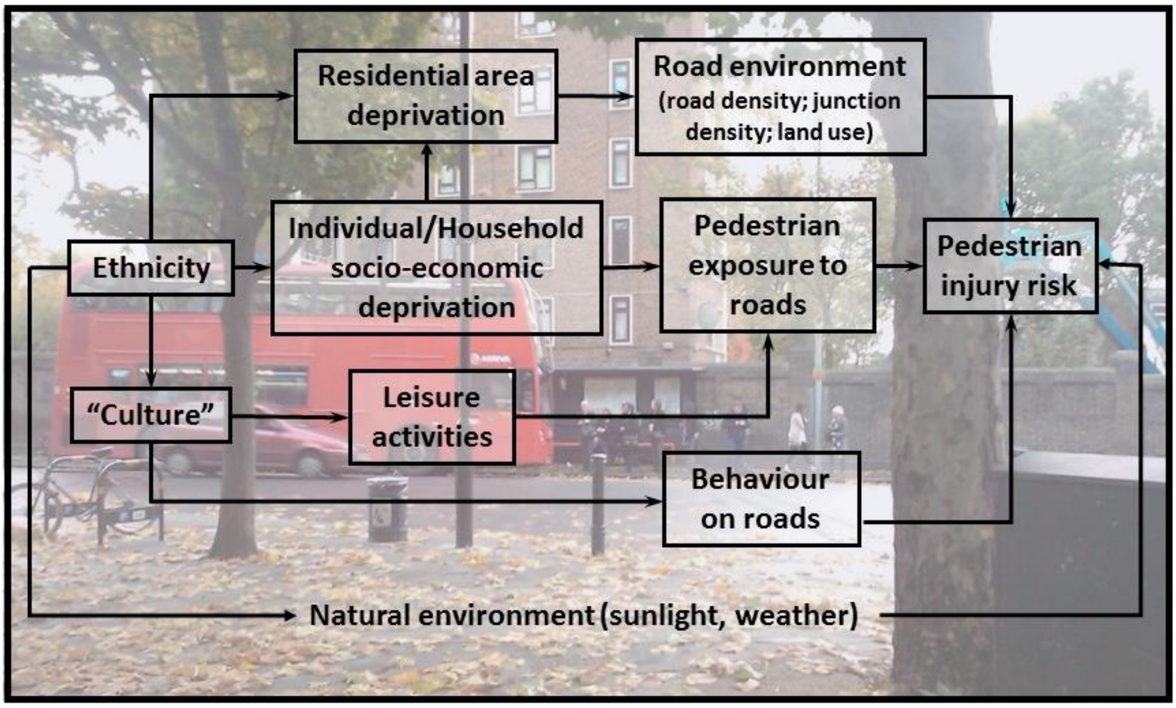
Identity elements of ethnicity include indications of how people choose to define themselves or others. Attributes such as particular beliefs or practices, religion, language, or skin colour can form the basis of ethnic identity elements. Ethnic identities are dynamic constructs formed within particular contexts and influenced by wider society. Providing both personal meaning and boundaries between groups (Karlsen and Nazroo 2002), they help locate people within a social milieu. Links between identity elements of ethnicity and health outcomes are complex and context specific. For instance, affiliations with an ethnic group may lead to greater social support in some contexts which can improve health (Kelleher 1996) but isolate individuals in other contexts. Similarly, health behaviours associated with certain beliefs and practices may be health promoting in some instances and health damaging in others.

To further our understanding of how ethnicity is linked to, for instance, child pedestrian injury risk, research needs to be directed at unpacking the mechanisms which potentially link both structural and identity elements of ethnicity with health outcomes.

While relatively few theoretical models in the literature link ethnicity to injury risk, there is a rich history of epidemiological and social science models of injury risk (Lund and Aarø 2004, Trifiletti, Gielen et al. 2005, Allegrante, Marks et al. 2006 , Lassarre, Papadimitriou et al. 2007). Perhaps the most well-cited epidemiological model of injury risk is Haddon's matrix, which specifies three factors related to injury: the 'host', the 'agent' and the 'environment' (Haddon 1972). While this is an informative foundation for injury models, as Baron-Epel and Ivancovsky (2013) have argued, a broader perspective considering social and cultural factors is needed when considering how ethnicity may relate to injury risk.

A useful starting point is to develop a conceptualisation of risk. In this thesis I have conceptualised 'risk' as "the probability that exposure to a hazard will lead to a negative consequence" (Ropeik and Gray 2002). Thus, the risk of child pedestrian injury is related to both exposure levels and the probability of a hazard where that exposure takes place. Figure 1.2 sets out a hypothesized model linking structural and identity elements of ethnicity to child pedestrian injury risk, adapted from previous work. In my hypothesized model, I have specified exposure levels as the 'quantity of pedestrian exposure' (i.e. how much time children spend as pedestrians). I have conceptualised the probability of a hazard where exposure takes place as the 'quality of the pedestrian exposure environment', which in this model is influenced by both the built environment and the natural environment. Drawing on behavioural models of injury, I have also included the behaviour of 'the host' (i.e. the child) as a factor influencing pedestrian injury risk. The following sections describe the casual pathways linking structural and identity elements of ethnicity to injury risk set out in Figure 1.2 and briefly discuss the evidence for each pathway.

Figure 1.2: Hypothesized model of links between ethnicity and pedestrian injury risk (adapted from Steinbach et al 2010)



1.4.1 Ecological exposure

The top-level casual pathway links ethnicity with road environment at an ecological level through structural associations between ethnicity and area deprivation. At an area level, the quality of the road environment in more deprived areas may be more hazardous than road environments in more affluent areas. Evidence suggests that a number of road environment features are associated with increased pedestrian injury risks, including fast vehicle speeds (Roberts, Norton et al. 1995, Agran

1996), high traffic volumes (Roberts, Norton et al. 1995, Stevenson 1997), high number of parked cars (Roberts, Norton et al. 1995, Agran 1996), wide roads (Garder 2004), and visual obstructions such as rubbish bins or telephone boxes (Stevenson 1997). If minority ethnic and relatively disadvantaged children live in areas characterized by these road environment features, the quality of local roads may, then, mediate the relationships between ethnicity, area deprivation and injury risk. However, whether ethnic minority and relatively deprived children are, in fact, more likely than their counterparts to spend time in more hazardous road environments has not been explored in epidemiological research.

1.4.2 Individual exposure

The second casual pathway describes an association between individual socio-economic disadvantage and injury risk. At an individual level, children from low-income households may be more likely to use riskier modes of transport. Such children may spend more time on the road and walk further distances than their more affluent counterparts, who may be more likely to travel to destinations by car. Since ethnic minorities are disproportionately from low-income households (Kenway and Palmer 2007), and 'Black' households are less likely to own cars (Department for Transport 2006), differences in time spent as pedestrians may also help to explain ethnic inequalities in injury risk in London.

There is limited evidence on the amount of time minority ethnic and relatively disadvantaged children spend as pedestrians and, unfortunately, no evidence from London. Some international and UK evidence suggests that relatively disadvantaged children have greater pedestrian exposure than their more advantaged counterparts (Towner, Jarvis et al. 1994, Macpherson 1998, Sonkin 2006). Evidence on differences in the quantity of pedestrian exposure by ethnicity is mixed, with some international studies suggesting that ethnic minorities walk more often and further distances than their counterparts (Roberts, Norton et al. 1996, Kerr, Frank et al. 2007), and national evidence suggesting that while ethnic minority children walk more often, journey times tend to be less than their counterparts (Bly 2005).

1.4.3 'Culture'

The next two causal pathways linking ethnicity to injury risk involve the link between ethnicity and what I have broadly called 'culture'. I use 'culture' as a rather tentative concept here, as there is wide-ranging and conflicting definitions about which values, norms and beliefs constitute 'culture' in the literature (Straub, Loch et al. 2002). In the model presented in Figure 2 'culture' describes lifestyle aspects that may be shared within ethnic groups. 'Culture' as a concept needs to be approached with care. Researchers have argued that designating 'cultural' differences as an explanation for the often relatively poor health of ethnic minority populations constitutes victim blaming and is a form of social control (Donovan 1984). Historically, much research has inappropriately used ‘culture’ as a synonym for any excess variance unexplained by empirical models (Edoerton and Cohen 1994, Reading, Langford et al. 1999, Karlsen and Nazroo 2006). Therefore, it is important to be specific about which ’cultural’ lifestyle aspects may relate to injury risk.

1.4.4 Leisure activities

Ethnicity may help shape cultural preferences for (or constraints against) specific leisure activities. Not all leisure activities carry the same risk of exposure to pedestrian injury. Children who enjoy playing games with friends in the street environment or who choose to express their identities by ‘hanging out’ on street corners would seem to face more risk of injury than those who play quietly on computers at home. Beyond individual choice, structural associations between ethnicity and socio-economic disadvantage may mean these children have less access to indoor space or private gardens than their more affluent counterparts, which in turn may shape inclinations for outdoor activity. Experiences of racism may also influence the leisure activities chosen by some, if children or their parents avoid certain outdoor activities for fear of race-driven confrontation. Cultural preferences due to religious beliefs and social norms may also affect amount of spare time enjoyed by children and which leisure activities are deemed appropriate for them (Phoenix and Husain 2007).

Qualitative evidence on children’s activity patterns suggests socio-economic status and ethnicity do influence which leisure activities are enjoyed by children. There is also some quantitative evidence on the differences where those leisure activities take place. Children from higher SES schools, qualitative research suggests, participate in more sports clubs and organized activities, while children from lower SES schools have more unstructured activities and ‘free play’ (Brockman, Jago et al. 2009). Evidence from London (Steinbach, Edwards et al. 2007) and elsewhere in England (Morrow 2000) also suggests potential ethnic differences in preferences for outdoor activities, with Asian children in particular reporting a preference for indoor activities due to outdoor experiences of racism.

Turning to the location of leisure activities, quantitative research from Sheffield suggests that relatively deprived children have greater access to public green space, while relatively affluent children have greater access to private green space (Barbosa, Tratalos et al. 2007). Additionally, some UK evidence suggests that children from households with either very high or very low incomes are more likely than those in the middle income groups to play or ‘hang out’ in the road environment (Bly 2005). There is relatively little evidence on potential differences in propensities to play or ‘hang out’ in the road environment by ethnic group, although one study found no evidence of a difference between ‘white’ and ‘non-white’ children within the UK, but reported small differences in France and Holland with ‘non-white’ children slightly more likely to play near roads compared to ‘white’ children (Bly 2005).

1.4.5 Behaviour on roads

The fourth casual pathway addresses the role of behaviour of children on or near roads. Ethnic differences in risk-taking behaviour, parental child protection practices, or risk perception, may help to explain injury inequalities. Evidence from other health-related fields suggests that structural associations between ethnicity and discrimination and socio-economic disadvantage may make risk taking behaviour more prevalent (Thom 2003, Bellair and McNulty 2005, Browning, Burrington et al. 2008). Children tend to exhibit more dangerous road behaviour when unaccompanied by an adult or in the presence of their peers (Wills, Kaufer Christoffel et al. 1997, Elliott and Baughan 2003), so theoretically any differences in child protection practices or group travel may be related to injury risk. Some have also suggested identity factors may lead to differences in parenting styles and risk perception (Department for Transport 2002).

Evidence on the contribution of differences in road behaviour to injury risk inequalities is somewhat weak. International evidence from Australia found ethnic differences in parental road danger risk perception, with Chinese and Arabic speaking parents perceiving the road environment as less dangerous for their children compared to English and Vietnamese speaking parents (Lam 2005). The only evidence on parental risk perceptions in Britain comes from a small case control study of parents in various locations, which found that a larger percentage of ‘non-white’ parents received a poorer risk perception score than ‘white’ parents (Christie 1995), although this study used some questionable components in calculating risk perception scores.

An observational study of children’s road behaviour found no differences in parental accompaniment on school or non-school travel by ethnic group, with the exception of travel to Mosque which was likely to be unaccompanied (Woodall, Green et al. 2007). The study also found no ethnic group differences in methods of parental supervision (hand holding, verbal cues, etc). There was, however, some suggestion that unaccompanied ethnic minority children (mostly South Asian in this study) were less likely than unaccompanied white children to wait at the kerb before crossing the street (Woodall, Green et al. 2007).

1.4.6 Natural environment

Finally, all exposure to injury occurs within the natural environment, where factors such as sunlight and rainfall may affect road user visibility and contribute to the quality of pedestrian exposure in the road environment (Broughton, Hazelton et al. 1999, Plainis, Murray et al. 2006). A study from the AA Foundation for Road Safety Research found that risks to pedestrians were nearly five times greater in darkness compared to daylight (AA Foundation for Road Safety Research 1994). Any differences in the relative 'visibility' of children at night may make exposure more hazardous for some groups.

The controversial 'conspicuity hypothesis' links one element of ethnicity, namely skin tone, with the visibility of children at night. The hypothesis suggests that minority ethnic children with darker skin tones may be less visible to drivers at night and therefore at greater risk of injury. Discussing this hypothesis presents an ethical dilemma. On the one hand, a focus on skin tone is reminiscent of racialised research of the past (Bhopal 1997, Ahmad and Bradby 2007). Moreover, by constructing the 'minority' skin tone as problematic, the 'conspicutity hypothesis' potentially blames victims, facilitates stereotypes and fuels racial prejudice (Bradby 2003).

Despite these concerns, however, the 'conspicuity hypothesis' is also scientifically plausible. Evidence based on simulations suggests that the contrast between a pedestrian's skin colour and the background can influence drivers' responses (Mather and DeLucia 2007). Retroflective materials in red and yellow colours can enhance a driver's detection and recognition of pedestrians (Kwan and Mapstone 2006). There is also some evidence that vehicle colour is associated with crash risk, with colours on the lower visibility index such as black, blue and green at higher risk of crashes compared to white vehicles (Newstead and D'Elia 2007). The 'conspicuity hypothesis' has not been addressed in the epidemiological literature, and a literature search revealed no studies examining the relative visibility of children at night.

1.5 Summary

This section has outlined the epidemiological puzzle of ethnic differences in child pedestrian injury in London. 'Black' children in London appear to have higher pedestrian injury rates compared to 'White' or 'Asian' children. This finding does not appear to be an artefact of the data nor is it explained by an association between ethnicity and area level disadvantage. An outlined model of links between ethnicity, deprivation and child pedestrian injury risk hypothesizes that the quantity and quality of pedestrian exposure act as mediators on the casual pathway between ethnicity and injury risk. However, it is unclear how far the quantity and quality of exposure, as opposed to other candidate explanations (for example, the behaviour of children on roads), account for inequalities in risk.

Potential differences in ecological exposure, i.e. hazard levels of local roads, could plausibly help to explain injury inequalities. However, epidemiological studies have yet to explore whether ethnic minority children tend to live in areas with more hazardous road environments. Ethnic differences in individual exposure, i.e. the amount of time spent on roads, may also help to explain injury inequalities, but relatively few studies have investigated ethnic differences in travel patterns and there have been no studies conducted in London. Preferences or constraints in leisure activities may also influence the amount of pedestrian exposure faced by different population groups. To date, though, there is relatively little evidence on population group differences in the propensity to play or enjoy other leisure activities in the road environment. Ethnic differences in behaviour on or near roads due to differences in risk perception, risk behaviour or parental accompaniment may also explain ethnic inequalities in injury risk, however there is, as yet, little evidence to support this hypothesis. Finally, elements of the natural environment are also likely to affect injury risk, making night time exposure more dangerous than day-time exposure. Therefore, any potential ethnic differences 'visibility' at night may help to explain injury inequalities, though this topic has not been explored in the literature.

1.6 AIMS AND OBJECTIVES:

A programme of work was designed to address gaps identified in the social epidemiological literature. In this thesis I aim to investigate a series of hypotheses about how ethnicity is related to child pedestrian injury risk in London. I have chosen to focus on candidate hypotheses related to the quantity and quality of pedestrian exposure rather than those related to how children behave in the road environment. I also aim to explore associations between ethnicity, deprivation and injury risk to examine why relationships between deprivation and pedestrian injury risk appear to be different for London's 'Black' children compared to 'White' and 'Asian' children.

Specifically I will address the following aims and objectives:

Aim 1: Explore the role of the quantity and quality of exposure in explaining ethnic differences in child pedestrian injury risk

1. Identify whether minority ethnic children live in areas with more hazardous road environments
2. Identify whether the quantity of exposure among London's children differs by ethnicity
3. Explore whether night time exposure is more hazardous for ethnic minority children.

Aim 2: Explore associations between ethnicity, deprivation and injury risk in London

4. Explore the relationship between ethnicity, deprivation and injury risk controlling for the quantity and quality of pedestrian exposure

5. Examine whether ‘group density’ effects can shed light on the relationship between ethnicity, deprivation and injury risk

1.7 Outline and structure of the thesis

This thesis includes a number of Research Papers (1-5) that have been have been published in peer reviewed journals. I have included these papers in chapters with an introductory section detailing how each paper relates to the aims and objectives of this thesis and a concluding section describing how the results of each paper contributes to an understanding of the relationship between ethnicity and child pedestrian injury in London.

Chapter 2 introduces the methods used in this thesis, defines some key concepts, and discusses implications of my chosen methodologies. A section of Chapter 2 includes Research Paper 1, which investigates an important methodological issue when defining appropriate area level boundaries and calculating area level injury rates. I then turn to the objectives of aim 1 of this thesis. Chapter 3 conceptualises the types of environments that theoretically may be hazardous for child pedestrians, reviews the literature on environmental correlates of pedestrian injury, and analyses the distribution of London’s child ethnic populations by different features of the road environment. Chapter 4 examines the social and environmental correlates of children’s walking activities (Research Paper 2) to illuminate whether there are ethnic differences in the quantity of travel time exposure among London’s children. Chapter 5 examines ethnic differences in child pedestrian injury rates by time of day (Research Paper 3) to explore whether night time exposure may be more hazardous for ethnic minority children. Turning to aim 2 of this thesis, Chapter 6 examines what happens to the relationship between ethnicity, deprivation and child pedestrian injury after controlling for both the quantity of exposure and quality of the road environment (Research Paper 4). Chapter 7 picks up on the findings of Chapter 6 and explores whether the ‘group density’ phenomenon can help explain why the relationship between deprivation and child pedestrian injury risk appears to differ by ethnicity (Research Paper 5). Chapter 8 concludes the thesis by summarizing findings from Chapters 3-7, discussing the strengths and limitations of the methods used to address the aims of this thesis, and providing recommendations for policy and future research.

2 METHODS

The previous chapter summarized the social epidemiological puzzle of ethnic inequalities in child pedestrian injury risk and outlined a hypothesized model of links between ethnicity, deprivation and child pedestrian injury risk. The chapter concluded with a discussion of why an exploration of the role of exposure was timely. This chapter outlines the study designs, concepts, and methodology I use to examine the role of exposure related hypotheses in explaining observed patterns of child pedestrian injury in London.

This thesis consists of five discrete studies. Following other research exploring hypotheses for ethnic inequalities in injury (Chen, Lin, and Loo 2012, Roberts, Norton, and Taua 1996), the first three studies (Chapters 3-5) each investigate one exposure related hypothesis in isolation in order to understand the contribution of each particular mechanism in explaining the relatively higher rates of injury of 'Black' children and relatively low injury rates of 'Asian' children in London. The final two studies (Chapters 6-7) focus on the role of exposure in explaining relationships between ethnicity, deprivation and injury: specifically, why does area affluence not appear to protect 'Black' children from pedestrian injury risk in the way that it does for 'White' and 'Asian' children? Together these five studies address important gaps in the social epidemiological literature.

Details of data sources and analysis methods are described in individual chapters, but Table 2.1 provides a broad brush view of the study design, data sources and analysis methods used in each chapter. Three study designs feature in this theses: three ecological studies (Chapters 3, 6 and 7), one cross sectional observational study (Chapter 4), and one retrospective population study (Chapter 5).

Throughout these five studies it was necessary to define some key concepts and make strategic methodological choices. The following sections discuss reasons for my choices and potential methodological implications including: definitions of 'ethnicity', selection of injury data sources, definitions of 'pedestrian' and 'pedestrian injury', design of appropriate ecological studies, and definitions of appropriate 'areas' for ecological analyses. Finally, all five studies drew on secondary analysis, and this chapter ends with a discussion of the implications of this.

Table 2.1: Summary of chapter and study designs

Chapter	Study design	Data sources	Analysis methods
3: Do minority ethnic children in London use more 'hazardous' roads than their counterparts?	Ecological study comparing population distribution by ethnicity in an area to features of the road environment	Population Census, LEGGI[1], ITN[2] road network, NaPTAN[3], Post-codes All Fields Directory, IMD[4]	Chi-squared test for differences in the proportion of 'White', 'Black' and 'Asian' children living in areas with particular features of the road environment.
4: Does the quantity of travel time exposure differ by ethnicity?	Cross sectional observational study examining distances walked by social and environmental variables	London Travel Demand Survey, IMD[4]	Logistic regression models predicting walking behaviour using social and environmental characteristics; Linear regression predicting distances walked using social and environmental characteristics.
5: Is night time exposure more hazardous for minority ethnic children?	Retrospective population study	STATS19[5], MIDAS[6] Land and Marine Surface Stations Data	Time series models estimating the effect of changing light levels on hourly counts of child pedestrian injuries. Case only analysis to assess whether light levels have differential effects on 'White', 'Black' and 'Asian' child injury.
6: Do ethnic differences in risk persist when the quality and quantity of pedestrian exposure are taken into account?	Ecological study examining the relationship between ethnicity, deprivation and injury risk during the morning commute to school	STATS19[5], Population census, London Travel Demand Survey, LEGGI[1], ITN[2] road network, Post-codes All Fields Directory, IMD[4]	Negative binomial regression models estimating the relationship between area deprivation and injury risk among 'White', 'Black' and 'Asian' children during the school commute controlling for characteristics of the road environment.
7: Can 'group density' effects help explain relationships between ethnicity, deprivation and injury risk?	Ecological study examining the relationship between ethnicity, deprivation, population distribution, and injury risk	STATS19[5], Population census, LEGGI[1], ITN[2] road network, Post-codes All Fields Directory, IMD[4]	Negative binomial regression models estimating the number of 'White', 'Black', and 'Asian' child pedestrian injuries in an area as a function of the percentage of the population in that area that are 'White', 'Black' and 'Asian', controlling for area deprivation and characteristics of the road environment.

[1] LEGGI: London Greenhouse Gas Inventory
[2] ITN: Integrated Transport Network
[3] National Public Transport Access Nodes
[4] IMD: Index of Multiple Deprivation
[5] STATS19: Police data on road collisions and resulting casualties
[6] Met Office Integrated Data Archive System

2.1 DEFINITIONS OF 'ETHNICITY'

As discussed in the previous chapter 'ethnicity' is a multi-faceted concept. A key limitation of much research into relationships between 'ethnicity' and health outcomes is that researchers often fail to explain how ethnicity is defined in particular studies.

In this thesis, I put forward an explicit definition of ethnicity in each individual chapter. However, for both conceptual and methodological reasons, the definition of ethnicity used in one chapter may not be identical to that of another. On a conceptual level, this variation is because different chapters explore links between different elements of ethnicity and injury. Chapter 5, for example, explores the relationship between injury and one specific element of ethnicity: skin-tone. Chapter 6, by contrast, examines structural links between ethnicity, deprivation and injury. Methodologically, this thesis uses a number of different data sources to explore ethnic inequalities in injury risk, each of which operationalise 'ethnicity' differently. For instance, Chapter 4 compares travel time exposure of children from different ethnic groups; my definition of 'ethnicity' is constrained by the way in which the ethnicity variable was conceptualised and measured in travel diary data (self-reported from census categories).

In order to reliably compare data from the multiple data sources used in this thesis, I categorized different categories of 'ethnicity' variables into four broad ethnic groupings in all quantitative analyses: 'White', 'Black', 'Asian' and 'Other'. I omitted the broad category 'Other' from analyses, as this typically represented a very heterogeneous group, and comparisons between data sources were untenable. Mappings of ethnicity variables from each data set onto these broad groupings of 'White', 'Black' and 'Asian' are discussed in each chapter.

There are some methodological and theoretical limitations of using such broad ethnic groupings. As discussed in the introductory chapter, results may be sensitive to the way I have mapped ethnicity variables. Theoretically, broad groups such as 'White', 'Black' and 'Asian' are unlikely to represent any real communities in London; using broad groupings risks masking considerable within-group differences and emphasizing between-group differences. These are serious threats to the policy usefulness of my findings, and I consider their implications in my interpretation of the relationships between ethnicity and child pedestrian injury risk. Broad groupings do, however, perhaps have one advantage in my analyses, which take place during various time periods over the 2001-2012 period. Definitions of ethnicity are time and context specific, and using broad groupings within London may help defend against the changing conceptualisations of ethnicity over time.

2.2 CHOOSING A SOURCE OF INJURY DATA

To explore links between ethnicity and child pedestrian injury, one of the first methodological choices I made was to select a source of data on road traffic injuries. There are two candidate data sources on pedestrian injuries in the UK: Hospital Episode Statistics (HES), which records admissions to National Health Service hospitals and STATS19, police records of personal injury road collisions and resulting casualties that occur on the public highway in the UK. Both data sources have advantages and disadvantages for investigating the links between ethnicity and child pedestrian injury.

A key advantage of HES data is that the variable used to record a patient's ethnicity uses codes comparable to those in the Census. In injury rate calculations, which use Census population data as a denominator, using HES data would minimise some threats from numerator denominator bias (discussed in section 1.3.2). However, there are unfortunately wide variations in terms of completeness of coding and historically a high proportion of missing ethnic codes (around 36%) for under 15 year olds (HES Online 2004).

The STATS19, by contrast uses the six-category Police National Computer 'Identity Code' as discussed in section 1.3.2, which rely on police officers to categorize casualties into identity codes using physical attributes. Since these codes are not likely to represent how people would define their own ethnicity, the ethnicity variable is usually considered to be a limitation of the dataset. However, the way ethnicity is collected in the STATS19 does have a number of advantages: coding is reasonably complete for child pedestrians (84%, see Appendix 2), 'identity codes' have been used to successfully investigate ethnic differences in injury in previous work (Steinbach et al. 2010, Malhotra, Hutchings, and Edwards 2008), and observer-defined ethnicity can provide a useful indicator of how children are viewed by others (a potential asset in some conceptualisations of ethnicity).

The usefulness of both the HES and STATS19 data sources in investigating the relationship between ethnicity and injury is threatened by self-selection bias. Some children (or their caregivers) are more likely to attend hospital than others when injured as a pedestrian, and therefore more likely to be included in HES data. Evidence suggests that differences in help-seeking behaviour are associated with deprivation and ethnicity (Morgan 2013) and 'Black' families report being socially excluded from some kinds of care (McLean, Campbell, and Cornish 2003). If 'Black' families are less likely to seek care when injured compared to 'White' and 'Asian' children than using HES data will underestimate 'Black' child pedestrian injury rates. Similarly, some children (or their caregivers) are more likely than others to call the police when injured, and therefore more likely to be included in STATS19 data. Evidence suggest that 30% of road traffic injuries are not reported to police in the UK, though reporting in London is relatively high compared to other places (Ward, Lyons, and Thoreau 2006). While self-selection bias in the STATS19 has not explicitly been explored in the literature, it is certainly plausible that the propensity to report a collision to the police is associated with deprivation and ethnicity. If 'Black' families are less likely to report a collision compared to 'White' or 'Asian' families than using STATS19 will underestimate 'Black' child pedestrian injury rates. These biases pose a considerable threat to any analysis of injury using routine data. However, the dangers appear conceptually similar in both the HES and STATS19 data.

Perhaps the greatest advantage of the STATS19 data set over the HES for investigations into the links between ethnicity and pedestrian injury is that police officers collect data on the location of the injury in STATS19 data. The hypothesized causal pathway presented in Chapter 1 identified the quality of road environment as a key mediator on the pathway between ethnicity and injury risk. In the STATS19, information on the location of the injury allows injuries to be linked to the road environments in which they took place. This facilitates analyses investigating the contribution of the quality of the road environment to pedestrian injury risk.

In this thesis I have therefore chosen to use the STATS19 as source of injury data. While far from a perfect data set, I felt the STATS19 had more potential to examine the causal pathways outlined in Chapter 1. Each chapter that uses the STATS19 (6-8) reflects on the limitations of the STATS19 in terms of both the way 'ethnicity' was operationalised and the potential for under-reporting to bias findings.

2.3 DEFINITIONS OF 'PEDESTRIAN' AND 'PEDESTRIAN INJURY'

The literature on pedestrian injury summarised in Chapter 1 tends to conceptualise who constitutes a 'pedestrian' and what exactly constitutes a 'pedestrian injury' in a variety of ways. Studies are rarely explicit on precise definitions. However a careful reading suggests that some studies define 'pedestrian injuries' as any injury sustained while outside a vehicle in the road environment (von Kries et al. 1998)[4], while other studies only include injuries requiring hospitalisation (Abdel-Rahman et al. 2013). Still other studies require any hospitalisation to involve an overnight stay (Hosking et al. 2013). Some definitions allow for a pedestrian to be injured by a collision with any type of vehicle, while others restrict definitions to include only collisions with motor-vehicles (Braddock et al. 1991, Mueller et al. 1990).

[4] Joly and colleagues (1991) include children injured while entering or exiting a vehicle in their definition of pedestrian injuries.

In this thesis, I define a ‘pedestrian’ as anyone on or near public roads in London that is not in or operating a motorized vehicle or bicycle. As such, ‘pedestrian’ represents somewhat of a residual category of road user categorized by what a road user was *not* doing rather than what they were doing. It is straightforward to envision a ‘pedestrian’ walking along the road for transport, but the definition of ‘pedestrian’ in this thesis also allows for children to play or ‘hang out’ in or near the road environment. The definition of ‘pedestrian’ also includes children using mobility aids such as wheelchairs, scooters, roller-skates, skateboards etc., while walking, playing or ‘hanging out’ in or near the road environment. These issues are further discussed in Chapter 5. Conceptually, I have defined a ‘pedestrian injury’ as an injury to a ‘pedestrian’ of any severity sustained in a crash with any type of vehicle. However, more practically, given that the chapters using data on pedestrian injuries in this thesis (Chapters 5-7) rely on police data, to be included in analyses, pedestrian injuries also need to be reported to the police and occur on a public highway. For more information on injury severity in the STATS19 see Appendix 2.

2.4 METHODOLOGICAL ADVANTAGES AND DISADVANTAGES OF ECOLOGICAL STUDIES

Chapters 3, 6 and 7 use ecological studies to examine population distributions and the road environment and explore the relationship between ethnicity, deprivation and injury risk. The unit of observation in these studies is the population in an ‘area’ rather than an individual. The epidemiological literature warns that results from these types of studies are particularly prone to associations. The ecological fallacy cautions against making causal inferences from area-level data to individual-level risk. For instance, a finding of an association between area-level deprivation and pedestrian injury risk in London (Edwards et al 2007) does not necessarily mean that children from low-income households are at higher risk. To address this challenge, I have been explicit in my hypothesized model about how different factors at both an individual- and area-level may relate to risk. I have also been vigilant in my interpretation of findings from the ecological studies present in this thesis and cautious of making inferences at the individual level. Ecological studies do offer a number of advantages for answering questions about injury risk (Stevenson and McClure 2005). In addition to practical advantages such as low cost and (often) ease of measurement (meaning a broader range of hypothesised factors can be examined), ecological studies are particularly useful when studying the environmental effects on health outcomes. As Shwartz (1994) has suggested, ecological studies can also be very useful in examining how structural properties of societies (such as area deprivation) relate to health outcomes. The ecological studies in this thesis are not designed as substitutes for individual-level models; rather they examine associations between environmental and structural factors on injury risk. It is important to note, however, that measures of area deprivation used in this thesis may not adequately adjust for individual socio-economic disadvantage. As a result, any found associations (or lack thereof) between ethnicity, area deprivation and injury risk may not exist at an individual level.

2.5 DEFINITION OF AN 'AREA'

A substantial methodological challenge I faced in this thesis was defining the boundaries of what constitutes an appropriate 'area' for the ecological analyses (Chapters 3, 6 and 7). There are two methodological decisions to be made: 1- what is the appropriate definition of 'area' for investigations into whether there are differences in the quality of the road environment where children are exposed to injury (Chapter 3) and 2- what is the appropriate definition of 'area' for investigations into the relationship between ethnicity, deprivation and injury rates (Chapters 6 and 7). Literature on the geographies of children indicates that children spend much of their time in their local neighbourhood (Collins et al. 2012), suggesting that children are likely to be exposed and injured as pedestrians in areas close to where they live. Given that my analyses in Chapters 3, 6, and 7 rely on a number of different data sources, including census population data-- which is only available at levels of geography corresponding to census or administrative boundaries-- my choices of an 'area' were somewhat limited. Four candidate geographies are presented in Figure 2.1.

Lower Super Output Areas (LSOAs) are geographic areas including an average of 1,500 people, defined by the Office of National Statistics (ONS) using measures of population size, mutual proximity and homogeneity of characteristics such as type of dwelling (detached/semi-detached etc.) and nature of tenure (owner-occupied, private rented etc...) There were 4,835 LSOAs in London in the 2011 census within 33 local authorities (Figure 2.1). The size of LSOAs in London ranges from 0.02 square km to 15.80 square km with a median of 0.21 square km (interquartile range 0.14 square km – 0.32 square km).

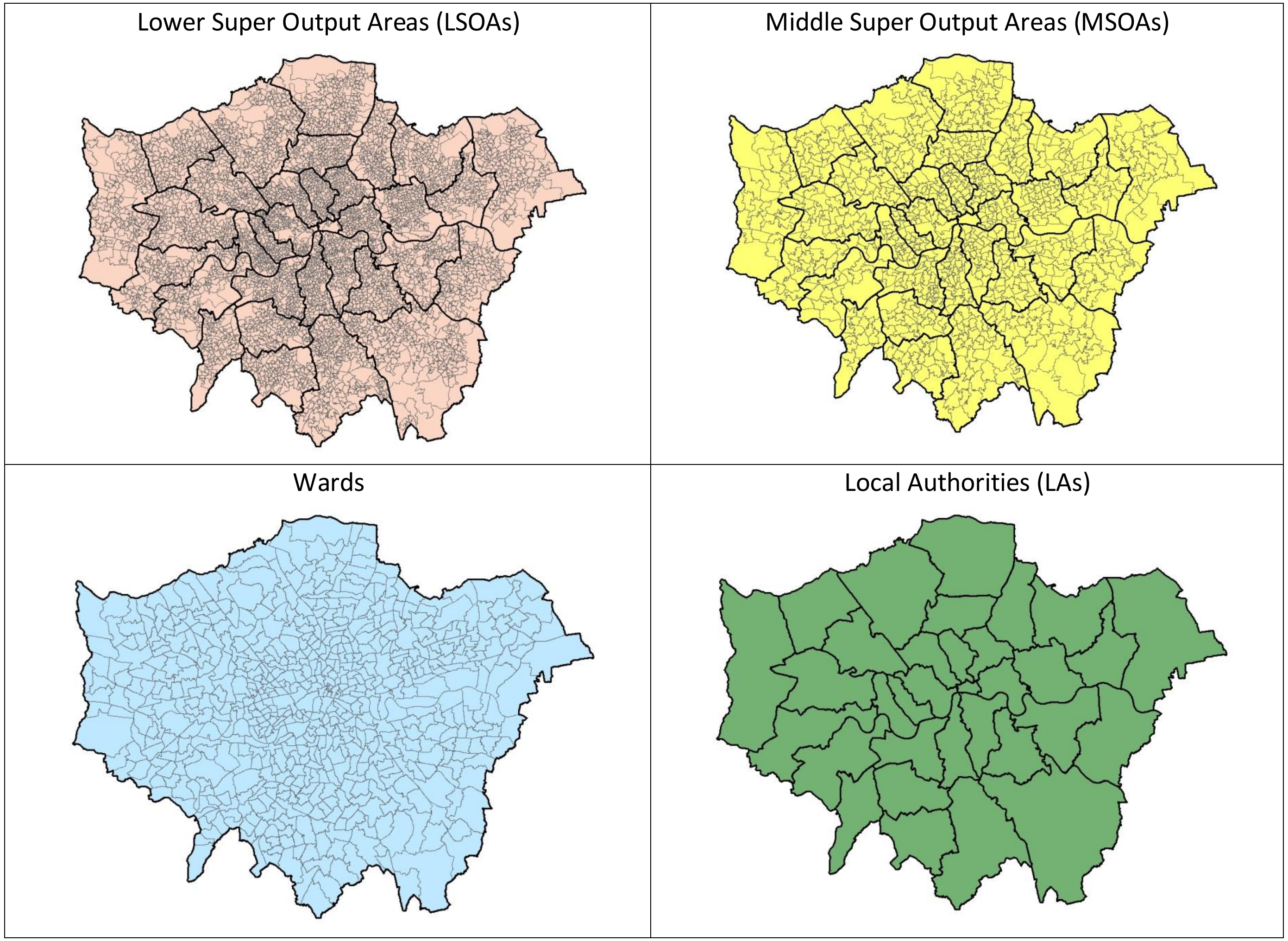
Middle Super Output Areas (MSOAs) are larger geographic areas containing an average of 7,500 people and are comprised of a number of LSOAs. There were 983 MSOAs in London in the 2011 census within 33 local authorities. The size of MSOAs in London ranges from 0.29 square km to 22.43 square km with a median of 1.16 square km (interquartile range 0.74 square km to 1.76 square km).

Wards are the spatial units used to elect local councillors and do not correspond to LSOAs, MSOAs or Local Authority boundaries. There were 632 Wards in London in 2011. The size of wards ranged from 0.13 square km to 29.04 square km with a median of 1.84 square km (interquartile range 1.20 square km to 2.87 square km).

Local authorities (LAs) are administrative government boundaries. Local authorities are responsible for local day to day services including maintaining local roads. The size of local authorities ranged from 3.15 square km to 150.15 square km with a median of 38.68 square km (interquartile range 27.25 square km to 56.59 square km).

In order to choose an appropriate geography for Chapter 3, I searched the literature for information on spatial activities of child pedestrians in London. While I failed to find any relevant studies on activities, I did find some evidence on the location of pedestrian injuries, particularly on how far from home children tend to be injured, which can be useful as a proxy indicator for where children are exposed to injury. A 2007 study from London found that on average, children were injured 1.7 km from home (Dunning, Jones, and Dix 2007). These types of studies are also useful in selecting an appropriate 'area' for injury rate calculations in Chapters 6 and 7. Any systematic difference in spatial patterns of injury by ethnic group or area deprivation, however, has implications for my choices of 'areas'. Whether there are any differences in distance from home to site of collision by ethnicity or deprivation has not been explored in the literature. Research Paper 1 addresses this gap by exploring the distance between home residence and collision site by mode of transport, geographic area and social characteristics in England with a focus on child pedestrian injuries in London.

Figure 2.1: Administrative boundaries in London



2.6 RESEARCH PAPER 1: THE ROAD MOST TRAVELLED: THE GEOGRAPHIC DISTRIBUTION OF ROAD TRAFFIC INJURIES IN ENGLAND

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COVER SHEET FOR EACH 'RESEARCH PAPER' INCLUDED IN A RESEARCH THESIS

1. For a 'research paper' already published

1.1. Where was the work published? **International Journal of Health Geographics**

1.2. When was the work published? **2013**

1.2.1. If the work was published prior to registration for your research degree, give a brief rationale for its inclusion**: N/A**

1.3. Was the work subject to academic peer review? **Yes**

1.4. Have you retained the copyright for the work? **Yes**

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I designed the study with Phil Edwards and Chris Grundy. I obtained STATS19 data covering all of England from the Department for Transport. I formatted data sets for analysis. With input from Phil Edwards and Chris Grundy I designed statistical analyses and analysed the data. I drafted the manuscript and made revisions based on comments from Phil Edwards and Chris Grundy.

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THE ROAD MOST TRAVELLED: THE GEOGRAPHIC DISTRIBUTION OF ROAD TRAFFIC INJURIES IN ENGLAND

ABSTRACT

Background: Both road safety campaigns and epidemiological research into social differences in road traffic injury risk often assume that road traffic injuries occur close to home. While previous work has examined distance from home to site of collision for child pedestrians in local areas, less is known about the geographic distribution of road traffic injuries from other modes. This study explores the distribution of the distance between home residence and collision site (crash distance) by mode of transport, geographic area, and social characteristics in England.

Methods: Using 10 years of road casualty data collected by the police, we examined the distribution of crash distance by age, sex, injury severity, area deprivation, urban/rural status, year, day of week, and, in London only, ethnic group.

Results: 54% of pedestrians, 39% of cyclists, 17% of powered two-wheeler riders and 16% of car occupants were injured within 1km of home. 82% of pedestrians, 83% of cyclists, 54% of powered two-wheeler and 53% of car occupants were injured within 5km of home. We found some social and geographic differences in crash distance: for all transport modes injuries tended to occur closer to home in more deprived or urban areas; younger and older pedestrians and cyclists were also injured closer to home. Crash distance appears to have increased over time for pedestrian, cyclist and car occupant injuries, but has decreased over time for powered two-wheeler injuries.

Conclusions: Injuries from all travel modes tend to occur quite close to home, supporting assumptions made in epidemiological and road safety education literature. However, the trend for increasing crash distance and the social differences identified may have methodological implications for future epidemiological studies on social differences in injury risk.

Key Words: accidents, wounds and injuries, social differences

BACKGROUND

While a growing body of work examines social differences in road traffic injury, there has been relatively little work exploring the geographic distribution of injuries (Whitelegg 1987), in particular the distribution of distance from home. A number of road safety initiatives have launched campaigns on the assumption that road traffic collisions occur close to home. In 2003, the Department for Transport's THINK campaign launched a "Knowing the Road" commercial as part of their Hedgehogs children's road safety advertising videos, which addresses awareness of dangers on roads close to home (Department for Transport 2007). More recently, in 2006 Transport for London's 'Losing Control' television and cinema advertising campaign warned motorcyclists to "Ride the roads you know as carefully as those you don't." (London Road Safety Unit 2013)

The few studies that have examined distance from home to site of road traffic collision (which we will refer to as crash distance) focus on small areas and restrict analyses to pedestrians or children. Some international evidence using data from one major trauma centre in the US, suggests that children and older citizens tend to be injured as pedestrians closer to home compared to other adults, and more severe pedestrian injuries occur further from home compared to less severe injuries (Anderson et al. 2012), but internationally there is little research on crash distances for other modes. Within the UK, examination of crash distance has focused on children (Petch and Henson 2000), and child pedestrians in particular (Preston 1972, Dunning, Jones, and Dix 2007, Sharples et al. 1990), mainly for methodological reasons.

In addition to a comparatively poor child pedestrian injury record overall in the UK (Bly 2005), there are well reported inequalities in child pedestrian injury risk. Research has documented inequalities in injury risk by employment status (Edwards 2006), area deprivation (Edwards et al. 2008, Grayling 2003, Hewson 2004) and ethnicity (Christie 1995, Lawson and Edwards 1991, Steinbach et al. 2010). Methodologically, in order to (a) maximize usable data (as home location is often missing from data) and (b) find appropriate denominators for injury rates, these studies often assume that child pedestrian injuries occur close to home. A study on child fatalities in the Northern region of England found that 80% of child pedestrian injuries occurred within 1.6km of home (Sharples et al. 1990), a finding replicated in a study focusing on the city of Salford (Petch and Henson 2000). A more recent study from London found that on average children were injured 1.7 km from home (Dunning, Jones, and Dix 2007). There is less evidence on whether distance varies by social characteristics, an important issue for studies that examine social differences in risk. A few of these small area studies have examined crash distance by age group and have found that distance was shorter among younger children (Petch and Henson 2000, Preston 1972, Dunning, Jones, and Dix 2007), however there is a paucity of studies that examine crash distance by deprivation and ethnicity.

METHODS

We obtained 10 years (2000-2009) of Police STATS19 data, the official data set of all injuries that occur on public highways in the UK from the Department for Transport (DfT). Officers collect data on the easting and northing coordinates of each collision location and the postcode of residence of each injured person. The DfT supplied us with straight line 'crow flies' distances from the site of collision to the centroid of the postcode of residence. Data also include age of casualty, which we grouped into five year age bands for analysis, sex, mode of travel (pedestrian, cyclists, powered two-wheeler, or car occupant), severity of injury (fatal, serious or slight injury), the government office region where the collision occurred, rural or urban status, and the Index of Multiple Deprivation (IMD) score of the Lower Super Output Area (LSOA) of the casualty's residence. For analysis, all LSOAs in England were ranked according to IMD score and grouped into deciles (1 least deprived to 10 most deprived). Analyses also consider trends in crash distance by year and day of week.

Nationally, police do not collect data on ethnicity of casualties, however in London ethnicity has been collected since 1996. To explore ethnic differences in distance we obtained 10 years of data (2000-2009) from Transport for London's London Road Safety Unit. The measure of ethnicity used is the six-category Police National Computer 'Identity Code', which we grouped into three broad categories based on previous research (Steinbach et al. 2010) 'White' (white-skinned European, dark-skinned European); 'Black' (Afro-Carribean); and 'Asian' (Asian). We calculated distance in the same manner as the DfT, a straight line 'crow flies' distance from the centroid of each casualty's postcode of residence to the coordinates of the site of collision. We focus our analysis on child pedestrians in London due to identified social inequalities in risk in the literature (Steinbach et al. 2010). Our data on child pedestrian injury in London also included information on time of road traffic collision. We have included an analysis of crash distance by time of day grouped into 5 categories (10pm-7am, 7am-9am, 9am-3pm, 3pm-6pm, and 6pm-10pm) during weekdays.

ANALYSIS

We calculated the median crash distance with interquartile ranges (25th percentile to 75th percentile) by travel mode in each population subgroup. To statistically compare subgroups we evaluated the difference in means of log- transformed variables using analysis of variance (ANOVA).

RESULTS

Between 2000-2009, 2,430,542 injuries were reported in STATS19 in England. Of those injuries 12% occurred to pedestrians, 7% to cyclists, 10% to powered two wheeler riders, 63% to car occupants and 8% to travellers using other transport modes (e.g. bus occupants, goods vehicle occupants, agricultural vehicle occupants). 1,617,482 (67%) had valid information on postcode of residence and therefore information on crash distance. Median distance was longest for car occupant injuries (4.5km, interquartile range [IQR] 1.7-12.2) followed by powered two wheeler injuries (4.3km, IQR 1.6-10.8) and was shorter for cyclist injuries (1.5km, IQR 0.6-3.5) and pedestrian injuries (0.8, IQR 0.2-3.2)].

Figure 1 shows the cumulative distribution of crash distance by mode of travel. The majority of injuries in all travel modes occurs relatively close to home, though the distribution varies by mode ($p=0.001$) with pedestrians and cyclists injured closer to home than to powered two-wheeler riders and car occupants.

54% of pedestrians, 39% of cyclists, 17% of powered two-wheeler occupants and 16% of car occupants were injured within 1km of home. 82% of pedestrians, 83% of cyclists, 54% of powered two-wheeler and 53% of car occupants were injured within 5km of home.

Younger and older pedestrians and cyclists tended to be injured closer to home than adult age groups (Figure 2). Powered- two wheeler riders show a similar relationship between age and crash distance though numbers of powered two wheeler injuries in young age groups are very small (Additional file 1). Median crash distance for car occupants was longest in those between the ages of 51-65 and shortest among those under 15. There was evidence for differences in crash distance by age for all travel modes ($p<0.001$).

Median crash distance in men was longer than in women for all travel modes, although absolute differences in distance tended to be relatively small (Additional file 1).

Fatal injuries tended to occur further from home for all travel modes (Additional file 1), except in pedestrians where slight injuries (median distance 0.86km, IQR 0.25-3.22) occurred similarly close to home compared to fatal injuries (median distance 0.84km, IQR 0.24-3.75), and further from home than serious injuries (median distance 0.77km, IQR 0.22-3.05)

For all travel modes, injuries tended to occur closer to home in more deprived areas compared to relatively affluent areas (Figure 3). There was evidence for differences in crash distance by decile of IMD for all travel modes ($p<0.001$).

Injuries in rural areas occurred further from home than injuries in urban areas (Additional file 1). This was particularly true for car occupants where median distance in rural areas (8.26km, IQR 3.43-21.70) was nearly three times longer than distance in urban areas (2.80km, IQR 1.09-6.92). There was evidence for differences in crash distance by urban rural status for all travel modes ($p<0.001$).

There was evidence for differences in distance by region: median distance for pedestrians, cyclists and powered-two wheeler riders were longest in London (1.31km, IQR 0.34-4.94; 2.46km, IQR 0.99-5.19; 5.05km, IQR 2.04-10.94), while distance for car occupants was shortest in London (3.58km, IQR 1.39-8.38). Distance for pedestrians was shortest in the North East (0.67km, IQR 0.18-2.55) and the North West (0.67km, IQR 0.20-2.45). Distance for cyclists was shortest in the North East (1.07km, IQR 0.33-2.95), while distance for powered-two wheeler riders was shortest in the West Midlands (3.50km, IQR 1.34-8.68). Distance for car occupants was longest in the East of England (6.04km, IQR 2.06 – 16.80). There was evidence for difference in crash distance by region for all travel modes ($p<0.001$).

Crash distance appears to be increasing over time for pedestrians, cyclists and car occupants but appears to decrease over time for powered two-wheeler riders (Additional File 1). There was evidence for a difference in distance by year for all travel modes ($p<0.001$).

Fewer casualties of all types occur on Sundays compared to other days of the week, but those that occur were further from home for car occupants and powered two-wheeler riders. Pedestrian injuries occur furthest from home on Saturday and Sundays, while cycling casualties occur closest to home on Saturdays and Sundays. There was evidence for a difference in crash distance by day of the week for all travel modes ($p<0.001$).

Between 2000-2009 there were 15,508 children aged 0-15 injured as pedestrians on London's road. Ethnicity was coded for 85% of the data. There were 6,971 'White' child pedestrian injuries (45%), 4,043 'Black' child pedestrian injuries (26%), and 1,816 'Asian' child pedestrian injuries (12%). 9,044 (58%) of the data had valid postcodes of residence, enabling us to calculate crash distance.

The median crash distance was 0.67km (IQR 0.20-2.12) among children injured as pedestrians on London's roads. Older children (11-15) tended to be injured further away (0.96km, IQR 0.32-2.52) than children in younger age groups (Table 1). Median crash distance among girls was significantly longer than boys ($p<0.001$) though the actual difference in distance was around 100 metres. Slight injuries tended to occur further from home than fatal or serious injuries, however, analysis of variance found no evidence that the distances were different than each other by injury severity ($p=0.792$). Crash distances tended to decrease with increasing levels of deprivation among child pedestrians in London. Median distance among children living in the most deprived areas of London (0.49km, IQR 0.16-1.80) was half as long as median distance among children living in the most affluent areas of London (1.01km, IQR 0.34-2.45). There was evidence of a difference in crash distance by IMD of residence for child pedestrians in London ($p<0.001$). 'Asian' children were injured as pedestrians closer to home (0.48km, IQR 0.13-1.69) than 'White' (0.67km, IQR 0.20-2.04) or 'Black' children (0.71km, IQR 0.23-2.45). There was evidence of a difference in crash distance by ethnicity for child pedestrians in London ($p<0.001$).

Distance for child pedestrians in London is variable by year, but distances tend to be increasing over time. Analysis of variance found a significant difference in distance from home by year ($p<0.001$). Distances appear to be relatively similar across all days of the week. Analysis of variance found a no difference in distance from home by day of week ($p=0.308$). Child pedestrians appear to be injured closest to home between 6pm-10pm on weekdays (0.45km, IQR 0.13-1.56), followed by the time of morning commute 7am-9am (0.64km, IQR 0.25-1.78) while crash distance appears to be relatively similar during the time of school hours 9am-3pm (0.73km, IQR 0.22-2.36) and during the time of the commute home from school 3pm-6pm (0.73km, IQR 0.23-2.08). Analysis of variance found a significant difference in distance from home by time of day on weekdays ($p<0.001$).

DISCUSSION

We examined distance from home to site of collision across England for all travel modes and found that injuries from all modes tend to occur quite close to home, confirming assumptions in the epidemiological and road safety education literature. Exposure is a likely mechanism to explain these findings. People tend to be injured close to home because that is where much of their transport activity takes place. Area familiarity may also play a role, as travellers develop expectations about the road environments which they encounter often. Indeed, evidence suggests that for drivers, eye movement changes after repeated exposure to a particular road environment, which may result in inadequate responses to unexpected changes in that environment (Martens and Fox 2007). While a growing body of work addresses the familiarity hypothesis among drivers (Rosenbloom, Perlman, and Shahar 2007, Charlton and Starkey 2012), evidence is less clear for other types of road users (Daff and Cramphorn 1994, Gårder 1989).

Our analysis suggests that distances are increasing over time for pedestrians, cyclists, and car occupants. Over the same time period data from the National Travel Survey suggests that average distances travelled by walking and motorcycles were relatively stable, distances travelled by car decreased over time, while distances travelled by cycling increased (Department for Transport 2012). We also found that car occupant, powered two-wheeler and pedestrian injuries occurred relatively far from home on Sundays suggesting that people travel further from home for leisure activities compared to their daily commutes.

Our findings on the relationship between age and distance are similar to previous international work on pedestrian injuries (Anderson et al. 2012) and national work on child pedestrian injuries (Petch and Henson 2000, Preston 1972, Dunning, Jones, and Dix 2007). We also found other social differences in crash distances. Because we obtained a large amount of data, differences in crash distance from home by subgroup tended to be statistically significant, even if actual differences were quite small. But a few subgroup differences stand out: for all user modes, injuries tend to occur closer to home in more deprived and urban areas.

Within London, we found some social differences in distance among child pedestrians. 'Asian' children and children from deprived areas appear to be injured closer to home. These findings may have implications for studies examining social differences in risk. The methodological challenges of finding appropriate denominators in which to assess area-level risk are well known (Eksler and Lassarre 2008, Hewson 2005). Research into social differences in pedestrian injury risk estimates injury rates by the ratio of the number of injuries that occur in an area (numerator) with the resident population (denominator). Other studies use an alternative estimate for the denominator and link injured child pedestrians to the areas in which they live. The most appropriate method is under debate (Hewson 2004, 2005), but our findings on social differences in crash distance suggest that some estimates of injury risk may be more accurate than others. Further work is needed to examine the methodological assumptions of studies addressing social differences in injury risk.

A limitation of our analysis is the under-reporting of road traffic injuries in the Stats19 data (Ward, Lyons, and Thoreau 2006). This under-reporting of injuries, however, will only affect our estimates if unreported injuries differ from reported injuries in terms of crash distance. A further threat is the 33% of reported injuries that are missing data on postcode of residence. Again, this missing data will affect our estimates if the distribution of crash distance differs among those who do and do not report a postcode of residence. Despite these weaknesses, we were able to examine over two million road traffic injuries to provide the most comprehensive description of distance from home to site of collision in England to date.

That our findings on pedestrian injury are similar to American findings suggests that our results may be generalisable to places with similar road environments and travel patterns. As there is good evidence that reducing speeds and (re)designing road environments for all types of road users are effective ways of reducing road traffic injuries(WHO 2013, Aarts and van Schagen 2006, Bunn et al. 2009), our findings may imply that these types of interventions are particularly important in residential areas in high income countries. However, more work looking at crash distance in low and middle income countries, where the burden of road traffic injury is highest(WHO 2013), is needed.

COMPETING INTERESTS

The authors declare that they have no competing interests.

AUTHORS' CONTRIBUTIONS

RS, PE, and CG all contributed to the design of the study, analysis of the data, and writing of the manuscript.

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FIGURES

Figure 1 Cumulative distribution of crash distance by travel mode

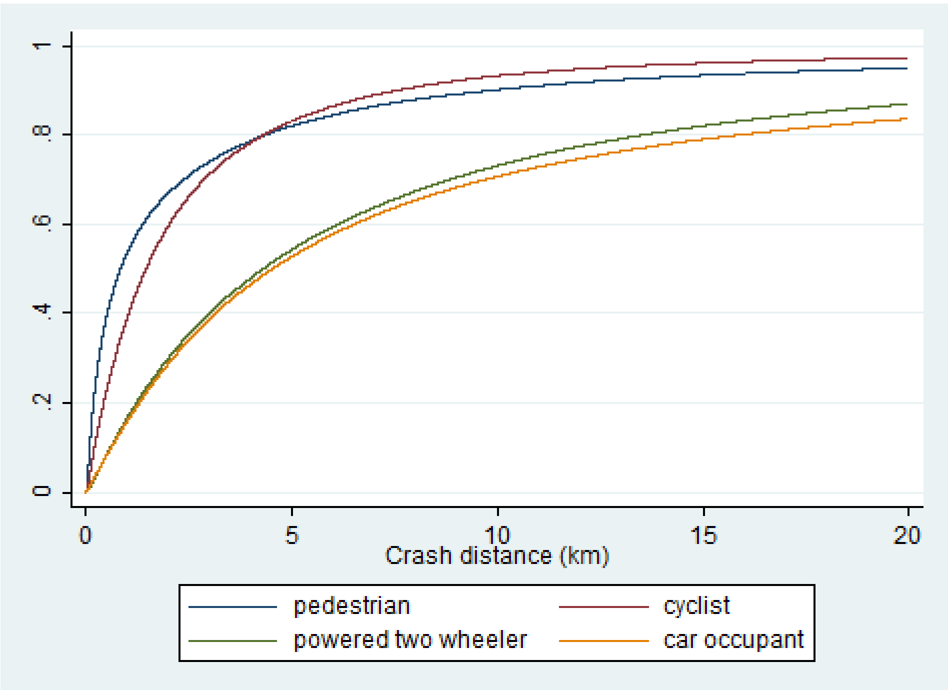


Figure 2 Distribution of crash distance by travel mode and age group

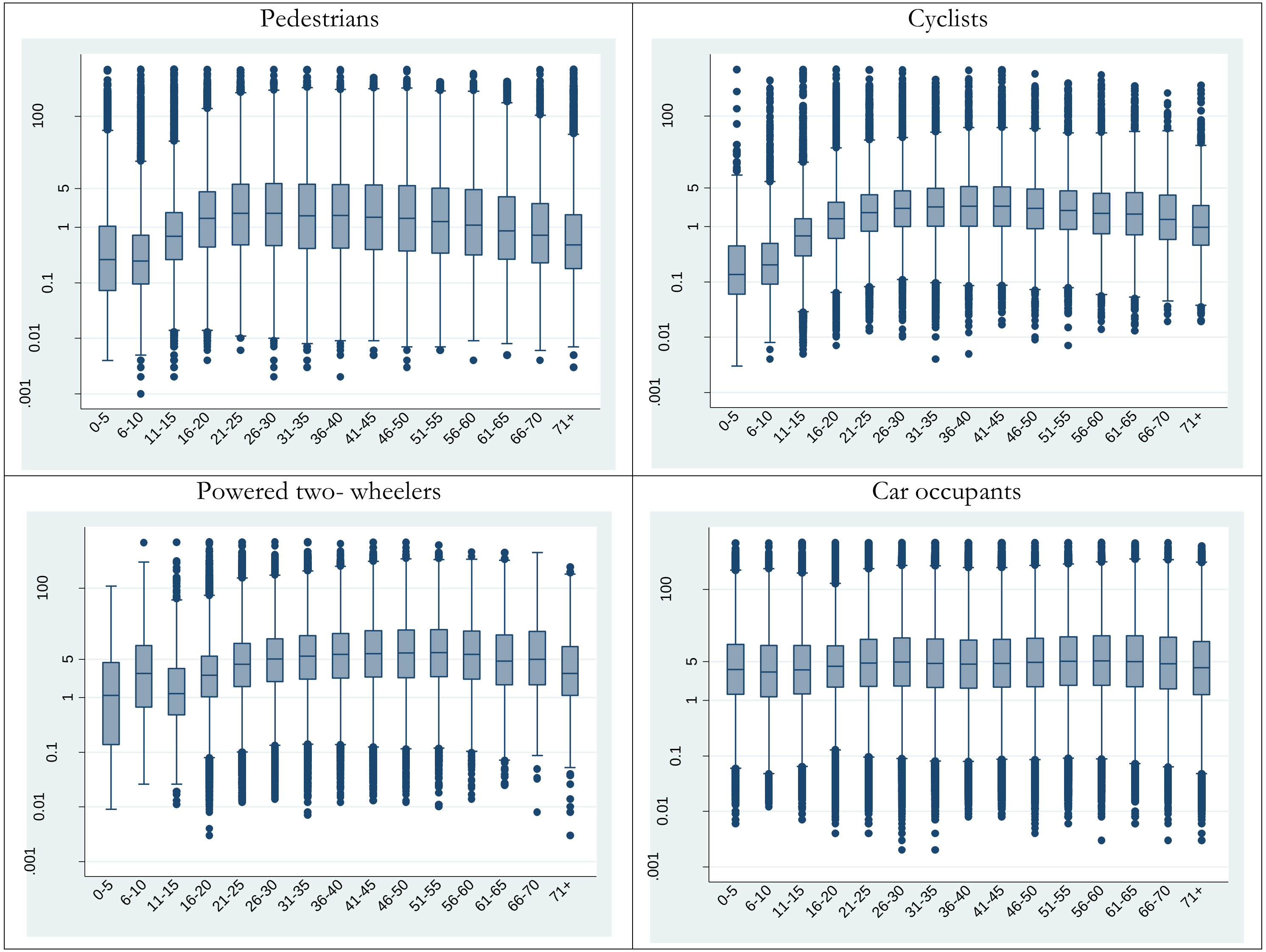


Figure 3 Distribution of crash distance by travel mode and decile of IMD

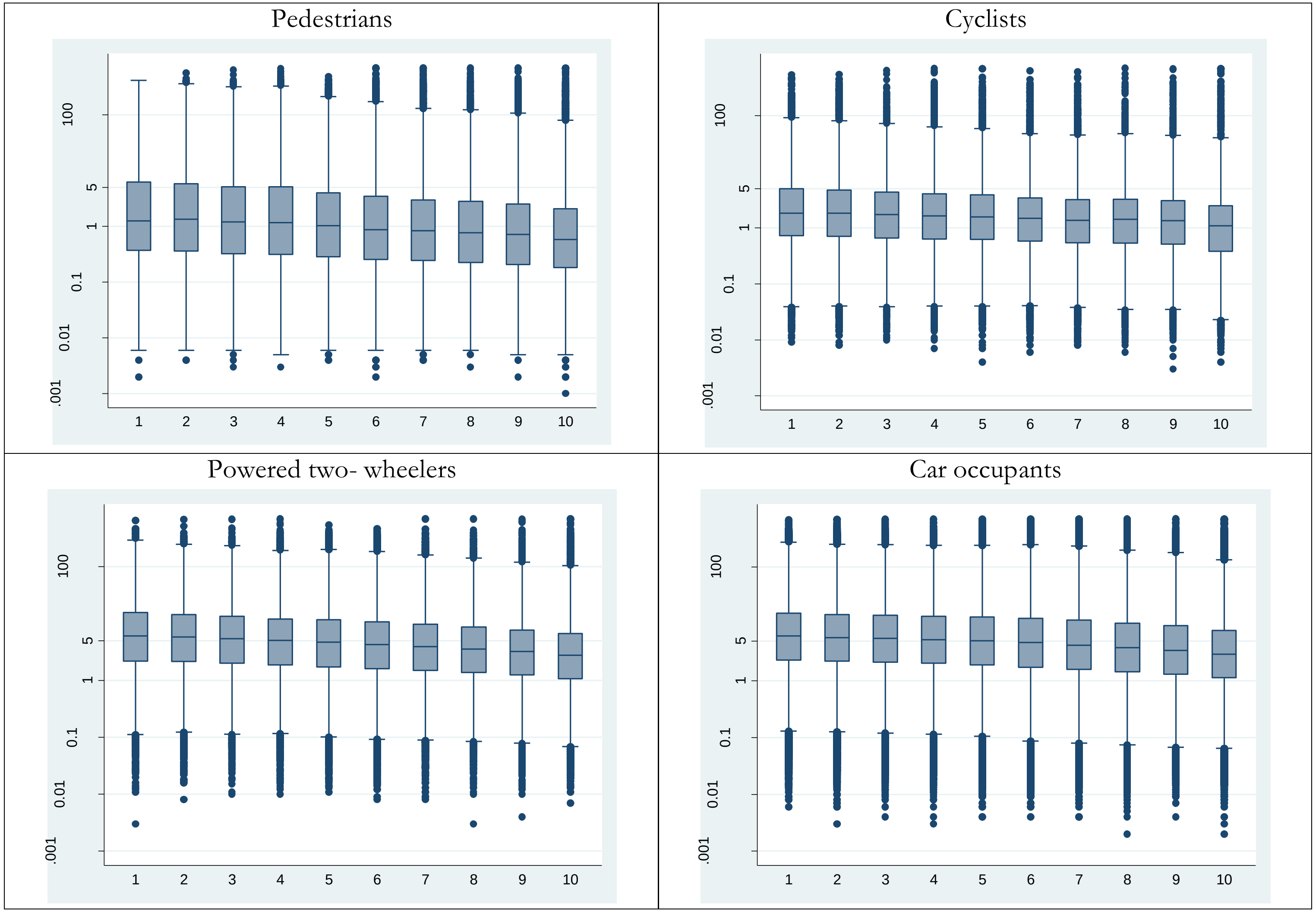


Table 1 Median crash distance among child pedestrians in London

Characteristic	n	25th	50^{th}	75th	Pvalue*
Age					
0-5	1521	0.11	0.49	1.97	<0.0001
6-10	2545	0.12	0.38	1.31	
11-15	4978	0.32	0.96	2.52	
Sex					
Male	5323	0.17	0.62	2.08	<0.0001
Female	3721	0.23	0.73	2.18	
Severity					
Fatal	36	0.21	0.57	4.12	0.7915
Serious	1714	0.18	0.60	2.23	
Slight	7294	0.20	0.68	2.11	
IMD of home residence					
(least deprived) 1	443	0.34	1.01	2.45	<0.0001
2	542	0.24	0.73	2.28	
3	537	0.25	0.82	2.12	
4	677	0.22	0.64	1.89	
5	731	0.21	0.73	2.33	
6	963	0.19	0.68	2.17	
7	1030	0.17	0.57	1.84	
8	1197	0.18	0.59	1.84	
9	1352	0.18	0.58	1.78	
(most deprived) 10	1382	0.16	0.49	1.80	
Ethnic group					
White	4140	0.20	0.67	2.04	<0.0001
Black	2378	0.23	0.71	2.45	
Asian	1029	0.13	0.48	1.69	

Table 1 continued Median crash distance among child pedestrians in London

Characteristic	n	25th	50^{th}	75th	Pvalue*
Year					
2000	1072	0.16	0.58	1.98	<0.0001
2001	1131	0.17	0.61	2.07	
2002	938	0.18	0.54	1.74	
2003	900	0.17	0.57	2.13	
2004	898	0.19	0.64	1.78	
2005	924	0.23	0.71	2.38	
2006	833	0.23	0.86	2.46	
2007	831	0.23	0.73	2.24	
2008	765	0.22	0.76	2.47	
2009	752	0.22	0.80	2.29	
Day of week					
Sunday	761	0.14	0.69	2.94	0.3077
Monday	1337	0.21	0.68	2.01	
Tuesday	1412	0.19	0.68	2.10	
Wednesday	1536	0.20	0.65	1.96	
Thursday	1432	0.21	0.62	1.93	
Friday	1510	0.21	0.68	1.97	
Saturday	1056	0.18	0.71	2.83	
Time of day (weekdays only)					
10pm - 7am	122	0.34	1.00	2.60	<0.0001
7am-9am	1277	0.25	0.64	1.78	
9am-3pm	1209	0.22	0.73	2.36	
3pm-6pm	3257	0.23	0.73	2.08	
6pm-10pm	1362	0.13	0.45	1.56	

*P value of ANOVA F-test

Table A1 Median crash distance among pedestrians in England 2000-2009

Characteristic		n	25th	50th	75th	Pvalue*
Age						
	0-5	9575	0.07	0.26	1.04	<0.0001
	6-10	18204	0.09	0.25	0.73	
	11-15	32168	0.26	0.69	1.84	
	16-20	19390	0.44	1.44	4.37	
	21-25	13317	0.48	1.80	5.96	
	26-30	10628	0.46	1.79	6.14	
	31-35	9201	0.42	1.62	6.00	
	36-40	8775	0.42	1.64	5.89	
	41-45	6069	0.39	1.51	5.78	
	46-50	7926	0.38	1.45	5.64	
	51-55	5618	0.34	1.28	5.06	
	56-60	5197	0.31	1.09	4.76	
	61-65	4344	0.26	0.86	3.56	
	66-70	4096	0.23	0.72	2.67	
	71+	14437	0.18	0.49	1.67	
Sex						
	Male	96764	0.24	0.89	3.47	<0.0001
	Female	74711	0.24	0.78	2.89	
Severity						
	Fatal	3035	0.24	0.84	3.75	<0.0001
	Serious	34839	0.22	0.77	3.05	
	Slight	133627	0.25	0.86	3.22	
IMD of home residence						
	1	8898	0.37	1.26	6.24	<0.0001
	2	10030	0.36	1.35	5.83	
	3	10799	0.33	1.20	5.16	
	4	11928	0.32	1.18	5.17	
	5	13597	0.28	1.03	4.02	
	6	15355	0.25	0.88	3.47	
	7	18223	0.24	0.83	3.01	
	8	22085	0.23	0.77	2.82	
	9	26821	0.21	0.72	2.54	
	10	33765	0.18	0.59	2.07	
Urban/Rural status						
	Urban	152957	0.24	0.83	3.00	<0.0001
	Rural	18473	0.27	1.01	5.69	

Characteristic	n	25th	50th	75th	Pvalue*
Government Office Region					
North East	7761	0.18	0.67	2.55	<0.0001
North West	29067	0.20	0.67	2.45	
Yorkshire and the Humber	18907	0.22	0.76	2.88	
East Midlands	9102	0.24	0.79	2.96	
West Midlands	25425	0.21	0.71	2.47	
East of England	13078	0.24	0.81	3.22	
London	35549	0.34	1.31	4.94	
South East	22513	0.26	0.88	3.25	
South West	9900	0.26	0.88	3.35	
Year					
2000	15027	0.23	0.79	3.00	<0.0001
2001	15446	0.22	0.77	2.96	
2002	15643	0.24	0.79	2.98	
2003	14954	0.23	0.81	3.12	
2004	16530	0.23	0.81	3.15	
2005	18714	0.25	0.87	3.29	
2006	18406	0.26	0.89	3.30	
2007	19716	0.26	0.89	3.36	
2008	18422	0.25	0.87	3.33	
2009	18643	0.25	0.89	3.27	
Day of week					
Sunday	15476	0.22	0.92	3.84	<0.0001
Monday	24394	0.23	0.79	2.88	
Tuesday	25586	0.23	0.78	2.89	
Wednesday	26087	0.24	0.80	2.97	
Thursday	26420	0.24	0.80	2.99	
Friday	29974	0.26	0.86	3.13	
Saturday	23564	0.26	1.03	4.08	

*P value of ANOVA F-test

Table A2 Median crash distance among cyclists in England 2000-2009

Characteristic		n	25th	50th	75th	Pvalue*
Age						
	0-5	793	0.06	0.14	0.45	<0.0001
	6-10	6646	0.09	0.20	0.50	
	11-15	16749	0.29	0.69	1.40	
	16-20	10543	0.62	1.39	2.78	
	21-25	9079	0.82	1.81	3.78	
	26-30	10838	1.01	2.16	4.46	
	31-35	10336	1.02	2.27	4.92	
	36-40	9631	1.02	2.36	5.29	
	41-45	6408	1.02	2.33	5.28	
	46-50	7483	0.90	2.13	4.82	
	51-55	4497	0.88	1.97	4.43	
	56-60	3495	0.74	1.76	4.02	
	61-65	2147	0.71	1.69	4.11	
	66-70	1324	0.59	1.36	3.72	
	71+	2023	0.46	0.98	2.42	
Sex						
	Male	82561	0.58	1.54	3.71	<0.0001
	Female	21146	0.50	1.23	2.72	
Severity						
	Fatal	651	0.77	2.15	5.30	<0.0001
	Serious	14575	0.59	1.57	3.89	
	Slight	88493	0.56	1.44	3.41	
IMD of home residence						
	1	8379	0.71	1.81	4.99	<0.0001
	2	8242	0.70	1.82	4.70	
	3	8487	0.65	1.72	4.32	
	4	8862	0.63	1.62	4.01	
	5	9306	0.62	1.57	3.86	
	6	10365	0.58	1.47	3.40	
	7	11393	0.54	1.36	3.19	
	8	12234	0.53	1.41	3.25	
	9	13233	0.51	1.34	3.04	
	10	13218	0.38	1.09	2.49	
Urban/Rural status						
	Urban	87771	0.53	1.36	3.11	<0.0001
	Rural	15907	0.78	2.47	6.38	

Characteristic	n	25th	50th	75th	Pvalue*
Government Office Region					
North East	3467	0.33	1.07	2.95	<0.0001
North West	13685	0.43	1.28	3.16	
Yorkshire and the Humber	10227	0.48	1.29	3.06	
East Midlands	6164	0.48	1.26	2.98	
West Midlands	10473	0.45	1.20	2.79	
East of England	11929	0.50	1.20	2.66	
London	21512	0.99	2.46	5.19	
South East	17906	0.57	1.35	3.20	
South West	8181	0.59	1.44	3.06	
Year					
2000	8854	0.49	1.31	3.06	<0.0001
2001	8925	0.51	1.35	3.17	
2002	8185	0.52	1.36	3.18	
2003	8337	0.51	1.33	3.26	
2004	9165	0.49	1.35	3.14	
2005	11098	0.53	1.41	3.36	
2006	11364	0.60	1.50	3.50	
2007	12299	0.62	1.54	3.63	
2008	12079	0.63	1.62	3.86	
2009	13413	0.67	1.74	4.18	
Day of week					
Sunday	8611	0.45	1.38	4.26	<0.0001
Monday	15696	0.56	1.45	3.36	
Tuesday	17763	0.62	1.55	3.58	
Wednesday	17716	0.60	1.52	3.54	
Thursday	17380	0.60	1.50	3.45	
Friday	16193	0.56	1.44	3.33	
Saturday	10360	0.44	1.27	3.33	

*P value of ANOVA F-test

Table A3 Median crash distance among powered two-wheelers in England 2000-2009

Characteristic		n	25th	50th	75th	Pvalue*
Age						
	0-5	34	0.14	1.09	4.37	<0.0001
	6-10	196	0.67	2.75	8.93	
	11-15	1572	0.47	1.18	3.37	
	16-20	43548	1.02	2.54	5.66	
	21-25	19364	1.57	4.04	9.81	
	26-30	19330	1.96	5.05	11.77	
	31-35	19249	2.18	5.69	13.52	
	36-40	18522	2.28	6.13	14.91	
	41-45	12201	2.35	6.38	16.67	
	46-50	12466	2.31	6.54	17.14	
	51-55	6443	2.36	6.61	17.43	
	56-60	3980	2.16	6.17	16.45	
	61-65	2006	1.68	4.65	13.87	
	66-70	874	1.68	5.00	16.11	
	71+	794	1.09	2.75	8.52	
Sex						
	Male	145052	1.60	4.33	10.86	0.1972
	Female	17545	1.57	4.11	10.35	
Severity						
	Fatal	3264	2.58	7.23	18.51	<0.0001
	Serious	38291	1.73	4.90	12.96	
	Slight	121069	1.54	4.09	10.09	
IMD of home residence						
	1	13850	2.17	6.12	15.67	<0.0001
	2	15190	2.15	5.86	14.42	
	3	15885	2.01	5.44	13.59	
	4	16229	1.89	5.07	12.13	
	5	16333	1.74	4.75	11.65	
	6	17069	1.61	4.29	10.76	
	7	17832	1.50	3.94	9.75	
	8	18540	1.37	3.58	8.80	
	9	17554	1.23	3.24	7.77	
	10	14142	1.08	2.78	6.75	
Urban/Rural status						
	Urban	111531	1.25	3.23	7.86	<0.0001
	Rural	51048	3.28	8.10	19.83	

Characteristic	n	25th	50th	75th	Pvalue*
Government Office Region					
North East	4361	1.26	3.80	10.22	<0.0001
North West	16936	1.34	3.61	9.08	
Yorkshire and the Humber	13458	1.44	3.94	10.55	
East Midlands	11891	1.62	4.66	12.67	
West Midlands	15674	1.34	3.50	8.68	
East of England	19984	1.59	4.42	11.89	
London	39719	2.04	5.05	10.94	
South East	27471	1.57	4.36	12.03	
South West	12862	1.49	3.97	10.24	
Year					
2000	13687	1.72	4.56	11.49	<0.0001
2001	15352	1.71	4.39	10.91	
2002	14808	1.62	4.46	10.79	
2003	15207	1.62	4.40	10.99	
2004	15665	1.55	4.06	10.26	
2005	18057	1.48	4.13	10.60	
2006	17396	1.57	4.23	10.58	
2007	18830	1.56	4.27	10.94	
2008	16820	1.58	4.28	10.55	
2009	16802	1.64	4.38	11.16	
Day of week					
Sunday	19795	1.86	5.92	18.19	<0.0001
Monday	22838	1.55	4.09	9.98	
Tuesday	24120	1.58	4.08	9.63	
Wednesday	25042	1.61	4.27	10.09	
Thursday	23989	1.55	4.01	9.55	
Friday	25799	1.56	4.20	10.42	
Saturday	21041	1.53	4.29	11.53	

*P value of ANOVA F-test

Table A4 Median crash distance among car occupants in England 2000-2009

Characteristic		n	25th	50th	75th	Pvalue*
Age						
	0-5	15839	1.30	3.60	10.21	<0.0001
	6-10	21952	1.16	3.27	9.77	
	11-15	25508	1.32	3.56	9.85	
	16-20	161776	1.72	4.14	9.66	
	21-25	147959	1.79	4.76	12.66	
	26-30	118977	1.81	4.94	13.44	
	31-35	106664	1.68	4.63	12.80	
	36-40	100174	1.63	4.50	12.20	
	41-45	67371	1.72	4.65	12.60	
	46-50	82631	1.76	4.85	13.25	
	51-55	53711	1.87	5.10	14.09	
	56-60	43912	1.89	5.14	14.62	
	61-65	30193	1.76	5.04	14.71	
	66-70	22203	1.60	4.62	13.74	
	71+	45027	1.28	3.90	11.53	
Sex						
	Male	527816	1.82	4.88	13.23	<0.0001
	Female	529966	1.57	4.22	11.22	
Severity						
	Fatal	7658	2.69	6.60	16.84	<0.0001
	Serious	73585	2.08	5.34	13.82	
	Slight	976817	1.65	4.46	12.04	
IMD of home residence						
	1	97941	2.28	6.09	15.51	<0.0001
	2	104847	2.17	5.72	14.55	
	3	107115	2.10	5.53	14.21	
	4	107671	2.00	5.28	13.60	
	5	105391	1.91	5.03	13.20	
	6	106020	1.71	4.68	12.53	
	7	102776	1.59	4.23	11.70	
	8	105633	1.42	3.79	10.25	
	9	106520	1.29	3.40	9.27	
	10	114146	1.13	2.92	7.63	
Urban/Rural status						
	Urban	590051	1.09	2.80	6.92	<0.0001
	Rural	467630	3.43	8.26	21.70	

Characteristic	n	25th	50th	75th	Pvalue*
Government Office Region					
North East	45988	1.64	4.26	10.29	<0.0001
North West	167362	1.40	3.65	9.39	
Yorkshire and the Humber	116130	1.64	4.26	11.29	
East Midlands	83029	1.99	5.54	15.85	
West Midlands	141184	1.48	3.80	9.57	
East of England	137765	2.06	6.04	16.80	
London	114885	1.39	3.58	8.38	
South East	170879	1.99	5.59	15.80	
South West	79437	2.08	5.81	16.89	
Year					
2000	94471	1.63	4.37	11.65	<0.0001
2001	101672	1.61	4.40	11.81	
2002	98357	1.64	4.41	11.88	
2003	93464	1.66	4.44	12.11	
2004	105501	1.66	4.47	11.96	
2005	118843	1.70	4.58	12.33	
2006	116669	1.71	4.59	12.33	
2007	118173	1.77	4.71	12.76	
2008	104841	1.71	4.60	12.23	
2009	106069	1.74	4.71	12.71	
Day of week					
Sunday	137236	1.83	5.08	14.80	<0.0001
Monday	145490	1.66	4.46	11.80	
Tuesday	146835	1.64	4.36	11.26	
Wednesday	148640	1.66	4.42	11.47	
Thursday	149561	1.65	4.39	11.54	
Friday	172269	1.67	4.55	12.53	
Saturday	158029	1.71	4.57	12.66	

*P value of ANOVA F-test

2.7 Implications of Research Paper 1 for definition of an 'area' in Chapter 3

The results of Research Paper 1 suggest that 'White', 'Black' and 'Asian' children in London all tend to be injured as pedestrians quite close to home, though there is some evidence that the distance between home residence and collision site differs by ethnicity. 'Asian' children tend to be injured closest to home (median 0.48km, interquartile range 0.13km – 1.69 km) while 'Black children' are injured furthest from home (median 0.71km, interquartile range 0.23km – 2.45km).

Using distance from home to site of collision as a proxy for the spatial patterns of where children are exposed to pedestrian injury, these results suggest that children will be most exposed to injury in the LSOA in which they live (LSOAs in London have a median area of 0.21 square kilometres, which corresponds to a square where each side is roughly 450 metres). I therefore selected LSOAs as the primary unit of geography for ecological analysis examining differences in the quality of the road environment where children from different ethnic groups live (Chapter 3). However, as a sensitivity analysis, I consider 'areas' defined at the MSOA, Ward, and Local Authority levels.

2.8 Implications of Research Paper 1 for definition of an 'area' in Chapters 6 and 7

Selecting an appropriate definition of an 'area' in Chapters 6 and 7 is less straightforward than in Chapter 3. These chapters explore relationships between pedestrian injury *rates* and area deprivation among 'White', 'Black' and 'Asian' children. As introduced in Research Paper 1, calculating injury rates requires another, related, methodological decision. To calculate rates, numbers of injuries must be assigned to population denominators at an 'area' level. There are two candidate assignment methods: the location of collision assignment method assigns casualties to the 'area' in which children were injured as a pedestrian, the location of residence assignment method assigns casualties to the 'area' in which children live. The location of residence assignment method ensures that population denominators are appropriate; however information on location of residence is missing from over 40% of the casualty data, making the location of collision assignment method attractive in order to make use of more data. The most appropriate assignment method is under debate (Hewson 2004, 2005), but findings from Research Paper 1 on ethnic differences in crash distance suggest that estimates of injury risk among 'Black' children may be more prone to numerator denominator bias, than estimates of 'White' or 'Asian' injury rates. The findings also indicate that children living in more deprived areas tend to be injured closer to home than children in more affluent areas, suggesting that injury rates in affluent areas may also be more prone to numerator denominator bias. To ensure that the location of collision assignment method minimises the potential for numerator denominator bias or any ethnic or deprivation level differences in numerator denominator bias, it is tempting to choose the largest possible definition of ‘area’, in this case local authorities.

However, there are other issues to consider. Chapters 6 and 7 focus on the relationship between injury rates and area deprivation. In London, where levels of deprivation can vary from street to street, data on area deprivation is likely to be more accurate at the smallest possible definition of ‘area’, in this case LSOAs. Analyses in Chapters 6 and 7 also control for features of the road environment which, arguably, are likely to be more discriminating at a smaller area level. Green and colleagues (2011) contend that using LSOAs as the definition of ‘area’ in child pedestrian injury studies examining relationships with area characteristics has a number of advantages over larger geographies as LSOAs were developed using measures of social homogeneity, dwelling and tenure types. The use of larger geographies, they argue, may “muddy the analytical waters”.

To summarise, choosing a larger geography to define ‘areas’ would defend against numerator-denominator bias (and any ethnic or deprivation level differences in numerator denominator bias), but choosing a smaller geography would provide more accurate estimates of deprivation and features of the road environment.

As noted in the previous section, results from Research Paper 1 do suggest that many ‘White’, ‘Black’ and ‘Asian’ children are likely to be injured in the LSOA in which they live. Before making a decision on choice of ‘area’, I examined whether this assumption was true. Between 2000 and 2009, 23% of ‘White’ children, 20% of ‘Black’ children, and 27% of ‘Asian’ children were injured in the same LSOA in which they lived. While those percentages are worryingly low, the majority of ‘White’, ‘Black’ and ‘Asian’ children were injured in an LSOA with a similar quintile of deprivation as the LSOA in which they lived (See Appendix 3).

Balancing these multiple (and sometimes conflicting) methodological issues is challenging. Ultimately, I decided to define ‘areas’ in injury rate analyses (in Chapters 6 and 7) as LSOAs[1]. To maximise the available data, the analyses in this thesis use the location of collision assignment method. These choices are consistent with previous research (Steinbach et al. 2010). To defend against numerator denominator bias, I conduct sensitivity analyses using the location of residence assignment method in Chapters 6 and 7.

[1] I completed analyses in Chapter 6 of this thesis before geographical boundaries from the 2011 census were made publically available. These analyses use boundaries from the 2001 census which differ slightly from 2011 boundaries. For instance, there were 4,765 LSOAs in London in the 2001 census within 33 local authorities. The size of LSOA boundaries in London in 2001 ranged from 0.02km2 to 15.80km2 with a median of 0.21km2 (interquartile range 0.14km2 – 0.33km2).

2.9 METHODOLOGICAL CHALLENGES IN SECONDARY ANALYSIS OF QUANTITATIVE DATA

This thesis relies entirely on secondary analyses of quantitative data. Methodologically, there are some important implications of employing quantitative data sources used that were not designed to answer my particular research question.

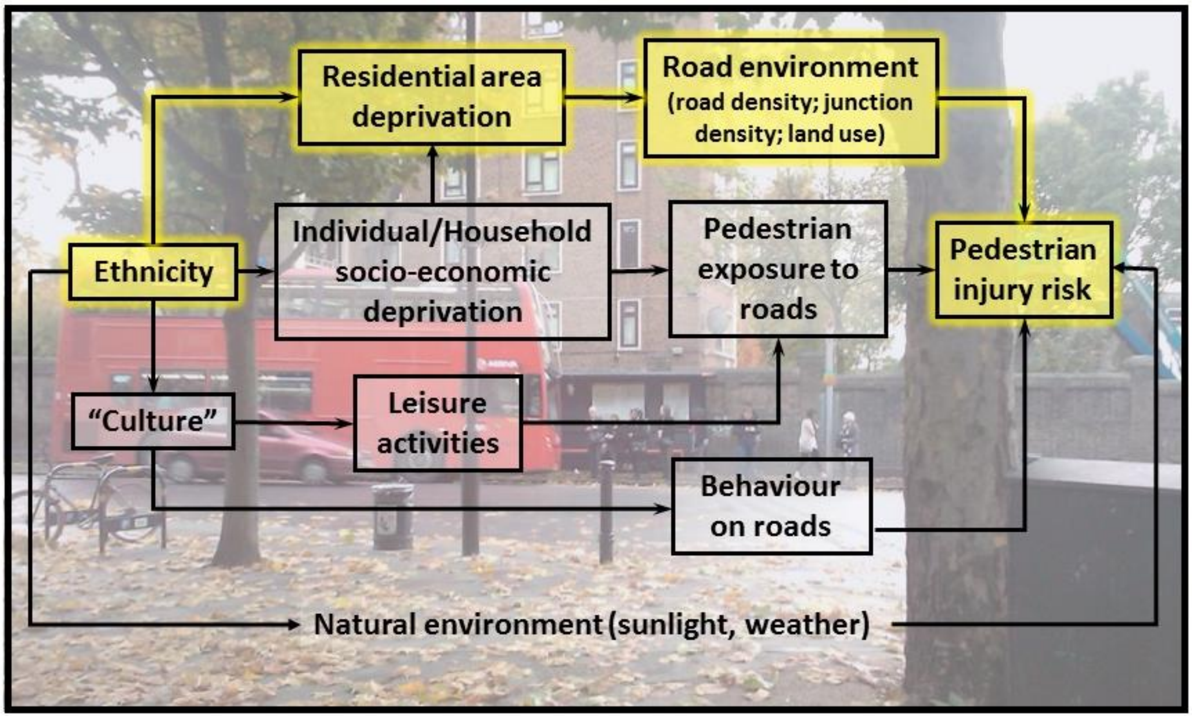
While there is a long tradition of secondary analysis in quantitative research, the data I analysed in this thesis were not always fit for purpose. Data often did not include desired variables (or categories), or address questions I wish it would have. While quantitative data has historically been considered 'objective', more recent critiques have argued that quantitative measures are socially constructed and depend on value judgement of data collectors. For instance, police data on road collisions includes data on casualties' ethnicity, but not hair or eye colour. Often these value judgements can be so engrained and taken for granted that they can be invisible. As Bowker and Star (2000) note in their discussion of classification "categories are historically situated artefacts and, like all artefacts, are learned as part of membership in communities of practice" (p287).

Using secondary data sources limits my ability to reflect on how the pre-dispositions of data collectors may have influenced the content and process of data collection. There are also a number of uncertainties about how data was collected. For example, as described above, the ethnicity variable included in police records of road traffic injury is the six-category Police National Computer 'Identity Code', which relies on observer identification of physical attributes of casualties. There is no information on how, in practice, London's police officers do characterize a casualty's ethnicity and how, for instance they distinguish between 'Dark-skinned European' or 'Arab' categories. I consider the implications of these types of challenges in the limitations section of each chapter.

3 DO MINORITY ETHNIC CHILDREN IN LONDON USE MORE 'HAZARDOUS' ROADS THAN THEIR COUNTERPARTS?

This chapter explores an important potential mechanism in the quest to understand differences in child pedestrian injury rates among ethnic groups in London: to what extent is the quality of the road environment (e.g. density of roads and junctions), responsible? The ecological exposure hypothesis set out in Chapter 1 (figure 3.1) is examined in depth. According to that hypothesis, 'Black' children may have relatively higher injury rates because the areas where they walk, run and play have more 'hazardous' road environments, while 'Asian' children, by contrast, may have relatively lower injury rates because they are exposed as pedestrians in areas with less 'hazardous' roads. The ecological exposure hypothesis is examined in two stages, focusing on distinct parts of the casual pathway. Sections 3.1-3.2 examine links between the road environment and pedestrian injury risk more generally. Section 3.1 sets out a conceptualisation of the types of environments that theoretically may be 'hazardous' for child pedestrians. Section 3.2 reviews the literature on road environment correlates of pedestrian injury, to examine features of the road environment that are associated with a higher probability of hazards. Section 3.3 describes an ecological analysis designed to examine potential links between the road environment, area deprivation and ethnicity in London. Using findings from the literature review, I gather information on road environment features in London that may make areas more or less 'hazardous' for child pedestrians.

Figure 3.1: Hypothesized model of links between ethnicity and pedestrian injury risk



Next, I explore associations between these road environment features and area deprivation, and compare the distribution of these features to the ethnic distribution of London's child population. Finally, section 3.4 discusses what the findings from sections 3.2 and 3.3 suggest about the contribution of the quality of the road environment to explaining reported ethnic inequalities in injury risk in London.

3.1 CHARACTERIZING 'HAZARDOUS' ROADS?

In order to explore the contribution of the quality of the road environment to ethnic inequalities in risk, a necessary first step is to identify at a conceptual level what types of environments are likely to be 'hazardous'[1] to child pedestrians. There are a number of different ways hazard levels have been theorized in the literature. However, all have limitations for exploring the role of hazard levels in ethnic inequalities in injury. Some work describes hazard levels in terms of perceptions of safety of children or their parents (Ampofo-Boateng and Thomson 1991), typically measured using surveys (Christie 1995). Perceptions of hazard levels, however, are likely to be subjective. Indeed there is evidence that parental perceptions of child pedestrian road safety vary by such factors as gender, employment status and language spoken (Lam 2005, Lam 2001). These differences in perception of hazards may lead to differences in levels of exposure to hazards by population group if children differentially avoid particular areas or parents differentially restrict children's movement. For the purposes of this thesis, ideally a conceptualisation of hazard levels would be similar across population groups.

Other research defines 'hazardous' roads as those where most child pedestrian injuries take place (Wang, Quddus, and Ison 2011). Preferably, a measure of hazard levels would take into account some form of denominator; for instance a measure of injury rates per child-time spent on the road. Unfortunately, the exposure data necessary for denominators is usually not available. As a result, a large methodological literature has developed to identify the best approach to classify collision 'hot spots' or 'black spots' (Loo 2009, Montella 2010). However, even measures with appropriate

[1] While from an epidemiological perspective, 'hazardous' is arguably a more accurate way to describe roads with a high probability of a hazard occurring (in this instance defined as a collision involving a child pedestrian), much literature uses the term 'dangerous' to refer to this concept. 'Dangerous', however, is a broader concept with a variety of meanings and complex political connotations. For instance, The Road Danger Reduction forum highlights that 'dangerous' can have both a transitive and intransitive meaning: (in the case of child pedestrians) children can kill, hurt or endanger other road users or children can be killed hurt or endangered by other road users. 'Dangerous' therefore is discursively tied up with who is at 'fault' in a collision, an issue which is beyond the scope of this thesis. Therefore, to focus on road environment features that increase or decrease the probability of a collision involving a child pedestrian on a particular road, I have chosen to use the terminology 'hazardous' and 'hazard levels' in this thesis.

exposure denominators are still problematic: perceptions of danger may lead more or fewer children to use the road (or to use the road differently), which may influence casualty numbers, or rates.

Other conceptualisations of hazard levels argue that it is the amount of kinetic energy present on a road that puts child pedestrians at risk (Morency et al. 2012, Roberts and Edwards 2010). The amount of kinetic energy on a road depends on the number and size of vehicles, and the speed of travel. This is a more promising objective measure of hazard levels, but lacks sophistication: it does not take into account other factors likely to contribute to the probability of a hazard, such as those affecting visibility of drivers or pedestrians.

In this thesis, I build on Elvik's (2008) theoretical definition of a 'hazardous' road as *"any location that has a higher expected number of accidents than other similar locations as a result of local risk factors present at the location."* I have divided local risk factors into three types: factors that affect the prospect of a space conflict, visibility factors and road-user reaction factors.

Collisions involving child pedestrians occur when a child pedestrian and another road user (usually but not exclusively a motor-vehicle) attempt to occupy the same space at the same time (Chalabi et al. 2008). Any factors that make a space conflict more probable are therefore likely to make roads more 'hazardous'. For instance, high traffic volumes, industrial or commercial activity, presence of schools, and lack of alternative (non-road) spaces for pedestrians (e.g. for children to play) may indicate more pedestrians and vehicles and therefore a higher potential for space conflict.

When two road users are headed for the same space at the same time, a key factor that influences whether or not a collision actually takes place is visibility. If drivers and pedestrians cannot see each other, collisions are more likely. Road environment characteristics that may affect visibility include street curvature, parked cars, and other visual obstructions.

If drivers and pedestrians do see each other on a collision course, their ability to react to each other largely determines if a crash will happen. Factors influencing reaction times include the speed of travel (faster speeds give road users less time to react) and road user 'distractions' (tiredness, music, alcohol, medicines, drugs, mobile phones). If such distractions are more likely to be concentrated in a particular area (for instance, alcohol related distractions near bars or liquor stores), then they have the potential to make road environments more 'hazardous'.

To examine the impact of space conflict factors, visibility factors and road-user reaction factors on child pedestrian injury risk, I conducted a search and review of the published epidemiological and road safety literature.

3.2 LITERATURE REVIEW OF ENVIRONMENTAL CORRELATES OF PEDESTRIAN INJURY

The literature review maps the range of road environment features found to be associated with pedestrian injury risk. Many studies investigating correlates of pedestrian injury are not solely focused on the road environment, but include measures of the social environment and demographic characteristics of injured pedestrians. This review concentrates on results relating to the road environment only (social and demographic correlates of pedestrian injury were reviewed in the introductory chapter of this thesis).

3.2.1 Methods

I reviewed published literature from January 1990- June 2010. I searched four electronic databases: Medline, Embase, International Bibliography of the Social Sciences, and Web of Science using terms such as 'physical/traffic/road/urban/built environment' or 'spatial/geographic variation' and 'injur(ies)/casualt(ies)/crash(es)/collision(s)/accident(s), as well as 'road danger/safety'. Details of my search strategy are detailed in Appendix 4.

I included all studies published in the English language addressing environmental correlates of pedestrian injury among healthy populations (in people of all ages), in any country in the world, using any study design. I excluded studies which reported correlates of road traffic injury generally and those examining pedestrian and cyclist injuries together. I further excluded studies focused on special populations, for instance studies investigating pedestrian injury among people with a disability.

Since June 2010, a number of additional studies have been published, most notably reviews by Rothman and colleagues (2013) and Dimaggio and colleagues (2012). Rothman and colleagues conducted a systematic review of the road environment correlates of pedestrian injury and amount of walking. Markedly, Rothman's review of literature from 1980-2012 found that less than 20% of included studies were published after 2008. Dimaggio and colleagues examined the road environmental correlates of child pedestrian injury risk and they estimated the contribution of roadway characteristics to injury risk. I assessed the included studies of the Rothman and Dimaggio reviews for inclusion in this literature review. Results were synthesised in a narrative summary.

3.2.2 Results

My search strategy returned 1,123 articles. I removed 374 duplicates and assessed the remaining 749 for inclusion: 603 articles were excluded on title and abstract. I obtained the full text of 146 articles. I excluded 118 articles for a range of reasons: mostly because they reported on road traffic crashes generally and did not separate out pedestrians from other road users, or did not present any new data (see Appendix 5 for characteristics of a selection of excluded studies). After reviewing the Rothman and Dimaggio systematic reviews, I included an additional two studies (figure 3.2).

Figure 3.2: Flow diagram of included studies

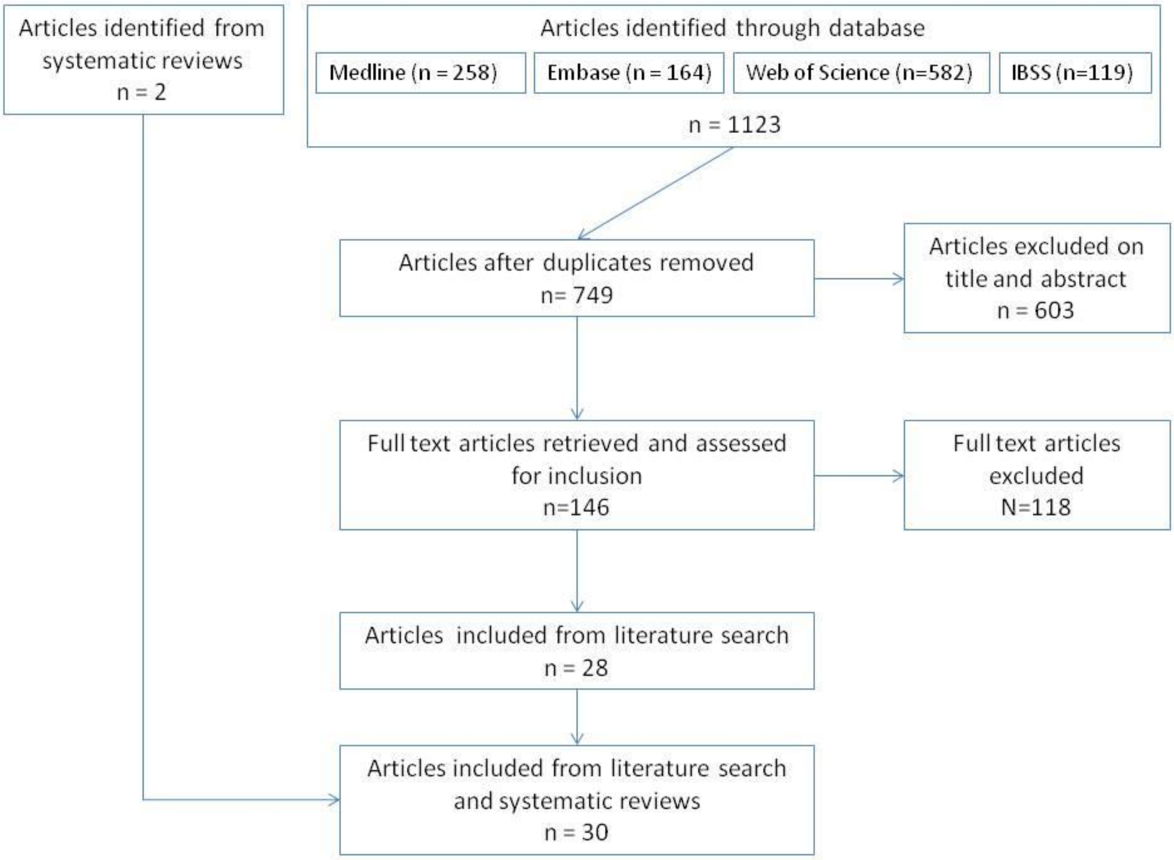


Table 3.1 presents the characteristics of the included studies. Nine studies used a case-control design, one study used a mixed methods observational design, and 20 studies used an ecological study design. Since the purpose of this review was to map the range of road environment correlates of pedestrian injury, rather than meta-analyse the effects of particular correlates, I have reported the salient features of the environment found in each study and whether any associations with pedestrian injury were positive or negative. The 30 included articles characterized features of the road environment in a variety of ways using many different indicators. I broadly grouped these into the three conceptual categories outlined in the previous section: factors that affect the prospect of a space conflict, factors that affect visibility, and factors that affect the abilities of road users to react to each other. Results are summarized in Table 3.2.

Table 3.1: Characteristics of included studies

Study	Setting	Time period	Population	Study design	Correlates of pedestrian injury
(Agran 1996)	Orange County, California, USA	1991-1993	39 Latino children (under 15) injured as pedestrians on the same street as their home, 62 controls matched for age, sex, ethnicity and city	Case control study examining neighbourhood characteristics of injured and non-injured children.	Associated with increased injury: high vehicle speeds, more vehicles parked on the street, more total pedestrians observed; Associated with decreased in jury: high traffic volumes.
(Berhanu 2004)	Addis Ababa, Ethiopia	1996-1997	54 sections of road covering 60% of arterial roads in Addis Ababa	Ecological analysis of road environments and pedestrian injury.	Associated with increased injury: high traffic flow; Association with decreased injury: low pedestrian flow, width of sidewalks, presence of raised kerb edge; No association with injury: number of lanes, lane width, minor junctions, paved sidewalk surfacing.
(Christie 1995)	Selected areas in England	Not stated	Cases: 152 school children injured as pedestrians, Controls: 484 school children in similar catchment areas as the hospitals attended by the injured cases.	Case control study examining the road environment features of roads crossed on school journeys, roads where children lived and roads where cases had been injured.	Associated with increased injury: low level of on-street parking, presence of pre-war (1914) housing developments.

Study	Setting	Time period	Population	Study design	Correlates of pedestrian injury
(Dai et al. 2010)	Urban Campus of Georgia State University, USA	2003-2007	Road environment features of the University campus	Examined ecological associations between road environment features and prevalence of pedestrian injuries.	Of all the intersections in the university campus more than 50% of those with crosswalk signs, pedestrian signals, public transport and location branding signs (>3) had pedestrian crashes. More than 50% of streets that were wide (>29ft), two-way, and in good condition had pedestrian crashes. Crashes were also clustered in areas with mixed land use and strong street compactness.
(Dissanayake, Aryaija, and Wedagama 2009)	Newcastle upon Tyne, UK	2000-2005	10 Wards (out of 11) in the Newcastle Urban periphery	Ecological analysis of child pedestrian injury rates and land use characteristics at the ward level.	Association with increased injury: secondary retail shops and stores; Association with decreased injury: high density residential land use.
(Donroe et al. 2008)	San Juan de Miraflores, Lima, Peru	2005-2006	40 children seriously injured as a pedestrian, 80 controls matched on gender and age	Case control sites examining environmental correlates of streets where children were exposed to pedestrian injury.	Associated with increased injury: high vehicle volume, high vehicle speed, more street vendors, absent lane demarcations.
(Ewing, Schieber, and Zegeer 2003)	USA	2000	448 metropolitan counties	Ecological county-level analysis of pedestrian fatalities and urban sprawl.	Associated with increased injury: high levels of Urban sprawl index.
(Garder 2004)	7 towns in Maine, USA	1994-1998	70 intersections and 52 midblock locations	Ecological analysis comparing observed versus predicted number of pedestrian crashes (predictions based on a Swedish and UK model including number of vehicles per day and number of pedestrians per day).	Low-speed locations, two-lane roads, non-signalised cross-walked intersections had lower than predicted numbers of crashes. Wider streets, median-speed and high-speed locations, and signalized crosswalk locations had higher than predicted number of crashes.

Study	Setting	Time period	Population	Study design	Correlates of pedestrian injury
(Graham and Stephens 2008)	England, UK	1998-2002	Wards in England	Ecological analysis examining associations between child pedestrian injury (under 16), deprivation and the road environment in London, Con-urban, and Rural areas.	Associated with increased injury in greater London: greater child population density, employment density, greater road density, greater Index of multiple deprivation crime score.
(Green, Muir, and Maher 2011)	Bradford and Leeds, UK	2000-2005	Lower super output areas	Ecological analysis examining correlations between child pedestrian casualties and environmental factors.	Associated with increased injury: greater junction density, higher pedestrian flow, higher vehicular flow; Associated with decreased injury: more domestic garden area.
(Hijar, Trostle, and Bronfman 2003)	Mexico City, Mexico	1994-1997	Road environments of pedestrian fatalities who die at the scene	Mixed methods observational study of 4 road environments selected from the 10 areas with the highest number of pedestrian deaths.	These environments tended to have wide avenues with high vehicle flows. In these environments spaces that were reserved for pedestrians tended to be invaded by cars and vendors.
(LaScala, Gerber, and Gruenewald 2000)	San Francisco, California, USA	1990	149 Census Tracts	Ecological analysis comparing demographic and environmental characteristics of census tracts to numbers of pedestrian injuries and number of pedestrian injuries where the pedestrian was determined to have been drinking alcohol.	Associated with increased injury: higher traffic flow and greater population per km of roadway. Bars per km of road way were positively associated with number of pedestrian injuries where the pedestrian was determined to have been drinking alcohol.
(LaScala, Gruenewald, and Johnson 2004)	California, USA	1992-1996	102 geographic units in 4 communities	Ecological analysis examining associations between annual pedestrian injury rates per km, social environment and road environment characteristics during school term and	Association with increased injury: greater density of youth population, higher traffic volume. Annual numbers of injuries during school months were greater in areas containing middle and high schools.

Study	Setting	Time period	Population	Study design	Correlates of pedestrian injury
				summer month.	
(Leden 2002)	Hamilton, Ontario, Canada	1983-1986	300 signalized intersections	Ecological analysis comparing pedestrian injury risk per pedestrian and flows of left turning and right tuning vehicles.	Associated with increased injury: higher traffic flow; Association with decreased injury: higher pedestrian flow.
(Lee and Abdel-Aty 2005)	Florida, USA	1999-2002	Road environments at 1563 signalized intersections where pedestrian crashes have occurred	Ecological analysis of road environments and pedestrian crashes at intersections.	Frequency of pedestrian crashes increases with traffic volumes.
(Mueller et al. 1990)	King County, Washington, USA	1985-1986	Cases: 98 children aged 0-15 as pedestrians Controls: 196 controls matched on age and sex	Case control study examining neighbourhood characteristics of cases and controls.	Associated with increased injury: high traffic volumes, high posted speed limit; Not associated with injury: lack of pedestrian crossing devices, crosswalks or sidewalks.
(Paulozzi 2006)	USA	1999-2002	States in the USA	Ecological analysis examining associations between percentage of pedestrian fatalities occurring on roads with posted speed limit >=35mph and state mortality quartile.	The posted speed limits on roads with pedestrian fatalities were more likely to be >=35mph in states with the highest pedestrian injury fatality rates, especially in urban areas.
(Priyantha Wedagama, Bird, and Metcalfe 2006)	Newcastle upon Tyne, England, UK	1998-2001	90 Enumeration Districts	Ecological analysis examining associations between numbers of child (age 0-16) pedestrian injuries and land use variables during working (Monday to Friday 7am-7am) and non-working (all other times) hours.	Association with increased injury: During working hours: high population density, high junction density, greater proportion of 'community' buildings (health, educational, community and religious buildings), greater proportion of 'retail' buildings (shops garages, pubs, restaurants) During non-working hours: greater proportion of retail buildings.

Study	Setting	Time period	Population	Study design	Correlates of pedestrian injury
(Roberts et al. 1995)	Auckland, New Zealand	1992-1994	Case sites of injury among 190 child pedestrian injuries, Control sites of 380 children matched for age and sex	Case control study examining the environmental characteristics of sites of child pedestrian injury compared to control site.	Associated with increased injury: high traffic volume, high density of curb parking, mean speeds over 40kph.
(Schneider, Ryznar, and Khattak 2004)	University of North Carolina Campus, USA	1994-1999	94 road segments and intersections	Ecological analysis estimating exposure, road way and land use correlates of police reported pedestrian injury.	Associated with increased injury: longer road segments/intersections, higher pedestrian volumes, presence of marked crosswalks; Associated with decreased injury: higher number of bus stops; Not associated with injury: traffic volumes.
(Schuurman et al. 2009)	Vancouver, British Columbia, Canada	2000-2005	32 pedestrian injury hotspots	Ecological analysis comparing the distribution of alcohol establishments across hotspots.	Bars were present at 21 pedestrian injury hotspots with 11 hotspots having high alcohol establishment density.
(Sebert Kuhlmann et al. 2009)	Denver, Colorado, USA	2000-2003	Census tract	Ecological analysis examining associations between land use and pedestrian motor vehicle collisions.	Associated with increased injury: greater proportion of the labour force who walk or take public transit to work, higher density of liquor license outlets, higher population density.
(Steinbach et al. 2010)	London, UK	1996-2005	4,765 lower super output areas in London	Ecological analysis examining associations between features of the road environment and ‘White’, ‘Black’, and ‘Asian’ child pedestrian injury rates.	Associated with increased injury: greater density of A roads, greater proportion of postcodes characterised as business, higher density of road junctions (‘White’ child pedestrian injury only); Associated with decreased injury: higher density of minor roads.
(Stevenson, Jamrozik, and Spittle 1995)	Perth, Australia	1991-1993	Cases: Children aged 1-14 injured as pedestrians Controls: 2 controls per case matched for sex and	Population based case control. Examined road environments around case injury sites and control sites matched on	Association with increased injury: greater traffic volume, greater proportion of vehicles exceeding the speed limit; Association with decreased injury: Absence of

Study	Setting	Time period	Population	Study design	Correlates of pedestrian injury
			age	distance.	footpaths.
(Stevenson, Jamrozik, and Burton 1996)	Perth, Australia	1991-1993	Cases: 100 Children aged 1-14 injured as pedestrians Controls: 400 controls matched for sex and age	Case control study. Examined road environments around where cases and controls habitually walked.	Association with increased injury: higher traffic volume on roads most frequently crossed, presence of visual obstacles on the verge of a child's street of residence; Association with decreased injury: Absence of footpaths.
(Stevenson 1997)	Perth, Australia	1991-1993	100 cases of children (1-14 years old) injured as pedestrians and 400 randomly selected non-injured child pedestrians	Case control study examining the environmental characteristics of roads where children were exposed to injury.	Associated with increased injury: higher volume of traffic, presence of visual obstacles.
(Tester et al. 2004)	Oakland, California, USA	1995-2000	100 child pedestrians injured on a minor road close to their home visiting an emergency ward and 200 controls who also visited an emergency ward matched for age and sex	Case control study examining whether children injured as pedestrian were less likely to live on a road with speed humps.	Associated with decreased injury: speed humps
(Thouez et al. 2002)	Montreal, Canada	1995-1997	Blocks (streets) within 2 territories: the city of Montreal and the periphery of Montreal	Ecological analysis predicting number of expected pedestrian fatalities using street characteristics.	In the city of Montreal, high posted speed limits and the presence of street lighting at night were associated with pedestrian fatalities. In the periphery of Montreal: more curved street (both flat-curve and grade-curve) were associated with pedestrian fatalities

Study	Setting	Time period	Population	Study design	Correlates of pedestrian injury
(Wier et al. 2009)	San Francisco, California, USA	2001-2005	176 Census Tracts	Ecological analysis modelling the number of injuries in a census tract as the function of road environment features in each area.	Association with increased injury: higher traffic volume, higher employee and resident populations, arterial streets without public transport, residential-neighbourhood commercial use; Associated with decreased injury: greater land area.
(Yiannakoulias et al. 2002)	Edmonton, Alberta, Canada	1995-1999	Census tracts	Ecological analysis comparing child pedestrian injury rates and traffic density.	Higher traffic density is associated with increased child pedestrian injury rates.

Table 3.2: Road environment correlates of pedestrian injury

	Factors that affect the prospect of a space conflict	**Factors that affect visibility**	**Factors that affect the abilities of road users to react to each other**
Factors associated with *increased* pedestrian injury	• Traffic volume • Pedestrian flow • Employment and residential density • Presence of schools • Junction density • Presence of community and retail buildings • Presence of marked crosswalks • Absent lane demarcations • Urban sprawl	• Parked cars • Visual obstacles • Street vendors • Street curvature (more curved streets)	• Traffic speeds • Proportion of cars exceeding speed limit • Alcohol establishment density
Factors associated with *decreased* pedestrian injury	• Traffic volume • Pedestrian flow • Absence of footpaths • Wide sidewalks • Raised kerb edges • High residential land use • Presence of bus stops • Domestic garden area	• Levels of on street parking	• Speed humps

Factors that affect the prospect of a space conflict

Many studies reported associations between increased pedestrian injury and factors that suggest pedestrian activity in particular areas. These factors include employment density (Wier et al. 2009, Graham and Stephens 2008), mixed land use(Dai et al. 2010, Wier et al. 2009), population density (LaScala, Gruenewald, and Johnson 2004, Priyantha Wedagama, Bird, and Metcalfe 2006, LaScala, Gerber, and Gruenewald 2000, Graham and Stephens 2008, Sebert Kuhlmann et al. 2009), presence of community and retail buildings (Priyantha Wedagama, Bird, and Metcalfe 2006, Dissanayake, Aryaija, and Wedagama 2009), presence of schools (LaScala, Gruenewald, and Johnson 2004), and presence of marked or signalized cross walks (Garder 2004, Dai et al. 2010, Schneider, Ryznar, and Khattak 2004). While these factors do not measure the actual number of pedestrians exposed to hazards in an area, they all suggest that pedestrian activity is likely to take place.

Factors that decrease the likelihood of pedestrian activity in a particular area were associated with reduced pedestrian injury. These factors include such features as high residential land use (Dissanayake, Aryaija, and Wedagama 2009), domestic garden areas (Green, Muir, and Maher 2011) and absence of footpaths (Stevenson, Jamrozik, and Spittle 1995, Stevenson, Jamrozik, and Burton 1996).

Overall, the evidence from the studies was relatively clear: factors that suggest high levels of pedestrian activity were associated with increased injury, while factors that suggest low levels of activity were associated with decreased injury. Evidence on the influence of actual pedestrian flows, however, was mixed. Some studies reported an association between higher pedestrian flows and increased injury (Agran 1996, Green, Muir, and Maher 2011, Schneider, Ryznar, and Khattak 2004), while others reported an association between high pedestrian flows and decreased injury (Leden 2002). It is difficult to reconcile these conflicting findings. Some studies on walking and bicycling have found a ‘safety in numbers’ phenomenon: the risk of a pedestrian (or cyclist) injury declines in areas with large numbers of pedestrians and cyclists (Jacobsen 2003, Geyer et al. 2006). These studies hypothesize that motorists change their behaviour in areas with large numbers of pedestrians. It is therefore plausible that in areas with relatively few pedestrians, greater pedestrian flows contribute to increased injury, while in areas with many pedestrians, greater pedestrian flows contribute to decreased pedestrian injury.

Evidence on traffic volumes is also mixed. The vast majority of studies reported a positive association between traffic volumes and pedestrian injury (Leden 2002, Stevenson, Jamrozik, and Spittle 1995, Hijar, Trostle, and Bronfman 2003, Berhanu 2004, LaScala, Gruenewald, and Johnson 2004, Lee and Abdel-Aty 2005, Stevenson, Jamrozik, and Burton 1996, Mueller et al. 1990, Roberts, Marshall, and

Lee-Joe 1995, Yiannakoulias et al. 2002, Donroe et al. 2008, Green, Muir, and Maher 2011, LaScala, Gerber, and Gruenewald 2000, Stevenson 1997, Wier et al. 2009). One study reported a negative association (Agran 1996) and one study reported no association (Schneider, Ryznar, and Khattak 2004). The study reporting a negative association investigated injuries to child pedestrians in a largely residential area. The authors explain their negative association by suggesting that in residential areas with high traffic volumes, parents and caregivers may be less likely to allow their children to play outside (Agran 1996).

At an area level, public transport may replace pedestrian or vehicle trips and therefore suggest a lower number of pedestrians or vehicles in an area. Conversely, the number of public transport stops may indicate an increased number of pedestrians in concentrated locations such as bus stops. There was some evidence that streets without public transport were associated with increased injury (Wier et al. 2009). Evidence on public transport stops is mixed, with one study finding an association between number of bus stops and decreased injury (Schneider, Ryznar, and Khattak 2004) and one study reporting that more than 50% of pedestrian injuries occurred at intersections with public transport (Dai et al. 2010).

The physical layout of spaces for pedestrian and vehicles was also found to influence injury. Areas where pedestrians had to cross wide roads were associated with increased injury (Hijar, Trostle, and Bronfman 2003, Dai et al. 2010). On the other hand, areas where pedestrian and traffic activity were separated, (e.g. wide sidewalks and presence of raised curb edge) were associated with decreased injury (Berhanu 2004). Areas with more junctions were also associated with increased pedestrian injury (Priyantha Wedagama, Bird, and Metcalfe 2006, Steinbach et al. 2010).

Visibility factors

There was good evidence linking visibility factors and pedestrian injury. Studies found that visual obstructions, including street vendors (Donroe et al. 2008, Hijar, Trostle, and Bronfman 2003), rubbish bins (Stevenson 1997), and parked cars(Agran 1996, Roberts et al. 1995, Hijar, Trostle, and Bronfman 2003) were associated with increased pedestrian injury. One study, however, found that low levels of on-street parking were associated with increased injury. The authors suggest that this finding may be explained by the types of roads which tended to have low-levels of parking in the sample (main roads with greater traffic volumes)(Christie 1995).

Street lighting is another visibility factor found to be associated with pedestrian injury. Thouez and colleagues (2002) found that the presence of street-lighting at night was associated with pedestrian fatalities in the city of Montreal; a surprising finding given that the majority of evidence suggests that introducing street-lighting at night reduces road traffic crashes (Beyer and Ker 2009). It is possible, however, that in the Montreal study, street-lighting represented a proxy for exposure; that is, street-lighting was more likely to be present in areas with relatively high amounts of pedestrian or vehicle volume.

The same Montreal study found that more curved streets were associated with pedestrian fatalities. More curved streets may offer less visibility for pedestrians and vehicle drivers. However, the literature on street curvature and road crashes more generally is more mixed. Studies do suggest that crashes are likely to occur on bends, however some studies also suggests that road curvature is associated with fewer road traffic crashes, likely due to reduced vehicle speeds (Haynes et al. 2007, Jones et al. 2008).

Road user reaction ability factors

There is good evidence from many countries around the world of an association between high traffic speeds and increased pedestrian injury (Agran 1996, Donroe et al. 2008, Garder 2004, Mueller et al. 1990, Paulozzi 2006, Roberts et al. 1995, Stevenson, Jamrozik, and Spittle 1995, Thouez et al. 2002). This association was consistent across a number of speed measures: posted speed limits, recorded speeds and proportion of vehicles exceeding the speed limit. One study found an association between speed humps and decreased pedestrian injury (Tester et al. 2004) which is consistent with a systematic review of effect of traffic calming on road traffic injuries more generally (Bunn et al. 2009). Finally, evidence from Canada and the USA suggests a link between alcohol establishment density and increased pedestrian injury (Schuurman et al. 2009, Sebert Kuhlmann et al. 2009, LaScala, Gerber, and Gruenewald 2000). Pedestrian injuries may increase in areas where it is more likely that alcohol inhibits the abilities of pedestrians or drivers to react to each other.

Overall, the literature suggested a number of road environment features that, when present, potentially make an area more or less ‘hazardous’ to pedestrians. In their systematic review Dimaggio and colleagues found that taken as a whole, these features are, indeed, significantly associated with child pedestrian injury risk (odds ratio 2.5, 95% credible interval 1.8-3.2). With this research as backdrop, the question arises: To what extent can the differences in pedestrian injury risk among ethnic groups in London summarised in Chapter 1 be explained by differences in the road environment where these population groups spend time exposed as pedestrians? To examine whether the quality of the road environment can help explain ethnic inequalities in child pedestrian injury risk in London, the next section explores association between the road environments and area deprivation and examines whether ‘White’, ‘Black’ and ‘Asian’ children are more or less likely to live in areas characterized by a selection of the ‘hazardous’ features of the road environment identified in this review.

3.3 Ecological analysis of the links between the road environment, area deprivation and ethnicity in London

To investigate whether the quality of the road environment is more 'hazardous' in deprived areas and in areas where ethnic minorities live, I designed an ecological study comparing the distribution of 'hazardous' features of the road environment to both measures of area deprivation and the ethnic distribution of London's child population. If the quality of the road environment can help to explain reported inequalities by level of deprivation and ethnicity I would expect to find:

- More deprived areas are characterized by relatively more 'hazardous' road environments
- A greater proportion of 'Black' children live in areas with more 'hazardous' road environments compared to 'White' children
- A smaller proportion of 'Asian' children live in areas with more 'hazardous' road environments compared to 'White' children

The analyses require three main sources of data: (i) summaries of 'hazardous' features of the road environment in London; (ii) data on area level deprivation; and (iii) data on child populations by ethnic group. The data sources used in the analysis are described below.

3.3.1 Features of the road environment

I collected information on all relevant features of the road environment available in London. For analysis, I summarized features of the road environment at a geographic area level (see section 2.7 for a description of how I defined an 'area'). Table 3.3 lists the sources of data, years and variables created for all road environmental characteristics used in this thesis. I was able to collect a number of indicators describing factors that influence the likelihood of a space conflict: density of A roads, density of minor roads, junction density, traffic volume, residential status, population density and density of bus stops; and one indicator of road-user reaction factors: traffic speed. I was unable to find any usable data on visibility factors in London.

Table 3.3: Data sources on environmental characteristics

Data Source	Year	Variables
Ordinance Survey (OS) Integrated Transport Network (ITN)	2010	Density of A roads (length of A roads/total road length in area) Density of minor roads (length of minor roads/total road length in area) Junction density (number of junctions/ total road length in area)
London Greenhouse Gas Inventory	2008	Traffic speed (miles per hour) Traffic volume (annual average daily traffic flow)
All Fields Postcode Directory	2009	Residential status (proportion of postcodes characterised as 'business')
NaPTAN	2012	Density of bus stops (number of bus stops/total geographic area)
Census	2011	Population density (persons per square km)

The Ordinance Survey Integrated Transport Network (ITN) is a detailed map of London's road network, available at a scale of 1:1250 metres. The ITN contains 18,864km of road including 2,437 km of A roads, 565km of B roads, and 12,956km of minor roads. To create variables on the length, number and density of A roads, B roads, minor roads and junctions in each area I overlaid geographic area boundaries onto the ITN and summarised the desired variables. Densities were calculated as, for instance, the length of A roads divided by the total length of road in the area.

Information on traffic speeds and traffic volumes came from the London Greenhouse Gas Inventory (LEGGI). LEGGI is a database of geographically referenced datasets of energy consumption within the Greater London area, produced annually by the Greater London Authority. It includes a road network with estimates of the average daily number of motorcycles, cars, taxis, coaches, LGV and HGVs travelling on selected roads in London as well as average recorded traffic speeds. Traffic speeds are averages of speeds recorded by Transport for London's floating car from 2003-2008 at three intervals (morning rush hour, inter-peak and evening rush hour). Traffic flows and speed estimates were not available for all roads in London. LEGGI traffic flow data covers 3,927km in road length, representing approximately 20% of the ITN.

To create area summaries of traffic volumes and speeds, I first assigned all roads in the ITN that were covered by LEGGI data speed and volume information. Next, I calculated local authority level averages of speeds and volumes by road type (A roads, B, roads, minor roads) using the available roads in the LEGGI data. Pedestrianised streets were assigned values of 0 for both speeds and traffic volumes. I then assigned each road in the ITN that was not covered by LEGGI data the local authority average speed and volume of that road type. Finally, I overlaid geographic area boundaries with my newly created road network and summarised the desired variables. For analysis, I created one traffic flow variable which summed the average annual daily flows for all types of vehicles.

Data on residential status comes from the 2009 All Fields Postcode Directory, a dataset of all postcodes in Great Britain. The data includes variables describing the geographic area corresponding to the postcode centroid (for England and Wales). Each postcode record also contains information on postcode user type, which has one of two values: large or small. Large postcode users are employers who receive more than 25 pieces of mail a day. I used the proportion of postcodes in an area characterized as 'business' as a proxy for residential status of an area. To create this variable I summed the number of large and small user postcode in an area and calculated the appropriate percentage.

Data on density of bus stops comes from The National Public Transport Access Node (NaPTAN) database which includes an easting and northing of every bus stop in the UK. To create a variable describing the density of bus stops in a geographic area I overlaid geographic area boundaries onto the NaPTAN data and summed the number of bus stops in each area. I then created densities by dividing the number of bus stops in each area by the area in square km of the geography.

I obtained data on population density from the 2011 decennial census which reports persons per square km for each geographic area in England and Wales.

3.3.2 Area deprivation

I used the 2010 Index of Multiple Deprivation (IMD) to score the level of deprivation of each area. IMD brings together 36 indicators across seven domains of deprivation into an overall score for each geographical area. The seven domains of deprivation are: Income, Employment, Health and disability, Education, skills and training, Barriers to housing and services, Living environment, and Crime. Low scores indicate less deprived areas while higher score indicate higher levels of deprivation. See Appendix 6 for more details on IMD.

3.3.3 Population data

I used population data from the census and the Greater London Authority (GLA) to create geographic area level estimates of the 'White', 'Black' and 'Asian' populations aged under 16 years. These data are used in this chapter to compare distributions of the population by ethnic group to distributions of the road environment features described above. These data are also used as denominators in injury rates in explorations of the relationship between ethnicity, deprivation and injury in Chapters 7 and 8.

Unfortunately, age specific population data are not available at small geographic area level by ethnic group so I obtained three different sources of data to estimate 'White', 'Black' and 'Asian' child populations:

Source 1: the population of each area by single year age from the 2011 census;

Source 2: estimates of the population of all ages living in each area by ethnic group from the 2011 census;

Source 3: local authority level estimates of child populations (0-15) by ethnic group from the Greater London authority from 2011.

Using estimates of the population of all ages living in each area by ethnic group from the 2011 census (source 2), I calculated the percentage of all residents in each LSOA that were 'White', 'Black', and 'Asian'. I estimated the population of 'White', 'Black', and 'Asian' children in each area by multiplying the numbers of children aged 0-15 years resident in each area in 2001 (source 1) by the percentages of residents of all ages that are 'White', 'Black', or 'Asian'. The estimates of area-level ethnic group child populations were then scaled to sum to the total child population estimates at local authority level (source 3), to allow for any ethnic differences in family size.

Ethnicity in census data

In the 2011 census, respondents self-identified their ethnic group from one of 18 fixed response categories:

- White: English/Welsh/Scottish/Northern Irish/British
- White: Irish, White: Gypsy or Irish Traveller
- White: Any other White background
- Mixed/multiple ethnic groups: White and Black Caribbean
- Mixed/multiple ethnic groups: White and Black African
- Mixed/multiple ethnic groups: White and Asian
- Mixed/multiple ethnic groups: any other Mixed/multiple ethnic background
- Asian/ Asian British: Indian, Asian/ Asian British: Pakistani
- Asian/ Asian British: Bangladeshi
- Asian/ Asian British: Chinese
- Asian/ Asian British: Any other Asian background
- Black/African/Caribbean/Black British: African
- Black/African/Caribbean/Black British: Caribbean
- Black/African/Caribbean/Black British: Any other Black/African/Caribbean background
- Other ethnic group: Arab
- Other ethnic group: Any other ethnic group.

Consistent with previous work (Steinbach 2010), to generate data on the percentage of all residents that were 'White', 'Black', and 'Asian' (from source 2), I pragmatically mapped these into the four broad ethnic categories (mappings can be found in table 3.4).

Ethnicity in GLA data

The ethnicity variable available in local authority level estimates of child populations by ethnic group (source 3) is the GLA Aggregated Ethnic Group (AEG) comprised of 10 categories: White, Black Caribbean, Black African, Black Other, Indian, Pakistani, Bangladeshi, Chinese, Other Asian, and Other. Table 3.4 displays the mappings of these ethnic categories to census ethnicity categories and the 'White', 'Black', and 'Asian' categories used in my analyses.

Table 3.4: Mappings of Census 2011 and GLA ethnicity categories

This thesis	**Census 2011**	**GLA Aggregated Ethnic Group**
'White'	White: English/Welsh/Scottish/Northern Irish/British	White
	White: Irish, White: Gypsy or Irish Traveller	
	White: Any other White background	
'Black'	Black/African/Caribbean/Black British: Caribbean	Black Caribbean
	Black/African/Caribbean/Black British: African	Black African
	Black/African/Caribbean/Black British: Any other Black/African/Caribbean background	Black Other
	Mixed/multiple ethnic groups: White and Black Caribbean	
	Mixed/multiple ethnic groups: White and Black African	
'Asian'	Asian/ Asian British: Indian	Indian
	Asian/ Asian British: Pakistani	Pakistani
	Asian/ Asian British: Bangladeshi	Bangladeshi
	Asian/ Asian British: Any other Asian background	Other Asian
	Mixed/multiple ethnic groups: White and Asian	
(excluded from main analysis)	Asian/ Asian British: Chinese	Chinese
	Other ethnic group: Arab	Other
	Other ethnic group: Any other ethnic group	
	Mixed/multiple ethnic groups: any other Mixed/multiple ethnic background,	

3.3.4 Analysis

As discussed in section 2.7, I defined 'area' in this analysis as a Lower Super Output Area (LSOA). Sensitivity analyses examine three different definitions of 'area': Middle Super Output Area (MSOA), Ward, and Local Authority (LA). I assembled four area level data sets (at the LSOA, MSOA, Ward and LA levels) including information on the numbers of 'White', 'Black', and 'Asian' children living in each area, the index of multiple deprivation score, and variables describing the features of the road environment. To examine whether more deprived areas are characterized by more 'hazardous' road environments, I calculated Pearson correlation coefficients between area level IMD scores and each feature of the road environment. To examine whether 'White', 'Black', and 'Asian' children live in areas with similar road environments, I divided the number of areas in London (for instance 4,835 LSOAs) into quartiles based on each feature of the road environment. I then summed the number of children by ethnic group living in each quartile and calculated the proportion of the total 'White', 'Black' and 'Asian' child population living in each quartile based on each road environmental feature. I used a Chi-squared test to examine evidence for whether the distribution of populations across quartiles was similar by ethnic group.

If the quality of the road environment is related to area deprivation I would expect correlations between increasing deprivation and:

> *space conflict factors:* high density of A roads, high traffic flows, high bus stop density, low residential status, high junction density, low density of minor roads, and high population density
>
> and
>
> *road-user reaction factors:* high speeds.

If differences in the quality of the road environment can help to explain ethnic inequalities in risk in London, I would expect that compared to the 'White' population, a larger proportion of the 'Black' population would live in areas characterized by these 'hazardous' features of the environment. I would expect a smaller proportion of the 'Asian' population to live in areas characterized by these features compared to the 'White' population.

3.3.5 Results

Table 3.5 displays correlation coefficients between Index of multiple deprivation scores and features of the road environment at different levels of geography. Correlation coefficients tended to be small. There was some evidence of a weak correlation between increasing deprivation and increasing density of bus stops and a stronger correlation between increasing deprivation and increasing population density. There was some suggestion of a weak correlation between increasing deprivation and *decreased* traffic speeds. Most findings appeared substantively similar across all definitions of 'area'. There was some weak evidence of a correlation between the density of minor roads and increasing deprivation at the local authority level, which did not appear at any other level of geography.

Table 3.5: Correlations between index of multiple deprivation score and features of the road environment

Feature of the road environment	LSOA	MSOA	Ward	LA
Density of A roads	0.13	0.18	0.16	0.10
Traffic flow	0.07	0.08	0.05	-0.03
Bus stop density	0.26	0.39	0.41	0.26
Residential status	0.01	0.01	-0.01	-0.09
Junction density	0.10	0.16	0.16	-0.01
Density of minor roads	-0.01	-0.01	0.05	0.27
Population density	0.42	0.49	0.49	0.69
Speed of roads	-0.19	-0.20	-0.24	-0.21

My population estimates suggest that 802,991'White' children, 361,015 'Black' children, and 351,927 'Asian' children between the ages of 0-15 lived in London in 2011. Table 3.6 displays the percentage of 'White', 'Black' and 'Asian' children living in LSOAs characterized by quartiles of road environment features. These findings suggest that a similar proportion of 'White', 'Black' and 'Asian' children lived in areas with relatively high densities of A roads (Q4), high traffic flows (Q4), high densities of bus stops (Q4), low residential status (Q4), high junction densities (Q4), and low densities of minor roads (Q1). There was some suggestion that a larger proportion of 'Black' children lived in areas characterized by *lower* speeds, but a chi-squared test indicated no evidence for a difference in the proportion of 'White', 'Black' and 'Asian' living in areas of lower and higher speeds. There was weak evidence that a higher proportion of 'Black' and 'Asian' children lived in areas of high population density compared to 'White' children. Tables 3.7-3.9 display the percentage of 'White', 'Black' and 'Asian' children living in areas characterized by quartiles of road environment features at the MSOA, Ward and LA area levels. Results at the MSOA and Ward levels were similar to those at the LSOA level: there was weak evidence that the proportion of 'Black' and 'Asian' children living in high population density areas is greater than the proportion of 'White' children in high population density areas; and no evidence that the proportion of children living in areas characterized by all other road environment features differs by ethnicity.

At the LA level, however, there was some evidence that a larger proportion of 'Black' children lived in areas with *lower* traffic volumes, higher bus stop density, *higher* residential status, higher population density, *higher* density of minor roads, and *lower* speeds. Apart from evidence on population density and bus stop density, these LA level findings suggest that a larger proportion of 'Black' children in London live in areas that are *less* 'hazardous' to pedestrians.

Results at the LA level also suggest that a larger proportion of 'Asian' children live in areas with higher traffic volumes and medium speeds, which may suggest that higher proportion of 'Asian' children live in areas that are *more* 'hazardous' to pedestrians.

3.4 DISCUSSION

Findings from the literature review provide evidence that the quality of the road environment can affect pedestrian injury risk. While evidence on the effect of some individual features of the road environment on pedestrian injury is mixed, on the whole the literature indicates that high traffic volumes, high levels of pedestrian activity, high traffic speeds, and visual obstacles such as parked cars make roads more 'hazardous' for pedestrians. Residential land use, non-road spaces for pedestrians (such as wide sidewalks and domestic gardens) and traffic calming features make roads less 'hazardous' for pedestrians.

To assess whether differences in the quality of the road environment can help to explain socio-economic and ethnic inequalities in child pedestrian injury risk in London, the ecological analysis collected available indicators on features of the road environment and compared the distribution of these features to both area-level deprivation measures and the distribution of London's child population by ethnic group. There was little evidence that more deprived neighbourhoods in London were characterized by more 'hazardous' road environments, though the results do indicate that more deprived areas tend to have higher population densities. At small area level, analyses suggest that a similar proportion of 'White', 'Black' and 'Asian' children live in areas characterized by 'hazardous' road environment features. A sensitivity analysis revealed that at a local authority area level, there is some indication that a smaller proportion of 'Black' children and a larger proportion of 'Asian' children live in areas characterized by relatively more 'hazardous' road environments. Overall, these findings suggest that differences in the quality of the road environment in London cannot explain the observed relatively higher injury risk of 'Black' children and lower injury risk of 'Asian' children. Results from the sensitivity analysis may suggest that risk compensation can help to explain ethnic differences in pedestrian injury risk. If 'Asian' children live in more hazardous road environments, 'Asian' children may not (be allowed to) spend as much time in the road environment as their peers from other ethnic groups, leading to lower levels of exposure to hazards among 'Asian children. Conversely, if 'Black' children live in relatively less hazardous road environments, 'Black' children may (be allowed to) spend more time in the road environment than their peers from other ethnic groups leading to higher levels of exposure among 'Black' children. Levels of exposure are explored in later chapters of this thesis: Chapter 4 explores amounts of travel time exposure by population group, while Appendix 7 explores activities that may expose children to hazards during their leisure time.

This Chapter's findings of associations between ethnicity and the road environment at local authority level but not a smaller area level are not easy to reconcile. They may, perhaps, be an example of an ecological fallacy. Alternatively, there may be some mechanism linking ethnicity to particular smaller areas within local authorities that can account for this phenomenon, although it is difficult to imagine what that might be. More research is needed to explain why associations between ethnicity and features of the road environment were found at a large area level but not at smaller area levels.

Both the literature review and the ecological analysis have a number of strengths and limitations for investigating the contribution of the road environment to ethnic inequalities in injury. The literature review compared studies using a variety of study designs, without assessing the quality of each study. Differences in quality of studies may partially explain some of the conflicting findings of the literature review results. However, the purpose of the review was to *map* the range of features that may make areas more or less 'hazardous' for pedestrians, rather than to quantify associations. Ultimately, the goal of the literature review was to provide information on what types of environments may be more 'hazardous' for child pedestrians in London. Pragmatically, the literature reviewed studies investigating environmental associations with injuries of all severities to pedestrians of all ages in a variety of different settings. Some findings, for instance those on alcohol establishments, may be less relevant for children; some findings may be less relevant for London's rather unique urban environment; and given that the outcome measure in many of the included studies was pedestrian fatalities or serious injuries, some findings may be less relevant for slight injuries.

While I gathered information on all available relevant features of the road environment in London in the ecological analyses, I was unable to locate any data on visibility factors that make environments more 'hazardous' for pedestrians. It is plausible that the proportion of 'White', 'Black' and 'Asian' children living in areas with 'hazardous' visibility features may differ. I was, however, able to include indicators of arguably the two most salient road environment features in the literature review: traffic volumes and traffic speeds. As noted in Chapter 2, defining the appropriate size of area for ecological analyses is a challenging methodological choice. The literature provides little guidance on where children are exposed to pedestrian injury. While indicators of features of the road environment are likely to be more discriminating at smaller area levels, larger definitions of area are likely to be more inclusive of the environments where children are exposed to injury. However, in this study, ‘area’ definitions did not appear to be a central issue: the overall findings that differences in the quality of the road environment cannot explain observed ethnic inequalities in child pedestrian injury risk were robust to a number of different definitions of area.

In conclusion, findings from this chapter indicate that while the quality of the road environment appears to be an important mediator of injury risk, it cannot explain observed ethnic inequalities in London. The next chapter examines a different causal pathway linking ethnicity to child pedestrian injury: the quantity of pedestrian exposure during travel time.

Table 3.6: Proportion of 'White', 'Black' and 'Asian' children living in LSOAs characterized by features of the road environment

LSOA			Proportion of children living in Quartile			
Outcome	Quartile values		White	Black	Asian	p-value
Density of A roads (length of A roads/total road length)	Q1	0 - 0	32%	31%	32%	0.999
	Q2	0 - 0.09	19%	19%	18%	
	Q3	0.09 - 0.19	25%	24%	24%	
	Q4	0.19 - 0.84	23%	26%	26%	
Traffic flow (aadf)	Q1	1810 - 6991	28%	25%	24%	0.995
	Q2	6991 - 8722	25%	26%	26%	
	Q3	8722 - 11042	24%	26%	24%	
	Q4	11042 - 63975	23%	24%	26%	
Bus density (bus stops per square km)	Q1	0 - 0.07	26%	21%	24%	0.912
	Q2	0.07 - 0.14	26%	23%	26%	
	Q3	0.14 - 0.23	25%	26%	24%	
	Q4	0.23 - 1.26	22%	30%	26%	
Residential status: Proportion of postcodes characterised as business	Q1&Q2	0 - 0	54%	58%	55%	0.925
	Q3	0 - 0.05	24%	21%	20%	
	Q4	0.05 - 0.96	23%	21%	25%	
Junction density (junctions per km of road)	Q1	0 - 14.47	25%	24%	25%	0.997
	Q2	14.47 - 19.73	26%	24%	24%	
	Q3	19.73 - 25.42	25%	25%	25%	
	Q4	25.42 - 88.09	23%	27%	27%	
Density of minor roads (length of minor roads/total road length)	Q1	0.01 - 0.72	24%	22%	26%	0.997
	Q2	0.72 - 0.83	25%	25%	25%	
	Q3	0.83 - 0.94	25%	25%	24%	
	Q4	0.94 - 1	25%	28%	25%	
Population density (persons per square km)	Q1	117-5202	29%	16%	19%	0.097
	Q2	5202-8386	28%	20%	23%	
	Q3	8386-12909	23%	31%	27%	
	Q4	12909-68360	20%	34%	31%	
Speed of roads (mph)	Q1	16 - 25	22%	26%	16%	0.320
	Q2	25 - 29	22%	27%	32%	
	Q3	29 - 32	26%	27%	29%	
	Q4	32 - 67	31%	20%	23%	

Table 3.7: Proportion of 'White', 'Black' and 'Asian' children living in MSOAs characterized by features of the road environment

MSOA			Proportion of children living in Quartile			
Outcome	Quartile values		White	Black	Asian	p-value*
Density of A roads (length of A roads/total road length)	Q1	0 - 0.06	26%	24%	24%	0.999
	Q2	0.06 - 0.11	25%	25%	24%	
	Q3	0.11 - 0.17	25%	26%	26%	
	Q4	0.17 - 0.49	23%	25%	26%	
Traffic flow (aadf)	Q1	3570 - 7783	27%	25%	24%	0.943
	Q2	7783 - 9456	25%	25%	25%	
	Q3	9456 - 11623	25%	26%	21%	
	Q4	11623 - 34917	23%	23%	29%	
Bus density (bus stops per square km)	Q1	0 - 0.1	28%	18%	25%	0.532
	Q2	0.1 - 0.14	27%	24%	25%	
	Q3	0.14 - 0.2	25%	28%	24%	
	Q4	0.2 - 0.45	20%	31%	26%	
Proportion of postcodes characterised as business	Q1	0 - 0.01	25%	28%	22%	0.982
	Q2	0.01 - 0.03	26%	25%	25%	
	Q3	0.03 - 0.07	25%	25%	28%	
	Q4	0.07 - 0.9	24%	22%	24%	
Junction density (junctions per km of road)	Q1	0-18	27%	22%	24%	0.965
	Q2	18-20	26%	24%	24%	
	Q3	20-23	25%	28%	25%	
	Q4	23-51	22%	26%	27%	
Density of minor roads (length of minor roads/total road length)	Q1	0.43 - 0.74	25%	22%	25%	0.991
	Q2	0.74 - 0.81	25%	26%	27%	
	Q3	0.81 - 0.87	25%	25%	24%	
	Q4	0.87 - 1	25%	28%	23%	
Population density (persons per square km)	Q1	287 - 4759	31%	16%	18%	0.092
	Q2	4759 - 7344	27%	23%	24%	
	Q3	7344 - 11613	23%	29%	28%	
	Q4	11613 - 24773	19%	32%	30%	
Speed of roads (mph)	Q1	18 - 25	22%	26%	16%	0.382
	Q2	25 - 29	21%	26%	32%	
	Q3	29 - 33	26%	26%	28%	
	Q4	33 - 54	31%	22%	25%	

Table 3.8: Proportion of 'White', 'Black' and 'Asian' children living in Wards characterized by features of the road environment

Ward			Proportion of children living in Quartile			
Outcome	Quartile values		White	Black	Asian	p-value*
Density of A roads (length of A roads/total road length)	Q1	0 - 0.07	26%	23%	24%	0.992
	Q2	0.07 - 0.12	26%	28%	24%	
	Q3	0.12 - 0.18	24%	24%	26%	
	Q4	0.18 - 0.57	23%	25%	26%	
Traffic flow (aadf)	Q1	4195 - 8056	29%	24%	24%	0.799
	Q2	8056 - 9797	26%	27%	22%	
	Q3	9797 - 12105	23%	27%	24%	
	Q4	12105 - 32919	23%	22%	30%	
Bus density (bus stops per square km)	Q1	0.02 - 0.1	29%	17%	24%	0.396
	Q2	0.1 - 0.14	26%	23%	27%	
	Q3	0.14 - 0.2	26%	32%	25%	
	Q4	0.2 - 0.48	19%	28%	25%	
Proportion of postcodes characterised as business	Q1	0 - 0.02	26%	27%	25%	0.993
	Q2	0.02 - 0.04	26%	24%	25%	
	Q3	0.04 - 0.11	23%	26%	28%	
	Q4	0.11 - 0.82	24%	22%	22%	
Junction density (junctions per km of road)	Q1	8 - 18	28%	20%	25%	0.733
	Q2	18 - 20	26%	28%	23%	
	Q3	20 - 23	25%	30%	25%	
	Q4	23 - 51	20%	22%	27%	
Density of minor roads (length of minor roads/total road length)	Q1	0.33 - 0.74	25%	18%	24%	0.86
	Q2	0.74 - 0.8	25%	26%	29%	
	Q3	0.8 - 0.86	25%	28%	25%	
	Q4	0.86 - 1	26%	28%	22%	
Population density (persons per square km)	Q1	176 - 4517	31%	15%	17%	0.041
	Q2	4517 - 6838	28%	23%	24%	
	Q3	6838 - 10909	22%	32%	31%	
	Q4	10909 - 26469	19%	31%	29%	
Speed of roads (mph)	Q1	16 - 25	21%	24%	14%	0.337
	Q2	25 - 29	22%	27%	32%	
	Q3	29 - 33	26%	27%	30%	
	Q4	33 - 49	32%	22%	25%	

Table 3.9: Proportion of 'White', 'Black' and 'Asian' children living in LAs characterized by features of the road environment

LA			Proportion of children living in Quartile			
Outcome	**Quartile values**		**White**	**Black**	**Asian**	**p-value***
Density of A roads (length of A roads/total road length)	Q1	0.07 - 0.12	34%	29%	27%	0.115
	Q2	0.12 - 0.14	26%	30%	19%	
	Q3	0.14 - 0.15	25%	23%	23%	
	Q4	0.15 - 0.07	15%	18%	31%	
Traffic flow (aadf)	Q1	7140 - 9490	32%	27%	20%	0.003
	Q2	9490 - 11301	25%	36%	16%	
	Q3	11301 - 12988	23%	24%	35%	
	Q4	12988 - 16075	20%	13%	29%	
Bus density (bus stops per square km)	Q1	0.06 - 0.1	36%	17%	26%	0.024
	Q2	0.1 - 0.13	24%	28%	33%	
	Q3	0.13 - 0.2	23%	31%	30%	
	Q4	0.2 - 0.41	17%	24%	11%	
Proportion of postcodes characterised as business	Q1	0.06 - 0.09	29%	44%	19%	0.004
	Q2	0.09 - 0.11	29%	19%	32%	
	Q3	0.11 - 0.13	22%	18%	33%	
	Q4	0.13 - 0.32	19%	19%	16%	
Junction density (junctions per km of road)	Q1	16 - 19	37%	26%	23%	0.209
	Q2	19 - 20	23%	35%	31%	
	Q3	20 - 22	24%	22%	22%	
	Q4	22 - 35	16%	17%	24%	
Density of minor roads (length of minor roads/total road length)	Q1	0.69 - 0.77	26%	16%	31%	0.06
	Q2	0.77 - 0.79	28%	19%	20%	
	Q3	0.79 - 0.81	19%	30%	25%	
	Q4	0.81 - 0.85	27%	36%	24%	
Population density (persons per square km)	Q1	2060 - 4200	37%	21%	18%	0.012
	Q2	4200 - 5377	23%	18%	29%	
	Q3	5377 - 9991	22%	40%	32%	
	Q4	9991 - 13872	18%	21%	21%	
Speed of roads (mph)	Q1	18 - 25	21%	22%	12%	0.036
	Q2	25 - 29	20%	32%	35%	
	Q3	29 - 33	24%	26%	30%	
	Q4	33 - 40	35%	20%	22%	

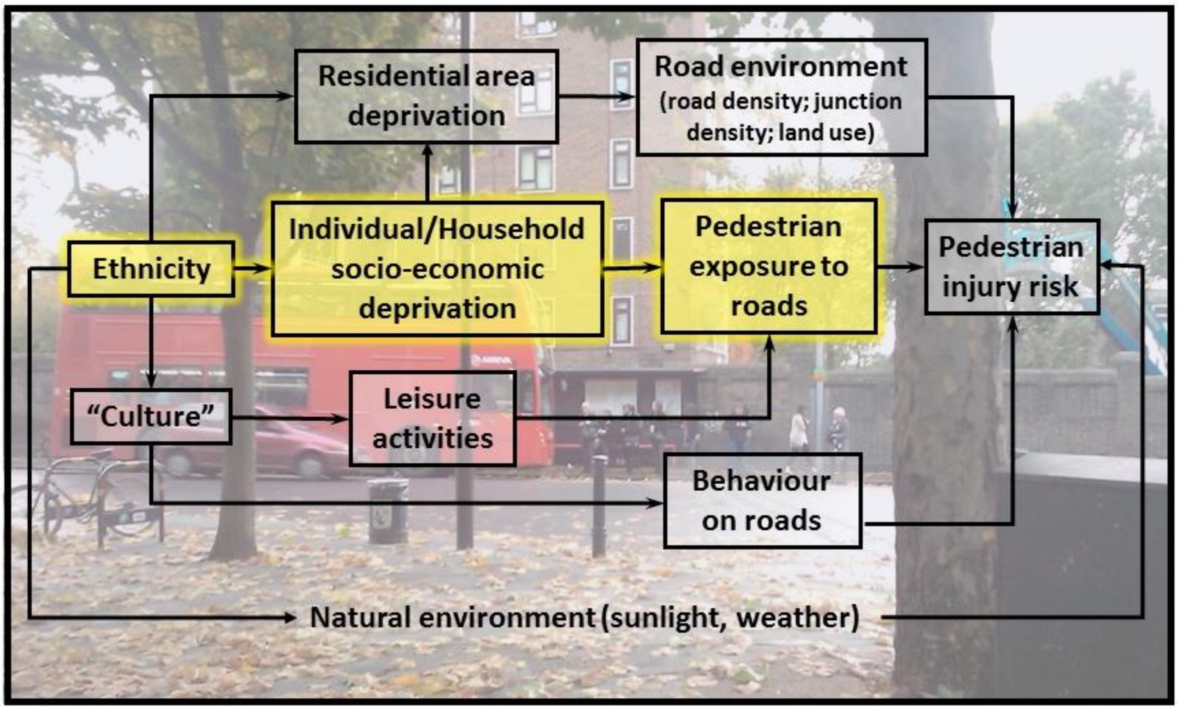
4 DOES THE QUANTITY OF TRAVEL TIME EXPOSURE DIFFER BY ETHNICITY?

The previous chapter investigated how the *quality* of exposure, at an ecological level, helps explain ethnic inequalities in child pedestrian injury risk in London. Findings suggested no evidence that the quality of the road environment differs in areas where ‘White’, ‘Black’, and ‘Asian’ children live. This chapter addresses the role of the *quantity* of exposure at an individual level. The quantity of exposure hypothesis proposes that ‘Black’ children have higher rates of pedestrian injury in London because they have greater levels of pedestrian exposure to road hazards, while ‘Asian’ children have lower rates because they have lower levels of pedestrian exposure.

Differences in exposure to the road environment may also help explain a paradoxical finding described in the introductory chapter – namely that the relationship between pedestrian injury rates and deprivation differs for ‘Black’ children when compared with their ‘White’ and ‘Asian’ counterparts. Specifically, we found that pedestrian injury rates declined for ‘White’ and ‘Asian’ children as area affluence increases, but that area affluence does not appear to protect ‘Black’ children, whose injury rates remained reasonably constant no matter where they lived. Exposure levels might explain this result if the relationship between deprivation and quantity of pedestrian exposure differs by ethnicity. That is, if, unlike ‘White’ or ‘Asian’ children, ‘Black’ children living in relatively affluent areas have similar or higher exposure levels than ‘Black’ children living in more deprived areas.

In this thesis, I have divided the quantity of pedestrian exposure into two categories: exposure during travel time and exposure during leisure time for both conceptual and pragmatic reasons. Conceptually, the factors linking ethnicity to travel time exposure and leisure time exposure may differ. For instance structural associations between ethnicity and lower socio-economic status, may suggest children from minority ethnic groups live in households with less access to vehicles, leading to more walking for transport and subsequently greater levels of travel time exposure (Figure 4.1). Other elements of ethnicity, for instance, structural experiences of racism or ‘cultural’ ideas about which activities are appropriate for children may lead to preferences for indoor activities among minority ethnic children, leading to lower levels of pedestrian exposure during leisure time. The separation of quantity of pedestrian exposure into two categories was also pragmatic. I was unable to find a data source that covered both types of exposure to road hazards. Therefore, in this thesis, the quantity of exposure hypothesis has two sub-hypothesis: the *travel time* exposure hypothesis and the *leisure time exposure* hypothesis. This chapter examines evidence for the travel time exposure hypothesis in explaining ethnic differences in injury rates, as highlighted in Figure 4.1. Appendix 7 explores pedestrian exposure during leisure time.

Figure 4.1: Hypothesized model of links between ethnicity and pedestrian injury risk



The travel time exposure hypothesis proposes that the relatively higher injury rates of 'Black' children and relatively lower rates of injury among 'Asian' children can be explained by greater levels of pedestrian exposure to road hazards during travel time among 'Black' children and lower levels of exposure among 'Asian' children. All children are exposed to pedestrian injury during travel time when they are walking in the road environment. Two key indicators of travel time exposure therefore, are time spent walking and distances walked. I address ethnic differences in these two indicators in Research Paper 2 (section 4.1) which uses travel diary data collected in the London Travel Demand Surveys to explore the social and environmental correlates of walking behaviour in children. The paper is framed rather differently than much of the work presented thus far in my thesis. Research Paper 2 takes a broader public health approach, justifying the need for research on the social and environmental correlates of walking from the perspective of its importance in providing opportunities for physical activity and less dependence on motorised travel, rather than on injury prevention only. However, the paper explicitly explores the relationship between walking and ethnicity (amongst other social and environmental indicators) and is therefore able to speak to the role of the travel time exposure hypothesis in explaining ethnic inequalities in injury risk. Specifically, Research Paper 2 calculates mean distances walked and time spent walking for 'White', 'Black' and 'Asian' children during three periods: the school commute, outside the school commute during term time, and during the summer and weekends. The paper also explores associations between ethnicity and doing some walking for transport in each of the three periods, and associations between ethnicity and walking distances among children who do some walking for transport.

Section 4.2 of this chapter presents further analyses of the travel diary data to examine whether the quantity of travel time exposure can help explain the different relationship between deprivation and injury in ‘Black’ children compared to ‘White’ children. I.e. Why area affluence does not appear to protect ‘Black’ children. Analyses describe mean distances walked and time spent walking over the whole year by ethnic group and level of area deprivation. Finally, Section 4.3 discusses the implications of the evidence presented in Sections 4.1 and 4.2 for the role of the quantity of travel time exposure in explaining both ethnic differences in child pedestrian injury rates overall, and in explaining the relationships between ethnicity, area deprivation and pedestrian injury in London. The section concludes with a brief discussion of the potential for the leisure time exposure hypothesis to help explain ethnic differences in child pedestrian injury.

4.1 RESEARCH PAPER 2: LOOK WHO'S WALKING: SOCIAL AND ENVIRONMENTAL CORRELATES OF CHILDREN'S WALKING IN LONDON

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I designed the study with Judith Green and Phil Edwards. I formatted and analysed the travel diary data. I drafted the manuscript and made revisions based on comments from Judith Green and Phil Edwards.

NAME IN FULL (Block Capitals) REBECCA STEINBACH

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LOOK WHO'S WALKING: SOCIAL AND ENVIRONMENTAL CORRELATES OF CHILDREN'S WALKING IN LONDON

ABSTRACT

A substantial literature examines the social and environmental correlates of walking to school but less addresses walking outside the school commute. Using travel diary data from London, we examined social and environmental correlates of walking: to school; outside the school commute during term time; and during the summer and weekends. Living in a household without a car was associated with all journey types; 'Asian' ethnicity was negatively associated with walking for non-school travel; environmental factors were associated with non-school journeys, but not the school commute. Interventions aiming to increase children's active travel need to take account of the range of journeys they make.

Keywords: Children, active travel, walking, environment, social differences

INTRODUCTION

There is a growing interest in active travel in public health. Encouraging walking and cycling has been suggested as one way to increase children's physical activity, and thus help tackle the increasing prevalence of overweight and obesity confronting many high income countries (Tudor-Locke et al., 2001). Although there is debate around how much activity is necessary to promote health at an individual level (Bauman, 2004; Saris et al., 2003; Wen et al., 2011), at the population level, incremental changes that decrease sedentary time and increase activity are likely to shift population risk. Efforts have therefore been directed at changing the social and environmental conditions leading to 'energy imbalance', specifically modifying environments such that they encourage physical activity and discourage excessive food intake (French et al., 2001; Roberts and Edwards, 2010). To this end, a large literature is emerging on which environments facilitate or hinder active transport.

THE SCHOOL COMMUTE

As almost all children make a journey to school each day, this represents a key opportunity to engage in active transport and potentially an important contribution to children's levels of physical activity (Roth et al., 2011). Walking to school in the UK is continuing to decline. In 1985, an estimated 67% of 5-10 year olds and 52% of 11-16 year olds walked to school (Department for Transport, 2001). By 2008, the percentages had decreased to 48% and 40% respectively (Department for Transport, 2009). A number of interventions in the UK have focused on reversing this decline. Programmes have included "Walk to School" campaigns (http://www.walktoschool.org.uk/), walking school buses (Mackett et al., 2005) and school travel coordinators (Rowland et al., 2003). However, there have been relatively few evaluations of interventions aimed at children (Ogilvie et al., 2007) and in the absence of evidence on effectiveness a growing literature on the predictors of children's active commuting to school has emerged to help inform policy interventions.

Much of this literature utilises a social ecological framework, which proposes that human behaviour (in this case the decision to walk to school) is influenced both by individual social characteristics and characteristics of the physical and social environment (Stokols, 1996). More complex models such as McMillan's conceptual framework (McMillan, 2005) and the Ecological and Cognitive Active Commuting (ECAC) framework build on social ecological models to suggest some of the ways that social and environmental characteristics may interact with each other to produce transport behaviour (Sirard and Slater, 2008). These types of models are designed to be dynamic and therefore continually modified as research illuminates a greater understanding of the mechanisms.

To date, however, reviews of the empirical evidence on relationships between social and environmental factors and active commuting to school have suggested that the findings are difficult to generalise, given the differences between studies on which factors are associated (Davison et al., 2008; Giles-Corti et al., 2009; Jacobsen et al., 2009; Sirard and Slater, 2008). Although, for instance, social characteristics such as age, gender, income and ethnicity (Larsen et al., 2009; McDonald, 2007; McDonald, 2008) have been identified as related to walking to school, associations are not universally found. For instance some international evidence (Ewing et al., 2004; McDonald, 2008; McMillan, 2007) and one UK national-level study (Brophy et al., 2011) have found associations between higher household income and less walking to school. In Norfolk, however, researchers found that children from less deprived areas were more likely to walk to school than children from more deprived areas (Panter et al., 2010). Other international evidence has found no significant associations between household income and walking to school (McMillan et al., 2006). In terms of ethnicity, American studies have suggested that Hispanic children in California (Braza et al., 2004) and African American children in North Carolina (Evenson et al., 2003; McDonald, 2007) and Georgia (US Department of Health and Human Services, 2000) are more likely to walk to school than their white counterparts. A US national study however, found that ethnic differences in travel patterns disappeared when other factors were controlled for (McDonald 2008). The literature on environmental predictors of walking is also difficult to summarise. Although evidence suggests that land use, traffic volumes, road density and street connectivity are all associated with children's use of active transport modes, the salience of any particular environmental characteristic appears to depend on local context (Giles-Corti et al., 2010; Panter et al., 2010; Timperio et al., 2006). One limitation of the empirical literature is that environmental factors are inconsistently defined across studies, and aggregated at varying geographical levels (Giles-Corti et al., 2009; Mitra and Buliung, 2011). Additionally, there are likely to be a number of cultural and infrastructural factors that modify relationships, but which are difficult to build into models. The social meaning of walking (as a mode of transport) is, for instance, likely to be locally constituted (Bostock, 2001; Brunton et al., 2006), suggesting that different social factors are likely to help shape transport decisions in different contexts. Second, alternative candidate modes of transport may differ by location if, for instance, some urban areas have relatively good bus provision compared to others. Socio-ecological models, while valuable, are likely to be very context specific.

NON-SCHOOL TRAVEL

In addition to the school journey, most children also undertake a wide range of other journeys, to activities such as friends' houses, shops, parks, places of worship and clubs. In the UK, the Department for Transport does not publish detailed information on non-school travel, although non-school journeys made up more than 70% of all journeys made by children under 17 in 2008 (Department for Transport, 2009). Despite potentially representing a considerable proportion of children's transport time, much less of the empirical and theoretical work on children's walking has focused on non-school travel. This type of active transport may represent a missed opportunity for public health advocates, as walking to non-school activities also provides opportunities for physical exercise. Theoretically, the factors that influence whether children walk to school may be different than those that influence walking during other times. First, the social meaning of walking may differ on school journeys compared to non-school journeys leading to differing associations between social factors and school compared to non-school walking. Second, school journeys are by and large mandatory, with parents responsible for their children's school attendance. Children may therefore have more transport options (for instance, an organised car pool) on school journeys compared to non-school journeys. Finally, school journeys, particularly on the way to school, tend to take place during peak travelling hours when issues such as traffic congestion or public transport overcrowding are more likely to influence transport decisions compared to journeys made at other times.

The limited international literature on children's non-school travel suggests associations between transport mode and parental attitudes (Hjorthol and Fyhri, 2009; Johansson, 2006; Timperio et al., 2004), vehicle density (Lin and Yu, 2011), urban area (Sjolie and Thuen, 2002) and perceptions of the local environment (Carver et al., 2005; Timperio et al., 2004), but evidence on the social and environmental correlates of walking outside the school commute is sparse. Within the UK, a small study from Birmingham found perceptions of high traffic volumes and unsafe streets were associated with higher levels of walking to leisure activities, while belonging to a minority ethnic group was negatively associated with number of non-school walking trips (Alton et al., 2007). To inform strategies to increase children's activity across the range of journeys they make, more research is needed to add to the evidence base on non-school travel.

This study aims to contribute to the limited evidence base on non-school active travel, taking London, where there are relatively good data, as a case study. We examine the social and environmental characteristics associated with walking to non-school destinations and compare these to the factors that influence walking on the school commute.

METHODS

DATA SOURCES

We obtained data on travel by children aged 5 to 17[1] years for the period 2006 to 2008 from the London Travel Demand Survey (LTDS), an annual survey of travel patterns in Greater London. The LTDS is a rolling survey that randomly selects a total of 8,000 households in London during the year using the UK postcode address file as a sampling frame. The sample design is stratified by London borough to provide 250 households in each of 32 boroughs (excluding City of London). In a face to face interview with a trained interviewer, every member of selected households aged over 5 years is asked to complete a one-day travel diary that recorded the starts, interchanges and ends of every trip on the travel day. The travel days cover both weekdays and weekends. Journey times are collected and 'crow fly' journey distances are estimated using the start-point and end-point of each interchange.

Walking time and distance

Because the LTDS collects data on each interchange of a journey we were able to calculate the total time spent walking and the distance walked, even if walking was not the primary mode of travel for a particular journey.

Social variables

The LTDS collects a number of social and household level characteristics including information on age, gender, ethnicity, household income, access to vehicles and household size. Respondents self-select their ethnicity from UK Census 2001 categories. For analyses, we grouped ethnicity into three main categories: 'White' (White-British, White-Irish, Other White), 'Black' (Black or Black British-Caribbean, Black or Black British-African, Black or Black British-Other Black background, Mixed-White and Black African, Mixed-White and Black African), and 'Asian' (Asian or Asian British- Indian, Asian or Asian British- Pakistani, Asian or Asian British-Bangladeshi, Asian or Asian British-other Asian background, Mixed-White and Asian). Other ethnic groups (4%) and those who declined to select an ethnicity (1%) were not considered in the analyses. Household income is available in banded income groups only which we analysed as terciles (0-£14,999, £15,000-£49,999, and £50,000 +).

[1] The minimum legal driving age in the UK is 17.

Environmental variables

We assigned each child to a neighbourhood (Census Lower Super Output Area, LSOA) using the centroid of the postcode where they live. LSOAs are small geographic areas corresponding to an average of 1,500 residents. Data on the social environment was obtained using the 2004 Index of Multiple Deprivation (IMD) which brings together 36 indicators across seven different domains of deprivation into an overall score (Noble et al., 2007). LSOAs were ranked according to IMD and divided into quintiles (1 least deprived to 5 most deprived). Based on evidence from the literature, we selected from available data on the physical environment those variables with known associations with walking among children (Frank et al., 2007; Giles-Corti et al., 2009; Giles-Corti et al., 2010; Jacobsen et al., 2009; McMillan, 2007; Panter et al., 2010; Schlossberg et al., 2006; Timperio et al., 2006). These included density of A roads, density of minor roads and number of junctions (as measures of street connectivity), the proportion of postcodes in an LSOA characterised as business (as a measure of residential density/land use), and average speed and volume of traffic.

Geographical Information System (GIS) analysis

To create variables describing the road environment in an LSOA, road network information from the Integrated Transport Network (ITN) supplied by Ordnance Survey was overlaid with LSOA boundaries provided by the census in ArcView GIS. Data on average traffic speeds and volumes came from the London Greenhouse Gas Inventory (LEGGI). LEGGI data, typically used to measure greenhouse gas emissions, includes measurements of volume of traffic by vehicle type and traffic speeds. To calculate LSOA summaries of average speeds and volumes the LEGGI road network was overlaid with LSOA boundaries.

STATISTICAL ANALYSES

We examined correlations between each environmental variable to assess the potential for multi-collinearity. Variables were included in the analysis if correlation coefficients were less than 0.6. Survey weights (adjusted for non-response and scaled to mid-2007 population projections) were used to ensure that the sample was representative of the London population. All analyses allowed for the stratification of the sample by London borough.

We fitted three logistic regression models to explore the relationship between social and environmental characteristics and walking for transport:

(1) doing some walking on the journey to school

(2) doing some walking to other destinations during term time

(3) doing some walking during summer holidays and weekends.

All social and environmental characteristics were included in models 1-3 simultaneously. To minimize the influence that potential under-reporting of very short trips might have on the results, children were categorized as 'doing some walking' if they walked more than 100 metres. Much research to predict walking behaviour has considered a child to be a 'walker' only if the child walks the entire way from start to the end of the journey (McDonald, 2008; Robertson-Wilson et al., 2008). However, travel using public transport modes may offer opportunities for substantial amounts of walking, particularly in urban areas (Julien and Carre, 2002). In London, where children have had access to free bus travel since 2005, walking en route to, or from, a bus stop may constitute a large proportion of the children's walking. Therefore, analyses consider all walking done by children, whether as part of a public transport trip or all the way to their destination. Sensitivity analyses were conducted that consider walking all the way to school as the outcome variable.

Linear regression models were used to explore factors related to the distance walked and total time spent walking across all journeys among children who did some walking. A natural logarithm transformation of distance and time variables was used to allow for non-normality of the distributions. In the descriptive analyses age was categorised into primary school aged (5-11) and secondary school aged (12-17) children. In the multivariable analyses we included age as an integer variable. Tables report analyses based on walking distance. Results on walking times are available in a web appendix.

RESULTS

The LTDS provided data on 36,473 interchanges within 18,537 trips among 8,082 children aged 5-17 years in London from 2006-2008. The sample included 4,513 children during term time and 3,569 during the summer and weekends. The survey suggests that 68% of children do some walking on the way to school, 24% do some walking to other destinations during term time and 48% do some walking during the summer and weekends. On average children in London walk for 16.8 minutes (95% CI 16.2-17.4) and a distance of 0.82 km (0.78-0.85) to school per day (including those who do not walk at all). Children walk a daily average of 5.4 minutes (4.8-5.9) and a distance of 0.28 km (0.26-0.30) to other activities during term time. During the summer and weekends children walk an average of 12.8 minutes (11.9-12.6) and a distance of 0.66 km (0.61-0.71) per day.

Older children (aged 12-17) appear to walk longer and further distances than younger children (aged 5-11) across all journey types (Table 1 for walking distances; Web-appendix for walking times). There was no evidence of gender differences in overall minutes or kilometres walked by children. 'Black' children appear to walk longer and further distances to school compared to children from other ethnic groups, but they appear to walk less than 'White' children outside the school commute and during summer/weekends (though differences are not significant). 'Asian' children appear to walk less than 'Black' or 'White' children outside of travel to school during the week and during summer/weekends. Children from households earning less than £15,000 annually and children from households without access to a vehicle walk further and longer than their more affluent counterparts. Children living in areas with relatively high traffic volumes spend more time walking outside the school commute and during summer/weekends, but spend similar amounts of time walking to school as children from areas with relatively lower traffic volumes.

Table 2 presents odds ratios with 95% confidence intervals and p values for the associations between social and environmental factors and walking to school, walking during term time for other purposes, and walking during the summer and weekends. F-adjusted mean residual goodness-of-fit tests (Archer et al., 2007) suggest that all models fit the data reasonably well (p=0.796 for walking to school and p=0.861 for both walking during term time for other purposes and during summer and weekends) Children living in households without access to a vehicle were considerably more likely to walk to school (OR 2.33 95% CI 1.86-2.92), outside the school commute during term time (1.38, 1.10-1.73), and during the summer/weekends (1.82, 1.47-2.26) than children living in households with vehicle access. 'Black' and 'Asian' children were marginally more likely to do some walking on the school journey compared to 'White' children, but 'Asian' children in particular were less likely to walk outside the school commute during term time. No characteristics of the social or physical environment significantly predicted children's walking to school. However, several environmental characteristics were associated with walking outside the school commute and during the summer and weekends. Living in an area with a larger proportion of postcodes characterized as 'business' was associated with an increased likelihood of walking outside the school commute and during summer/weekends, whereas a higher number of road junctions was associated with a decreased likelihood of walking. Living in an area with higher traffic volumes and lower speeds was associated with an increased likelihood of walking during the summer/weekends.

Among children who did do some walking, age and living in a household without access to a vehicle were positively associated with walking distances (Table 3) and times (Web appendix). Being 'Black' or 'Asian' was negatively associated with walking times and distances. While we found no gender differences in the total amount of time spent walking, being female was marginally associated with greater walking time among children who did some walking (Web appendix). Traffic speeds were negatively associated with walking distance and marginally negatively associated with walking times. Traffic volumes were marginally positively associated with walking distances and times. Density of A roads and density of minor roads were marginally negatively associated with walking distances.

A sensitivity analysis examining the social and environmental correlates of walking all the way to school suggested that children living in a household without access to vehicles, children living in households earning between £15,000-50,000 and 'Asian' children were more likely to walk all the way to school compared to their counterparts, while older children and 'Black' children were less likely to walk all the way to school compared to others (Web appendix). Traffic volumes were negatively associated and traffic speeds were positively associated with walking all the way to school among children.

DISCUSSION

PRINCIPAL FINDINGS

We have used travel diary data from the LTDS to examine the social and environmental correlates of walking for transport among children in London. We found that living in a household without access to vehicles was strongly associated with walking on the school commute, and associated (though less strongly) with non-school travel. Belonging to a 'Black or 'Asian' minority ethnic group was marginally associated with walking on the way to school. This study hypothesized that characteristics that influence walking to school might differ from those that influence walking behaviour outside the school commute. While we found no association between the physical environment and doing some walking on the school journey, we did find some evidence that high traffic volumes, low traffic speeds, and a high proportion of businesses in an area were associated with walking outside the school commute or during weekends/summer. We also found that unlike the school commute, belonging to an 'Asian' minority ethnic group was associated with less walking for non-school journeys.

STRENGTHS AND WEAKNESSES

Using travel diaries to assess walking behaviour has some notable limitations including under-reporting of short walking trips. However, other methods such as accelerometers and GPS devices have their own difficulties (Mackett et al., 2007) and travel diaries have been successfully used to examine children's walking in international contexts (Frank et al., 2007; McDonald, 2008). Travel diary data also has a number of benefits. The LTDS allowed for analyses of all walking behaviour (including any walking undertaken as part of a public transport journey) and integration of multiple data sources on the physical and social environment. The use of straight line 'crow fly' distance to measure kilometres walked may be problematic as this method tends to underestimate distances walked (Stigell and Schantz, 2011). The actual distance travelled can be substantially longer than the 'crow fly' distance in suburban areas, whereas the difference would be less in inner-city neighbourhoods. In other words, measurement error will not be equal or random across space.

We investigated this potential bias by repeating our analyses of the social and environmental associations of distance walked among children who do some walking (Table 3) using minutes walked as an alternative outcome measure (Web-appendix). As reported above, we found that the characteristics associated with distance walked were similar to the characteristics associated with minutes walked. We did not investigate the potential influence on our results of distances to schools, and other destinations (e.g. to bus or train stations), Distance is an important predictor of mode choice (McMillan, 2007; Nelson et al., 2008; Sjolie and Thuen, 2002), and may confound some of the observed relationships between social and environmental characteristics and walking all the way to school (presented in the web-appendix). For example, the negative association between age and walking all the way to school may be partly explained by older children attending schools further from home.

Similar to other studies (Panter et al., 2010), this study used the Index of Multiple Deprivation as a measure of the social environment, which may be an imperfect proxy for the complex ways in which social processes are spatially embedded. We found no association between our measure of the social environment and walking during the school commute or during non-school travel.

Other studies have found associations between the social environment and active travel using more specific measures including neighbourhood cohesion (McDonald, 2007), perceived criminal danger (Kerr et al., 2006), and abduction fears (Timperio et al., 2006).

This study was only able to access 'objective' measures of the road environment, measured using GIS systems. Research in urban planning has identified conceptual links between perceived characteristics of the built environment and objective measures (McMillan, 2005; Mitra et al., 2010). Empirically, there is some evidence that perceived characteristics of the environment are more salient in predicting walking behaviour compared to objectively measured environmental characteristics (McGinn et al., 2007). Unfortunately these types of data on the perceived characteristics of the social and physical environment were not available for London.

Finally, quantitative analyses of the social and environmental correlates of walking behaviour can't tell us anything about the experience of walking or draw out how the meaning of walking may differ by social or environmental contexts. Given the difficulties in generalising the social and environmental correlates of walking, both across studies from different locations and (in this study) across different journeys, more qualitative research may be needed to illuminate these meanings in context.

INTERPRETATION AND MECHANISMS

Our findings on the social correlates of walking to school reflect those in other studies: living in a household without access to a vehicle (Frank et al., 2007) and belonging to a minority ethnic group (McDonald, 2007) were positively associated with walking to school. However unlike other studies (Giles-Corti et al., 2010; Timperio et al., 2006), we found little evidence that the social or physical environment was associated with walking to school. This may reflect the way in which we defined walking (i.e defining a child as a 'walker' if they walked during any part of their school journey). In an environment like London, where the level of car ownership is relatively low compared the rest of the nation and public transport provision is relatively good (Transport for London, 2009), the physical environment may be less relevant in predicting walking to school than in other settings.

Our findings on the social correlates of walking outside the school commute are similar to the only other UK study to address non-school active travel (Alton et al., 2007); living in a household without access to a vehicle was positively associated with non-school active travel; while belonging to an 'Asian' minority group was negatively associated. Unlike travel to school, we found a number of characteristics of the physical environment were associated with walking outside school commutes. This may indicate, as others have suggested (Ewing et al., 2004), that the walking environment may be relatively more important on discretionary trips compared to the school commute. Speculatively, areas with higher volumes of traffic and, crucially, lower speeds (which were associated with an increased likelihood of walking), may be perceived as safer to walk around than those with higher speeds. There is some evidence that the influence of the environment on walking differs by walking purpose among adults where research has found that environmental attributes associated with walking for exercise differed from those associated with walking for transport (Owen et al., 2004).

Our conflicting findings on ethnicity and active travel highlight the importance of considering walking on the school commute and non-school transport separately. While this research did not set out to unpick the complex ways that ethnicity may be related to transport decisions it is important to recognise the potential mechanisms that may link ethnicity to walking behaviour. A number of factors related to both ethnicity as identity and ethnicity as structure may be related to the amount of walking done by children (Steinbach et al., 2010).

This study found that 'Black' children appear to be more likely to do some walking on the way to school compared to 'White' children but are less likely to walk all the way to school. Further, among those who do walk for any purpose, distances tend to be shorter than those among 'White' children. Structural links between ethnicity and household socio-economic disadvantage suggest that 'Black' children may be less likely to live in a household with access to a vehicle (Department for Transport, 2009) and so they may be more likely to do some walking on the school journey.

However, in London 'Black' children tend to live further away from school (Department for Education, 2010) which may make walking all the way to school impractical. Evidence suggests that walking all the way to school is only considered feasible for relatively short distances of roughly 1-1.5 kilometres (McDonald, 2007; Nelson et al., 2008). Walks to bus stops are likely to be relatively shorter. Structural associations between ethnicity and area disadvantage suggest that Black children also live in more dense urban areas, particularly in London where the proportion of the population that is 'Black' is twice as high in inner London compared to outer London (ONS, 2010). In denser urban areas travels outside the school commute (ie. to see friends/to shops/etc) may cover less distance.

We did not find strong evidence to suggest that 'Asian' children were less likely to walk to school compared to 'White' children. However we did find that 'Asian' children were considerably less likely to do any walking outside the school commute or during the summer/weekends. Other research has suggested that 'Asian' children have lower physical activity levels overall compared to 'White' children (Brodersen et al., 2007; Owen et al., 2009). Again, these findings may be related to both ethnicity as identity and ethnicity as structure. Qualitative evidence suggests that structural associations with experiences of racism may deter some 'Asian' children from non-school activities (Morrow, 2000; Steinbach et al., 2007). Ethnic identity factors, such as cultural preferences due to religious beliefs and social norms, may affect the amount of spare time enjoyed by children and therefore the number of leisure activities in which they are able to participate (Phoenix and Husain, 2007).

Finally, the cultural significance of walking for transport may very well differ by ethnicity, leading to ethnic differences in active travel. Social identities shape transport decisions (Steinbach et al., 2011), as transport mode choice depends not only on the attributes of a particular mode but also the meanings of each mode in local context. There is relatively little work examining the cultural resonances of transport modes in different ethnic groups, and more research is needed to examine the meaning of walking and explore how it might differ among social groups.

IMPLICATIONS

This study suggests that the factors that influence walking to school can differ from factors that influence walking for other journeys. While currently an area that tends to be overlooked by policy makers, increasing children's non-school active travel has the potential to offer public health benefits but may require different public health strategies. Public health strategies are generally designed to increase the amount of physical activity within the population, rather than to necessarily achieve clinically important changes in individual behaviour, such as getting children to achieve a threshold of activity. This study therefore included all walking, rather than just journeys where walking was the main mode, as this is important at a population level. Given that few children walked the whole distance to school, but the majority did some walking, interventions that increase the number of children doing some walking, and increase the amount of walking they do, may be as important as those aiming to change the main mode of transport. Here, interventions to improve access to public transport may be useful for increasing the general level of activity among young people. Our data suggest that even in London, with a relatively good public transport infrastructure and low car ownership compared to the rest of the UK (Transport for London, 2009), lacking access to a car was associated with walking for all types of journey: there may be more scope for reducing children's car use, and thus increasing their physical activity rates as they move to public transport options. Given the range of findings from the literature on the social and environmental correlates of walking, and the suggestion that local social and cultural contexts are important determinants of walking, it is perhaps not surprising that our study identified differences in the correlates of school and non-school walking. The meaning of choosing walking compared with other candidate modes is likely to vary depending on whether the journey has to be done (eg for school) and what the alternatives are. For discretionary non-school journeys, the alternative may be forgoing the journey. Disincentives to active transport are therefore potentially also disincentives for social participation, and more attention must be paid to factors that restrict children's mobility. For non-school journeys, our findings suggest that the environment is a more important influence on walking, and that more efforts to reduce traffic speeds, in particular, are likely to encourage active transport.

This study, like much of the current evidence base, used a cross sectional design to examine walking. Further research, in particular using more sophisticated and qualitative methods is needed to examine the social meaning of walking in particular environments to help deepen our understanding.

Highlights

- Social and environmental correlates of children's non-school and school commute walking differ in one large urban setting
- The social meaning of walking may be as significant as the environment in predicting travel behaviour
- Increasing children's non-school active travel has the potential to offer public health benefits but may require different public health strategies

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Table 1: Mean distances (kilometres) walked by children by selected social and environmental characteristics

	Term time weekday travel to school			Term time weekday other travel		Summer and weekend travel	
Demographic	% Do some walking	% Walk all the way	Mean distance walked (km)	Mean distance walked (km)	sample size	Mean distance walked (km)	sample size
Social characteristics							
Age							
5-11	69%	15%	0.62 (0.58 - 0.65)	0.20 (0.17 - 0.23)	2486	0.54 (0.49 - 0.59)	1,948
12-17	67%	31%	1.04 (0.98 - 1.10)	0.37 (0.33 - 0.41)	2027	0.80 (0.70 - 0.87)	1,621
Gender							
Male	68%	23%	0.83 (0.78 - 0.87)	0.27 (0.23 - 0.30)	2315	0.64 (0.58 - 0.71)	1,770
Female	68%	23%	0.81 (0.76 - 0.86)	0.30 (0.26 - 0.33)	2198	0.68 (0.60 - 0.76)	1,799
Ethnic group							
'White'	65%	23%	0.82 (0.77 - 0.87)	0.31 (0.28 - 0.34)	2560	0.70 (0.63 - 0.76)	1,909
'Black'	74%	22%	0.86 (0.79 - 0.93)	0.27 (0.22 - 0.32)	882	0.62 (0.53 - 0.70)	721
'Asian'	71%	26%	0.78 (0.69 - 0.87)	0.18 (0.13 - 0.22)	831	0.51 (0.42 - 0.60)	716
Household income							
>£50k	62%	19%	0.75 (0.68 - 0.81)	0.30 (0.25 - 0.35)	1143	0.67 (0.56 - 0.77)	880
£15-50	67%	24%	0.81 (0.75 - 0.86)	0.24 (0.21 - 0.27)	2068	0.67 (0.59 - 0.75)	1,677
<£15k	74%	25%	0.88 (0.82 - 0.94)	0.32 (0.27 - 0.36)	1302	0.65 (0.58 - 0.72)	1,012
Vehicle access							
Access	63%	21%	0.75 (0.71 - 0.79)	0.25 (0.23 - 0.28)	3371	0.59 (0.54 - 0.65)	2,702
No access	81%	29%	0.98 (0.92 - 1.04)	0.35 (0.30 - 0.40)	1142	0.83 (0.73 - 0.93)	867

Table 1 continued: Mean distances (kilometres) walked by children by selected social and environmental characteristics

	Term time weekday travel to school			Term time weekday other travel		Summer and weekend travel	
	% Do some walking	% Walk all the way	Mean distance walked (km)	% Do some walking	% Walk all the way	Mean distance walked (km)	% Do some walking
Environmental characteristics							
Location							
Inner London	73%	26%	0.81 (0.75 - 0.87)	0.28 (0.25 - 0.32)	1546	0.68 (0.60 - 0.75)	1,178
Outer London	65%	22%	0.82 (0.78 - 0.86)	0.28 (0.25 - 0.31)	2967	0.65 (0.59 - 0.72)	2,391
Area Deprivation							
(least deprived) Q1	63%	20%	0.81 (0.73 - 0.89)	0.28 (0.22 - 0.34)	821	0.72 (0.57 - 0.87)	736
Q2	64%	21%	0.84 (0.75 - 0.93)	0.31 (0.24 - 0.38)	851	0.57 (0.49 - 0.66)	704
Q3	68%	22%	0.88 (0.78 - 0.98)	0.29 (0.24 - 0.34)	927	0.73 (0.62 - 0.84)	690
Q4	69%	23%	0.78 (0.72 - 0.85)	0.25 (0.20 - 0.29)	936	0.64 (0.55 - 0.74)	733
(most deprived) Q5	75%	30%	0.78 (0.72 - 0.84)	0.28 (0.23 - 0.32)	978	0.64 (0.54 - 0.73)	706
Mean traffic volumes							
(least traffic) T1	69%	24%	0.82 (0.76 - 0.88)	0.21 (0.18 - 0.24)	1552	0.57 (0.48 - 0.65)	1,205
T2	70%	22%	0.84 (0.78 - 0.90)	0.30 (0.26 - 0.34)	1565	0.70 (0.61 - 0.78)	1,302
(most traffic) T3	66%	24%	0.79 (0.72 - 0.85)	0.33 (0.29 - 0.38)	1396	0.72 (0.63 - 0.80)	1,062
Traffic speeds							
<25 kph	72%	24%	0.79 (0.72 - 0.85)	0.28 (0.23 - 0.33)	873	0.71 (0.62 - 0.80)	739
25-35 kph	68%	23%	0.84 (0.80 - 0.89)	0.28 (0.25 - 0.31)	2997	0.66 (0.60 - 0.73)	2,417
>35 kph	65%	25%	0.74 (0.65 - 0.83)	0.27 (0.20 - 0.34)	643	0.56 (0.44 - 0.67)	413

Table 2: Associations between social and environmental characteristics and doing some walking for transport

Characteristic		Term time weekday travel to school			Term time weekday other travel			Summer and weekend travel		
		OR	95% CI	p-value	OR	95% CI	p-value	OR	95% CI	p-value
Social Characteristics										
Age	age (single year)	0.999	(0.979 - 1.02)	0.928	1.085	(1.060 - 1.110)	p<0.001	1.047	(1.025 - 1.069)	p<0.001
Gender	male	reference category			-	-	-	-	-	-
	female	0.984	(0.849 - 1.141)	0.835	1.164	(0.986 - 1.375)	0.073	0.952	(0.815 - 1.111)	0.530
Ethnic group	'White'	reference category			-	-	-	-	-	-
	'Black'	1.227	(0.993 - 1.517)	0.058	0.855	(0.679 - 1.078)	0.186	0.953	(0.770 - 1.179)	0.657
	'Asian'	1.218	(0.994 - 1.491)	0.057	0.572	(0.445 - 0.735)	p<0.001	0.916	(0.735 - 1.142)	0.436
Household income	>£50k	reference category			-	-	-	-	-	-
	£15-59k	1.126	(0.941 - 1.348)	0.196	0.899	(0.731 - 1.107)	0.316	1.073	(0.880 - 1.308)	0.484
	<£15k	1.053	(0.838 - 1.323)	0.658	1.035	(0.796 - 1.346)	0.799	1.055	(0.825 - 1.348)	0.669
Household residents	# of household residents	1.034	(0.978 - 1.094)	0.234	0.962	(0.902 - 1.025)	0.234	0.926	(0.871 - 0.984)	0.014
Access to vehicle	access	reference category			-	-	-	-	-	-
	no access	2.334	(1.861 - 2.926)	p<0.001	1.375	(1.095 - 1.726)	0.006	1.82	(1.468 - 2.256)	p<0.001
Environmental Characteristics										
Location	Inner London	reference category			-	-	-	-	-	-
	Outer London	0.825	(0.657 - 1.035)	0.096	1.118	(0.865 - 1.445)	0.394	1.212	(0.956 - 1.536)	0.112
Area Deprivation	(least deprived) IMD Q1	reference category			-	-	-	-	-	-
	IMD Q2	0.958	(0.755 - 1.216)	0.724	0.918	(0.693 - 1.216)	0.549	0.919	(0.716 - 1.179)	0.506
	IMD Q3	1.037	(0.812 - 1.325)	0.770	1.015	(0.771 - 1.335)	0.918	1.000	(0.777 - 1.286)	0.997
	IMD Q4	0.938	(0.728 - 1.207)	0.618	0.785	(0.587 - 1.051)	0.104	0.752	(0.576 - 0.981)	0.036
	(most deprived) IMD Q5	1.007	(0.748 - 1.356)	0.962	0.828	(0.596 - 1.150)	0.259	0.888	(0.657 - 1.201)	0.441

Table 2 continued: Associations between social and environmental characteristics and doing some walking for transport

Characteristic		Term time weekday travel to school OR	95% CI	p-value	Term time weekday other travel OR	95% CI	p-value	Summer and weekend travel OR	95% CI	p-value
Physical environment	traffic volume (1,000 vehicles)	0.985	(0.967 - 1.003)	0.100	1.014	(0.994 - 1.034)	0.180	1.025	(1.005 - 1.046)	0.016
	speed (kph)	1.006	(0.985 - 1.027)	0.565	0.999	(0.975 - 1.024)	0.939	0.975	(0.955 - 0.996)	0.022
	# of junctions	0.999	(0.996 - 1.002)	0.528	0.993	(0.989 - 0.997)	p<0.001	0.993	(0.989 - 0.997)	0.001
	density of A roads	0.999	(0.994 - 1.004)	0.698	1.004	(0.998 - 1.010)	0.150	1.001	(0.996 - 1.007)	0.567
	density of minor roads	1.001	(0.999 - 1.002)	0.411	1.001	(0.999 - 1.003)	0.346	1.001	(0.999 - 1.003)	0.287
	Proportion of postcodes characterised as business	0.998	(0.982 - 1.016)	0.853	1.023	(1.004 - 1.042)	0.017	1.038	(1.018 - 1.058)	p<0.001

Table 3: Associations between social and environmental characteristics and walking distances (log transformed) among children who do some walking

Characteristic		All travel Coef	95% CI	p-value
	Social Characteristics			
Age	age (single year)	0.061	(0.053 - 0.068)	<0.001
Gender	male	reference category		
	female	0.045	(-0.012 - 0.103)	0.124
Ethnic group	'White'	reference category		
	'Black'	-0.110	(-0.186 - -0.035)	0.004
	'Asian'	-0.225	(-0.307 - -0.143)	<0.001
Household income	>£50k	reference category		
	£15-59k	-0.009	(-0.087 - 0.068)	0.819
	<£15k	-0.034	(-0.126 - 0.059)	0.475
Household residents	# of household residents	0.003	(-0.018 - 0.023)	0.802
Access to vehicle	access	reference category		
	no access	0.282	(0.206 - 0.358)	<0.001
Environmental Characteristics				
Location	Inner London	reference category		
	Outer London	0.086	(-0.005 - 0.177)	0.064
Area Deprivation	(least deprived) IMD Q1	reference category		
	IMD Q2	-0.057	(-0.159 - 0.046)	0.279
	IMD Q3	0.022	(-0.078 - 0.121)	0.672
	IMD Q4	-0.070	(-0.175 - 0.035)	0.192
	(most deprived) IMD Q5	-0.090	(-0.209 - 0.029)	0.139
Physical environment	traffic volume (1,000 vehicles)	0.006	(-0.001 - 0.014)	0.099
	speed (kph)	-0.012	(-0.020 - -0.003)	0.009
	# of junctions	0.000	(-0.001 - 0.002)	0.701
	density of A roads	-0.002	(-0.004 – 0.000)	0.093
	density of minor roads	-0.001	(-0.001 – 0.000)	0.052
	Proportion of postcodes characterised as business	0.002	(-0.004 - 0.008)	0.481
Constant		-0.435	(-0.735 - -0.134)	0.005

Web Appendix: Mean times (minutes) walked by children by selected social and environmental characteristics

Demographic	Term time weekday travel to school	Term time weekday other travel	Summer and weekend travel
Social characteristics			
Age			
5-11	14.16 (13.46 - 14.86)	4.31 (3.55 - 5.07)	11.78 (10.62 - 12.95)
12-17	19.78 (18.73 - 20.84)	6.55 (5.84 - 7.26)	13.81 (12.59 - 15.04)
Gender			
Male	16.71 (15.86 - 17.56)	4.96 (4.18 - 5.75)	12.46 (11.29 - 13.62)
Female	16.94 (16.01 - 17.87)	5.80 (5.10 - 6.49)	13.08 (11.86 - 14.31)
Ethnic group			
'White'	16.44 (15.58 - 17.30)	6.00 (5.23 - 6.77)	13.79 (12.49 - 15.10)
'Black'	18.65 (17.21 - 20.10)	5.26 (4.19 - 6.33)	11.92 (10.47 - 13.37)
'Asian'	15.90 (14.69 - 17.11)	3.33 (2.54 - 4.13)	9.99 (8.60 - 11.38)
Household income			
>£50k	14.29 (13.12 - 15.46)	5.36 (4.44 - 6.29)	12.84 (10.94 - 14.74)
£15-50	16.80 (15.81 - 17.78)	4.54 (3.97 - 5.11)	12.32 (11.13 - 13.52)
<£15k	18.55 (17.44 - 19.65)	6.46 (5.24 - 7.68)	13.33 (11.84 - 14.82)
Vehicle access			
Access	15.14 (14.43 - 15.85)	4.59 (4.12 - 5.06)	11.43 (10.49 - 12.37)
No access	21.02 (19.75 - 22.28)	7.31 (5.91 - 8.72)	16.20 (14.45 - 17.96)
Environmental characteristics			
Location			
Inner London	17.20 (16.14 - 18.26)	5.44 (4.70 - 6.17)	14.16 (12.59 - 15.72)
Outer London	16.61 (15.83 - 17.39)	5.33 (4.63 - 6.04)	11.98 (11.00 - 12.96)
Area Deprivation			
(least deprived) Q1	15.51 (14.12 - 16.90)	5.06 (3.96 - 6.17)	12.66 (10.82 - 14.51)
Q2	16.13 (14.69 - 17.57)	5.03 (4.08 - 5.98)	11.90 (10.06 - 13.74)
Q3	17.60 (16.00 - 19.21)	6.21 (4.56 - 7.87)	14.86 (12.44 - 17.27)
Q4	16.38 (15.02 - 17.73)	4.94 (4.02 - 5.85)	11.57 (10.06 - 13.08)
(most deprived) Q5	18.01 (16.79 - 19.24)	5.47 (4.48 - 6.46)	12.85 (11.14 - 14.56)
Mean traffic volumes			
(least traffic) T1	16.36 (15.38 - 17.33)	3.92 (3.34 - 4.50)	10.62 (9.27 - 11.97)
T2	17.23 (16.19 - 18.27)	5.38 (4.65 - 6.12)	13.73 (12.18 - 15.27)
(most traffic) T3	16.90 (15.62 - 18.17)	7.00 (5.67 - 8.34)	14.03 (12.59 - 15.47)
Traffic speeds			
<25 kph	16.72 (15.36 - 18.08)	5.11 (4.17 - 6.04)	14.50 (12.77 - 16.23)
25-35 kph	17.02 (16.24 - 17.80)	5.55 (4.86 - 6.23)	12.47 (11.41 - 13.53)
>35 kph	15.93 (14.22 - 17.64)	4.86 (3.49 - 6.23)	11.27 (9.09 - 13.44)

Web Appendix: Associations between social and environmental characteristics and walking times (log transformed) among children who do some walking

Characteristic		All travel Coef	95% CI	p-value
Social Characteristics				
Age	age (single year)	0.030	(0.023 - 0.036)	<0.001
Gender	male		reference category	
	female	0.054	(0.003 - 0.105)	0.037
Ethnic group	'White'		reference category	
	'Black'	-0.104	(-0.172 - -0.037)	0.003
	'Asian'	-0.170	(-0.238 - -0.102)	0.000
Household income	>£50k		reference category	
	£15-59k	0.002	(-0.066 - 0.070)	0.955
	<£15k	-0.018	(-0.100 - 0.063)	0.659
Household residents	# of household residents	-0.003	(-0.021 - 0.015)	0.739
Access to vehicle	access		reference category	
	no access	0.217	(0.148 - 0.286)	<0.001
Environmental Characteristics				
Location	Inner London		reference category	
	Outer London	0.036	(-0.041 - 0.113)	0.359
Area Deprivation	(least deprived) IMD Q1		reference category	
	IMD Q2	-0.018	(-0.109 - 0.074)	0.708
	IMD Q3	0.069	(-0.023 - 0.161)	0.140
	IMD Q4	-0.026	(-0.120 - 0.068)	0.584
	(most deprived) IMD Q5	0.041	(-0.064 - 0.146)	0.448
Physical environment	traffic volume (1,000 vehicles)	0.006	(0.000 - 0.013)	0.057
	speed (kph)	-0.006	(-0.014 - 0.001)	0.090
	# of junctions	0.001	(-0.001 - 0.002)	0.375
	density of A roads	-0.001	(-0.003 – 0.000)	0.135
	density of minor roads	0.000	(-0.001 – 0.000)	0.358
	Proportion of postcodes characterised as business	0.000	(-0.005 - 0.006)	0.882
Constant		2.773	(2.508 - 3.039)	<0.001

Web Appendix: associations between social and environmental characteristics and walking all the way to school

Characteristic		Term time weekday travel to school OR	95% CI	p-value
Social Characteristics				
Age	age (single year)	0.853	(0.836 - 0.871)	<0.001
Gender	male		reference category	
	female	1.041	(0.901 - 1.202)	0.588
Ethnic group	'White'		reference category	
	'Black'	0.737	(0.602 - 0.902)	0.003
	'Asian'	1.244	(1.025 - 1.511)	0.027
Household income	>£50k		reference category	
	£15-59k	1.353	(1.123 - 1.630)	0.001
	<£15k	1.129	(0.896 - 1.422)	0.305
Household residents	# of household residents	1.022	(0.97 - 1.078)	0.414
Access to vehicle	access		reference category	
	no access	1.784	(1.466 - 2.17)	<0.001
Environmental Characteristics				
Location	Inner London		reference category	
	Outer London	0.841	(0.676 - 1.047)	0.122
Area Deprivation	(least deprived) IMD Q1		reference category	
	IMD Q2	0.966	(0.758 - 1.231)	0.779
	IMD Q3	0.962	(0.746 - 1.239)	0.761
	IMD Q4	0.880	(0.681 - 1.137)	0.327
	(most deprived) IMD Q5	1.181	(0.886 - 1.575)	0.256
Physical environment	traffic volume (1,000 vehicles)	0.977	(0.960 - 0.994)	0.008
	speed (kph)	1.029	(1.009 - 1.049)	0.004
	# of junctions	0.998	(0.995 - 1.002)	0.331
	density of A roads	1.002	(0.997 - 1.006)	0.433
	density of minor roads	1.001	(1.000 - 1.003)	0.098
	Proportion of postcodes characterised as business	0.996	(0.980 - 1.013)	0.643

4.2 FURTHER ANALYSES

Research Paper 2 examined mean distances and minutes walked during the school commute, outside the school commute during term time and during the summer and weekends by ethnic group. Results suggest some differences in walking patterns among 'Asian' children compared to 'White' and 'Black' children. These provide useful evidence to assess the ability of the travel time exposure hypothesis to explain overall ethnic differences in injury rates in London, which will be discussed in section 4.3. To assess whether the travel time exposure hypothesis can help explain the different relationship between deprivation and injury rates among 'Black' children compared to 'White' and 'Asian' children, additional analyses examining walking patterns broken down by both ethnic group and area deprivation are needed.

4.2.1 Methods

I used the same LTDS dataset described in Research Paper 2 to estimate kilometres and minutes walked by ethnic group and quintile of area deprivation. My methods of analysis, however, differed slightly. Sample sizes of children divided into ethnic group and quintile of area deprivation were too small to reliably estimate distances and times walked by the three time periods used in Research Paper 2. Instead, analyses estimate mean distances and times over the whole year including weekdays and weekends in both term time and summer months. Sample sizes of 'Black' (and to some extent 'Asian') children living in the least deprived quintile of deprivation were still relatively small. A sensitivity analysis was, therefore conducted to estimate mean distances and times walked by ethnic group and by *tercile* of areas based on the index of multiple deprivation 2004. For more details on IMD cut-off points used see Appendix 6.

4.2.2 Results

Across all levels of deprivation, 'White' and 'Black' children walk similar distances and for similar amounts of time over the year (Table 4.1). There was some evidence that 'Asian' children walk shorter distances and times than their 'Black' and 'White' counterparts. Among 'White' children there was no clear evidence of a difference in distances or times walked by quintile of deprivation, although estimates suggest walking distances and times were largest in quintile 3. There was also no clear evidence of a difference in distances or times walked among 'Black' children by quintile of deprivation. Estimates of walking distances among 'Black' children were largest in quintile 3 while estimates of walking times were largest in the least deprived quintile, however confidence intervals around both outcomes were large and overlapped with estimates of walking distance and times among 'Black' children in other deprivation quintiles. Walking distances were largest among 'Asian' children in the least deprived quintile, while walking times were largest in quintile 3. Again, however, confidence intervals were large and overlapped with estimates of walking distances and times among ‘Asian’ children in other deprivation quintiles. Looking across ethnic groups, there was some suggestion that ‘Asian’ children living in quintile 2 walked shorter distances than ‘White’ children and fewer times than ‘White’ or ‘Black’ children. Table 4.1 also suggests that ‘Asian’ children living in the most deprived quintile walked shorter distances and for less time than their ‘White’ and ‘Black’ counterparts living in the most deprived quintile.

A sensitivity analysis using terciles of area deprivation, suggested no relationship between deprivation and walking distances among ‘White’, ‘Black’ and ‘Asian’ children. There was some suggestion that ‘White’ children living in the middle tercile of deprivation walked for longer times than ‘White’ children living in the least deprived tercile. Estimates suggested that among ‘Black’ children and ‘Asian’ children walking times were also greatest in the middle tercile of deprivation however, confidence intervals remained large and overlapped with estimates of walking times among ‘Black’ and ‘Asian’ children living in the least and most deprived areas.

4.2.3 Discussion

Overall results from the further analyses suggest that ‘Asian’ children walked less than ‘White’ and ‘Black’ children over the year. Analyses investigating the walking patterns by deprivation and ethnic group revealed no clear relationship between deprivation and walking among ‘White’, ‘Black’ or ‘Asian’ children. A key limitation of these analyses is the small sample size of minority ethnic children living in the least deprived areas of London, leading to large confidence intervals around estimates. However, a sensitivity analysis using terciles of deprivation rather than quintiles of deprivations revealed similar results: there is little relationship between deprivation and walking patterns among ‘White’, ‘Black’ or ‘Asian’ children in London. Looking at point estimates alone, it appears that both ‘White’ and ‘Black’ children living in the middle tercile of deprivation walk further distances and more times than their counterparts in the least and most deprived areas of London: i.e. the relationship with deprivation appears somewhat similar across ‘White’ and ‘Black’ children (and ‘Asian’ children in terms of times). However, as confidence intervals are large and overlapping, these results may be due to chance alone.

Table 4.1: Mean distances and times walked by ethnic group and area deprivation quintile

	'White'		'Black'		'Asian'	
	Mean (95% CI)	**n**	**Mean (95% CI)**	**n**	**Mean (95% CI)**	**n**
Distance walked (km)						
(Least deprived) Q1	0.87 (0.78 - 0.95)	1,235	1.02 (0.71 - 1.33)	80	0.89 (0.66 - 1.12)	181
Q2	0.95 (0.86 - 1.04)	948	0.75 (0.60 - 0.90)	193	0.66 (0.51 - 0.81)	319
Q3	1.02 (0.92 - 1.12)	908	1.05 (0.89 - 1.21)	313	0.83 (0.65 - 1.01)	292
Q4	0.93 (0.84 - 1.03)	773	0.80 (0.70 - 0.89)	449	0.73 (0.58 - 0.87)	337
(Most deprived) Q5	0.93 (0.83 - 1.02)	605	0.92 (0.82 - 1.03)	568	0.68 (0.60 - 0.77)	418
Total	**0.94 (0.89 - 0.98)**	**4,469**	**0.90 (0.84 - 0.96)**	**1603**	**0.74 (0.67 - 0.81)**	**1,547**
Times walked (minutes)						
(Least deprived) Q1	16.55 (15.12 - 17.98)	1,235	20.57 (14.54 - 26.60)	80	15.48 (12.55 - 18.41)	181
Q2	18.37 (16.73 - 20.01)	948	16.39 (12.80 - 19.99)	193	11.83 (9.68 - 13.98)	319
Q3	21.35 (18.91 - 23.78)	908	19.95 (17.21 - 22.68)	313	16.22 (13.63 - 18.80)	292
Q4	17.72 (16.04 - 19.41)	773	16.20 (14.13 - 18.27)	449	15.09 (12.89 - 17.29)	337
(Most deprived) Q5	19.99 (18.01 - 21.98)	605	19.71 (17.90 - 21.53)	568	15.02 (13.34 - 16.71)	418
Total	**18.64 (17.81 - 19.47)**	**4,469**	**18.42 (17.27 - 19.57)**	**1603**	**14.68 (13.69 - 15.67)**	**1,547**

Table 4.2: Mean distances and times walked by ethnic group and area deprivation tercile

	'White'		'Black'		'Asian'	
	Mean (95% CI)	**n**	**Mean (95% CI)**	**n**	**Mean (95%CI)**	**n**
Distance walked (km)						
(Least deprived) Q1	0.89 (0.82 - 0.96)	1,882	0.83 (0.66 - 1.01)	208	0.79 (0.64 - 0.94)	392
Q2	1.02 (0.94 - 1.10)	1,475	0.96 (0.85 - 1.08)	513	0.76 (0.64 - 0.88)	528
(Most deprived) Q3	0.90 (0.82 - 0.97)	1,112	0.87 (0.80 - 0.95)	882	0.70 (0.61 - 0.79)	625
Total	**0.94 (0.89 - 0.98)**	**4,469**	**0.90 (0.84 - 0.96)**	**1603**	**0.74 (0.67 - 0.81)**	**1,547**
Times walked (minutes)						
(Least deprived) Q1	17.15 (16.02 - 18.28)	1,882	16.65 (13.36 - 19.95)	208	13.15 (11.27 - 15.02)	392
Q2	20.45 (18.70 - 22.20)	1,475	19.27 (17.11 - 21.43)	513	15.64 (13.74 - 17.53)	528
(Most deprived) Q3	18.58 (17.17 – 20.00)	1,112	18.31 (16.83 - 19.78)	882	14.86 (13.40 - 16.32)	625
Total	**18.64 (17.81 - 19.47)**	**4,469**	**18.42 (17.27 - 19.57)**	**1603**	**14.68 (13.69 - 15.67)**	**1,547**

4.3 IMPLICATIONS OF RESEARCH PAPER 2 AND FURTHER ANALYSES FOR THE TRAVEL TIME EXPOSURE HYPOTHESIS

The implications of Research Paper 2 and the further analyses are mixed for the role of the quantity of travel time exposure in explaining ethnic inequalities in child pedestrian injury in London. Results from Research Paper 2 on a key indicator of socio-economic status are clear: children living in a household without access to a vehicle walked greater distances and for longer times than children living in households with vehicle access. Living in a household without a vehicle was a strong predictor of walking to school, outside the school commute during term time and during the summer and weekends. However, results from Research Paper 2 suggested little difference in walking patterns by household income or area deprivation. Further analyses (Section 4.2) also failed to find evidence of a relationship between deprivation and walking patterns among 'White', 'Black' or 'Asian' children.

In terms of ethnicity, unadjusted analyses from Research Paper 2 suggested that 'Black' children walked longer and further distances to school compared to children from other ethnic groups, and regression analyses adjusting for social and environmental factors confirmed that 'Black' children were more likely than 'White' children to do some walking on the way to school. Outside the school commute, however, unadjusted analyses suggested that 'Black' children walk less than 'White' children in the evenings and during the summer and weekends. Overall, among children who did some walking, being 'Black' was negatively associated with walking times and distances after controlling for other social and environmental characteristics. Over the year, the further analyses suggested no difference in walking distance or times between 'Black' and 'White' children. Taken together, these findings from Research Paper 2 and the further analyses suggest little difference in the quantity of pedestrian exposure to road hazards among 'Black' and 'White' children during travel time. The findings, therefore, provide little support that the travel time exposure hypothesis can explain the higher rates of pedestrian injury among 'Black' children compared to 'White' children.

However, findings from Research Paper 2 and the further analyses do provide some support for the hypothesis that lower levels of pedestrian exposure to road hazards among 'Asian' children may help to explain lower rates of pedestrian injury among 'Asian' children. Research Paper 2 indicates that while 'Asian' children were marginally more likely to do some walking on the way to school compared to 'White' children, 'Asian' children were less likely to walk during the evenings and during the summer and weekends; and among children who did some walking being 'Asian' was negatively associated with walking times and distances. Results from the further analyses suggest that across the year, ‘Asian’ children spend less time walking and walk shorter distances compared to ‘Black’ or ‘White’ children.

Results from these analyses, then, suggest that lower amounts of travel time exposure may help to explain the lower child pedestrian injury rates of ‘Asian’ children, but that the travel time exposure hypothesis cannot explain the higher rates of injury among ‘Black’ children. To investigate whether the travel time exposure hypothesis can help to explain the different relationship between deprivation and injury rates among ‘Black’ children compared to ‘White’ and ‘Asian’ children, the further analyses examined distances walked and time spent walking by deprivation and ethnicity. Results, which are somewhat limited by small sample sizes, suggest no concrete relationship between area deprivation and walking patterns among ‘White’, ‘Black’ or ‘Asian’ children. Point estimates from the further analyses (albeit with large overlapping confidence intervals) suggest a similar relationship between deprivation and walking patterns among ‘White’ and ‘Black’ (and to some extent ‘Asian’) children. Given that the relationship between deprivation and injury is different among ‘Black’ compared to ‘White’ and ‘Asian’ children (as reported in the introductory chapter), these findings may suggest that other mechanisms apart from travel time exposure are influencing relationships between ethnicity, deprivation and injury.

In conclusion, this chapter provided little evidence that the travel time exposure hypothesis can explain the relatively high rates of ‘Black’ child pedestrian injury overall, or why area affluence does not protect ‘Black’ children from injury. The chapter provides some evidence, however, that lower levels of travel time exposure may help to explain the relatively low rates of child pedestrian injury among ‘Asian’ children. Travel time exposure, however, is only one component of overall exposure levels. Children may also be exposed to injury while playing or ‘hanging out’ in the road environment, exposures which are not captured in travel diary data. Unfortunately, despite investigating a number of data sources (see Appendix 7 for details) I was unable to find a quantitative data source that would allow a calculation of time exposed to road hazards (or distances travelled in the road environment) during leisure activities for ‘White’, ‘Black’ and ‘Asian’ children. Appendix 7 provides a first step in developing an understanding of leisure time exposure, by qualitatively exploring how, and why, children are exposed to road hazards during their leisure time in London.

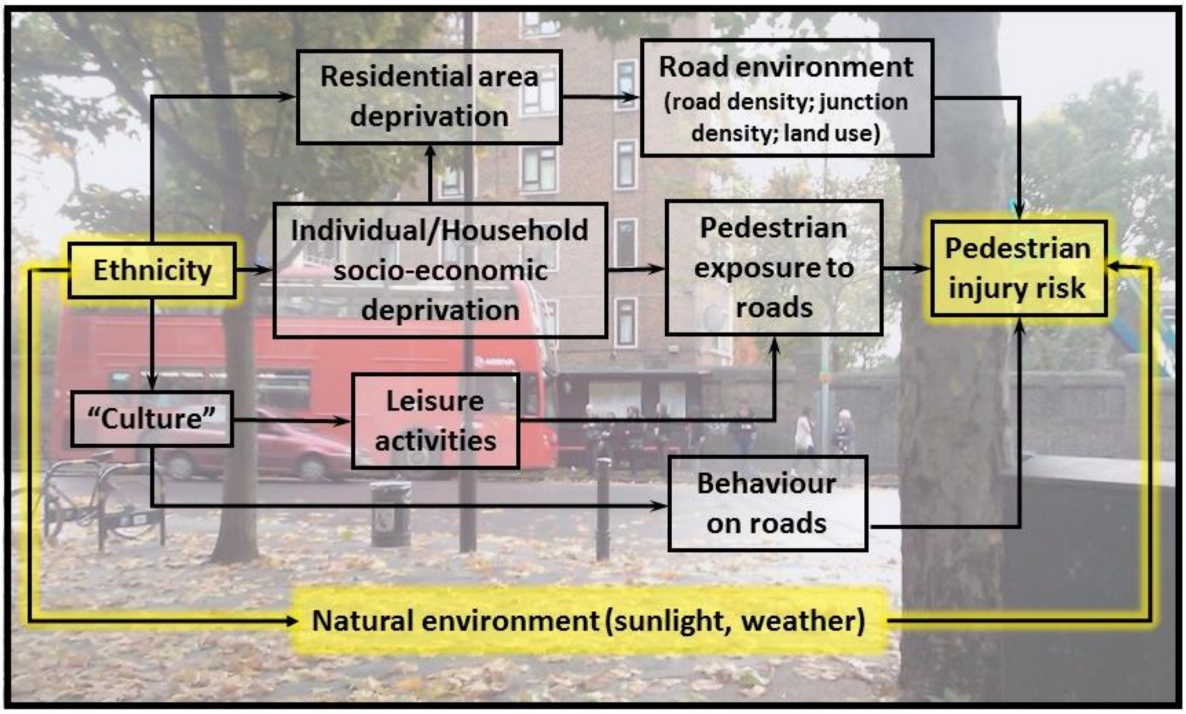
Young people participate in a wide range of activities in their leisure time, and these accomplish a number of explicit and implicit goals. However, many of these activities - such as ‘wandering around’, traveling to unknown locations, and purposefully creating mobility related risks - can leave young people exposed to road hazards. Qualitative analyses suggested ways that social factors such as socio-economic status and ethnicity may influence levels of exposure road hazards during leisure time. For instance, associations with lower socio-economic status may mean that 'Black' children have less access to indoor space. 'Black' children, therefore may be more likely to socialise with friends outdoors, which may increase their exposure to injury during leisure time. Analyses also suggested that all young people lead lives that they experience as overly structured, and that some react by creating mobility related risks in the road environment as a way of resisting adult control. Belonging to an ethnic minority group can restrict the choices and opportunities enjoyed by 'Black' children even further. Perhaps this additional 'structure' makes mobility-related risk taking more attractive for 'Black' children, leading to greater exposure to road hazards. However, findings also confirm that developing quantitative measures of leisure time exposure to road hazards is not feasible using current methodological tools. It is therefore possible that the leisure time hypothesis can help explain ethnic differences in injury risk in London, but more work is needed to examine links between ethnicity and leisure activities.

5 IS NIGHT TIME EXPOSURE MORE HAZARDOUS FOR ETHNIC MINORITY CHILDREN?

Aim 1 of this thesis was to explore whether ethnic differences in child pedestrian injury rates are the result of differences in the quality and quantity of pedestrian exposure among ethnic groups. Chapter 3 investigated the role of hazard levels of local roads and Chapter 4 investigated the quantity of exposure during travel time, Findings provide little evidence that differences in hazard levels in neighbourhoods where 'White', 'Black', and 'Asian' children live can explain the relatively high rates of pedestrian injury among 'Black' children, or the relatively low rates of 'Asian' children in London. Findings on the role of pedestrian exposure levels are mixed. Chapter 4 provided some evidence that 'Asian' children are exposed less as pedestrians during travel time, which may help explain their relatively low injury rates. However, there was no evidence that travel time exposure levels differed between 'Black' and 'White' children, and therefore no support for the hypothesis that higher levels of travel time exposure among 'Black' children can explain their relatively high injury rates. Appendix 7 used qualitative data to posit reasons why young people may be exposed to road hazards during their leisure time, but ethnic differences in leisure time exposure levels could not be quantitatively assessed.

This chapter focuses on the final hypothesis put forward in Aim 1 of this thesis: whether the natural environment makes pedestrian exposure at night more 'hazardous' for ethnic minority children (Figure 5.1). This 'conspicuity' hypothesis postulates that ethnic minorities with darker skin tones may have higher rates of injury at night because they are less visible to vehicle drivers. The skin tones of children categorised as 'Black' in this thesis, are likely to be darker than the skin tones of 'White' and 'Asian' children. It therefore seems possible that the 'conspicuity' hypothesis may explain the higher rates of injury among 'Black' children. If darker skin tones do contribute to ethnic inequalities in injury, I would expect that features describing the visibility of the natural environment (such as light levels, rain, or temperature) would have stronger associations with pedestrian injury rates among 'Black' children compared to 'White' or 'Asian' children. The 'conspicuity' hypothesis, however, seems unable to explain the lower rates of injury among 'Asian' children, as 'Asian' skin tones are generally considered to be similar or darker than that of 'White' children. Section 5.1 of this chapter includes Research Paper 3, which examines evidence for the 'conspicuity' hypothesis in London. Following this, section 5.2 examines the implications of Research Paper 3 for the role of the natural environment in explaining inequalities in injury rates. Finally, section 5.3 summarizes the evidence thus far for the role of exposure in explaining ethnic inequalities in child pedestrian injury in London.

Figure 5.1: Hypothesized model of links between ethnicity and pedestrian injury risk



5.1 Research Paper 3: The contribution of light levels to ethnic differences in child pedestrian injury risk: a case-only analysis

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COVER SHEET FOR EACH ‘RESEARCH PAPER’ INCLUDED IN A RESEARCH THESIS

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    1.1. Where was the work published? **Journal of Transport & Health**

    1.2. When was the work published? **2014**

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I designed the study with Phil Edwards and Judith Green. Ben Armstrong provided statistical methods advice. I formatted data for analysis, analysed the data and drafted the manuscript. I revised the manuscript based on comments from Phil Edwards, Judith Green and Ben Armstrong.

NAME IN FULL (Block Capitals) REBECCA STEINBACH

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CANDIDATE’S SIGNATURE: Date: 01/08/2014

SUPERVISOR’S SIGNATURE: PEdwards

THE CONTRIBUTION OF LIGHT LEVELS TO ETHNIC DIFFERENCES IN CHILD PEDESTRIAN INJURY RISK: A CASE-ONLY ANALYSIS

ABSTRACT

Background: Many studies in countries across the world have identified minority ethnic children at higher risk of pedestrian injury compared to their majority counterparts. Understanding why minority ethnicity increases risk has proved challenging. One hypothesis which has not, to date been explicitly tested in the published literature is the 'conspicuity hypothesis': namely that ethnic differences in pedestrian risk may reflect differences in the relative 'visibility' of some groups in traffic environments. This study investigates whether the 'conspicuity hypothesis' can help explain ethnic inequalities in child pedestrian injury risk in London.

Methods: Using a time series of police injury records in London from 2000-2009 we assess the impact of sunlight levels on child pedestrian injury controlling for diurnal patterns of injuries and weather conditions. We then explore the distribution of casualties by ethnic group using a case-only analysis to assess whether light intensity has a differential effect on injury risk by ethnic group.

Results: All children were at increased injury risk during civil twilight (the hour after sunrise and the hour before sunset) compared with during the day. We found no association between astronomical twilight (the hour after sunset and the hour before sunrise) and night time and injury. We found no evidence for the conspicuity hypothesis. A similar proportion of 'Black' and 'White' child pedestrian injuries occur during darkness, and our models found that light levels had a similar effect on injury risk to children from all ethnic groups.

Conclusion: There was no evidence that non-White minority ethnic children in London are at higher risk of injury because they are less conspicuous at night time.

INTRODUCTION

Ethnic differences in vulnerability to pedestrian injury have been identified in a range of different contexts, with most (Abdalla 2002, Campos-Outcalt et al. 2002, Harrop et al. 2007, Savitsky 2007, Stirbu 2006) but not all (Al-Madani and Al-Janahi 2006) studies identifying children from minority ethnic communities at relatively higher risk of injury. In London, UK, for instance, a city with a diverse ethnic population (Greater London Authority Intelligence Unit 2013), our previous work reported that pedestrian injury rates among 'Black' children are 50% higher than rates among 'White' children (Steinbach et al. 2010). Understanding why minority ethnicity increases risk has proved challenging. This is, in part, because 'ethnicity' is a complex, often poorly defined, variable which conflates a number of different components, including, depending on the setting: own and parents' nationality; heritage; self-identified ethnicity; observed differences in physical characteristics; and religion. These components may also be associated with factors such as income and area deprivation (Steinbach et al. 2010), which are independently associated with injury risk. Theoretical models and empirical research have explored a number of these components of ethnicity in explaining inequalities in risk, with more or less sophistication in accounting for potential confounding. Provisional explanations of higher risk in particular minority ethnic communities that have been investigated to date include: differences in exposure to pedestrian risk (Roberts, Norton, and Taua 1996); structural associations with socio-economic disadvantage (Savitsky 2007); spatial associations with more dangerous road environments (Steinbach et al. 2010); different 'safety cultures' in immigrant communities (Chen, Lin, and Loo 2012); and the complexity of infrastructural, resource access and possible behavioural differences (Abdel-Rahman et al. 2013). There has been no conclusive evidence to explain why those in minority ethnic groups tend to be at higher risk. One hypothesis which has not, to date, been explicitly tested in published epidemiological literature is the so-called 'conspicuity hypothesis'. Baldly stated, this suggests that ethnic differences in pedestrian risk may reflect differences in the relative 'visibility' of some groups in traffic environments.

There are some good reasons why this hypothesis has not yet been tested, and indeed, given the ethical and methodological complexities associated with research into ethnicity and health outcomes (Ahmad and Bradby 2007, Bhopal 1997, Bradby 2003), it is legitimate to question whether the conspicuity hypothesis warrants scientific investigation. There are many reasons to leave the question both unasked and unanswered. First, this hypothesis reduces the complex multifaceted concept of ethnicity to just one component, skin tone. Not only is this reminiscent of racialised research of the past (Ahmad and Bradby 2007, Bhopal 1997), it problematises the 'minority' characteristic, positing the visibility of darker skin in poorer light as a research problem, and other skin tones as the norm: 'Black' skin is thus implied as 'different' and potentially 'riskier' than 'White' skin. As others have warned, such comparisons are victim blaming and potentially facilitate stereotypes and fuel racial prejudice (Bradby 2003). Public disdain for 'conspicuity' explanations is evident in the reactions to a number of public figures who have suggested that visibility is related to skin tone (Moore 2007, Satran 2013). Second, different ethnic minorities of varying skin tones across the world have been identified as at higher risk of pedestrian injury (Abdalla 2002, Campos-Outcalt et al. 2002, Harrop et al. 2007, Savitsky 2007, Stirbu 2006), suggesting that there is likely to be something structural about belonging to a minority group that increases risk, rather than biological factors. In general, 'best practice' on research into ethnic inequalities in health outcomes would incorporate a focus on socio-economic position and experiences of racism as mechanisms, rather than inherent biological differences between ethnic groups (Ahmad and Bradby 2007). However, little of the epidemiological research on injury does follow such best practice, in that it largely focuses on particular aspects of ethnicity in isolation, and on the specific contexts in which particular groups are at higher risk.

Whilst concurring that what is needed is more sophisticated theoretical and methodological approaches to accounting for ethnic inequalities in general, we argue that it is legitimate to assess whether there is any evidence for this 'conspicuity hypothesis' in one setting (Steinbach et al. 2010, Steinbach, Edwards, and Green 2014, Steinbach, Green, and Edwards 2012). Our experience in disseminating research on ethnicity and pedestrian injury in London is that this is a hypothesis that both the general public, interested community groups, and other researchers do raise spontaneously, if (for the above reasons) rarely formally. Although public interest in a hypothesis may not be a sufficient rationale for investigation, there are also some good practical and theoretical grounds for assessing the role of relative visibility in accounting for ethnic inequalities. Ethically, given that ethnic differences in pedestrian risk have already been identified, any research that helps to unravel the contribution of different mechanisms to generating inequalities may be useful for identifying possible interventions (Bhopal 1997).

Scientifically, the conspicuity hypothesis is theoretically plausible. First, there is good evidence that visibility is a key risk factor for injury (Peden et al. 2004) and theoretically light levels may affect the conspicuity of pedestrians and therefore injury risk (Broughton, Hazelton, and Stone

1999, Plainis, Murray, and Pallikaris 2006). Evidence suggests that light levels affect the reaction times of motorists, which in turn influence stopping distances (Plainis, Murray, and Pallikaris 2006). There has long been evidence for a strong association between light levels and the risk of fatal pedestrian crashes (Sullivan and Flannagan 2002, Owens and Sivak 1993, Owens and Sivak 1996). Estimates from studies using daylight saving times as a "natural experiment" suggest that pedestrian fatality risk may be 3-6.75 times greater in the dark compared to the daylight (Sullivan and Flannagan 2002). Contrast may also affect conspicuity. Evidence based on simulations suggests that the contrast between a pedestrian's skin colour and the background can influence drivers' responses (Mather and DeLucia 2007) and retroflective materials in red and yellow colours can enhance a driver's detection and recognition of pedestrians (Kwan and Mapstone 2006). There is also some evidence that vehicle colour is associated with crash risk, with colours on the lower visibility index such as black, blue and green at higher risk of crashes compared to white vehicles (Newstead and D'Elia 2007).

This paper explores the conspicuity hypothesis using data on child pedestrian injuries in London. We assess the impact of light levels on injury overall and we then explore the distribution of casualties by ethnic group to assess whether light intensity has differential effects on injury risk by ethnic group.

METHODS

We obtained a dataset of police STATS19 data that included all reported casualties and collisions occurring in London between 2000-2009. Casualties were included in the analysis if they were aged 0-15 years and were injured as pedestrians.

MEASURES OF ETHNICITY

Police rely on physical attributes to categorize casualties into one of six ethnic 'Identity Codes', designed for descriptive purposes in crime detection and prevention, rather than monitoring, purposes. For analysis, we grouped casualties into four categories based on previous research: 'White' (White-skinned European, Dark-skinned European); 'Black' (Afro-Caribbean'); Asian ('Asian'); and Other ('Arab', 'Oriental', missing ethnicity) (Steinbach et al. 2010).

MEASURES OF LIGHT

Police data include information on dates and times of collisions. We divided casualties into four light levels based on the time of day (and day of year) the collision occurred; 'Daytime', 'Civil twilight', 'Astronomical twilight', and 'Night time'. We defined 'Astronomical twilight' as the hour before sunrise and the hour after sunset; 'Civil twilight' as the hour after sunrise and the hour before sunset; 'Daytime' as the remaining hours between sunrise and sunset; and 'Night time' as the remaining hours between sunset and sunrise. As a sensitivity analysis we assigned a measure of light intensity (lux) to each light level: Daytime 10,000 lux; Civil twilight 400 lux; Astronomical twilight 10 lux; and Night time 0 lux (Schlyter 2006).

CONTROLS FOR VISIBILITY

As there is evidence that weather can change the visibility of the road environment for pedestrians and drivers, particularly at night (N Hautière et al. 2009), we included controls for rainfall and temperature in our models. Data on rainfall and temperature were obtained from the Met Office Integrated Data Archive System (MIDAS) Land and Marine Surface Stations Data. We obtained hourly estimates of rainfall and temperature from the Heathrow weather station. For analysis, we created four temperature categories based on quartiles of the distribution (below 7 degrees Celsius, 7-12 degrees Celsius, 12-16 degrees Celsius, and above 16 degrees Celsius).

STATISTICAL ANALYSIS

Two statistical models were estimated: a time series regression and a case-only regression analysis. The first was conducted to obtain estimates of the main effects of light levels on child pedestrian injury. The second was used to assess evidence for whether any effects of light levels differed by ethnic group.

Time series analysis

Hourly counts of the number of child pedestrian casualties for each day between 2000-2009 were analysed. We sought a method which controlled tightly for seasonal variation (e.g. holidays). To this end we used a conditional fixed effects Poisson model where the panel variable was day of the year (i.e. 365 panels each comprising the hours of that day for each of the ten years included). Conditional Poisson models are used widely in matched cohort injury studies (Cummings, McKnight, and Greenland 2003), in time series contexts in econometrics (Hausman, Hall, and Z. 1984), and in self-controlled case series studies (Farrington 1995, Whitaker, Hocine, and Farrington 2007). We thereby estimated the main effects of change in light level on the number of child pedestrian casualties controlling for season, diurnal patterns, rainfall and temperature.

The number of casualties, $y_{h,d,t}$ in hour h of day d in year t is thus modelled as follows:

- $Y_{h,d,t} \sim \text{Poisson}(\mu_{h,d,t})$
- $\log(\mu_{h,d,t}) = \alpha_d + Z(h,d) + S(t) + ßx_{h,d,t}$

where α_d is the day-of-year effect; Z(h,d) is a function of hour and day of week to allow for diurnal patterns in casualties during the week and on weekends; S(t) is a linear function of year to allow for London-wide trends in casualties; $x_{h,d,t}$ is a vector of indicator variables identifying light and weather conditions; and ß is a vector of coefficients representing the effect of these covariates on casualties. The α_h nuisance parameters are "conditioned out" in the conditional fixed effects Poisson model to avoid having to fit 365 parameters in the model.

Case-only analysis

Rather than add complexity to the model by including interaction terms, we used a case-only analysis (Armstrong 2003) to assess evidence for whether light levels have differential effects on children of different ethnicity. Case-only analyses have been applied to assess differential impacts of weather conditions and pollution on mortality (Armstrong 2003, Medina-Ramon et al. 2006, Schwartz 2005) and have a number of advantages for a study of this type, namely computational efficiency and stringent control for confounding. A case-only analysis draws its information from how, among cases, the distribution of ethnicity depends on environmental conditions. If, for example, a lower light level presents a larger risk to 'Black' children compared to 'White' children, a greater proportion of children injured at night would be expected to be 'Black' than among those injured during the day. Following the standard approach to case-only analysis (Armstrong 2003), the data set comprised one observation for each child pedestrian injury. Using variables on the date and time of injury we added information on daylight and weather conditions to the data set. We then fitted a multinomial logistic regression model with: a function of hour of day during the week and on weekends; light levels, and controls for month of year and weather conditions as the explanatory variables; and ethnic group as the dependent variable. Because the odds ratios from such analyses represent interactions between effects of ethnicity and of the natural environment variables on injury, we refer to these as interaction rate rations (IRRs).

RESULTS

Between 2000-2009, 15,508 children were injured as pedestrians in London. Ethnicity was recorded for 85% of casualties, and there was no evidence of an association between missing ethnicity and time of collision. Of those casualties 6,971 were coded as 'White', 4,043 were coded as 'Black' and 1,816 were coded as 'Asian'.

During the week, most injuries occurred between 3pm-8pm (Figure 1), followed by 6am-9am. Diurnal patterns are different at weekends, when injuries steadily increase from 10am-4pm and then steadily decrease from 4pm-8pm. Generally, injuries tend to increase as the temperature increases. Monthly trends suggest that children tend to be injured in the summer and autumn months with the exception of August, when some families may be away from London during school holidays.

Most injuries occur during daytime hours. From the crude analyses (Table 1) there was some evidence that a greater proportion of injuries to 'Asian' children occur during the day compared to injuries to children from other ethnic groups. More than 90% of casualties occurred in non-rainy conditions with some evidence that a smaller proportion of 'Asian' injuries occurred when it is raining. There was good evidence that the distribution of casualties by temperature quartile differed by ethnic group: 'Asian' children were more likely to be injured on warmer days compared to 'Black' and 'White' children. Children from all three ethnic groups were least likely to be injured in the winter months. Of the other seasons 'Asian' children were most likely to be injured in the summer, while 'Black' and 'White' children were most likely to be injured in the spring.

Table 2 shows incident rate ratios from the time series models. Based on diurnal patterns in casualties during the week and at weekends we grouped the hours between 12am-6am into one category (leaving each of the other 18 hours as separate categories). We also included an hour category/weekend status interaction variable because a likelihood ratio test indicated that the addition of this term provided a better fit for the data ($p<0.001$).

The models suggest that overall child pedestrian injuries appear to be declining over time, by 9% annually; though the decline appears slightly greater in 'White' children, compared to 'Black' and 'Asian' children. There was some evidence that the presence of rain reduced the number of pedestrian injuries among 'Asian' children but no evidence of effect among 'White' or 'Black' children. There was some evidence of a positive association between the highest temperature quartile (Q4) and overall pedestrian injuries (IRR 1.19, 95% CI 1.09-1.29) as well as injuries among 'White' (IRR 1.21, 1.06-1.37) and 'Black' (IRR 1.23, 1.04-1.46) children. Compared to daytime, there was evidence of a positive association between civil twilight and injuries among children in all three ethnic groups. There was no evidence that night time or astronomical twilight was associated with injury in any ethnic group. A sensitivity analysis modelling a linear association between injury and light levels measured in ten thousands of lux (appendix A) suggested that a negative association with all injuries (IRR 0.89, 95% CI 0.83-0.94) and the association appeared broadly similar across ethnic groups.

Table 3 shows interaction rate ratios from the case-only analysis, which quantify evidence for the differences in associations of natural environment variables with ethnicity that were observed in table 1, mutually adjusted. We found no indication that the relative risk associated with a change in level of light differs by ethnic group more than can be explained by chance. There was strong evidence that the annual decline in injuries is less steep among 'Black' (IRR 1.04 95% CI 1.03-1.05) and 'Asian' (IRR 1.05, 1.03-1.07) children than among their 'White' counterparts, albeit only slightly so. We found some evidence that the effect associated with the presence of rain was stronger in 'Asian' children compared to 'White' children (p=0.024).

DISCUSSION

After controlling for diurnal patterns in casualties during the week and at weekends, we found evidence that light levels and weather conditions are associated with child pedestrian injury in London. We found that while civil twilight (the hour after sunrise and the hour before sunset) is associated with increased injury rates of children in all ethnic groups, there is no association between astronomical twilight (the hour after sunset and the hour before sunrise) and night time and injury. Increased levels of exposure during civil twilight potentially explain this finding if, for example, young people are travelling during civil twilight in order to make it home before a sunset curfew. Alternatively, this finding may be related to street lighting; the hours of operation of street lighting are determined by local authorities, but generally street lights tend to come on from 30 minutes before sunrise to 30 minutes after sunset (British Standards Institute 2003). Civil twilight, therefore, includes some time when levels of light are low and street lights are not yet in operation.

This finding seems to contradict other work indicating that light levels have a protective effect (Sullivan and Flannagan 2002, Owens and Sivak 1993, Owens and Sivak 1996). London is a densely populated urban area, where road lighting is normally provided; suggesting that visibility in night time and astronomical twilight may be better in London compared to other areas. Guidance on lighting level varies based on road type, but the British Standards on Road lighting recommends that street lights should increase luminescence to between 10-50 lux in areas where there is pedestrian traffic (British Standards Institute 2003).

We found that the number of 'White', 'Black', and 'Asian' children injured as pedestrians is decreasing over time, but the annual decline among 'White' children appears to be greater. Our analysis was based on changes in counts rather than rates, so this finding may reflect changes in population size. Population data from the Greater London Authority suggest that 'Black' and 'Asian' child populations grew more quickly than the 'White' child population over the 2001-2010 period (Greater London Authority Intelligence Unit 2013). Other studies have found no difference in the decline in child pedestrian injury rates over time by ethnic group in London (Malhotra, Hutchings, and Edwards 2008).

In terms of weather conditions, we found that temperatures above 16 degrees Celsius were associated with an increased number of child pedestrian injuries. This is likely to be related to exposure, as research from the UK suggests that preferences in outdoor activities are correlated with higher temperatures (Nikolopoulou, Baker, and Steemers 2001). Young people may therefore be more likely to walk or otherwise spend time in the road environment, for example playing or 'hanging out', when temperatures are higher.

Our findings add to the literature exploring the mechanisms linking ethnicity to child pedestrian injury risk in London. Previous work has investigated different potential hypotheses including: structural links between deprivation, ethnicity and child pedestrian injury in London (Steinbach et al. 2010); spatial differences in the road characteristics where pedestrian injuries occur (Steinbach et al. 2010); and walking patterns of London youth (Steinbach, Green, and Edwards 2012), but we found that none of these hypothesis can fully explain ethnic differences in risk. This study assessed an alternative hypothesis, whether ethnic differences in visibility can explain the elevated injury risk of 'Black' children in London. We found no support for this conspicuity hypothesis. A similar proportion of 'Black' and 'White' child pedestrian injuries occur during night time, and our models found that light levels had a similar effect on injury risk to children from all ethnic groups. Future research on ethnic inequalities in child pedestrian risk therefore should focus on other candidate hypotheses. Given that the results of this study suggest that exposure is the mechanism through which aspects of the natural environment affect injury risk, exploring potential ethnic differences in the quantity (amount of time) and quality ('danger' of the road environment) of pedestrian exposure may prove more illuminating.

STRENGTHS AND LIMITATIONS

One limitation of our analysis is the underreporting of injuries in the STATS19 data, which may well differ by ethnic group. However, reporting in London is relatively good compared to the rest of the country (Ward, Lyons, and Thoreau 2006) and this issue will only threaten the validity of our results if the within-ethnic group propensity to report a child pedestrian injury differs by time of day, which is unlikely.

Another limitation of this study is that we were unable to obtain precise measures of luminescence in London, and therefore used time relative to sunrise/sunset as an approximation. While our model controlled for some aspects of the natural environment that may affect visibility (e.g. rainfall) we were unable to control for measures of the urban environment (such as street lighting) that may affect luminescence. If the relative impact of street lights on pedestrian injury risk differs by ethnic group than our results may be biased.

Epidemiological research on ethnicity should select component(s) of ethnicity that are theoretically related to the health outcomes of interest. For most work on ethnicity and health, self-identified measures of ethnicity, which are able to incorporate indicators of nationality, heritage, culture and religion, are likely to be more relevant. In health research, variables that match those used in national censuses can be particularly useful for calculation of rates, to enable assessment of potential ethnic differences. The observer-defined measures of ethnicity in the STATS19 data, recorded by the police, are typically considered problematic. However, they are an asset to this analysis: casualties in the STATS19 data are categorized based largely on physical attributes which may be a more valid measure of conspicuity than self-identified ethnic group measures.

Overall, the case-only analysis proved to be a very efficient and useful method for examining the conspicuity hypothesis. This design enabled us to compare associations between levels of light and child pedestrian injury by ethnic group without using an estimate of the population exposed to risk. Exposure measures are often difficult to obtain in research on road traffic injury risk, and in practice, those chosen for research on social differences in risk present methodological challenges (Steinbach, Edwards, and Grundy 2013). A strength of the case-only approach is that it was able to avoid these sources of bias. One weakness of the case-only approach for this particular analysis is that it cannot shed light on the mechanisms that may, or may not, have led to effect modification. If there is a separate mechanism that puts black children at higher proportionate risk in daytime then there may still be some truth to the conspicuity hypothesis, although it is difficult to identify plausible candidate mechanisms that would operate in this way.

CONCLUSION

To our knowledge this is the first study that has investigated whether light levels have a differential impact on the injury risk of children from different ethnic groups. We were able to analyse data on over 15,000 child pedestrian injury events with hourly data on the natural environment and have at last shed some light on the credibility of the ‘conspicuity hypothesis’. In one city, at least, there was no evidence that minority ethnic children are at higher risk of injury because they are less conspicuous at night time. Research on inequalities in risk should focus on other hypotheses.

HIGHLIGHTS

There is no evidence that ethnic differences in visibility can explain differences in pedestrian injury risk; light levels have a similar association with pedestrian injury in 'Black', 'White' and 'Asian' children.

Future research on ethnic inequalities in child pedestrian risk should explore the potential for ethnic differences in the quantity and quality of pedestrian exposure.

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COMPETING INTERESTS

The authors have no competing interests to declare

Table 1: Ethnic profile among injured persons by characteristics of the natural environment

Characteristic	Total	White	Asian	Black	P valueǂ
Daylight					
Daytime	9208 (59%)	4102 (59%)	1136 (63%)	2395 (59%)	0.027
Civil Twilight	2366 (15%)	1053 (15%)	273 (15%)	621 (15%)	
Astronomical twilight	903 (6%)	425 (6%)	106 (6%)	225 (6%)	
Night time	3028 (20%)	1391 (20%)	299 (16%)	801 (20%)	
Rainfall					
Not raining	14122 (91%)	6323 (91%)	1680 (93%)	3689 (91%)	0.037
Raining	1383 (9%)	648 (9%)	134 (7%)	353 (9%)	
Temperature					
Quartile 1 (coldest)	2372 (15%)	1118 (16%)	236 (13%)	605 (15%)	<0.001
Quartile 2	3866 (25%)	1792 (26%)	406 (22%)	996 (25%)	
Quartile 3	3574 (23%)	1621 (23%)	436 (24%)	908 (22%)	
Quartile 4 (warmest)	5693 (37%)	2440 (35%)	736 (41%)	1533 (38%)	
Season					
Winter	3077 (20%)	1440 (21%)	312 (17%)	810 (20%)	<0.001
Spring	4333 (28%)	2014 (29%)	494 (27%)	1100 (27%)	
Summer	4009 (26%)	1655 (24%)	563 (31%)	1068 (26%)	
Autumn	4086 (26%)	1862 (27%)	445 (25%)	1064 (26%)	

ǂ chi-squared test of null hypothesis of no association between weather variable and ethnicity.

Table 2: Main effects on injuries

	Total			White			Asian			Black		
Variable	IRR	95% CI	P	IRR	95% CI	P	IRR	95% CI	P	IRR	95% CI	P
hour category*weekend status	not shown			not shown			not shown			not shown		
year	0.91	(0.90 - 0.91)	<0.001	0.88	(0.87 - 0.89)	<0.001	0.93	(0.91 - 0.94)	<0.001	0.92	(0.91 - 0.93)	<0.001
not raining (comparison group)	-	-	-	-	-	-	-	-	-	-	-	-
raining	0.97	(0.91 - 1.02)	0.243	1.00	(0.92 - 1.09)	0.991	0.81	(0.68 - 0.97)	0.023	0.95	(0.85 - 1.07)	0.405
temp Q1 (comparison group)	-	-	-	-	-	-	-	-	-	-	-	-
temp Q2	0.96	(0.90 - 1.01)	0.130	0.94	(0.87 - 1.02)	0.158	0.99	(0.83 - 1.18)	0.926	0.98	(0.87 - 1.09)	0.677
temp Q3	1.07	(0.99 - 1.15)	0.078	1.09	(0.98 - 1.21)	0.120	1.17	(0.94 - 1.46)	0.151	1.04	(0.90 - 1.2)	0.606
temp Q4	1.19	(1.09 - 1.29)	<0.001	1.21	(1.06 - 1.37)	0.004	1.16	(0.90 - 1.51)	0.251	1.23	(1.04 - 1.46)	0.015
daytime (comparison group)	-	-	-	-	-	-	-	-	-	-	-	-
civil twilight	1.16	(1.10 - 1.23)	<0.001	1.12	(1.02 - 1.22)	0.013	1.23	(1.03 - 1.46)	0.022	1.16	(1.04 - 1.3)	0.009
astronomical twilight	0.97	(0.88 - 1.06)	0.503	0.93	(0.81 - 1.07)	0.322	1.11	(0.84 - 1.47)	0.452	0.97	(0.80 - 1.16)	0.717
night time	1.03	(0.95 - 1.11)	0.509	0.96	(0.85 - 1.08)	0.488	1.02	(0.80 - 1.29)	0.880	1.10	(0.94 - 1.28)	0.243

Table 3 Case-only analysis

	White (comparison group)			Asian			Black		
	IRR	95% CI	P	IRR	95% CI	P	IRR	95% CI	P
hour category*weekend status	not shown			not shown			not shown		
month	not shown			not shown			not shown		
year	-	-	-	1.05	(1.03 - 1.07)	<0.001	1.04	(1.03 - 1.05)	<0.001
not raining (comparison group)	-	-	-	-	-	-	-	-	-
raining	-	-	-	0.80	(0.65 - 0.97)	0.024	0.95	(0.83 - 1.09)	0.486
temp Q1 (comparison group)	-	-	-	-	-	-	-	-	-
temp Q2	-	-	-	1.04	(0.86 - 1.26)	0.695	1.07	(0.94 - 1.23)	0.305
temp Q3	-	-	-	1.07	(0.84 - 1.35)	0.594	1.01	(0.85 - 1.19)	0.942
temp Q4	-	-	-	0.97	(0.74 - 1.28)	0.827	1.09	(0.89 - 1.33)	0.414
daytime (comparison group)	-	-	-	-	-	-	-	-	-
civil twilight	-	-	-	1.08	(0.89 - 1.31)	0.444	1.04	(0.90 - 1.20)	0.607
astronomical twilight	-	-	-	1.26	(0.92 - 1.72)	0.146	1.05	(0.83 - 1.32)	0.693
night time	-	-	-	1.09	(0.85 - 1.40)	0.506	1.15	(0.96 - 1.38)	0.126

IRR: Interaction rate ratio.

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5.2 Implications of Research Paper 3 for the role of the natural environment in explaining inequalities in injury rates in London.

Research Paper 3 identified associations between features describing the visibility of the natural environment, such as light levels, rainfall, and temperature on the pedestrian injury risk of all children in London. The paper provided no evidence that these associations differ by ethnicity. In other words, Research Paper 3 indicates that the natural environment appears to influence the injury risk of 'White', 'Black' and 'Asian' children in a similar way. These findings provide no evidence that features of the natural environment can help explain the relatively higher injury rates of 'Black' children in London, nor the relatively low rates of 'Asian' children in London.

5.3 The role of the quantity and quality of exposure in explaining ethnic inequalities in child pedestrian injury in London

This exploration of the role of the natural environment was the last in a series of investigations addressing Aim 1 of this thesis: to explore the role of exposure in explaining ethnic inequalities in child pedestrian injury in London. Chapter 3 examined the hypothesis that ethnic differences in the quality of the road environment where children from different ethnic groups live may help to explain ethnic differences in injury. Results suggested that while the road environment is an important mediator of injury risk generally, in London, 'White', 'Black' and 'Asian' children live in areas with similar levels of road hazards. Therefore, Chapter 3 found no evidence that the quality of the road environment can help explain higher injury rates of 'Black' children or lower injury rates of 'Asian' children in London.

Chapter 4 investigated the hypothesis that ethnic differences in the quantity of pedestrian exposure may help explain differences in injury risk. Chapter 4, which focused on exposure levels during travel time, provided some evidence that 'Asian' children walk less for transport than 'White' or 'Black' children in London. However, results found no differences in walking for transport between 'White' and 'Black' children. Appendix 7 explored pedestrian exposure during leisure time. Qualitative results were able to suggest a number of ways that young people are exposed to road hazards during their leisure time. However, results indicated that current methodological tools prohibit a quantitative exploration of exposure levels during leisure time by ethnicity. Taking findings on travel time exposure levels and leisure time exposure levels together, this thesis provides evidence that overall, the quantity of exposure to road hazards does appear to be an important mediator of injury risk. Further, there was some evidence that this hypothesis may help explain lower rates of injury among ‘Asian’ children in London. There was no evidence, however, that the quantity of exposure hypothesis can explain higher injury rates of ‘Black’ children.

Finally, this chapter explored whether the natural environment made pedestrian exposure more hazardous for minority ethnic children. There was no evidence that the natural environment contributes to ethnic differences in child pedestrian injury rates in London.

To summarize, these investigations suggest that both the quality and quantity of exposure to road hazards are important mediators of child pedestrian injury risk. Lower levels of walking for transport may help explain the lower rates of injury among ‘Asian’ children, however, there was little evidence across the four studies that the quality and quantity of exposure can explain the higher rates of pedestrian injury observed among ‘Black’ children in London.

All of these studies have methodological limitations that may have influenced results and thereby the conclusions reached in this thesis. These are discussed in each of the individual chapters in turn, however, I would like to emphasise one limitation that the four studies share: imperfect measurement of ‘exposure’. Appendix 7 explicitly underscored the problems in measuring leisure time travel exposure, however, other chapters are hampered by difficulties as well. For instance, Chapter 3 examined the hazard levels of areas where ‘White’, ‘Black’ and ‘Asian’ children live (i.e. the quality of exposure). Children spend time exposed to the road environment in many locations outside the area in which they live. Any ethnic differences in hazard levels in those areas could plausibly still partly explain ethnic differences in risk. Chapter 4 relied on travel diary data to examine ethnic differences in walking for transport. Research suggests that short walking trips tend to be underreported in travel diary. Any ethnic differences in this type of underreporting by ethnic group may have influenced results. Finally, Chapter 5 investigated whether there was any evidence that ‘Black’ children were at higher risk of injury at night, but was unable to include precise measures of light levels to account for street lights in London. Differences in street lighting provision in neighbourhoods where ‘White’, ‘Black’, and ‘Asian’ children are exposed to road hazards at night may mediate the relationships between ethnicity and light levels found in Research Paper 3.

Difficulties in the measurement of exposure is not unique to studies addressing ethnic differences in child pedestrian injury in London. Rather this is a persistent challenge in much epidemiological research. Scholars have noted that measuring environmental exposures is a particular challenge for epidemiology as a discipline (Pekkanen and Pearce 2001).

Given these limitations of the measurement of exposure in epidemiological research in general, and in research on child pedestrian injury in particular, a useful next step in exploring ethnic differences in injury in London is to try to limit the influence of differing exposure levels. In other words, it would be useful to attempt to control for exposure and hazard levels to examine whether the patterns of ethnic differences in injury found in previous work remain. If, after controlling for exposure and hazard levels, ethnic differences in risk disappear, then findings would highlight the limitations of the measurements of exposure used in Chapters 3-5 of this thesis. However, if ethnic differences in injury risk persist after controlling for exposure, then findings may indicate that alternative mechanisms are driving ethnic inequalities.

The next chapter, Chapter 6, therefore explores the sensitivity of ethnic inequalities in child pedestrian injury rates in London to controls for both the quality and quantity of exposure. Beyond examining how results on ethnic differences may or may not change when controls for exposure are introduced, Chapter 6 also investigates how these controls affect the relationships between ethnicity, deprivation and injury risk. Consequently, Chapter 6 marks the beginning of two chapters designed to address Aim 2 of this thesis: to explore associations between ethnicity, deprivation and injury risk in London.

6 DO ETHNIC DIFFERENCES IN RISK PERSIST WHEN THE QUALITY AND QUANTITY OF PEDESTRIAN EXPOSURE ARE TAKEN INTO ACCOUNT?

The previous four chapters of this thesis each examined a hypothesis relating to the quality and quantity of pedestrian exposure in explaining identified ethnic differences in child pedestrian injury rates in London. Findings provide some evidence that less travel time pedestrian exposure may help account for lower rates of injury among 'Asian' children. While findings suggested that both the quality and quantity of exposure are important mediators of pedestrian injury risk, there was no evidence that these exposure hypotheses can explain the higher injury rates among 'Black' children in London. Investigations were limited by difficulties in measuring exposure, particularly exposure to road hazards during leisure time.

Questions remain about how the measurement of exposure may have influenced results and conclusions from the investigations presented in Chapters 3-5. This chapter attempts to explore these issues further by examining the sensitivity of results on ethnic inequalities in injury risk in London to controls for the quality and quantity of exposure. To control for exposure levels, this chapter restricts analyses to injuries that occur during the morning commute to school (7am-9am, weekdays). This is a period when children are more likely to have similar levels of exposure as pedestrians, as most children must make a journey to school. Findings from Chapter 4 indicate that 'White', 'Black' and 'Asian' children walk broadly similar distances on the term time school commute. As the morning journey to school is often a rushed time for families (Backett-Milburn and Harden, 2011), children may also be less likely to play or 'hang out' in the road environment during this period. To control for the quality of exposure, analyses adjust for features of the road environment with known associations with child pedestrian injury.

If, after controlling for the quality and quantity of exposure, 'White', 'Black' and 'Asian' children have similar rates of injury, then inequalities may be explained by inequalities in exposure. If, however, ethnic differences persist, this would point to another mechanism driving inequalities.

This chapter also addresses aim 2 outlined in the introduction of this thesis: to explore associations between ethnicity, deprivation and injury risk in London. As introduced in earlier chapters, in addition to overall ethnic inequalities in injury risk in London, previous work has identified that the relationship between deprivation and injury risk is different for 'Black' children compared to 'White' and 'Asian' children. While greater levels of area deprivation are associated with increased injury risk among 'White' and 'Asian' children in London, 'Black' children face relatively similar injury risks across the city. This presents an interesting question: Why does area affluence not appear to protect 'Black' children from injury risk? Chapter 4 of this thesis investigated whether this relationship could be explained by differences in travel time exposure, but found no evidence that the relationship between deprivation and quantity of pedestrian travel time exposure differs by ethnicity. However, analyses were limited by small sample sizes.

This chapter investigates whether the relationships between ethnicity, deprivation and injury change when controls for the quality and quantity of exposure are introduced. Section 6.1 presents Research Paper 4, which models relationships between ethnicity, deprivation, and injury in London after controlling for the quality and quantity of pedestrian exposure. Section 6.2 discusses the implications of Research Paper 4 for the role of exposure in explaining ethnic inequalities in injury overall. Section 6.3 discusses the implications of the findings of Research Paper 4 for associations between ethnicity, deprivation and injury risk.

6.1 Research Paper 4 Controlling for exposure changes the relationship between ethnicity, deprivation, and injury: an observational study of child pedestrian injury rates in London

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    I designed the study with Phil Edwards and Judith Green. I formatted data for analysis, analysed the data and drafted the manuscript. I revised the manuscript based on comments from Phil Edwards, Judith Green.

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CANDIDATE'S SIGNATURE: Date: 01/08/2014

SUPERVISOR'S SIGNATURE:

CONTROLLING FOR EXPOSURE CHANGES THE RELATIONSHIP BETWEEN ETHNICITY, DEPRIVATION, AND INJURY: AN OBSERVATIONAL STUDY OF CHILD PEDESTRIAN INJURY RATES IN LONDON

ABSTRACT

Background: Research has suggested that inequalities in risk exposure may help explain identified ethnic inequalities in child pedestrian injury risk. However, addressing risk exposure in epidemiological research presents theoretical and methodological challenges. This article conceptualizes the risk of child pedestrian injury as related to both exposure levels (the quantity of time children spend as pedestrians) and the probability of a hazard where that exposure takes place (the quality of the road environment).

Objective: To investigate the sensitivity of results on ethnic inequalities in child pedestrian injury risk in London to controls for exposure and hazard levels.

Methods: Using police records of injury 2000-2009 we modelled the relationship between ethnicity, deprivation and child pedestrian injury rates in London using characteristics of the road environment to control for hazard levels and restricting the analysis to the time of the weekday morning commute (7am-9am), when most children must make a journey to school, to control for exposure levels.

Results: Controlling for risk exposure in this way fundamentally changed the nature of the relationship between ethnicity, deprivation and child pedestrian injury. During the time of the morning commute to school 'Black' children were found to have higher pedestrian injury rates in the least deprived areas.

Conclusion: To inform effective strategies for reducing injury inequality, it is vital that exposure to risk is both acknowledged and considered.

BACKGROUND

A number of studies have suggested ethnic differences in road traffic injury risk. While there is no consensus in the international literature about specifically who is at risk, most studies suggest that children from minority ethnic groups have higher pedestrian injury risks than their majority ethnic counterparts(Abdalla, 2002, Campos-Outcalt et al., 2002, Harrop et al., 2007, Rivara and Barber, 1985, Savitsky, 2007, Stirbu, 2006), though a few studies have identified minority ethnic groups at lower injury risk(Al-Madani and Al-Janahi, 2006). Understanding what these differences mean for injury prevention and other areas of policy and practice is not straightforward, as deconstructing the complex concept of ethnicity poses a challenge for both researchers and policy makers.

Ethnicity is a shifting and multidimensional concept making both definition and measurement problematic. The many components of ethnic identity such as nationality, skin colour, country of origin, and religion may have different implications for health. In addition to ethnic identities (indications of how people choose to define themselves or others), structural elements of ethnicity (associations with socio-economic factors and experiences of racism) may also influence health(Karlsen and Nazroo, 2002). For research to be useful for policies addressing inequalities in health, it needs to be directed not only at documenting inequalities, but discovering the mechanisms which potentially link identity and structural components of ethnicity with health outcomes such as pedestrian injury events.

In London, home to half of the UK's ethnic minority population, our previous work reported that pedestrian injury rates among 'Black' children are 50% higher than rates among 'White' children(Steinbach et al., 2010). Theoretically, such observed inequalities potentially arise: from artefacts of measurement; as indicators of confounding by other variables (e.g. socio-economic status); or as 'real' indicators of a causal relationship between one or more aspects of ethnicity. Despite limitations with the data (e.g. underreporting of road traffic injuries, imperfect measures of ethnicity), these results have been shown to be robust to a number of sensitivity analyses and do not appear to be spurious, or easily attributable to a particular bias. In terms of possible confounders, structural associations between deprivation and ethnicity are one plausible explanation of these observed inequalities, but we found no evidence of this (Steinbach et al., 2010). When the relationship between area deprivation and child pedestrian injury rates was examined separately by ethnic group, pedestrian injury rates were found to increase with increasing levels of deprivation in 'White' and 'Asian' children; there was no equivalent relationship between area deprivation and injury risk among 'Black' children (Steinbach et al., 2010). In other words, while area affluence appears to protect 'White' and 'Asian' children, 'Black' children face higher injury risks across all areas of London.

This presents two epidemiological puzzles: why are 'Black' children apparently at higher risk of pedestrian injury than those from other ethnic groups in London? And why is lower area deprivation not associated with lower pedestrian injury rates among 'Black' children? This paper explores the role of one set of candidate explanations for casual relationship for injury inequalities: those relating to higher exposure to injury risk as a mechanism.

Accounting for risk exposure, however, is an enduring problem in epidemiological research. Critics of current epidemiological research have argued that definitions of exposure are often inadequately conceptualized. Even when the concept of risk exposure has been sufficiently considered in theory, in practice, measurement difficulties often lead to epidemiologic exposure measures collected "due to convenience, availably of data, or convention, rather than based on models of disease process."(Wing, 1994) Child pedestrian injury is a good example of such problems, as pedestrian exposure has multiple components and measurement is challenging.

Risk can be conceptualized as "the probability that exposure to a hazard will lead to a negative consequence"(Ropeik and Gray, 2002). Thus, the risk of child pedestrian injury is related to both exposure levels (the quantity of time children spend as pedestrians) and the probability of a hazard where that exposure takes place (e.g. the quality of the road environment). The higher rates of injury for 'Black' children in London may reflect more time spent as pedestrians than their counterparts, or that the roads where they spend their time are somehow more "hazardous". The large literature on environmental correlates of child pedestrian injury provides some information about the level of hazard in different areas. Evidence suggests that traffic speed, traffic volume, presence of major roads, presence of parked cars, street vendors and rubbish bins are all associated with higher child pedestrian injury rates(Agran, 1996, Roberts et al., 1995, Donroe et al., 2008, Jones et al., 2008, Mueller et al., 1990, von Kries et al., 1998, Graham and Stephens, 2008, Haynes et al., 2007, Petch and Henson, 2000, Stevenson, 1997, Graham and Glaister, 2003, Noland and Quddus, 2005). Urban density, presence of minor roads, street curvature (more curved streets), and traffic calming measures are associated with lower pedestrian injury rates(Graham and Glaister, 2003, Haynes et al., 2007, Jones et al., 2008, Noland and Quddus, 2005, Bunn et al., 2009). Controlling for differences in these road environment characteristics therefore provides some control for the probability of hazard.

There are a number of potential methods for estimating 'time exposed ' but these all have limitations for examining the range of different exposures to risk. Pedestrian counting methods can determine the volume of pedestrian traffic at particular locations; however, manual methods require high labour costs and automated pedestrian counting devices are generally not capable of collecting information on characteristics such as ethnicity(Bu, 2007). Travel diaries can estimate time or distance walked at a population level, but sampling strategies are typically not designed to be representative of the places where exposure occurs at the population level, and walking trips in particular are subject to underreporting(Clarke et al., 1981, Ettema et al., 1996). Further, walking for transport is only one component of pedestrian exposure levels. Children may also be injured as pedestrians while participating in leisure activities that involve playing or 'hanging out' in the road environment, exposures which are typically not collected in travel diaries.

Accounting for exposure and hazard levels, then, presents an additional methodological challenge to studies examining population differences in risk. These types of studies often rely on ecological designs, where even simply calculating injury rates offers difficulties. Some work on social differences in pedestrian injury events calculate injury rates by comparing the number of injuries that occur in an area (numerator) with the resident population (denominator). Other studies use an alternative estimate for the denominator and link injured child pedestrians to the areas in which they live. While the most appropriate method is under debate(Hewson, 2004, Hewson, 2005), neither method is able to adequately account for social differences in exposure levels.

To study the role of exposure in explaining relationships between ethnicity, deprivation and risk, we investigate the sensitivity of results on ethnic inequalities in child pedestrian injury risk in London (Steinbach et al., 2010) to some important controls for exposure and hazard levels. To control for exposure levels, we restrict analysis to injury events occurring during 7am to 9am on weekdays. Compared with other times and days, this time period is when children are more likely to have similar levels of exposure as pedestrians, as most children of school age, regardless of ethnicity, must make a journey to school. Further, recent evidence suggests that relatively few social and environmental characteristics are salient in predicting "doing some walking on the way to school" compared to doing some walking to other activities(Steinbach et al., 2012). The morning journey to school is also likely to be more direct than journeys at other times of the day. As the morning is often a rushed time for families(Backett-Milburn and Harden, 2011), children may be less likely to play or 'hang out' in the road environment on the commute to school. We therefore suggest that the time of the morning commute is a proxy control for the quantity of exposure. To provide some control for hazard levels, we adjust for several known environmental correlates of child pedestrian injury.

METHODS

We used an observational study to examine the role of exposure and hazard levels in explaining social differences in child pedestrian injury. We model the relationship between ethnicity, deprivation and injury rates during the time of the morning commute to provide some control for possible ethnic differences in exposure levels; and we adjust for characteristics of the road environment known to be associated with pedestrian injury events to provide some control for possible differences in hazard levels between areas where children from different ethnic groups spend time. The time of the morning commute is not a perfect control for exposure levels, as it is likely that both distance to school and mode of travel vary by social and environmental characteristics. Therefore, this analysis also incorporates data from travel diaries on the social characteristics of mode and distance travelled during the morning commute.

TRAVEL DIARY DATA

We obtained an extract of the London Travel Demand Survey (LTDS) 2006–2008, an annual survey of travel patterns representative of all households in Greater London. In a face to face interview with a trained interviewer, every member of selected households aged over 5 years is asked to complete a one-day travel diary that recorded the starts, interchanges and ends of every trip on the travel day. 'Crow fly' journey distances are estimated using the start-point and end-point of each interchange. Using variables on journey purpose and main mode of travel we were able to calculate distances and main mode of travel to school for children 5 to 15 years. We combined data from three years of the survey. Between 2006-2008, the LTDS collected information on the travel patterns of 1,916 'White' children, 690 'Black' children, and 641 'Asian' children aged 5-15. All analyses were weighted to represent the population during weekday term time and allowed for the stratification of the sample by London borough.

NUMERATOR: INJURY EVENTS

We obtained a dataset of police STATS19 data 2000-2009 that included all reported casualties and collisions occurring in London. Casualties were included in the analysis if aged 0 to 15 years and injured as pedestrians. We analysed all casualties (occurring at any hour or day) and those occurring between the hours of 7am and 9am on weekdays separately. Each casualty was assigned to a lower super output area (LSOA) based on the Ordnance Survey grid reference of the location where the collision occurred. The level of deprivation of each LSOA was scored using the Index of Multiple Deprivation 2004 (IMD)(Noble et al., 2007). The 4,765 LSOAs in London were ranked according to IMD score and divided into deciles (1 least deprived to 10 most deprived). Casualties were assigned to the LSOA in which they were injured. We chose to assign casualties in this way as there is evidence that child pedestrians tend to be injured close to home in London, (Edwards et al., 2007) and in order to maximize the use of available data. A sensitivity analysis was conducted to compare results when assigning casualties to the LSOAs in which they live (the alternative approach to estimating casualty rates).

DENOMINATORS: POPULATION ESTIMATES

To derive population rates, we used mappings reported in previous research(Steinbach et al., 2010) to assign STATS19 ethnicity categories to aggregated ethnicity groupings used by the Greater London Authority (GLA) drawn from 2001 Census categories. The analysis uses three broad categories of ethnicity, which we have called 'White', 'Black, and 'Asian', based on these mappings. Estimates of resident populations were derived from Census 2001 data. Age specific population data are not available at LSOA level by ethnic group, so the population of 'White', 'Black', and 'Asian' children in each LSOA was estimated by multiplying the numbers of children resident in each LSOA by the percentages of residents of all ages that are 'White', 'Black', or 'Asian' (both from the 2001 Census). The estimates of LSOA-level ethnic group child populations were then scaled to sum to the available borough level total estimates in 2005 (supplied by the GLA), to allow for both population growth and ethnic differences in family size.

ROAD ENVIRONMENT VARIABLES

We included available road environment and area characteristic variables found to be associated with injury events in the literature. These included: density of road junctions, A roads and minor roads in the LSOA, the proportion of postcodes in an LSOA characterized as 'business', the area (in square metres) of an LSOA, average vehicle speeds and traffic flows. To create variables describing the road environment in an LSOA, current road network information from the Integrated Transport Network (ITN) supplied by Ordnance Survey was overlaid with LSOA boundaries provided by the census in ArcView GIS. Data on average traffic speed and volume came from the London Greenhouse Gas Inventory (LEGGI). To calculate LSOA summaries of average speeds and volumes the LEGGI road network was overlaid with LSOA boundaries.

ANALYSIS

Negative binomial multivariable regression models were used to estimate the rate of children of each ethnic group injured as pedestrians in each LSOA at all times of the day, and separately during the time of the morning commute. We estimated injury rate ratios, with 95% confidence intervals, comparing rates in each decile of LSOAs with the rate in the least deprived decile, adjusting for road environment variables. Robust standard errors were estimated that allowed for within-borough correlations in LSOA injury rates. A more detailed discussion of these methods is presented elsewhere (statistical appendix) (Steinbach et al., 2010). To examine the relative contribution of deprivation and hazard levels to child pedestrian injury rates among 'Black', 'White' and 'Asian' children we compared unadjusted injury rates by decile of deprivation to rates adjusted for the road environment characteristics.

Travel diary data on trips to school by main mode of travel were analysed descriptively using tests for heterogeneity across subgroups.

RESULTS

TRAVEL DIARY DATA

Data from the LTDS (Table 1) suggest differences in the distributions of mode of travel to school according to age (p<0.001), ethnic group (p<0.001), household income (p<0.001), quintile of deprivation (p<0.001), area of London (p<0.001), and vehicle access (p<0.001). Children least likely to travel to school by car are 'Black', from the most deprived areas, living in inner London, from low income households and households without access to a vehicle. Children more likely to travel to school by bus are older, 'Black', from low income families and households without access to a vehicle. Children more likely to walk to school are younger, 'Asian', from low income households, from households without access to a vehicle, from more deprived areas and living in inner London.

The children who travel furthest to school (Table 2) are older, from higher income families, living in less deprived areas, and in households with access to a vehicle. 'Asian' children have lower mean distances to school compared to their counterparts. 'Black' children and children living in outer London appear to have higher median distances to school.

ETHNICITY, DEPRIVATION AND ROAD TRAFFIC INJURY

Between 2000 and 2009 there were 15,508 children aged 0-15 injured as pedestrians on London's roads, of which 2,042 (13%) were injured during the time of the morning commute to school. Ethnicity was recorded for 85% of casualties. On weekday mornings there were 848 'White', 598 'Black', and 217 'Asian' child pedestrian casualties.

Of the 15,508 children injured, location of residence was available for 9,044 (58%) casualties. We excluded 190 casualties who were resident outside London, leaving a total of 8,854 casualties in our analysis based on location of residence (1,261 children injured during the time of the morning commute).

Overall, the average pedestrian injury rate among 'White' children was 86 (95% CI 84-88) per 100,000 children during all hours of the day and 10 (10-11) per 100,000 children during the time of the morning commute. Among 'Black' children, the rate was 50% higher compared to 'White' children (131; 127-135 per 100,000) during all hours of the day and 85% higher (19; 18-21 per 100,000) during the time of the morning commute. Rates among 'Asian' children were lower than those among 'White'or 'Black' children (65; 63-69 per 100,000 during all hours of the day and 8; 7-9 per 100,000 during the time of the morning commute).

Relationships between ethnicity, deprivation and road traffic injury rates differ during the time of the morning commute compared with at all times of the day (Figure 1). For 'White' and 'Asian' children the rates increase with increasing levels of deprivation during all times of the day. After taking into account characteristics of the road environment (Figure 2), the relationship during the time of the morning commute between 'White' injury rates and deprivation was broadly similar to the relationship during all times of day, although considerably less strong. There did not appear to be a relationship between 'Asian' injury rates and deprivation during the time of the morning commute after controlling for the road environment. Among 'Black' children there did not appear to be a relationship between injury rates and deprivation during all times of the day, however during the time of the morning commute injury rates appeared to decrease with increasing levels of deprivation. The sensitivity analysis using LSOA of residence as an alternative measure for the denominator found no relationship between deprivation and injury rates among 'Asian' and 'Black' children, and increasing injury rates with increasing levels of deprivation among 'White' children (though confidence intervals are very large) during the time of the morning commute.

Associations between road environment characteristics and 'White', 'Black' and 'Asian' pedestrian injuries appeared to be relatively similar (Table 3). Density of A roads, junction density and proportion of business postcodes are associated with increased pedestrian injury risk among children, while density of minor roads and traffic flows are associated with decreased injury risk. Speed, however, appeared to be associated with increased injury risk in 'White' and 'Asian' children, but decreased risk in 'Black' children. Associations between road environment characteristics and injury risk appear similar during the time of the morning commute compared to at all times of day.

Figure 3 compares unadjusted child pedestrian injury rates by decile of deprivation to rates adjusted for the road environment. The Figure suggests that based solely on the road environment characteristics of an area, we would expect to see injury rates increase with increasing levels of deprivation (dotted lines). The difference between the adjusted and unadjusted rates may be interpreted as the impact of deprivation on 'White', 'Black' and 'Asian' child pedestrian injury rates. During all hours of the day, area affluence appears to have a protective effect on pedestrian injury for 'White' and 'Asian' children (the adjusted rate is higher than the unadjusted rate in deciles 1-3), while high levels of area deprivation appear to have harmful effect on 'White' and 'Asian' rates (the unadjusted rate is higher than the adjusted rate in deciles 7-10). For 'Black children' area affluence does not appear to have the same protective effect at low levels of deprivation during all hours of the day, and during the time of morning commute area affluence appears to have a harmful effect. High levels of area deprivation, however, appear to have a protective effect on 'Black' child pedestrian injury rates both during the time of the morning commute, and during all hours of the day.

DISCUSSION

Even after accounting for some indicators of exposure levels, we found that 'Black' children in London had higher pedestrian injury rates compared to their 'White' and 'Asian' counterparts, particularly in less deprived areas of London. This result may in part be due to our imperfect measures of both hazard and exposure levels. However, results from the LTDS suggest only small differences in exposure levels during the morning commute. 'Black' children are more likely to travel by bus, and less likely to travel by car, compared to their counterparts, while 'Asian' children are more likely to walk to school. In terms of distance travelled to school, our analysis suggests higher distances to school among 'Black' children and lower distances among 'Asian' children and children living in relatively deprived areas. These results are consistent with data on secondary school pupils from the Department for Education, which suggest that in London 'Black' pupils are more likely to travel more than 3 miles to school, while 'Asian' children tend to live closer to school(Department for Education, 2010).

These ethnic differences in travel patterns during the morning commute are relatively small compared to the observed differences in child pedestrian injury rates. The median distance travelled to school among 'Black' children is 9% longer than the median distance among 'White' children, but injury rates during the time of the morning commute are 85% higher among 'Black' children compared to 'White' children. While we did find that 'Black' children were more likely to use modes of travel that involve some walking (e.g. taking the bus) compared to 'White' children, evidence suggests that the number of minutes walked on the commute to school (regardless of the main mode of travel) is similar among 'Black' and 'White' children(Steinbach et al., 2012). This suggests that exposure levels cannot completely explain the observed higher pedestrian injury rates among 'Black' children.

On hazard levels, we were able to account for some characteristics of the road environment in our analysis. Similar to other studies(Agran, 1996, Graham and Stephens, 2008, Graham and Glaister, 2003, Haynes et al., 2007, Jones et al., 2008, Noland and Quddus, 2005) we found density of A roads, junction density and proportion of business postcodes to be associated with increased child pedestrian injury rates, while density of minor roads and traffic flows were associated with decreased rates. We found that area deprivation had an impact over and above that of the road environment and that this impact differed by deprivation level. While our findings that ethnic inequalities in injury rates are largest in the *less* deprived areas of London may seem counterintuitive, our measures of the road environment tell us little about the meaning of being exposed in these environments. Ethnicity may not only be associated with the distance or mode of travel to school, but it may also shape experiences of travelling. It is plausible that being a visible minority (for example a 'Black' child in an affluent area) may change the meaning of being exposed in that environment. Our findings that high levels of deprivation appear to have a protective effect on 'Black' child pedestrian injury rates may be evidence of a "group density" effect on health more generally, where ethnic minorities living in an area with a higher proportion of people from a similar ethnic group enjoy better health that those who live in areas with a lower proportion(Pickett and Wilkinson, 2008). Psychosocial factors, such as stigma and lack of social integration (shared culture, social networks and social capital) may form the mechanism for these types of findings(Pickett and Wilkinson, 2008). Although it is perhaps more difficult to conceptualise injury risk being mediated by such psychosocial factors, it is plausible that analogous structural mechanisms relating to density, or minority status, might change the meaning of pedestrian exposure. Speculatively, these might relate to (for instance) whether children are likely to move more, or less, quickly when crossing roads, or whether they are more or less likely to travel with others. More research is needed on how such social factors might differentially affect exposure type and injury risk across settlements with differing ethnic densities.

Though methodologically challenging, correctly accounting for levels of exposure in risk research has important policy implications, particularly for work that aims to compare risks. The recent debate around use of the drug 'ecstasy' and horse riding highlights this point: Writing in an academic paper(Nutt, 2009) David Nutt, the UK government's drug advisor, suggested that taking ecstasy was no more dangerous than horse riding. Comparing the relative 'dangerousness' of these activities (rather than comparing the scale of the social problem) relies on some measure of how often the target population are exposed to the hazard. Only if we can agree on a measure of risk exposure (e.g. hours exposed; number of times the activity is undertaken) and if we know something about relative levels of exposure (e.g. how much time people spend on horses; how often people take ecstasy) can we meaningfully compare the relative risks of the activities.

Our analysis compared risks for different population groups rather than the risks of different activities, but the methodological and social policy questions are similar. Measuring the hazards and exposure levels for child pedestrians has a number of unsolved challenges. We attempted to resolve some of the methodological difficulties of risk exposure measurement by including characteristics of the road environment to control for hazard levels in different areas, and restricting our analysis to the time of the morning commute to control for levels of exposure. We found that accounting for risk exposure in this way changed the observed relationship between ethnicity, deprivation, and injury risk.

LIMITATIONS

Our data sources have some limitations that may have affected our results. Travel diary data often under-represents short walking trips, however this is unlikely to have affected results on travel to school (typically not a very short trip). In our analysis of injury rates, a weakness of STATS19 is underreporting of injuries, which may very well differ by ethnicity or area deprivation. However, reporting in London is relatively good compared to the rest of the country(Ward et al., 2006) and this issue will only affect our results on the relationship between ethnicity, deprivation and pedestrian injury if the within-ethnic group propensity to report or record an injury differs by area deprivation. Further limitations of STATS19 data relate to the potential for numerator-denominator bias. Definitions of ethnicity in STATS19 are not easily mapped to definitions of ethnic groups used in the census. We mapped data pragmatically according to previous research(Steinbach et al., 2010), which revealed that alternative mappings had little effect on results. Another form of numerator-denominator bias potentially present in our analysis arises from assigning casualties to the area in which they occur, rather than to the area in which the child resides. The resident population is only a proxy for the number of children exposed to pedestrian injury risk in that area, and any ethnic differences in distances travelled may mean that our estimates are more valid for some ethnic groups compared to others. Our analysis of travel diary data suggested that 'Asian' children tend to travel shorter distances to school compared with other children, however, 'White' and 'Black' children travel relatively similar distances.

Our results using location of collision to identify the denominator suggest decreasing levels of pedestrian injury rates during the time of the morning commute with increasing levels of deprivation among 'Black' children. However, a sensitivity analysis using location of residence to identify the denominator found no such relationship. Although the results using location of residence are based on a much smaller sample size (postcodes are not available for all casualties) the relationship should be interpreted with caution.

IMPLICATIONS

Even if the technical question of how to measure exposure can be answered, important policy questions remain about the *meaning* of different kinds of exposure for society as a whole. Pedestrian risk exposure, like horse riding, has benefits as well as risks for young people: indeed 'risk' is unlikely to be the primary framework within which decisions about (say) travelling are made(Green, 2009). Reducing the quantity of pedestrian risk exposure potentially reduces young people's independence, and their levels of healthier and socially desirable 'active travel'(Department for Transport, 2011). Further, the meanings of differential pedestrian risk exposure are also socially constituted. The greater vulnerability of boys compared with girls to injury, for instance, may be normalised in policy discourse and rarely the object of interventions, whereas the greater vulnerability of minority ethnic young people may be problematised. However, if there are policy aims to ameliorate observed ethnic inequalities in injury risk, these findings have some profound implications for policy and practice. Our findings suggest that exposure matters, in that the relationship between ethnicity and deprivation changes when we control (to some extent) for non-travel exposure by restricting an analysis to the time of the morning commute (when there is, theoretically, less 'non-travel' exposure). However, differences in exposure do not explain all the differences between ethnic groups, or the relationship with deprivation. This implies that we need to know far more about the meaning of different kinds of exposure to hazards for different population groups in different areas. Practitioners report that identifying strategies for addressing injury inequality, particularly ethnic inequalities, is challenging(Green and Edwards, 2008) and current strategies rely largely on targeting particular minority ethnic communities, using educational strategies. However, we suggest that a priority is explaining the observed higher risk of black child pedestrian injuries in affluent areas, where it may be more difficult to target such interventions, as there are less likely to be identifiable 'communities'. Further, the finding that most road environment variables appear to affect different ethnic groups in similar ways suggests that interventions that reduce the hazards to which children are exposed are likely to reduce risks for all groups without exacerbating inequalities in injury risk.

WHAT IS ALREADY KNOWN ON THIS SUBJECT

Mortality rates from child pedestrian injuries are higher in less affluent families

Children living in most deprived areas in London experience pedestrian injury rates nearly three times higher than children living in least deprived areas

'Black' children in London have higher pedestrian injury rates compared to 'White' and 'Asian' children, which are not explained by the association between ethnicity and deprivation.

WHAT THIS STUDY ADDS

Incorporating indicators of child pedestrian exposure modifies the relationship between ethnicity, deprivation and injury risk.

During the time of the morning commute to school 'Black' children were found to have higher pedestrian injury rates in the least deprived areas.

Though methodologically challenging, accounting for exposure in risk research has important policy implications.

CONTRIBUTORSHIP

All authors contributed to the design of the study, analysis of the data, interpretation of results and the writing of the manuscript.

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Table 1 LTDS 2006-2008 Percentage of trips to school by main mode of travel

Characteristic	Walk % (95% CI)	Cycle % (95% CI)	Car % (95% CI)	Bus % (95% CI)	Other private % (95% CI)	Other public % (95% CI)	p-value % (95% CI)
Total	47 (45 - 49)	1 (1 - 1)	26 (25 - 28)	21 (20 - 23)	1 (0 - 1)	3 (3 - 4)	
Age 5-9	59 (56 - 62)	1 (0 - 2)	30 (28 - 33)	8 (6 - 9)	1 (0 - 1)	1 (0 - 1)	
Age 10-15	37 (34 - 39)	1 (1 - 1)	23 (21 - 25)	33 (30 - 35)	1 (0 - 1)	6 (4 - 7)	p<0.001
Male	46 (44 - 49)	1 (1 - 2)	27 (24 - 29)	22 (20 - 25)	1 (0 - 1)	3 (2 - 4)	
Female	48 (45 - 51)	1 (0 - 1)	26 (24 - 29)	21 (18 - 23)	1 (0 - 1)	4 (3 - 5)	p=0.325
White	46 (43 - 48)	1 (1 - 2)	29 (27 - 32)	19 (17 - 21)	1 (0 - 1)	4 (3 - 5)	
Asian	55 (51 - 59)	1 (0 - 2)	27 (23 - 31)	15 (12 - 18)	0 (0 - 1)	2 (0 - 3)	p<0.001
Black	44 (39 - 48)	0 (0 - 0)	19 (16 - 23)	32 (28 - 36)	1 (0 - 2)	4 (2 - 6)	
Low income	52 (48 - 55)	0 (0 - 1)	17 (14 - 19)	27 (24 - 31)	1 (0 - 2)	3 (1 - 4)	
Middle income	47 (44 - 50)	1 (1 - 2)	29 (27 - 32)	18 (16 - 20)	1 (0 - 1)	3 (2 - 4)	p<0.001
High income	39 (36 - 43)	1 (0 - 2)	36 (32 - 39)	19 (16 - 21)	1 (0 - 1)	5 (3 - 6)	
IMD1	40 (36 - 45)	2 (1 - 3)	37 (33 - 41)	15 (11 - 18)	1 (0 - 2)	5 (3 - 7)	
IMD2	44 (39 - 48)	2 (1 - 3)	34 (30 - 38)	18 (15 - 22)	0 (0 - 0)	2 (1 - 3)	
IMD3	41 (37 - 45)	1 (0 - 1)	31 (27 - 35)	23 (19 - 26)	0 (0 - 1)	4 (3 - 6)	p<0.001
IMD4	47 (43 - 51)	0 (0 - 1)	22 (19 - 26)	25 (21 - 29)	1 (0 - 2)	4 (3 - 6)	
IMD5	59 (55 - 63)	1 (0 - 1)	13 (10 - 16)	24 (21 - 28)	1 (0 - 1)	2 (1 - 3)	
Inner London	54 (51 - 58)	1 (0 - 1)	17 (15 - 19)	23 (21 - 26)	1 (0 - 2)	4 (2 - 5)	
Outer London	43 (41 - 45)	1 (1 - 2)	32 (30 - 34)	20 (18 - 22)	0 (0 - 1)	3 (2 - 4)	p<0.001
Access to vehicles	41 (39 - 43)	1 (1 - 2)	36 (34 - 38)	17 (16 - 19)	1 (0 - 1)	4 (3 - 5)	
No access to vehicles	62 (58 - 65)	1 (0 - 1)	3 (2 - 4)	32 (28 - 35)	0 (0 - 1)	2 (1 - 4)	p<0.001

Table 2 LTDS 2006-2008 Reported distances travelled to school (km)

Distance to school	Mean (95% CI)	Median
Total	2.03 (1.83 - 2.23)	0.99
Age 5-9	1.37 (0.99 - 1.75)	0.62
Age 10-15	2.60 (2.41 - 2.78)	1.53
Male	2.02 (1.84 - 2.20)	0.98
Female	2.04 (1.67 - 2.42)	0.99
White	2.08 (1.91 - 2.25)	1.08
Black	2.07 (1.85 - 2.29)	1.18
Asian	1.40 (1.21 - 1.59)	0.71
Low income	1.89 (1.38 - 2.40)	0.87
Middle income	1.88 (1.70 - 2.06)	0.95
High income	2.56 (2.26 - 2.86)	1.38
IMD1	2.20 (1.92 - 2.49)	1.13
IMD2	2.11 (1.76 - 2.46)	1.11
IMD3	2.61 (1.76 - 3.45)	1.22
IMD4	1.97 (1.76 - 2.19)	0.98
IMD5	1.42 (1.25 - 1.59)	0.69
Inner London	1.92 (1.44 - 2.40)	0.82
Outer London	2.10 (1.94 - 2.25)	1.11
Access to vehicles	2.24 (1.96 - 2.52)	1.12
No access to vehicles	1.51 (1.36 - 1.66)	0.75

Table 3 Rate ratios showing changes in injury rates associated with change in road environment and area characteristics of LSOAs

		'White' Children			'Asian' Children			'Black' Children		
	Variable	Rate ratio	95% CI	P value	Rate ratio	95% CI	P value	Rate ratio	95% CI	P value
All times	Density of A roads	1.008	(1.005 - 1.010)	<0.001	1.005	(1.001 - 1.010)	0.009	1.011	(1.008 - 1.013)	<0.001
	Density of minor roads	0.996	(0.994 - 0.997)	<0.001	0.998	(0.995 - 1.000)	0.023	0.996	(0.995 - 0.997)	<0.001
	Junction density	1.086	(1.030 - 1.146)	0.002	1.008	(0.919 - 1.105)	0.868	1.064	(1.004 - 1.127)	0.035
	Traffic flow (1000 vehicles)	0.977	(0.968 - 0.987)	<0.001	0.983	(0.971 - 0.995)	0.005	0.995	(0.984 - 1.007)	0.434
	Speed (kph)	1.019	(1.007 - 1.030)	0.001	1.024	(1.004 - 1.045)	0.019	0.969	(0.957 - 0.981)	<0.001
	Proportion of business postcodes	1.047	(1.039 - 1.055)	<0.001	1.040	(1.031 - 1.050)	<0.001	1.040	(1.033 - 1.048)	<0.001
	area (square meters)	1.000	(0.999 - 1.000)	0.299	1.000	(0.999 - 1.001)	0.778	1.000	(0.999 - 1.001)	0.688
Time of the morning commute	Density of A roads	1.010	(1.005 - 1.014)	<0.001	1.001	(0.992 - 1.011)	0.747	1.014	(1.010 - 1.017)	<0.001
	Density of minor roads	0.994	(0.991 - 0.997)	<0.001	0.989	(0.983 - 0.996)	0.001	0.994	(0.992 - 0.997)	<0.001
	Junction density	1.157	(1.013 - 1.321)	0.031	1.226	(0.972 - 1.546)	0.085	1.143	(1.016 - 1.287)	0.026
	Traffic flow (1000 vehicles)	0.976	(0.959 - 0.992)	0.004	0.961	(0.933 - 0.989)	0.007	0.980	(0.960 - 1.000)	0.051
	Speed (kph)	1.023	(1.006 - 1.041)	0.007	1.050	(1.019 - 1.081)	0.001	0.966	(0.948 - 0.984)	<0.001
	Proportion of business postcodes	1.038	(1.025 - 1.051)	<0.001	1.050	(1.033 - 1.068)	<0.001	1.030	(1.018 - 1.041)	<0.001
	area (square meters)	1.000	(0.999 - 1.000)	0.406	0.993	(0.987 - 0.998)	0.011	0.999	(0.997 - 1.001)	0.457

Figure 1 Annual child pedestrian injury rates per 100,000 children by decile of deprivation of location of collision, 2000-2009

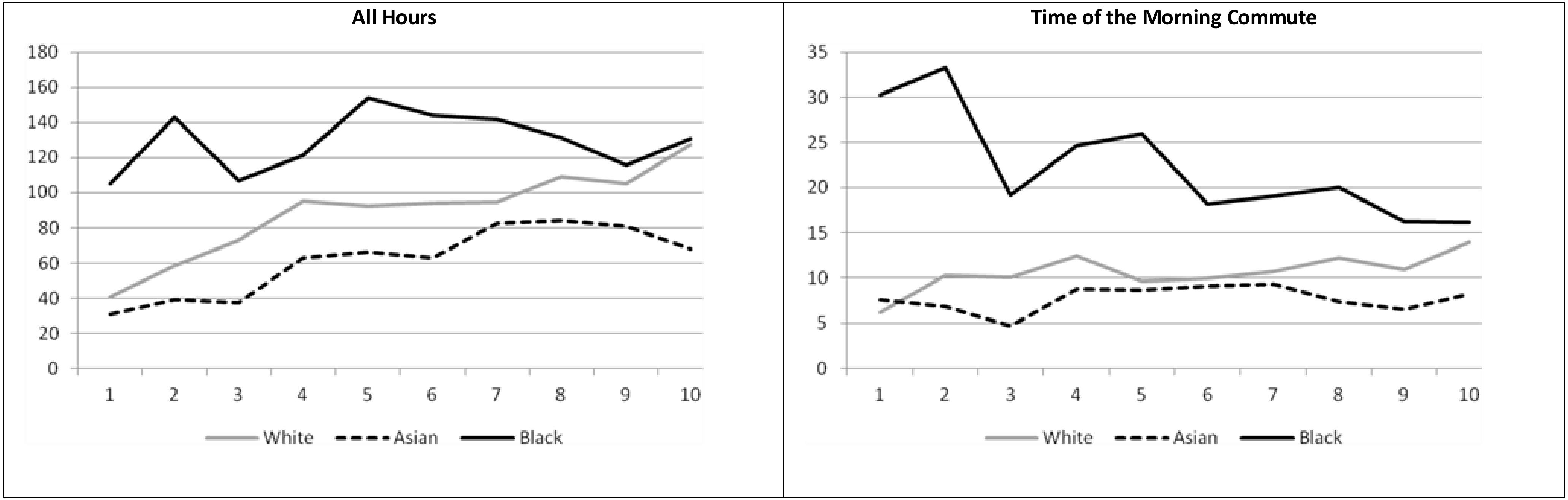


Figure 2 Injury rate ratios comparing pedestrian injury rates by decile of deprivation of location of collision with that in the least deprived decile

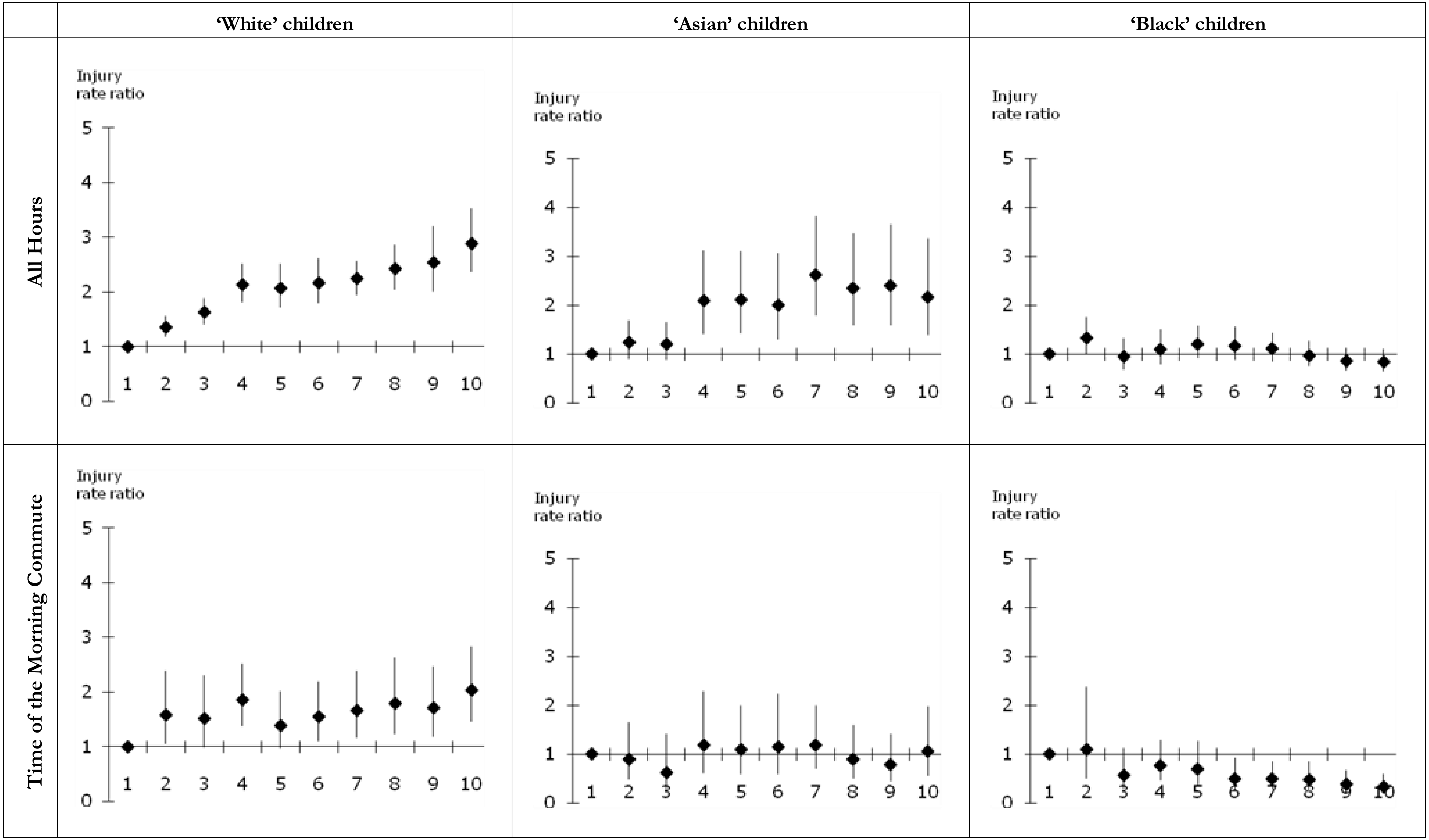
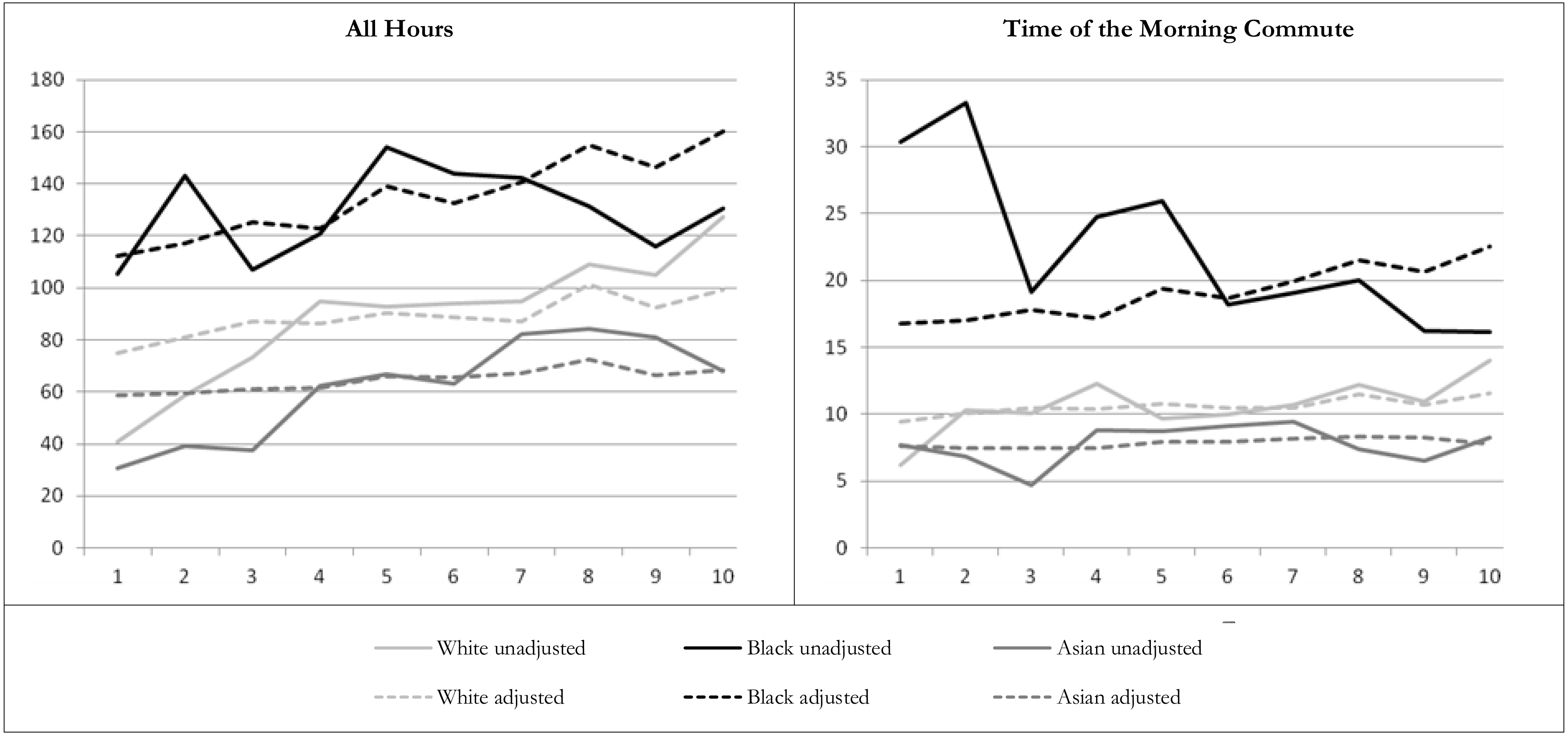


Figure 3 Pedestrian injury rates per 100,000 children, unadjusted and adjusted for road environment characteristics


All Hours
Time of the Morning Commute
180
160
140
120
100
80
60
40
20
0
1
2
3
4
5
6
7
8
9
10
35
30
25
20
15
10
5
0
White unadjusted
Black unadjusted
Asian unadjusted
White adjusted
Black adjusted
Asian adjusted

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6.2 IMPLICATIONS FOR THE ROLE OF THE QUALITY AND QUANTITY OF EXPOSURE IN EXPLAINING OVERALL ETHNIC INEQUALITIES IN CHILD PEDESTRIAN INJURY IN LONDON

Findings from Research Paper 4 have important implications for the role of exposure in explaining ethnic inequalities in injury rates in London. The paper estimated the rates of injury in 'White', 'Black' and 'Asian' children during the term time morning commute to provide a control for the quantity of exposure. During all times of the day, findings on average child pedestrian injury rates indicate that compared to 'White' children, pedestrian injury rates were 50% higher among 'Black' children and 14% lower for 'Asian' children. Limiting the calculations to period of the morning commute produced significantly different results, especially for 'Black' children. After controlling for exposure in this fashion, 'Black' children's injury rates were 85% higher than 'White' children's, while 'Asian' children's injury rates were 20% lower than 'White' children's. Given that inequalities in injury rates between 'White' and 'Black' children *increased* after introducing controls for the quantity of exposure, it appears that the overall higher injury rates among 'Black' children are unlikely to be due to higher levels of pedestrian exposure. Similarly, after controlling for exposure, inequalities in injury rates between 'Asian' and 'White' children also increased, although not by very much. This would also suggest that the overall lower rates of injury among 'Asian' children are unlikely due to lower levels of pedestrian exposure.

Limiting analyses to the morning commute is not a perfect control for the quantity of exposure. Differences in walking behaviour or distances to school, for example, may bias results. Using travel diary data, Research Paper 4 reported that while 'White' and 'Black' children travel on average similar distances to school (Research Paper 4, table 2), there are some differences in both the median distance travelled (Research Paper 4, table 2) and the mode of travel (Research Paper 4, table 1). Compared to 'White' children, 'Black' children travel greater median distances to school and are more likely to take the bus rather than commute in a car. Children travelling by bus typically walk to and from bus stops and thus are more exposed to road hazards than their counterparts travelling by car, where walking is minimal. Consequently, 'Black' children may have greater levels of exposure during the morning commute, which would, if true, help to explain their increased injury risk during those hours. However, findings from Chapter 4 suggest that, overall, the distances and minutes walked among 'White' and 'Black' children during the school commute are roughly equivalent. This would support the case for limiting injury rate calculations to the morning commute as, perhaps, a reasonable control for pedestrian exposure levels among 'White' and 'Black' children.

Even if the control is imperfect, as discussed in Research Paper 4, differences in travel patterns between 'Black' and 'White' children are relative small compared to the relative differences in injury rates before and after controls for exposure were introduced. For instance 'Black' children have median distances to school that are 9% greater than 'White' children. 'Black' children had average pedestrian injury rates that were 50% higher during all times of the day. After limiting analyses to the morning commute 'Black' children had average pedestrian injury rates that were 85% higher than 'White' children. Inequalities in injury between 'Black' and 'White' children therefore grew by roughly 40% after introducing controls for the quantity of exposure. Overall, this suggests that different exposure levels cannot explain differences in injury rates among 'White' and 'Black' children.

There is, perhaps, another pertinent drawback of controlling for exposure by limiting analyses only to the morning commute: what if the ethnic inequalities in injury rates are the result of significant differences in exposure levels during leisure time? The data reported in Research paper 4 suggests that leisure time exposure such as 'hanging out' or playing in the road environment is less likely to occur between 7-9am on weekday mornings. While measuring leisure time exposure to road hazards is fraught with methodological difficulties, it seems intuitively plausible that leisure time exposure would be minimized during the morning commute to school. However, if 'Black' children are more likely than 'White' children to 'hang out' or play near the road environment during 7-9am on weekday mornings, differences in leisure time exposure may help explain results.

Turning to inequalities between 'Asian' and 'White' children, evidence is mixed on whether limiting injury rate calculations to the morning commute provides a reasonable control. Findings from Research Paper 4 suggest that 'Asian' children are more likely than 'White' children to walk to school (Research Paper 4, table 1), which would indicate more pedestrian exposure during the morning commute. However, 'Asian' children have shorter median and mean distances to school than 'White' children (Research Paper 4, table 2), which may indicate lower levels of pedestrian exposure. Findings from Chapter 4 of this thesis suggest that compared to 'White' children, 'Asian' children on average walk shorter distances and for less time on the way to school (Research Paper 2 table 1 and Web Appendix 1), although confidence intervals around both outcomes overlap. If true, lower levels of exposure during the morning commute might help to explain why injury rates among 'Asian' children versus 'White' children were even lower during the morning commute than at all times of the day. This suggests that conclusions about whether the quantity of exposure can help explain inequalities in injury rates between 'White' and 'Asian' children should be interpreted with care. It seems possible that 'Asian' children have comparatively lower levels of exposure during the morning commute, which may explain their comparatively lower rates of pedestrian injury. Additionally, differences in the propensity to play or 'hang out' in the road environment may also help explain results if ‘Asian’ children are less likely than ‘White’ children to engage in leisure time activities that expose them to road hazards during 7-9am on weekday mornings.

It is important to note that Research paper 4’s calculations of average pedestrian injury rates did not include controls for the quality of pedestrian exposure. However, other analyses in Research Paper 4 do include variables describing features of the road environment in models of the relationship between deprivation and injury rates among ‘White’, ‘Black’ and ‘Asian’ children during the morning commute (Research Paper 4, table 3). Model results suggested that a number of these characteristics were associated with injury rates, including density of A roads, density of minor roads, junction density, traffic flow, speed, and proportion of postcodes in an area characterized as business. With the notable exception of traffic speeds[1], which were associated with decreased ‘Black’ pedestrian injury rates and increased ‘White’ and ‘Asian’ pedestrian injury rates, all features of the road environment had similar associations with ‘White’, ‘Black’ and ‘Asian’ injury rates: density of A roads, junction density, and proportion of business postcodes were associated with increased injury while density of minor roads and traffic flows were associated with decreased injury.

Research paper 4 largely suggests then, that the quality of the road environment affects the injury rates of ‘White’, ‘Black’ and ‘Asian’ children in a similar way. Chapter 3 indicated that ‘White’, ‘Black’ and ‘Asian’ children live in areas with similar features of the road environment. Taking findings from Research Paper 5 and Chapter 3 together, children from all ethnic groups in London appear to face similar levels of road hazards, which affect children in similar ways. Therefore it seems unlikely that the quality of exposure can explain either the higher rates of injury among ‘Black’ children in London, or the lower rates of injury among ‘Asian’ children.

To summarize, similar to findings from Chapters 3-5 of this thesis, findings from Research Paper 4 provide no evidence that the quality or quantity of exposure can help explain overall ethnic inequalities in injury rates in London. The next section discusses how these findings help illuminate an understanding of the relationships between ethnicity, deprivation and injury risk.

[1] This finding is further discussed in Chapter 8.

6.3 IMPLICATIONS FOR EXPLAINING THE RELATIONSHIP BETWEEN ETHNICITY, DEPRIVATION AND INJURY RATES IN LONDON

Research Paper 4 modelled the relationship between area deprivation and pedestrian injury rates among ‘White’, ‘Black’ and ‘Asian’ children in London, before and after introducing controls for the quality and quantity of exposure. Before controls were introduced, the relationships between area deprivation and injury rates were similar to findings from previous work: there was a trend of rising injury rates with increasing levels of deprivation among ‘White’ and ‘Asian’ children, and no relationship between area deprivation and injury rates among ‘Black’ children. After controlling for the quality and quantity of exposure, by limiting analyses to the morning commute and introducing variables describing features of the road environment, relationships between area deprivation and injury changed. Among ‘White’ children, the pattern of increasing injury rates with increasing levels of deprivation was less pronounced, while among ‘Asian’ children, the relationship between area deprivation and injury rates was no longer found. For ‘Black’ children, an unexpected pattern emerged: after controlling for the quality and quantity of exposure, increasing levels of deprivation were associated with *decreased* injury rates.

These findings initially seem counterintuitive. If levels of exposure were solely driving relationships between ethnicity, deprivation and injury, I would expect to find a similar relationship between area deprivation and injury among ‘White’, ‘Black’ and ‘Asian children after introducing controls for the quality and quantity of exposure. On the other hand, if the quantity and quality of exposure has no role in explaining these relationships, I would expect the relationships between area deprivation and injury among (for instance) ‘Black’ children to be similar before and after the controls were introduced. Neither of those scenarios occurred. Findings from Research Paper 4 seem to indicate that exposure does play some role in explaining relationships between ethnicity, deprivation and injury, although mechanisms appear more complex than the ones conceptualised in this thesis thus far. Why, after controlling for exposure, does area deprivation, rather than affluence, have a protective effect on ‘Black’ pedestrian injury?

Of course, bias may play a role. Perhaps, as discussed in Chapter 2, the method of assigning casualties to areas introduced numerator-denominator bias which partly explains results. Research Paper 4 assigned casualties to the LSOA (and corresponding level of deprivation) where the collision took place. Measures of deprivation levels in areas where casualties were injured may not be the same as deprivation levels in areas where children live (Appendix 3). A sensitivity analysis assigning casualties to the areas (and levels of deprivation) in which they live found that, after introducing controls for exposure, no relationship was found between deprivation and injury rates for ‘Black’ and ‘Asian’ children, whereas among ‘White’ children increasing injury rates were found with increasing levels of deprivation. While the protective effect of deprivation on ‘Black’ pedestrian injury rates was not robust to the method of casualty assignment, the finding of no relationship between deprivation and injury rates confirms that the quality and quantity of exposure cannot fully explain why area affluence does not protect ‘Black’ children from injury.

To begin to make sense of these findings, I first decided to re-examine the ways in which Research Paper 4 was able to ‘control’ for exposure. Results control for the amount of time/distance spent exposed to road hazards (i.e. quantity of exposure) and the levels of road hazards faced by children (i.e. quality of exposure). These controls are useful, but a key element of ‘exposure’ is missing: Controls for the quality and quantity of exposure fail to characterize what it *means* to be exposed to road hazards. Conceivably, structural and identity elements of ethnicity may influence these experiences. As noted in Research Paper 4, it seems plausible that being a visible minority (for instance a ‘Black’ child in an affluent area where there may be relatively fewer other ‘Black’ children) may shape the experience of being exposed in that environment.

Thinking about, for instance, how being a ‘Black’ child in an affluent area may change the meaning of walking, playing or ‘hanging out’ in that environment, pointed me to towards the ‘group density’ phenomenon. Reported most often in research on mental health outcomes (Becares and Nazroo, 2013, Das-Munshi et al., 2010, Shaw et al., 2012), ‘group density’ effects exist when ethnic minorities living in an area with a higher proportion of people from a similar ethnic group enjoy better health than do those who live in areas with a lower proportion, even though areas with dense minority ethnic populations can be relatively more materially disadvantaged. Researchers have suggested that psychosocial mechanisms such as social networks, shared cultures and social capital may drive the ‘group density’ phenomenon.

Conceptualising how psychosocial factors relate to injury risk is challenging. However, it seems plausible that the relative influence of different structural or identity elements of ethnicity may change in areas with dense versus sparse minority ethnic populations. Moreover, these differences may alter what it means to be exposed to road hazards. For instance, walking to a mosque in a neighbourhood where many others are doing the same activity may be a very different experience than walking to the mosque in an area where you may be the only one. In the same way, looking different to other children may change the meaning of ‘hanging out’ on a particular street. Put another way, perhaps it is not simply the activity, but also the surrounding community that influences how children interact with(in) the road environment, including how much children walk, play, or ‘hang out’ in the road environment, how quickly they cross the roads, or how appealing it is for the child to display one's identity or create mobility related risks, such as racing from bus to bus, in the road environment (Appendix 7).

The findings from Research Paper 4 have, then, guided me towards a new way of thinking about relationships between ethnicity, deprivation and injury in London. The 'group density' phenomenon may help to explain the trend of decreasing injury with increasing levels of deprivation among 'Black' children during the morning commute. Perhaps the 'group density' phenomenon also underlies the overall (lack of a) pattern of deprivation and injury among 'Black' children. If 'group density' effects can help explain why area affluence does not protect London's 'Black' children from injury risk, I would expect that, after accounting for minority ethnic population density in an area, I would see a similar relationship between deprivation and injury among 'Black' children compared to 'White' and 'Asian' children. The next chapter picks up on this 'group density' hypothesis and investigates associations between ethnic density and child pedestrian injury risk.

7 CAN 'GROUP DENSITY' EFFECTS HELP EXPLAIN RELATIONSHIPS BETWEEN ETHNICITY, DEPRIVATION AND INJURY RISK?

Findings from the previous chapter pointed to a new hypothesis to help explain relationships between ethnicity, deprivation, and injury risk: 'group density' effects. This chapter contributes to Aim 2 of the thesis – to explore the relationships between ethnicity, deprivation, and injury - by examining the role of 'group density' effects in explaining observed relationships.

To recap on the findings of this thesis so far, Chapter 1 introduced that the relationships between area deprivation and child pedestrian injury rates in London differ by ethnicity (Steinbach et al. 2010). Among 'White' and 'Asian' children, the risk of injury steadily increases as area deprivation increases. For 'Black' children, however, this association is not found. 'Black' children have relatively similar rates of pedestrian injury across all areas of London, irrespective of level of neighbourhood deprivation. The previous chapter examined whether controlling for the quality and quantity of pedestrian exposure could shed any light on the mechanisms for these differences. Results indicated that after controls were introduced, the relationships did change. Among 'White' children, the relationship between rising area deprivation and increased injury rates persisted, but was less pronounced. Among 'Asian' children, there no longer appeared to be any relationship between area deprivation and injury rates. Among 'Black' children, the introduction of controls for exposure produced the most dramatic results: there appeared to be a relationship between increasing levels of deprivation and *decreased* injury rates. These results, which should be interpreted with caution, suggest a protective effect of area deprivation on injury risk among 'Black' children after controlling for the quality and quantity of pedestrian exposure.

These findings seem to contradict hypothesised links between exposure, area deprivation and injury and therefore warrant a deeper investigation. The analyses in Chapter 6 controlled for the quality and quantity of pedestrian exposure, but they could not account for the *meaning* of that exposure. Appendix 7 indicated that pedestrian exposure during leisure time appears to have different meanings depending on context. For example, the meaning of 'wandering around' the streets changed depending on whether young people were aiming to, for instance, carve out private space to socialise with a close friend, or to relieve boredom by casually observing society. Others have suggested that context may also change the meaning of pedestrian exposure during travel time. For example, Bostock (2001) has demonstrated that walking may have different meanings when it is a choice rather than a necessity, and when it takes place in affluent as opposed to disadvantaged areas.

It therefore seems plausible that structural and identity components of ethnicity may be linked to the meaning of being exposed to hazards in the road environment. It also seems possible that these associations may vary in areas of differing levels of deprivation. Theoretically, these meanings of exposure may influence, for instance, whether children are likely to be travelling with others, how attractive it is to take mobility related risks in the road environment, or how quickly children cross the road.

Pedestrian injury rates among ‘Black’ children are not the only health outcome to exhibit an unexpected relationship with deprivation. Social epidemiological research into ethnic inequalities in mental health outcomes has found evidence for ‘group density’ effects (Shaw et al. 2012). These effects exists when ethnic minorities living in areas with higher concentrations of people from the same minority ethnic group enjoy better health than do ethnic minorities living in areas with lower concentrations, even though areas with dense minority ethnic populations can be more materially disadvantaged than other areas. One hypothesis is that psychosocial factors such as stigma and lack of social integration (e.g. shared culture, social networks and social capital) may form the mechanisms for these types of ‘group density’ findings (Pickett and Wilkinson 2008).

Given that ethnic minorities in London tend to live in more deprived areas (Jivraj and Khan 2013), in Chapter 6 I proposed that relationships between deprivation and child pedestrian injury among ‘Black’ children may be evidence of a ‘group density’ effect on health. Conceivably, psychosocial factors may mediate the associations between ethnicity and the meaning of pedestrian exposure. That is, the meaning of being a minority ethnic child pedestrian exposed to road hazards may change in areas where ethnic minority populations are more or less dense.

Ascertaining the different meanings of pedestrian exposure in different contexts is a challenging task. Such a research topic is most suited to a qualitative exploration, designed to compare experiences of pedestrian exposure among ethnic minorities in areas that differ in terms of deprivation levels and minority ethnic population density. Embarking on a study like this, which would entail considerable resources, seems premature given that results from Chapter 6 were only suggestive of ‘group density’ trends. To further examine whether the ‘group density’ hypothesis may be worth exploring, this chapter investigates quantitatively whether ‘group density’ effects can help to explain the different relationship that area deprivation and injury rate among ‘Black’ children has, compared to ‘White’ and ‘Asian’ children in London.

The ‘group density’ hypothesis posits that minority ethnic children exposed to road hazards will have higher rates of injury in areas where a smaller proportion of the resident population is from a similar ethnic group. Hence ‘Black’ children will have higher rates of injury in areas with fewer ‘Black’ children, while 'Asian' children will have higher rates of injury in areas with fewer 'Asian' children. Because 'White' children (as defined in this thesis) form the majority ethnic group in London, I would not expect the proportion of 'White' children in an area to influence 'White' child pedestrian injury risk. While it is possible that 'group density' mechanisms may affect the injury rates of some 'White' ethnic sub-groups, such as Irish, Polish, etc., subgroup 'group density' hypotheses unfortunately cannot be tested with current data. If 'group density' mechanisms are also driving relationships between ethnicity, deprivation, and injury in London, I would expect that introducing controls for ethnic population density would change the relationships identified in previous work among minority ethnic children.

Section 7.1 contains Research Paper 5 which uses variations in minority ethnic population densities between two census periods to examine associations between ethnicity, deprivation, ethnic population density and child pedestrian injury. Section 7.2 explores findings from Research Paper 5 on the relationship between ethnicity, deprivation, and injury in greater detail. Finally, Section 7.3 discusses the implications of Sections 7.1 and 7.2 for the role of the 'group density' hypothesis in explaining observed relationships between ethnicity, deprivation, and child pedestrian injury in London.

7.1 Research Paper 5: Is ethnic density associated with risk of child pedestrian injury? A comparison of inter-census changes in ethnic populations and injury rates

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   I designed the study with Phil Edwards and Judith Green. Mike Kenward provided statistical methods advice. I formatted data for analysis, analysed the data and drafted the manuscript. I revised the manuscript based on comments from Phil Edwards, Judith Green and Mike Kenward.

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IS ETHNIC DENSITY ASSOCIATED WITH RISK OF CHILD PEDESTRIAN INJURY? A COMPARISON OF INTER-CENSUS CHANGES IN ETHNIC POPULATIONS AND INJURY RATES

ABSTRACT

Objective: Research on inequalities in child pedestrian injury risk has identified some puzzling trends: although, in general, living in more affluent areas protects children from injury, this is not true for those in some minority ethnic groups. This study aimed to identify whether 'group density' effects are associated with injury risk, and whether taking these into account alters the relationship between area deprivation and injury risk. 'Group density' effects exist when ethnic minorities living in an area with a higher proportion of people from a similar ethnic group enjoy better health than those who live in areas with a lower proportion, even though areas with dense minority ethnic populations can be relatively more materially disadvantaged.

Design: This study utilised variation in minority ethnic densities in London between two census periods to identify any associations between group density and injury risk. Using police data on road traffic injury and population census data from 2001 and 2011, the number of 'White', 'Asian' and 'Black' child pedestrian injuries in an area were modelled as a function of the percentage of the population in that area that are 'White', 'Asian' and 'Black', controlling for socio-economic disadvantage and characteristics of the road environment.

Results: There was strong evidence ($p<0.001$) of a negative association between 'Black' population density and 'Black' child pedestrian injury risk (IRR 0.575, 95% C.I. 0.515-0.642). There was weak evidence ($p=0.083$) of a negative association between 'Asian' density and 'Asian' child pedestrian injury risk (IRR 0.901, 0.801-1.014) and no evidence ($p=0.412$) of an association between 'White' density and 'White' child pedestrian injury risk (IRR 1.075, 0.904-1.279). When group density effects are taken into account, area deprivation is associated with injury risk for all ethnic groups.

Conclusions: Group density appears to protect 'Black' children living in London against pedestrian injury risk. These findings suggest that future research should focus on structural properties of societies to explain the relationships between minority ethnicity and risk.

Key Words: children, ethnic density, injury

Word Count: 7,587

BACKGROUND

A large literature links socio-economic disadvantage with increased risk of child pedestrian injury (Laflamme et al., 2010, Laflamme and Diderichsen, 2000). Increasingly, a number of studies in a range of countries have also suggested ethnic differences in child pedestrian injury risk, with most (Abdalla, 2002, Campos-Outcalt et al., 2002, Harrop et al., 2007, Rivara and Barber, 1985, Savitsky, 2007, Stirbu, 2006, Abdel-Rahman et al., 2013), but not all, (Al-Madani and Al-Janahi, 2006) studies reporting that minority ethnic groups are at greater risk than their majority counterparts. Given that minority ethnic status is often correlated with both individual and area deprivation, it is perhaps unsurprising that minority children are often at higher risk. However, recent research to unpick the links between socio-economic disadvantage, ethnicity and child pedestrian injury (Steinbach et al., 2010) suggests that the relationships are complex: material disadvantage does not explain differences in injury rates across ethnic groups.

In London, for example, home to half of the United Kingdom's ethnic minority population, our previous work reported that pedestrian injury rates are associated with area deprivation, and that pedestrian injury rates among 'Black' children are 50% higher than rates among 'White' children. Although there was a clear gradient of risk for 'White' and 'Asian' children, with those in more deprived areas at higher risk than those in the most affluent areas, this gradient did not hold for 'Black' children, whose risk remained the same across all levels of deprivation. That is, although minority ethnic populations are disproportionately located in least affluent areas, while area affluence appears to protect 'White' and 'Asian' children from increased road injury risk, 'Black' children face higher risks of injury across the city (Steinbach 2010). Explaining both the high risk of 'Black' children in London, and the lack of any apparent area deprivation effect, has been challenging. We have found little evidence to date that the quality of the road environment (Steinbach 2010), the quantity of pedestrian exposure (Steinbach 2012), or potential differences in vulnerability to risk by time of day (Steinbach 2014) can account for overall differences in risk, or explain why living in more affluent areas does not also protect 'Black' children from risk. Indeed, when we control for the quantity and quality of pedestrian exposure (i.e., the distances travelled and the kinds of roads walked) it appears that 'Black' children in the most affluent areas of London face *higher* injury risks than 'Black' children living in more deprived areas (Steinbach et al., 2014a).

This negative association between affluence and risk is puzzling in the light of the majority of research which associates high risk with deprivation. One potential explanation lies in the very different experiences of 'Black' children in less affluent areas, where they may be more likely to be living with people from the same ethnic group. Given that ethnic minorities in London tend to live in more deprived areas (Jivraj and Khan, 2013), the findings that higher levels of area deprivation appear to have a protective effect on 'Black' child pedestrian injury rates may be evidence of the effects of social composition itself on a health outcome. One candidate explanation is 'group density' effects.

Group density effects arise from the compositional and/or contextual consequences of living in an area with a higher proportion of people 'like you' (Pickett and Wilkinson, 2008), and can be identified when individuals living in areas with a high proportion of people from the same ethnic group enjoy better health than those who live in areas with a lower proportion, even though areas with dense minority ethnic populations can be relatively more materially disadvantaged (Becares and Nazroo, 2013, Das-Munshi et al., 2010, Shaw et al., 2012). Theoretically, compositional explanations for such effects relate primarily to different components of social capital and social cohesion (Kawachi and Berkman, 2000). The adequate theorisation and operationalization of social capital in terms of its likely relation to health outcomes is controversial (Portes and Vickstrom, 2011, Szreter and Woolcock, 2004), and whether such effects are found depends in part on the measure of social capital used (Becares and Nazroo, 2013) but, briefly, hypothetical consequences of ethnic density incude increased social cohesion, trust, social reciprocity, and social integration, which are associated with positive health outcomes. Contextual correlates of living in areas of high ethnic density theoretically include better access to services and goods that are important determinants of health, such as preferred foods, appropriate and respectful health services, or opportunities to engage in sports or leisure. Conversely, living in areas with low proportions of similar people may be associated with higher levels of stigma, disrespect and overt discrimination (Becares et al., 2013), as well as potential pscyo-social impacts from visible social inequality (Wilkinson et al., 1998). Minority ethnic individuals may face fewer experiences of racism in ethnically dense areas, buffering the adverse effects of racism on health (Bécares et al., 2009). Whether, and to what extent, any of these theoretical pathways are likely to be salient depends on the political and historical context of ethnic segregation and density (Smaje, 1995). Given the putative pscyo-social pathways that link elements of social capital to health, group density effects have been mostly consistently found for mental health outcomes such as psychoses (Shaw et al., 2012). However, some empirical studies have also suggested group density effects on physical health, mortality and health behaviours (Bécares et al., 2012b) and self reported health (Smaje, 1995). Stigma and a lack of social integration (shared culture, social networks and social capital), are hypothesised as the mechanism for such effects, whereby those living in areas with fewer people of the same ethnic group may be less likely to encounter positive social interactions, and more likely to encounter status inconsistencies or discriminatory practices (Pickett and Wilkinson, 2008).

Although pedestrian road injury is not an obvious candidate for psycho-social pathways linking social structures to health outcomes, the risks of injury are clearly socially patterned by deprivation and ethnicity. As a first step in identifying whether there is any evidence for whether there may be similar structural explanations for ethnic inequalities in injury risk, we explore whether there is any empirical evidence for group density effects on pedestrian injury rates and if so, whether these can shed light on the social epidemiological puzzle of ethnic inequalities in child pedestrian injury in London. This study aimed to determine whether the ethnic density of an area is associated with child pedestrian injury risk in London, and whether ethnic density effects can help explain the lack of relationship found between area deprivation and risk for Black children in London.

METHODS

This study used a comparison between two census periods, 2001 and 2011, to investigate our hypothesised links between ethnic group density and child pedestrian injury risk in areas of London. Using police data on road traffic injury and population census data, we modelled the rate of 'White', 'Black', and 'Asian' child pedestrian injuries in an area as a function of the proportion of the population in that area that are 'White', 'Black' and 'Asian', controlling for socio-economic disadvantage and road environment characteristics. We used data from two time periods in order to provide a greater sample size of areas in London, to capitalize on changes over time, and to implicitly control for area level effects on injury risk. If the ethnic density of an area is associated with injury rates, we would expect that areas with changes in population make-up between 2001 and 2011 would also experience changes in child pedestrian injury rates. We included controls for road environment characteristics, since a large literature links area attributes, such as traffic volumes and traffic speeds, to pedestrian injury risk (DiMaggio and Li, 2012). Our study controlled for available road environment characteristics in London. Using data from two time periods helps isolate the effect of population make-up on pedestrian injury by implicitly controlling for road environment and other area level factors not included in our model; while populations, ethnic densities and injury events vary over time, other area level characteristics such as amounts of street furniture, access to green space or street parking are arguably less likely to change over a 10 year time period.

UNIT OF ANALYSIS

We analysed data at the census lower super output area (LSOA) level. LSOAs are geographic areas including an average of 1,500 people, defined by the Office of National Statistics (ONS) using measures of population size, mutual proximity and homogeneity of characteristics such as dwelling types and tenure. There were 4,765 LSOAs in London in the 2001 census. Due to some significant changes in population, the ONS redrew LSOA boundaries in 2011. There were a total of 4,835 LSOAs in London in 2011, including 4,642 (96%) LSOAs with the same boundaries used in 2001. In some cases, the 2001 LSOA boundaries were split into multiple LSOAs in 2011, in other cases multiple 2001 LSOA boundaries were merged together to form one 2011 LSOA boundary, and in 25 cases 2011 boundaries were redrawn in a way that did not map onto 2001 LSOA boundaries. In order to include as many areas as possible in the analyses, we determined the largest geographic area common in 2001 and 2011. We then computed average figures for these areas. For 2001 boundaries that were subsequently merged in 2011 this meant summing all of the figures from all 2001 boundaries included within a 2011 boundary and dividing by the number of 2001 boundaries. For 2001 boundaries that were subsequently split into multiple 2011 boundaries this meant summing the figures from all 2011 boundaries included within a 2001 boundary and dividing by the number of 2011 boundaries. In total we included 4,723 areas in our analysis.

INJURY EVENTS

We obtained a dataset of police STATS19 data for the periods 2000-2002 and 2010-2012 that included all reported casualties and traffic collisions occurring in London. Since 1995, London Metropolitan Police have included information on the ethnicity of casualties in their reports. The classification of ethnicity used is the six-category Police National Computer 'Identity Code', which is designed for descriptive purposes in crime detection and prevention, rather than for monitoring purposes. Police rely on physical attributes to categorise casualties into one of the six codes: White-skinned European, Dark-skinned European, Afro-Caribbean, Asian, Arab, or Oriental. This classification of ethnicity has a number of disadvantages: there are no other routine population level data that use them, they do not reflect how most people would define their ethnicity identity, and there are uncertainties as to how, in practice, police officers distinguish people using these codes. However, by carefully grouping identity codes into broad ethnic groupings and employing a number of sensitivity analyses to test these groupings, we have successfully used them to investigate ethnic differences in road traffic injury risk in a number of circumstances (Steinbach et al., 2014a, Steinbach et al., 2014b, Steinbach et al., 2010). In these previous analyses we found that using numerous plausible groupings of identity codes did not substantially change our results. For this analysis, we grouped casualties into four broad categories based on groupings used in previous research: 'White' (White-skinned European, Dark-skinned European); 'Black' (Afro-Caribbean'); Asian ('Asian'); and Other ('Arab', 'Oriental', missing ethnicity). The category 'Other' is omitted from this analysis as the heterogeneity of the grouping does not allow for reliable comparisons with population data: it is impossible to map population data to a 'missing' identity code and ethnicity codes in the population data do not easily map on to 'Oriental' and 'Arab' identity codes.

Consistent with previous work on inequalities in child pedestrian injury in London, casualties were included in the analysis if aged 0 to 15 years and injured as pedestrians. In order to calculate injury rates, casualties must be assigned to population denominators at an LSOA level. There are two candidate assignment methods: the location of collision assignment method assigns casualties to the area in which children were injured as a pedestrian using the Ordnance Survey grid reference of each collision; the location of residence assignment method assigns casualties to the area in which children live using the centroid of the postcode of residence. The most appropriate assignment method is under debate (Hewson, 2004, Hewson, 2005). The location of residence assignment method ensures that population denominators are appropriate; however information on location of residence is missing from over 40% of the casualty data, making the location of collision assignment method attractive in order to make use of more data. Additionally, there is evidence that in London child pedestrians tend to be injured close to home (Steinbach et al., 2013). We therefore decided to assign casualties to a LSOA using the location of collision assignment method. A sensitivity analysis was conducted to compare results when assigning casualties using the location of residence assignment method. We used 3 years of casualty data around the 2001 census (2000-2002) and the 2011 census (2010-2012) in order to minimize the impact of random yearly fluctuations in number of injury events.

CHILD POPULATION ESTIMATES

Age specific population data are not available at LSOA level by ethnic group, so the population of 'White', 'Black', and 'Asian' children in each LSOA was estimated by multiplying the numbers of children aged 0-15 years resident in each LSOA in 2001 and 2011 by the proportion of residents of all ages that are 'White', 'Black', or 'Asian' (as described below). The estimates of LSOA-level ethnic group child populations were then scaled to sum to the total child population estimates (available at borough level in 2001 and 2011; supplied by the GLA), to allow for ethnic differences in family size.

ETHNIC DENSITY

We obtained estimates of the population of all ages living in each LSOA by ethnic group in 2001 and 2011 from the population censuses. To derive proportions of the population by ethnicity, we used mappings reported in previous research (Steinbach et al., 2010) to assign STATS19 identity codes to the aggregated ethnicity groupings used by the Greater London Authority (GLA) drawn from 2001 Census categories. For a full discussion on mappings of STATS19, GLA and Census ethnicity categories see Steinbach et al 2010. Based on these mappings, we then estimated ethnic density as the proportion of residents of all ages that are 'White'(British, Irish, Other White), 'Black' (Caribbean, African, Other Black, Mixed-White & Black Caribbean, Mixed-White & Black African), and 'Asian' (Indian, Pakistani, Bangladeshi, Other Asian, Mixed-White & Asian) in each LSOA in 2001 and 2011. We used a logarithmic transformation of the ethnic density variable in analyses as the data were highly skewed.

SOCIO-ECONOMIC DISADVANTAGE

The average level of deprivation of each LSOA was scored using the Index of Multiple Deprivation (IMD) which brings together 36 indicators across seven domains of deprivation into an overall score of relative deprivation for each geographical area. We assigned IMD scores from 2004 to our 2001 data, and IMD scores from 2010 to our 2011 data. Because of small changes in the way IMD was calculated in 2004 and 2010, the scores are not directly comparable. However ranks of geographical areas can be compared (McLennan et al., 2011). For our analysis we ranked LSOAs according to their IMD score (from 1 to 4,762; higher ranks indicate more deprived areas) in 2001 and 2011, and we also used three other specifications of the IMD variable: raw score (1.7 to 76.78), normal score (-3.5 to 3.5), and IMD deciles (1-10) in sensitivity analyses.

ROAD ENVIRONMENT VARIABLES

We included available road environment and area characteristic variables found to be associated with injury events in the literature (DiMaggio and Li, 2012). These included: density of road junctions in the LSOA; density of A roads in the LSOA; density of minor roads in the LSOA, the proportion of postcodes in an LSOA characterized as 'business', the area (in square metres) of an LSOA, average vehicle speed (km per hr) and traffic volume (in 1000s of vehicles per day). To create variables describing the road environment in an LSOA, current road network information from the Integrated Transport Network (ITN) supplied by Ordnance Survey was overlaid with LSOA boundaries provided by the census in ArcView GIS. Data on average traffic speed and volume came from the London Greenhouse Gas Inventory (LEGGI). To calculate LSOA summaries of average speeds and volumes the LEGGI road network was overlaid with LSOA boundaries.

STATISTICAL ANALYSIS

The dataset comprised one observation per LSOA per broad ethnic grouping per year. The outcomes which were modelled in the analysis were the ethnic group specific counts of child pedestrians injured for each of the two years. To accommodate over-dispersion and the repeated measures nature of the data, negative binomial multivariable log-linear regression models were used with robust (sandwich) estimates of error. The denominators, which defined the offsets for the analyses, were the corresponding populations by ethnic group. Independent variables included in the models were: logarithm of ethnic density, rank of IMD, year, and road environment variables. We included a term for each local authority in the model, to allow for aspects of road engineering and road danger reduction specific to each of the 33 London boroughs. We ran three models, one for each ethnic group (Model 1-'White; Model 2- 'Asian'; Model-3 'Black'). To examine whether any associations between the independent variables and the numbers of children injured differed by ethnic group, we fitted a fourth model that included all three ethnic groups and we used Wald tests to examine interaction effects: between ethnicity and ethnic density; between ethnicity and area deprivation; and between ethnicity and year. The coefficients estimated by the models are presented here as incidence (of injury) rate ratios (IRRs) with 95% confidence intervals.

RESULTS

Between 2000 and 2002, there were 3,320 'White' children, 1,667 'Black' children and 727 'Asian children injured as pedestrians in London. By 2010-2012, the numbers had fallen substantially: 1,221 'White' children, 990 'Black' children and 450 'Asian children. Pedestrian injury rates declined from 123 (95% C.I. 118–127) per 100,000 children in 2001 to 64 (95% C.I. 61-68) per 100,000 in 2011; 'Black' child pedestrian injury rates declined from 194 (95% C.I 185-204) per 100,000 in 2001 to 76 (95% C.I. 71-81) per 100,000 in 2011; 'Asian' child pedestrian injury rates declined from 95 (95% C.I 88-102) per 100,000 in 2001 to 37 (95% C.I. 33-40) per 100,000 in 2011.

Ethnic density also changed considerably from 2001 to 2011 in London. The mean proportion of residents that identify as 'White' fell from 71% (range 5%-99%, median 75%, interquartile range 59%-87%) in 2001 to 61% (range 4%-98%, median 63%, interquartile range 46%-78%) in

2011. The mean proportion of residents that identify as 'Black' increased from 12% (range 0%-65%, median 7%, interquartile range 4%-18%) in 2001 to 15% (range 0%-68%, median 11%, interquartile range 6%-22%) in 2011. The mean proportion of residents that identify as 'Asian' increased from 13% (range 0%-87%, median 7%, interquartile range 4%-14%) to 17% (range 1%-88%, median 12%, interquartile range 7%-21%). Ethnic minority populations were still concentrated in similar geographical areas in London in 2011 compared to 2001; however, the number of those areas appeared to grow (Figure 1).

If the ethnic density of an area is associated with injury rates, we would expect that areas with changes in population make-up between 2001 and 2011 would also experience changes in child pedestrian injury rates. Figure 2 shows changes in ethnic density from 2001 to 2011 against changes in ethnic specific child pedestrian injury rates from 2001 to 2011. Specifically, the plots show on the x-axis the logarithm of the change in proportion of residents who are 'White', 'Black' and 'Asian' from 2001 to 2011 and on the y-axis the logarithm of the change in 'White', 'Black' and 'Asian' child pedestrian injury rates from 2001 to 2011. Figure 2 shows little evidence of a relationship between change in ethnic density and change in injury rates among 'White' children, but suggest a relationship of decreased injury rates with increased ethnic density among 'Black' children, and a similar, but weaker, relationship among 'Asian' children.

Table 1 presents the incidence (of injury) rate ratios (IRRs) from Models 1-3 which model the number of 'White' (Model-1), 'Asian' (Model-2), and 'Black' (Model-3) child pedestrian injuries in an area as a function of the percentage of the population in that area that are 'White', 'Black' and 'Asian', controlling for area disadvantage and characteristics of the road environment. Models 1-3 confirm the trends suggested by the descriptive analysis shown in Figure 2. The models indicated strong evidence ($p<0.001$) of a negative association between 'Black' density and 'Black' child pedestrian injury risk (IRR 0.575, 95% C.I. 0.515-0.642) (Table 1). There was weak evidence ($p=0.083$) of a negative association between 'Asian' density and 'Asian' child pedestrian injury risk (IRR 0.901, 0.801-1.014) and no evidence ($p=0.412$) of an association between 'White' density and 'White' child pedestrian injury risk (IRR 1.075, 0.904-1.279). There was a positive association between injury risk and rank of the IMD among 'White', 'Asian' and 'Black' children, although the association appears slightly larger in 'White' children compared to 'Black' and 'Asian' children. Sensitivity analyses (not shown) using the different specifications of the area disadvantage variable also identified positive associations between risk and IMD scores among all three groupings. There was evidence that injury risk declined by more than a half between 2001 and 2011 among 'White', 'Asian' and 'Black' children with the greatest decline among 'Asian' children.

In terms of the road environment, there was evidence that the density of A roads and the proportion of postcodes that are business was associated with increased injury risk among 'White', 'Black' and 'Asian' children. The density of minor roads and road traffic speeds were associated with decreased injury risk among all three ethnic groupings. There was weak evidence that the density of road junctions was positively associated with injury risk among 'White' and 'Black' children.

A fourth model (results not shown), which examined interaction effects between ethnicity and a selection of independent variables found strong evidence ($p<0.001$) that the effect of ethnic density differed by ethnic group, good evidence ($p=0.016$) that the association between injury risk and area deprivation differed by ethnic group, and good evidence ($p=0.037$) that the decline in injury risk over time differed by ethnic group.

A sensitivity analysis assigning casualties to areas based on postcode of residence rather than postcode of injury found broadly similar results to Models 1-3 (Appendix table 1), although some relationships were weakened. Ethnic density continued to be associated with lower pedestrian injury risk in 'Black' children (IRR 0.811, 95% CI 0.713-0.922) but there was no evidence of a relationship between ethnic density and injury risk among 'White' or 'Asian' children. Area disadvantage also continued to be positively associated with 'White', 'Asian' and 'Black' injury risk, with similar magnitude to the relationship found in table 1. Injury risk was estimated to decline significantly in 2011 compared to 2001 among 'White' (IRR 0.790, 95% CI 0.722 – 0.866), 'Asian' (IRR 0.676, 95% CI 0.575-0.794) and 'Black' (IRR 0.722, 95% CI 0.648-0.805) children.

DISCUSSION

After controlling for area disadvantage and the road environment, we found strong evidence for a group density effect in 'Black' children: pedestrian injury risk was substantially lower in areas with a higher percentage of 'Black' population. We found weak evidence of more moderate group density effects in 'Asian' children and no evidence for a relationship between ethnic density and 'White' child pedestrian injury risk.

Similar to other studies we found that pedestrian injury risk is declining over time for children from all three ethnic groups (Malhotra et al., 2008), however unlike other work, we found evidence that this decline differs by ethnic group: injury risk has fallen more quickly in 'Asian' children compared to 'White' and 'Black' children. Our paper compares injury risk in 2001 to injury risk in 2011, while Malhotra and colleagues compare risk in 2001 through to 2006. Injury risk may have declined at different rates for 'White', 'Asian', and 'Black' children between 2007 and 2011.

Our findings of associations between characteristics of the road environment and child pedestrian injury concur with much of the literature on environmental correlates of pedestrian injury (DiMaggio and Li, 2012). An important exception is findings on speed. While most other studies report that increased vehicle speeds are associated with increased injury risk, our results suggest an association between increased vehicle speeds and decreased injury risk. London has a unique urban environment where recorded traffic speeds rarely exceed 20mph (30kph) apart from arterial roads (Transport for London, 2012). Our findings may reflect decreased child pedestrian exposure on to injury on arterial roads with higher speeds (if, for instance, these roads are less likely to have sidewalks or parents or children perceive them as more dangerous to walk on). Our sensitivity analysis using the location of residence to assign casualties to LSOAs found few relationships between environmental characteristics and injury among 'White', 'Black', and 'Asian' children, possibly due to the large number of casualties missing information on location of residence (40%) that were necessarily excluded.

Interestingly, our results suggest that after taking population make-up into account, part of the social epidemiological puzzle of ethnic inequalities in injury risk disappeared: area affluence appeared to protect 'White', 'Asian' and 'Black' children from injury risk. Our findings are now therefore congruent with the many studies that have suggested that area disadvantage increases pedestrian injury risk (Laflamme and Diderichsen, 2000). However, we did find evidence that the protective effect of area affluence was not as strong among 'Black' and 'Asian' children as it is among 'White' children.

As 'Black' children in London tend to live in more deprived areas (Jivraj and Khan, 2013), this finding may suggest ethnic density helps protect 'Black' children against the increased injury risk associated with high deprivation, providing some insight into why 'Black' children appear to face similar child pedestrian injury risks across London in studies that do not take ethnic density into account. Accounting for why ethnic density may protect Black children (and have less apparent effect for 'Asian' children) is more challenging, and inevitably speculative. Whereas mechanisms such as the effects of stigma or social recognition are plausible for mental health outcomes, and for health outcomes such as heart disease, it is more difficult to conceptualise how psychosocial factors could mediate child pedestrian injury risk. However, it should be noted that direct evidence of psychosocial factors as mediators for mental health outcomes is often lacking. Das-

Munshi et al (2010) for instance, found ethnic density effects for mental health in England, concluding that those living in areas of high own group density experienced less stigma and improved social support: but also found that these factors did not appear to mediate the density effect. Given the lack of clear evidence to date on what does link aggregate structural effects to individual health outcomes, it is therefore plausible that analogous structural mechanisms might operate to link ethnicity with injury. These include two candidate possibiliites. One relates to the contextual effects of ethnic density. In areas where there are few people of a similar ethnicity, there is evidence that adults travel further in order to access culturally appropriate or valued services and goods (Whitley et al., 2006). This is likely to apply to children and young people, who may be travelling further from low-ethnic density areas in order to accesss (for example) Black churches (Krause, 2009), youth clubs or supplementary schools (Mirza and Reay, 2000). This would extend the time in which children are exposed to pedestrian injury risk. The other possibility relates to the more compositional elements of ethnic density, and how the meanings of either ethnic identity or minority status might change with density, and the implications this might have for pedestrian exposure. Given that Black youth report, for instance, feeling less 'safe' in areas where there are fewer Black people (Reynolds, 2013), this might have implications for how young people walk, play or 'hang out' in the road environment; whether they are likely to move more, or less, quickly when crossing roads, or whether they are more or less likely to travel with others. There is a need for more detailed ethnographic work on what ethnic density means in terms of young people's travel across different ethnic groups.

LIMITATIONS

Our data sources have some limitations that may have affected our results. A weakness of STATS19 is the under-reporting of road traffic injuries, which may differ by ethnicity or area deprivation. However, reporting in London has been found to be good compared with the rest of the country (Ward et al., 2006) and differences in reporting would only affect our results on the relationship between ethnicity, ethnic density and pedestrian injury if the within-ethnic group propensity to report or record an injury differs by the population make-up of an area. Further limitations arise from our choice of assigning casualties to the area in which they occurred, rather than the area in which the child resides. The resident population is only a proxy for the number of children exposed to pedestrian injury risk in that area, and any ethnic differences in travel patterns may mean that our estimates are more valid for some ethnic groups than others. However, our sensitivity analysis using LSOA of residence produced broadly similar results to our models assigning casualties to LSOA of collision. The finding that 'Black' density appears to have a large protective effect on 'Black' child pedestrian injury risk was robust to the assignment method, however the weak finding of a relationship between 'Asian' density and 'Asian' child pedestrian injury risk was not replicated in our sensitivity analysis and should be interpreted with caution.

The main limitation of our analyses is the broad categories of 'White', 'Asian' and 'Black' children. It was necessary to use these broad groupings in order to pragmatically map police ethnicity codes onto population data, to estimate injury rates. However these groupings do not represent any real communities (with shared culture, social networks or social capital) in London. Given that other studies have found that separating out the effects of, for instance, Caribbean ethnic density and Black ethnic density changes the relationship found between density and health outcomes (Bécares et al., 2012a), we cannot know whether our analyses would hold for more homogenous ethnic groups. For instance 'Black African' Londoners and 'Black Caribbean' Londoners may face similar structural environments, leading to similar experiences of racism, but may have different orientations to, for instance, education, affecting whether children are travelling long distances to school or not. Similarly, the broad category 'Asian' aggregates diverse communities with known differences in terms of health outcomes (Smith et al., 2000). Utilising broad categories could possibly have diluted the psychosocial benefits of living in areas with people 'like you', thus making our analysis somewhat conservative. Alternatively, and given the range of findings for different groups and outcomes in the literature (Bécares et al., 2012b) it is probable that we have underestimated strong group density effects for some ethnic groups within these groupings, and missed negative associations for others. More research to identify possible group density effects in homogenous ethnic groups is needed.

IMPLICATIONS

To our knowledge, this is the first study to identify ethnic density effects for road traffic injury. It has been noted that fewer studies in the UK, compared with the US, have identified density effects (Bécares et al., 2012b), and that this may reflect both the smaller range of ethnic densities in the UK population and the smaller sample sizes, which are under-powered to identify structural effects. This case study used London, where there is a range of ethnic densities, and where they have changed between two censuses, and where there are (unfortunately) sufficient injury events to provide an analysis by broad ethnic groupings.

While a number of studies have empirically investigated plausible mechanisms to explain ethnic differences in child pedestrian injury risk, research has yet to uncover any conclusive evidence to explain the higher risk to minority ethnic children. This may be, perhaps, in part due to the way ethnicity has been theorized to relate to injury risk. First, there are well known conceptual difficulties of defining ethnicity: the many structural and identity 'factors' of ethnicity may have different, and even conflicting implications, for child pedestrian injury risk. Theoretical models tend to focus on two main mechanisms: exposure to risk, and risk behaviour. Minority ethnic status may lead to greater exposure to risk through either structural associations with individual socio-economic disadvantage leading to more time spent in the road environment (Roberts et al., 1996), or through structural associations with neighbourhood disadvantage and more dangerous road environments (Steinbach et al., 2010). Behavioural explanations have focused on the way cultural identity may lead to ethnic differences in individual risk behaviour (Chen et al., 2012).

Despite acknowledging that the mechanisms linking minority ethnicity to injury risk are inter-related (Steinbach et al., 2010), empirical studies tend to focus on one mechanism or another (with more or less sophistication in accounting for potential confounding). However, it is very difficult to theoretically isolate particular pathways. For example, structural associations with socio-economic disadvantage suggest that ethnic minorities are more likely to live in deprived areas. Deprived areas may be more likely to have more dangerous road environments (which we would expect to increase risk). However, living in areas with dangerous road environments may affect children's choice of leisure activities if they (or their parents) choose not to (allow them to) play or hang out outside. This, in turn, may decrease the amount of time children in these areas are exposed to risk (which we would expect to decrease risk). The 'danger' of the road environment may also change the meaning of exposure in those environments, leading to differences in risk behaviour. Disentangling the relative contributions of road environments, exposure and behaviour is therefore challenging, and is exacerbated by the well-documented measurement difficulties with ethnicity, exposure and behaviour, leading researchers to use imperfect proxies in empirical investigations.

This study's finding that 'Black' child pedestrian injury risk is associated with ethnic group density, in addition to the methodological and conceptual challenges of exploring individual mechanisms, suggests that we may need to re-think the way we examine explanations for ethnic differences in risk. Our findings that the ethnic make-up of an area can help predict child pedestrian injury risk for some ethnic groups, but not others, suggests that not only is injury risk determined by relationships between individuals and the environment, but also interdependencies between individuals.

These findings suggest that further investigation of individual casual explanations may have diminishing returns. Rather, a broader focus on the 'system' may prove more fruitful. Systems approaches emphasize that population health is a function of many inter-related components at different levels of influence (Galea et al., 2010, Koopman and Lynch, 1999). Within public health, these systems can be quite complex: characterized by heterogeneous interdependent units, related in non-linear ways with feedback loops and their own emergent properties. As Diez Roux (2011) suggests, systems approaches can be particularly useful for examining health inequalities when traditional epidemiological methods have failed to provide satisfying explanations. In systems approaches, she notes "because the effect of a given input depends on other conditions in the system, emphasis shifts from isolating the casual effect of a single factor to comprehending the functioning of the system as a whole" (Diez Roux, 2011).

If we begin to conceptualise ethnic inequalities in child pedestrian injury using a systems approach, the risk of injury would be a function of not only an individual's circumstances (e.g. socio-economic position, travel preferences), but also interdependencies between individuals (transmission of social norms about meaning of 'walking', playing or 'hanging out' on roads; the meaning of being exposed in particular social environments) and emergent properties of the 'system' (such as those arising from, for example, the social organization of transport or the traffic environment) and the dynamic relationship between individual behaviour and the environment (e.g. whether walking or risk taking is more appealing in different types of environments). Systems approaches would also conceptualise how these different levels of influence affect vehicle driver behaviour: whether different physical or social environments prompt more or less attention to the road, greater or fewer traffic volumes, or faster or slower traffic speeds. Thinking more explicitly about these dynamic processes may not only help further our understanding of pedestrian injury risk but may also help to identify new intervention points to not only reduce ethnic inequalities in road injury but injury risk overall.

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Table 1 Rate ratios showing changes in child pedestrian injury rates associated with characteristics of LSOAs.

	Model 1-'White'			Model 2-'Asian'			Model 3-'Black'		
Variable	**IRR**	**95% C.I.**	**p-value**	**IRR**	**95% C.I.**	**p-value**	**IRR**	**95% C.I.**	**p-value**
Density									
Natural log of the percentage of residents that are of a similar ethnic group	1.075	(0.904 - 1.279)	0.412	0.901	(0.801 - 1.014)	0.083	0.575	(0.515 - 0.642)	p<0.001
Area Deprivation									
Rank of IMD (100s)	1.020	(1.015 - 1.024)	p<0.001	1.015	(1.007 - 1.022)	p<0.001	1.014	(1.007 - 1.021)	p<0.001
Year									
2001		Reference group			Reference group			Reference group	
2011	0.488	(0.453 - 0.526)	p<0.001	0.420	(0.368 - 0.481)	p<0.001	0.489	(0.448 - 0.534)	p<0.001
Road environment variables									
Density of A roads	1.007	(1.004 - 1.009)	p<0.001	1.009	(1.005 - 1.012)	p<0.001	1.008	(1.005 - 1.010)	p<0.001
Proportion of business postcodes	1.044	(1.039 - 1.050)	p<0.001	1.041	(1.032 - 1.050)	p<0.001	1.041	(1.034 - 1.049)	p<0.001
Density of minor roads	0.997	(0.996 - 0.998)	p<0.001	0.998	(0.996 – 1.000)	0.040	0.997	(0.995 - 0.998)	p<0.001
Speed (kph)	0.958	(0.938 - 0.979)	p<0.001	0.964	(0.925 - 1.004)	0.081	0.956	(0.931 - 0.983)	0.001
Junction density	1.103	(1.024 - 1.189)	0.010	1.034	(0.948 - 1.127)	0.454	1.086	(1.002 - 1.178)	0.046
Area (square metres)	1.000	(0.999 - 1.001)	0.832	1.000	(0.999 - 1.002)	0.869	1.000	(0.999 - 1.001)	0.752
Traffic volume (1000 vehicles)	1.007	(0.996 - 1.018)	0.234	0.999	(0.979 - 1.020)	0.949	1.013	(0.997 - 1.029)	0.114
Local Authority fixed effects		Not shown			Not shown			Not shown	

Figure 1 Map of London population by ethnic group (each dot represents 10 people)

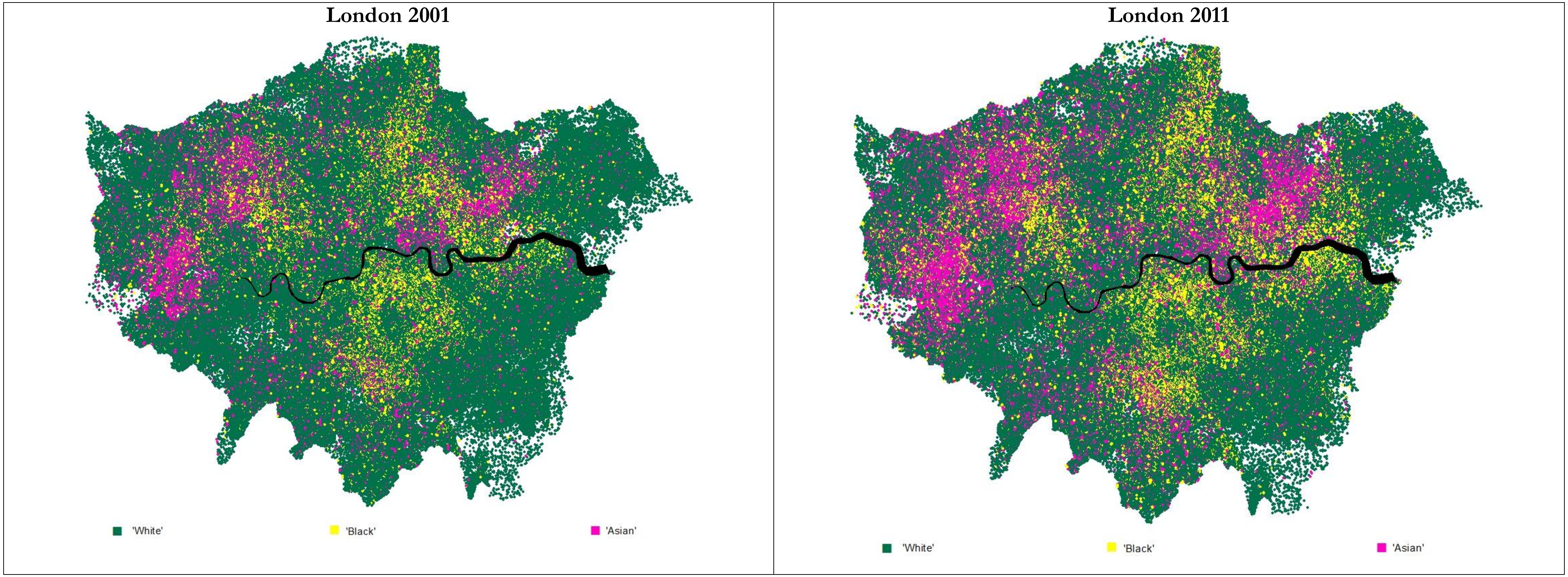
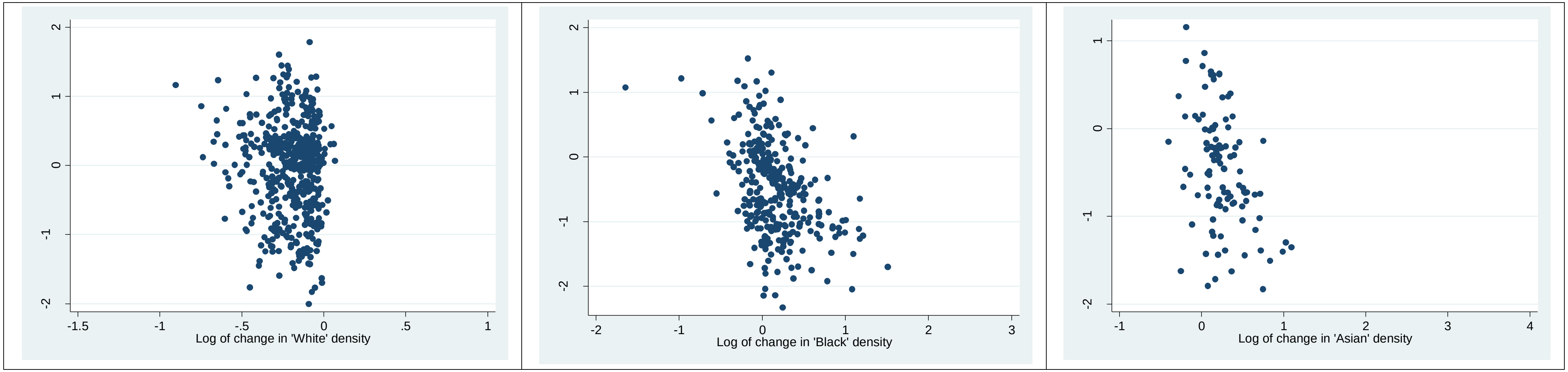


Figure 2 Scatter plots of the change in ethnic density 2001-2011 and the change in child pedestrian injury rates 2001-2011



7.2 FURTHER ANALYSIS OF RELATIONSHIPS BETWEEN ETHNICITY, DEPRIVATION AND INJURY

Section 7.1 explored the relationships between ethnicity, area deprivation, ethnic population density and child pedestrian injury. Results present evidence of a strong negative association between 'Black' population density and 'Black' child pedestrian injury, suggesting that exposure to the road environment in areas with fewer 'Black' residents is more hazardous for 'Black' children than exposure in areas with relatively more 'Black' residents. Interestingly, when 'Black' population density was included in models exploring the relationship between deprivation and injury among 'Black' children, the relationship appeared to change. Unlike previous work, which suggested no relationship between deprivation and injury, models including 'Black' population density suggested that increased levels of deprivation were associated with *increased* injury risk among 'Black children. This is potentially a very important finding for Aim 2 of this thesis which intended to explore why area affluence fails to protect 'Black' children from injury; this section explores that finding in more depth.

Previous work, including analyses described in the introductory chapter and analyses in Research Paper 4 of this thesis, used deciles of the Index of Multiple Deprivation to characterize deprivation levels. The measure of area deprivation used in the main analyses in Research Paper 5 was slightly different. The main analyses used the rank of the Index of Multiple Deprivation. Research Paper 5 does describe a sensitivity analysis using deciles of deprivation (detailed results not shown in the paper). This sensitivity analyses found a similar relationship to analyses using rank of IMD; increasing deciles of deprivation were associated with increased injury rates among 'Black' children in models including ethnic population density, year and features of the road environment. This section aims to allow comparisons with earlier chapters by presenting analyses which model the relationship between *decile* of deprivation and injury among 'White', 'Asian' and 'Black' children. To isolate the effects of ethnic density on the relationship between decile of deprivation and injury, this section presents models of the relationships between decile of deprivation and injury with and without variables describing the ethnic density of an area.

7.2.1 Methods

Using the same data and methods of analysis in Research Paper 5, this section presents two sets of models examining the relationship between pedestrian injury rates and *decile* of deprivation in each LSOA for 'White', 'Asian' and 'Black' children (see Appendix 6 for more information on IMD deciles). The first set of models include independent variables describing decile of deprivation, year (2001 vs 2011), and features describing the road environment. The second set of models are identical to the first set, except they also include an independent variable describing the logarithm of ethnic density.

Like the analyses in Research Paper 5, both sets of models include terms for each local authority to allow for local authority-specific trends in injury. To examine whether the association between deprivation and injury differed by ethnic group after ethnic population density was included in the model, I fitted one model that included all three ethnic groups and used Wald tests to examine interaction effects between ethnicity and decile of deprivation.

7.2.2 Results

Figure 7.1 displays the incident rate ratios comparing injury rates in each decile of deprivation to injury rates in the least deprived decile of deprivation for 'White', 'Asian' and 'Black' children in the two sets of models. The top row of graphs were derived from models excluding ethnic population density, while the bottom row of graphs were derived from models which included the logarithm of ethnic density as an independent variable. Results indicate that relationships between decile of deprivation and injury rates in models excluding ethnic population density are similar to those reported in previous work (Steinbach, Edwards, and Green 2014, Steinbach et al. 2010): increasing levels of deprivation were associated with increasing injury rates among 'White' and 'Asian' children, but there was no evidence of a relationship between decile of deprivation and injury rates among 'Black' children. When ethnic population density was introduced into the models, there was still evidence of a relationship between increasing deciles of deprivation and increased injury rates among 'White' and 'Asian' children, with relationships appearing very similar to models excluding ethnic population density. Relationships, however, among 'Black' children changed. After including ethnic density as an independent variable, there appears to be a relationship of increasing deciles of deprivation and *increased* injury rates among 'Black' children. That is, after including ethnic density in models, the nature of the relationship between deprivation and injury appears broadly similar across ethnic groups. Wald tests provided no evidence that the relationship between decile of deprivation and injury rates differed by ethnic group (p=0.462).

Tables 7.1 and 7.2 display the rate ratios showing changes in child pedestrian injury rates associated with area characteristics (excluding changes associated with decile of deprivation which are shown in Figure 7.1). Table 7.1 shows results from models excluding ethnic population density, while table 7.2 shows results from models including ethnic population density. Overall these provide strong evidence of a negative association between ethnic population density and 'Black' injury rates, weak evidence of a negative association between ethnic population density and 'Asian' injury rates, and no evidence of an association between ethnic population density and 'White' injury rates. The inclusion of ethnic population density did not substantially change associations between year and child pedestrian injury among 'White', 'Asian' and 'Black' children, nor did it substantially change associations between features of the road environment and injury among children from all three ethnic groups.

Figure 7.1 Relationships between deprivation and injury among 'White', 'Black' and 'Asian' children

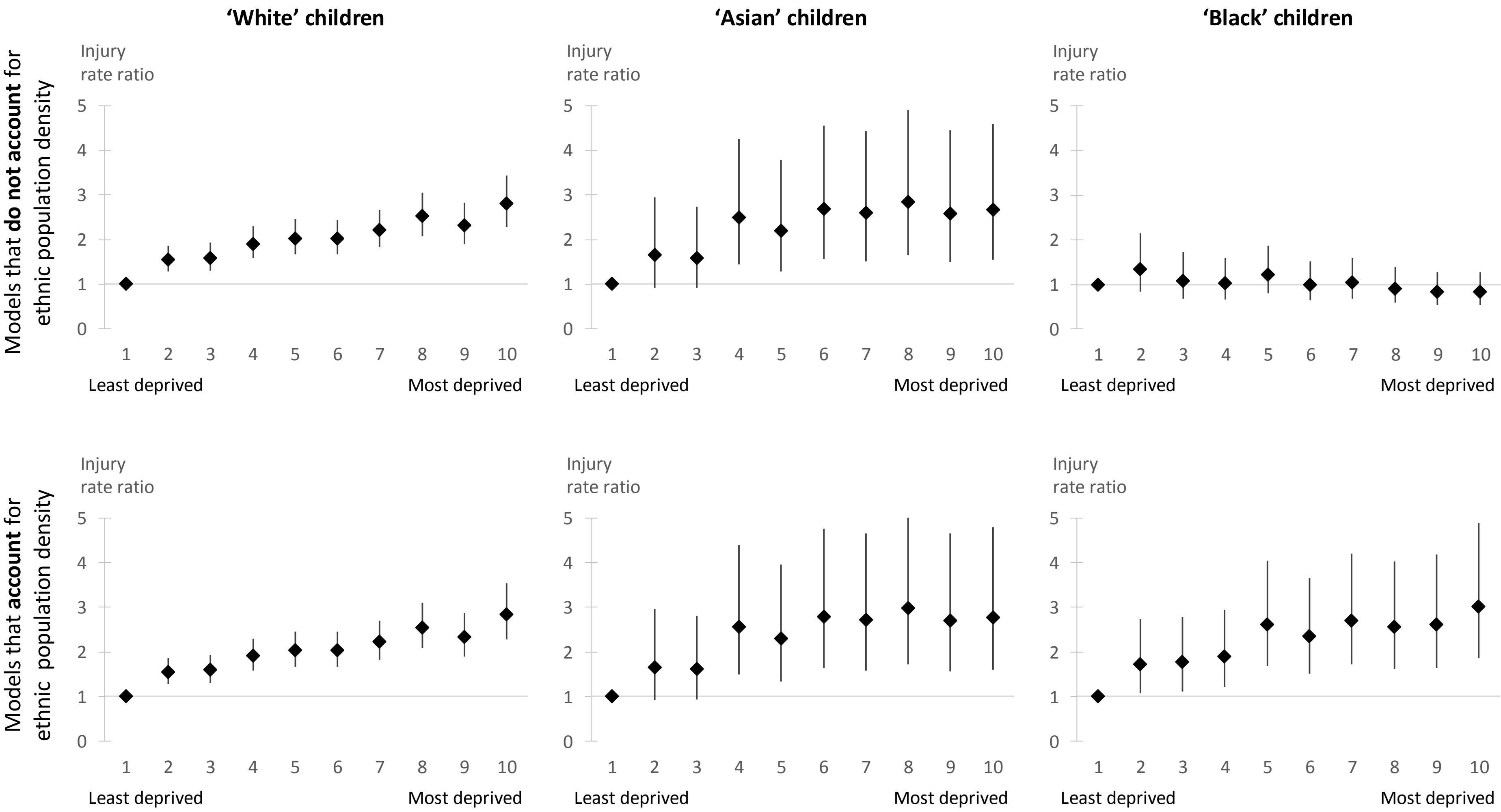


Table 7.1 Rate ratios showing changes in child pedestrian injury rates associated with characteristics of LSOAs in models *excluding* ethnic population density

	White			Asian			Black		
Variable	IRR	95% C.I.	p-value	IRR	95% C.I.	p-value	IRR	95% C.I.	p-value
Year									
2001	Reference group			Reference group			Reference group		
2011	0.485	(0.453 - 0.520)	P<0.001	0.408	(0.358 - 0.465)	P<0.001	0.429	(0.393 - 0.469)	P<0.001
Road environment variables									
Area (square metres)	1.000	(0.999 - 1.001)	0.921	1.000	(0.999 - 1.002)	0.786	1.000	(0.999 - 1.001)	0.844
Junction density	1.102	(1.023 - 1.186)	0.01	1.044	(0.961 - 1.134)	0.309	1.069	(0.979 - 1.166)	0.135
Density of A roads	1.007	(1.004 - 1.009)	P<0.001	1.009	(1.005 - 1.012)	P<0.001	1.009	(1.006 - 1.012)	P<0.001
Density of minor roads	0.997	(0.995 - 0.998)	P<0.001	0.997	(0.995 - 0.999)	0.009	0.996	(0.995 - 0.998)	P<0.001
Proportion of business postcodes	1.044	(1.038 - 1.049)	P<0.001	1.040	(1.031 - 1.050)	P<0.001	1.046	(1.038 - 1.054)	P<0.001
Speed (kph)	0.960	(0.939 - 0.980)	P<0.001	0.965	(0.926 - 1.006)	0.092	0.952	(0.925 - 0.979)	0.001
Traffic flow (1000 vehicles)	1.005	(0.995 - 1.016)	0.333	0.999	(0.977 - 1.020)	0.897	1.012	(0.995 - 1.028)	0.160
Local Authority fixed effects	Not shown			Not shown			Not shown		

Table 7.2 Rate ratios showing changes in child pedestrian injury rates associated with characteristics of LSOAs in models *including* ethnic population density

	White			Asian			Black		
Variable	IRR	95% C.I.	p-value	IRR	95% C.I.	p-value	IRR	95% C.I.	p-value
Density									
Natural log of the percentage of residents that are of a similar ethnic group	1.030	(0.868 - 1.223)	0.735	0.885	(0.786 - 0.997)	0.044	0.563	(0.505 - 0.627)	P<0.001
Year									
2001	Reference group			Reference group			Reference group		
2011	0.488	(0.453 - 0.526)	P<0.001	0.422	(0.369 - 0.482)	P<0.001	0.492	(0.451 - 0.537)	P<0.001
Road environment variables									
Area (square metres)	1.000	(0.999 - 1.001)	0.927	1.000	(0.999 - 1.002)	0.871	1.000	(0.999 - 1.001)	0.658
Junction density	1.102	(1.023 - 1.187)	0.010	1.037	(0.953 - 1.129)	0.403	1.086	(1.002 - 1.176)	0.045
Density of A roads	1.007	(1.004 - 1.009)	P<0.001	1.009	(1.005 - 1.012)	P<0.001	1.007	(1.005 - 1.010)	P<0.001
Density of minor roads	0.997	(0.995 - 0.998)	P<0.001	0.998	(0.995 - 1.000)	0.022	0.997	(0.995 - 0.998)	P<0.001
Proportion of business postcodes	1.044	(1.038 - 1.049)	P<0.001	1.041	(1.031 - 1.050)	P<0.001	1.041	(1.033 - 1.048)	P<0.001
Speed (kph)	0.959	(0.939 - 0.980)	P<0.001	0.964	(0.925 - 1.004)	0.077	0.957	(0.932 - 0.984)	0.002
Traffic flow (1000 vehicles)	1.005	(0.995 - 1.016)	0.326	0.999	(0.978 - 1.002)	0.918	1.013	(0.997 - 1.028)	0.117
Local Authority fixed effects	Not shown			Not shown			Not shown		

7.2.3 Discussion

Further analyses using deciles of deprivation for ease of comparison with previous work mostly confirm trends suggested in Research Paper 5. There is a strong association between 'Black' population density and 'Black' child pedestrian injury. Further, the addition of ethnic population density in models changes the relationship between deprivation and injury among 'Black' children. However, findings from these further analyses differ from Research Paper 5 in one important respect: They suggests that when ethnic population density is included in models, there is no longer any evidence that the relationship between decile of deprivation and injury differs by ethnic group. This finding conflicts with results from the main analyses in Research Paper 5 which examined relationships with deprivation using the *rank* of IMD to characterize deprivation. Similar to the further analyses, the main analyses in Research Paper 5 indicated that the relationship between deprivation and injury appeared broadly similar across ethnic group, however, a Wald test provided good evidence that the association between rank of IMD and injury differed by ethnic group. Therefore, it appears that whether the relationship between deprivation and injury differs by ethnic group is sensitive to the specification of the deprivation variable (e.g. rank or decile). This suggests that care should be taken in interpreting the finding from the further analyses that there are no ethnic differences in the relationship between deprivation and injury.

7.3 IMPLICATIONS FOR THE ROLE OF THE 'GROUP DENSITY' HYPOTHESIS IN EXPLAINING OBSERVED RELATIONSHIPS BETWEEN ETHNICITY, DEPRIVATION, AND CHILD PEDESTRIAN INJURY IN LONDON.

Sections 7.1 and 7.2 explored whether observed relationships between ethnicity, deprivation and child pedestrian injury rates could be explained by 'group density' effects. Findings from these sections provide strong evidence of a negative association between ethnic density and 'Black' child pedestrian injury. There was weak evidence of a negative association between ethnic density and 'Asian' child pedestrian injury and no evidence of an association between ethnic density and 'White' child pedestrian injury. These results indicate that for 'Black' children (and to some extent 'Asian' children), exposure to the road environment entailed less risk in areas where a larger proportion of the resident population was of a similar ethnicity. 'Group density' effects, therefore, do appear to play some role in child pedestrian injury risk.

Notably, results from the previous sections also suggest that adjusting for ethnic population density in models of the relationship between deprivation and injury rates changes the nature of those relationships for 'Black' children. Relationships between area deprivation and injury among 'White' and 'Asian' children were similar before and after ethnic population density was introduced. Among

‘Black’ children, models indicated that there was no relationship between area deprivation and injury before ethnic population density was introduced as an independent variable. After the introduction of ethnic population density, however, there was a relationship of increased injury rates with increased deprivation. Further, after accounting for ethnic population density, relationships between deprivation and injury appeared broadly similar across ethnic groups.

Section 1.3 of this thesis introduced a social epidemiological ‘puzzle’ of why area affluence does not protect ‘Black’ children from pedestrian injury. Comparing the relationships shown in Figure 1.1 with the relationships displayed in Figure 7.1 (in models that account for ethnic density), the social epidemiological puzzle seems to have been resolved. Indeed, findings from section 7.2 indicate that after accounting for ethnic population density, there is no evidence that the relationship between decile of deprivation and pedestrian injury differs by ethnic group.

Given that ‘Black’ children in London tend to live in deprived areas, findings from sections 7.1 and 7.2 may suggest that ethnic density helps protect ‘Black’ children against the increased injury risk associated with deprivation. These findings may, therefore, help to explain why ‘Black’ children face similar injury risks across the city (Figure 1.1). Consequently, it is tempting to conclude that the ‘group density’ hypothesis ‘solves’ the social epidemiological puzzle of why area affluence does not protect ‘Black’ children. However, the finding of no difference in the relationship between area deprivation and injury by ethnic group has been shown to be sensitive to the specification of the deprivation variable. Models using rank of IMD rather than decile of IMD suggested that although relationships appear broadly similar across ethnic group, differences still remain. These findings therefore must be interpreted with care.

While ‘group density’ effects do appear to have changed the relationship between area deprivation and injury among ‘Black’ children, they do not appear to have influenced these relationships among ‘Asian’ children. As shown in Figure 7.1, the relationship between decile of deprivation and ‘Asian’ child pedestrian injury in models that do not account for the proportion of residents who are ‘Asian’ are virtually identical to the relationship in models that do account for ethnic population density. This is an interesting finding, as it suggests that ‘group density’ mechanisms may be driving relationships between area deprivation and injury among some minority ethnic children but not all. It is possible that the broad ethnic grouping ‘Asian’ may contribute to these findings: the ‘Asian’ group used in this thesis included children likely to be of Indian, Pakistani and Bangladeshi origin, among others. Findings from section 7.2 may have underestimated the influence of ‘group density’ trends for some of these groups and overestimated the influence for others. Further implications of using the broad groupings of 'White', 'Black' and 'Asian' in this chapter have already been discussed in Research Paper 5.

While this chapter was able to quantify associations between ethnic population density and injury and establish that 'group density' effects are likely to play a role in child pedestrian injury risk, it was not able to clarify how 'group density' mechanisms work to protect minority ethnic children from injury. Future work could explore how psychosocial factors such as social capital, social networks and shared cultural experiences relate to injury risk. Qualitative explorations of how the ethnic make-up of an area shapes experiences of walking, playing or 'hanging out' may help to illuminate 'group density' mechanisms.

Despite these limitations, this chapter provides evidence that 'group density' effects protect 'Black' (and to some extent 'Asian') children from pedestrian injury risk in London. Findings also suggest an explanation for why 'Black' children face similar risks of injury across London: the higher proportion of 'Black' residents in deprived areas protects 'Black' children from risk.

8 DISCUSSION

This thesis investigated a series of hypotheses to explain observed differences in ethnic patterns in injury rates in London. In particular, it has explored the role of exposure in explaining why ‘Black’ children in London have relatively high pedestrian injury rates; why ‘Asian’ children have comparatively lower pedestrian injury rates; and finally, why area affluence does not have the same protective effect on the pedestrian injury risk of ‘Black’ children as it seems to have for ‘White’ and ‘Asian’ children. Sections 9.1-9.3 of this chapter discuss the evidence for each of these topics in turn; Section 9.4 presents a brief summary of key findings; Section 9.5 discusses strengths and limitations of the methods used in this thesis; and Sections 9.6 and 9.7 discuss the implications of the findings of this thesis for future research and injury prevention policy.

8.1 WHY DO ‘BLACK’ CHILDREN HAVE HIGHER PEDESTRIAN INJURY RATES?

The introduction to this thesis set out the social epidemiological puzzle of ethnic differences in child pedestrian injury risk in London. Why are ‘Black’ children’s injury rates 50% higher than ‘White’ children’s? A long-standing weakness in injury epidemiology is inadequately conceptualising and measuring exposure to injury risk (Wing 1994). Directly confronting these challenges, Chapters 3-6 explored hypotheses relating to exposure in explaining the relatively high injury risks of ‘Black’ children in London.

Chapter 3 investigated whether ‘Black’ children have higher injury rates because the roads in their neighbourhoods were more hazardous. Findings from a literature review suggested that road hazard levels are an important mediator of injury risk generally, with features of the road environment such as high traffic volumes, high traffic speeds, and visual obstructions associated with increased pedestrian injury risk. To examine whether levels of road hazards were higher in areas where ‘Black’ children live in London, ecological analyses compared the distribution of available features of the road environment to the ethnic distribution of London’s child population. Main analyses at a small area level provided no evidence that ‘Black’ children live in areas that are more hazardous than their ‘White’ and ‘Asian’ counterparts. Further, a sensitivity analysis using larger areas suggested that a larger proportion of ‘Black’ children in London live in local authorities that are characterized by *less* hazardous road environments, including areas with lower traffic volumes, higher residential status and lower traffic speeds. It therefore seems unlikely that differences in the hazard levels of local roads can help explain the relatively high pedestrian injury rates among ‘Black’ children.

Chapter 4 examined whether the higher pedestrian injury rates of 'Black' children were due to greater amounts of walking to school and other destinations. Analyses of travel diary data in London suggested that 'Black' children walk slightly more to school, but less to destinations outside school. Across the year, analyses suggested that 'Black' children walk similar amounts of times and distances as 'White' children. Therefore, there was no evidence that differences in the amount of walking can help explain the relatively high injury rates among 'Black' children.

Methodological limitations meant that this thesis could not quantitatively examine whether these relatively high pedestrian injury rates were due to greater amounts of exposure to the road environment during leisure activities. Qualitative analyses, however, suggested many different ways that children might be exposed to pedestrian injury during their leisure activities (Appendix 7). Speculatively, there are many factors that could potentially lead to higher levels of leisure time exposure among 'Black' children but these cannot be quantitatively measured using current methodological tools.

Chapter 5 explored whether 'Black' children's relatively high injury rates were visibility-related, caused by differences in drivers' inability to see 'Black' versus 'White' children at night. While findings suggested that features of the natural environment such as light levels, rainfall and temperature were associated with child pedestrian injury, there was no evidence that these associations differed between 'White' and 'Black' children. Therefore, there was no basis for suggesting that the higher rates of injury among 'Black' children can be explained by differences in visibility in the natural environment.

Given the difficulties in measuring leisure time exposure and the methodological limitations of exposure measurement in Chapters 3, 4 and 5, Chapter 6 examined the sensitivity of results on ethnic differences in injury rates in London to controls for the quality and quantity of exposure. Analyses limited injury rate calculations to the morning commute during term time, when all children must make a journey to school, and when leisure time exposure such as playing or 'hanging out' is likely to be minimal. Results suggested that inequalities in injury rates between 'Black' and 'White' children increased after the introduction of one control for of exposure. This suggests that differences in the quantity of pedestrian exposure are unlikely to explain the higher risks of 'Black' children. Further, almost all features of the road environment appeared to influence the risk of pedestrian injury among 'Black' and 'White' children in a similar way[1]. Considering these findings

[1] The notable exception to this is traffic speeds which were associated with increased injury in 'White' and 'Asian' children (p=0.007 and p=0.001 respectively) and decreased injury in 'Black'

together with the results from Chapter 3 (which indicate that 'White' and 'Black' children live in areas with similar road environments), the *quality* of pedestrian exposure is unlikely to explain the relatively high risk of injury among 'Black' children.

Overall, then, findings from Chapters 3-6 provide little evidence that the relatively high pedestrian injury rates among 'Black children are due to ethnic differences in the quality or quantity of pedestrian exposure.

8.2 WHY DO 'ASIAN' CHILDREN HAVE LOWER INJURY RATES?

While investigations found little evidence that an exposure-related hypothesis could explain the higher rates of injury among 'Black' children, evidence was more mixed on whether the quality and quantity of exposure could explain the lower rates of 'Asian' children. Chapter 3 found no evidence that the road hazard levels in areas where 'Asian' children live differ from areas where 'White' children live at a small area level. Further, sensitivity analyses at a larger area level suggested that a higher proportion of 'Asian' children live in local authorities characterized by *more* hazardous roads, including higher traffic volumes and medium traffic speeds. Therefore, there was no evidence that differences in the quality of the road environment could explain lower rates of injury among 'Asian' children.

Theoretically, if 'Asian' children do live in more hazardous areas, and children or their parents perceive these increased hazard levels, this may suggest that 'Asian' children are comparatively less likely to (be allowed to) walk to destinations or play and 'hang out' in the road environment near their homes. That is, the quantity of pedestrian exposure among 'Asian' children may be comparatively low. Chapter 4 explored ethnic differences in the quantity of pedestrian exposure during travel time.

Chapter 4 provided some evidence that 'Asian' children walk less to school and other destinations than 'White' children, which may indicate lower levels of pedestrian exposure. This thesis was

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children ($p<0.001$) in Chapter 6. In Chapter 7, however, models of ethnicity, deprivation, road environment features and injury which also included variables describing ethnic population density produced different results. In these models speed was associated with decreased injury risk in 'White', 'Asian' and 'Black' children ($p=<0.001$, $p=0.081$, and $p=0.001$ respectively). Reconciling these sets of findings is challenging. More research is needed to address the potential for traffic speeds to influence the injury risks of 'White', 'Asian' and 'Black' children in different ways.

unable to shed light on the ways in which 'Asian' children may have lower levels of pedestrian exposure during leisure time. However, previous work has suggested that experiences of racism may lead these children to prefer indoor activities (Steinbach et al. 2007). If 'Asian' children do live in areas with more hazardous road environments as described in a sensitivity analysis in Chapter 3, this may also contribute to preferences for indoor activities during leisure time. Therefore, lower levels of travel time exposure and, more speculatively, lower levels of leisure time exposure, may help to explain lower rates of injury among 'Asian' children.

Chapter 5 found some evidence that 'Asian' children are less likely than their 'White' and 'Black' counterparts to be injured during rainy conditions. These findings may indicate that 'Asian' children are less likely to be outside when it rains. For 'Asian' children, then, preferences for outdoor activities may have a role in mediating their exposure. There was no evidence, however, that light levels had a different association with pedestrian injury among 'Asian' compared to 'White' children. Different levels of visibility in the road environment, therefore, cannot explain lower rates of injury among 'Asian' children.

After controlling for the quality and quantity of pedestrian exposure, Chapter 6 found that inequalities in injury between 'Asian' children and 'White' children increased, albeit slightly. That is, injury rates among 'Asian' children during the morning commute were even lower when compared to 'White' children, than during all times of the day. There was, however, some question as to whether the morning commute provides a reasonable control for the quantity of exposure among 'Asian' children, since evidence from Chapter 6 and Chapter 4 suggested that 'Asian' children may walk shorter distances to school compared to 'White' children. These findings, therefore, must be interpreted with care.

Overall, results from Chapters 3-6 indicate that lower quantities of pedestrian exposure among 'Asian' children may play some role in explaining their relatively low rates of pedestrian injury.

8.3 WHY DOESN'T AREA AFFLUENCE PROTECT 'BLACK' CHILDREN FROM INJURY?

In line with 'good practice' guidelines on epidemiological research into ethnicity and health (Bhopal 1997), my initial explorations into ethnic differences in injury rates in London focused on structural associations between 'Black' ethnicity and area deprivation (Steinbach et al. 2010). As described in Chapter 1, these explorations uncovered an unanticipated result: while increasing levels of deprivation were linked to higher injury risk among 'White' and 'Asian' children, the relationship did not hold for 'Black children. Instead 'Black' children faced similar injury risks across London. Aim 2 of this thesis set out to explore why the area deprivation-injury risk association appeared to be different for 'Black' children compared to others.

Chapter 3 began the search for answers to this puzzle by examining the quality of the road environment in London's more deprived neighbourhoods. The analyses found little evidence that the city's more deprived areas had more hazardous roads. Additionally, there was little difference in the hazard levels of neighbourhoods where 'White', 'Black' and 'Asian' children live. These findings suggest that the quality of the road environment cannot explain why rising levels of deprivation are associated with increasing injury among 'White' and 'Asian' children, much less why this relationship does not hold for 'Black' children.

Chapter 4 explored whether differences in travel time exposure could help explain relationships, using data from routine travel surveys in London. Findings were limited by small sample sizes (of 'Black' children living in relatively affluent areas in particular), but provided no evidence that the relationship between deprivation and quantity of pedestrian travel time exposure differs by ethnicity. Methodological challenges meant that this thesis was unable to examine whether these relationships were related to leisure time exposure.

To address whether exposure was driving the observed relationships between ethnicity, deprivation and injury in light of the methodological difficulties faced in earlier chapters, Chapter 6 attempted to limit the influence of exposure by restricting analyses to the morning commute. Controlling for the quality and quantity of exposure in this way changed the nature of observed relationships: there was a relationship of increasing levels of deprivation and *decreased* injury risk among 'Black' children. Given that the relationship changed, these findings suggest that the quality and quantity of exposure do play some role in associations between ethnicity, deprivation and injury. However, differences in exposure do not appear to explain why area affluence does not protect 'Black' children from injury. Instead, it appears that the mechanisms linking exposure to ethnicity, deprivation and injury are more complex than originally conceptualised in this thesis.

Restricting analyses to the morning commute provided a reasonable control for the quantity of exposure among 'Black' children, and models included features of the road environment to control for the quality of exposure. However, these controls were not able to capture potential differences in the meaning of exposure. It is plausible that the experience of walking, playing or 'hanging out' in the road environment differs by ethnicity and level of area deprivation. Findings also pointed to another potential hypothesis to explain relationships: '*group density*' effects. Psychosocial factors, such as stigma or lack of social integration, may change the meaning of being exposed to the road environment for 'Black' children living in areas with relatively few 'Black' residents in ways that increase their injury risk.

In Chapter 7 I used injury and population data from two census periods to explore whether 'group density' effects could help explain observed relationships between ethnicity, deprivation and injury. Findings not only indicated a strong negative association between the proportion of the resident population that was 'Black' and 'Black' child pedestrian injury rates: accounting for ethnic population density also changed the relationship between deprivation and injury among 'Black' children. When regression models adjusted for ethnic population density, risk to 'Black' children no longer appeared different than their 'White' and 'Asian' counterparts. Instead, as area deprivation levels increased, so, too, did injury risk among 'Black' children. In other words, when models included ethnic population density, the area deprivation-injury risk association among 'White', 'Asian' and 'Black' children was largely the same. Given that 'Black' children in London tend to live in deprived areas, these findings, therefore, may suggest that higher proportions of 'Black' residents may buffer the adverse effects of increasing area deprivation on 'Black' child pedestrian injury. In this thesis, then I have been able to suggest an answer to the question of why area affluence does not protect 'Black' children from injury. The higher rates of injury among 'Black' children in affluent areas may be related to *the meaning of being exposed in neighbourhoods where few others are 'like you'*.

8.4 SUMMARY

To summarise, this thesis was able to identify the quality and quantity of pedestrian exposure as important mediators of child pedestrian injury risk. There was however, little evidence that differences in exposure can explain the relatively high injury rates among 'Black' children in London. There was some evidence that lower levels of pedestrian exposure may contribute to the lower rates of injury among 'Asian' children. The quality and quantity of exposure cannot explain why area affluence does not protect 'Black' children from injury risk. However, this thesis suggests that accounting for ethnic population density changes the relationship between area deprivation and pedestrian injury among 'Black' children such that it appears similar to the relationship between area deprivation and pedestrian injury among 'White' and 'Asian' children. 'Group density' mechanisms may then help to explain why area affluence does not appear to protect 'Black' children from injury risk.

8.5 STRENGTHS AND LIMITATIONS

This thesis analysed secondary data sources to investigate hypotheses to explain ethnic patterns in injury rates in London. Despite shortcomings of individual data sources, secondary analyses largely provided an opportunistic and efficient way to address my research questions. All of my investigations, however, faced both conceptual and methodological limitations which have largely been discussed in the individual chapters. It is useful, however, to highlight two general shortcomings. First, the focus of this thesis on the relationships between injury and 'ethnicity' (rather than other ways of characterising children) may have falsely emphasised the importance of 'ethnicity' in determining injury risk. Secondly, the broad definitions of 'ethnicity' in this thesis limits the usefulness of findings in both research and policy.

A wide-ranging limitation of this thesis and indeed all research into inequalities in child pedestrian injury, is that the very act of researching particular inequalities risks reifying and reproducing certain social categories. Ethnicity, by its nature, is a social construct, and only exists because society collectively accepts that ethnicity is a useful way of distinguishing people. Research into ethnic inequalities not only reflects political or societal interest in 'ethnicity', it also serves to reproduce ethnicity as a way of defining people. Arguably, the scientific connotations of 'research' may even lend legitimacy to characterising people in this way.

By identifying and exploring differences in injury rates by ethnicity rather than other ways of differentiating people, this thesis may have contributed to the problematisation of some social categories (such as 'Black'), while 'naturalising' others (for instance, 'male'). This thesis did not investigate inequalities in injury by other demographic variables such as age and gender which Chapter 1 reported have also been identified as indicators or markers of child injury pedestrian risk. Nor did it explore interactions between ethnicity and gender, or ethnicity and age. It is possible that ethnic patterns of injury (or ethnic patterns of exposure to road hazards) in London differ by gender or age group. Understanding how ethnicity interacts with age and gender to produce potentially different patterns of injury or exposure could prove illuminating. Future work could examine these interactions.

Methodologically, the broad groupings of ethnicity into 'White', 'Black' and 'Asian' used in my thesis were necessary in order to reliably compare data from multiple data sources. However, as noted in Chapter 2, analyses using broad definitions of ethnicity may have emphasised between-group differences, which may facilitate racial stereotypes. Broad definitions like the ones in this thesis may also have masked with-in ethnic group differences. Work on other health outcomes has suggested real differences in specific health outcomes between Indian and Pakistani and Bangladeshi communities (Kelly et al. 2006). Differences in health outcomes between Caribbean and African populations have also been reported (Panico et al. 2007). In my thesis, I did not explore patterns of child pedestrian injury at this more detailed level.

This is a particular limitation of Chapter 7, where my research aimed to investigate the impact on child pedestrian injury risk of living in an area where many people share the same culture, social capital and social networks. Including potentially diverse groups in broad categories could possibly have diluted the psychosocial benefits of living in areas with people 'like you'. Alternatively, analyses may have underestimated strong 'group density' effects for some ethnic groups within these groupings, and missed negative associations for others.

This methodological limitation has real consequences for the policy implications of this research. These broad groupings of 'White', 'Black' and 'Asian' are unlikely to represent any real communities in London. From a policy perspective then, these broad groupings can't provide recommendations on which communities should be emphasised for injury prevention efforts.

My thesis also has a number of strengths. Most work inequalities in injury (and health outcomes in general) is unable to adequately account for potential differences in exposure due to conceptual and measurement problems. A key strength of this thesis was that it was able to address these challenges head on. Findings from Chapter 6 underscore the importance of adequately considering exposure in risk research, by suggesting that accounting for exposure can change relationships between injury events and risk.

Given that ethnic inequalities in child pedestrian injury have already been identified, this thesis was able to examine the contribution of number of different mechanisms, helping to open up the black-box (Senior and Bhopal 1994) linking ethnicity to child pedestrian injury risk. While more work is necessary to understand the mechanisms driving inequalities more fully, my research has been able to rule out unhelpful explanations such as the 'conspicuity' hypothesis, and to provide a focus for future research.

8.6 IMPLICATIONS FOR FUTURE RESEARCH

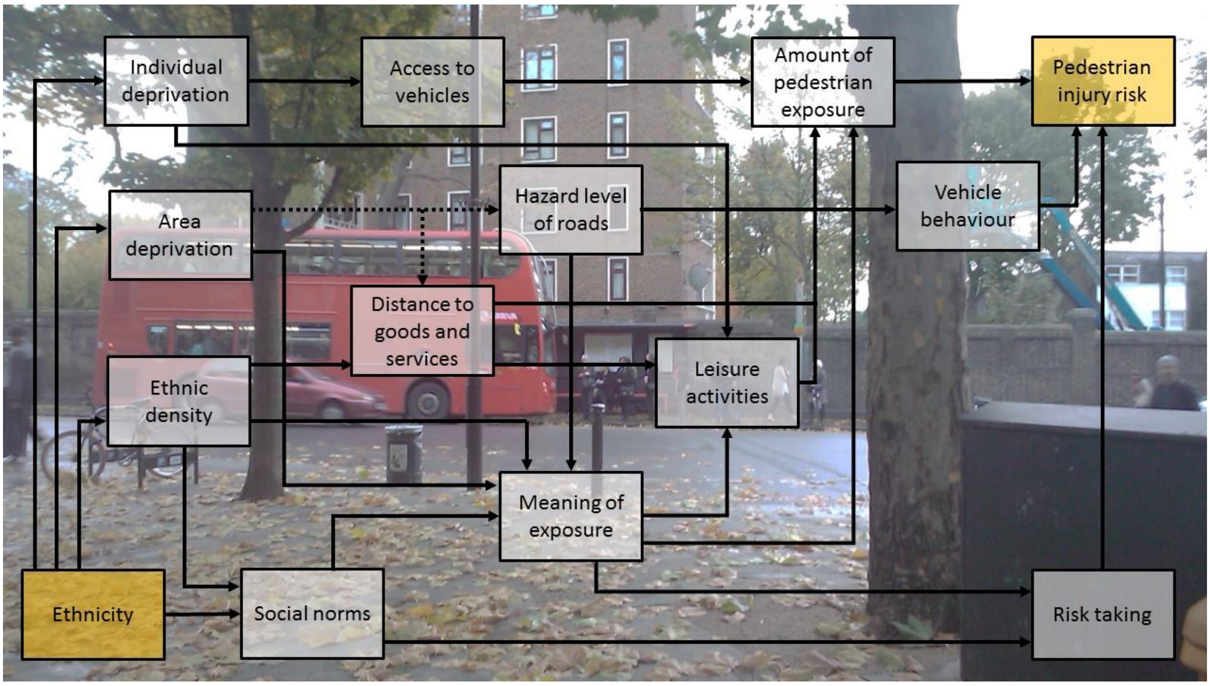
Overall findings from this thesis have three main implications for research. First, pathways linking structural and identity elements of ethnicity to child pedestrian injury risk are more complex than originally conceptualised. Secondly, complex and interrelated pathways suggest that investigations of individual causal mechanisms to explain ethnic inequalities in injury risk may provide diminishing returns. Finally, more qualitative work is needed to gain a better understanding of the mechanisms linking structural and identity elements of ethnicity in different environments to both pedestrian exposure and pedestrian injury. These implications are summarised in Box 8.1 at the end of the section.

8.6.1 Complex casual pathways

Findings throughout this thesis suggest that my conceptualisation of the link between ethnicity and pedestrian injury risk outlined in Figure 1.2 is overly simplistic. Instead, relationships are more complex. Chapter 6, for example, describes my finding that 'Black' child pedestrian injury rates actually decrease in areas of relatively high deprivation, after controlling for the quality and quantity of exposure. Such a finding suggests that while exposure does indeed play a role in the pedestrian injury risk of 'Black' children, that role is not as simplistic as the one outlined in the introduction of this thesis. In fact, injury risk is not just related to the level of exposure or the hazard levels of roads where that exposure occurs. The meaning of exposure in different physical and social environments also appears to play a role.

Based on the findings of this thesis, figure 8.1 outlines my current, more nuanced understanding of the relationships between ethnicity, exposure and pedestrian injury. As my thinking has evolved, new elements have been added to figure 8.1, including vehicle behaviour, the meaning of exposure, access to vehicles, distance to goods and services, and ethnic density. Other elements, such as "Culture" and "Behaviour on roads", have been re-conceptualised. The remainder of this section discusses each of the elements and pathways linking ethnicity and pedestrian injury risk in my current understanding of relationships.

Figure 8.1 Revised hypothesised links between ethnicity and pedestrian injury risk



Similar to Figure 1.2, Figure 8.1 links both structural and identity elements of ethnicity to pedestrian risk. Structural links between ethnicity and individual deprivation can lead to increased pedestrian injury risk through two pathways. Children from deprived households may have less access to vehicles leading to greater levels of walking for transport. Indeed, the analysis of travel diary data in Chapter 4 found that one variable — no access to vehicles — was the most salient predictor of time and distance walked among children in London. Individual deprivation can also affect the types of leisure activities available to children. Children from deprived households may be less able to participate in leisure activities which rely on money (such as cinemas) and therefore more likely to participate in the types of leisure activities that expose them to pedestrian injury (such as wandering around the streets) (Appendix 7).

Findings from this thesis suggest that structural links between ethnicity and area deprivation may lead to increased pedestrian injury risk but through multiple and more complex pathways than the ones identified in Figure 1.2. The introduction of this thesis posited that the road environment in more deprived areas may be more hazardous than road environments in more affluent areas. Chapter 3, however found no evidence that hazard levels of roads were greater in deprived areas in London. This may suggest that a link between area deprivation and hazard levels of roads should be omitted from the re-conceptualised diagram in Figure 8.1. On the other hand, one cannot conclude that there is evidence of no association between area deprivation and hazard levels from Chapter 3's finding. It is an epidemiological truism that no evidence for an association is not the same as evidence of no association. It is plausible that measurement limitations in Chapter 3 resulted in missed associations between area deprivation and the road environment. To reflect this uncertainty I have represented the pathway between area deprivation and hazard levels of roads with a dotted line.

The literature review in Chapter 3 provided evidence of an association between hazard levels of roads and pedestrian injury risk. To reflect a more systems approach to conceptualising pedestrian injury risk (as suggested in Chapter 7), I have included a new element, vehicle behaviour, as one of the mechanisms linking hazard levels of roads to pedestrian injury risk. This thesis did not investigate links between hazard levels of roads and vehicle behaviour. Theoretically, hazard levels of roads may encourage or discourage certain types of driving behaviour, which, in turn, can influence pedestrian injury risk. Future research could focus on whether different types of road environments prompt different types of vehicle behaviours (such as speeding or different levels of driver attention).

Hazard levels of roads may also influence the meaning of pedestrian exposure. The meaning of pedestrian exposure is a new and crucial element to the causal diagram, motivated from findings in

Chapters 7-8 and Appendix 7. The meaning of exposure is a rather broad concept which, I will suggest is an important area for future research. Here, I use it to encompass the experience of walking, playing or 'hanging out' in the road environment in terms of both the affective feelings of being a pedestrian (i.e. how it feels to be a pedestrian in a particular environment) and, the social meaning of being a pedestrian (i.e. what your presence as a pedestrian in particular environment area says about you). I have hypothesized that the meaning of pedestrian exposure can influence pedestrian injury risk through three pathways: amounts of pedestrian exposure, leisure activities and risk taking. Links between the meaning of exposure and amount of exposure are clear cut: if walking in a particular area is a pleasant experience, individuals may increase their amount of pedestrian exposure. Alternatively if walking is unpleasant, individuals may travel by other modes or avoid particular neighbourhoods.

What it means to be a pedestrian can also influence children's choice of leisure activities in the road environment. Children play and 'hang out in the road environment during their leisure time to accomplish many different 'goals' (such as socialising with friends, escaping boredom, and forming and reproducing social identities) in ways that can expose them to pedestrian injury (appendix 7). The meaning of being a pedestrian in a particular environment can help enhance these leisure time 'goals'. For instance, walking down a high street with a group of friends can accomplish a 'goal' of escaping boredom. How it feels to be a pedestrian in this context with the spectacle of the city (including many shops and large crowds) is part of the appeal of this leisure activity. To give another example, presence as a pedestrian in a particular area with certain social meanings can help signal particular identities to peers or others. 'Hanging out' outside a shop where the 'popular' kids 'hang out' can help identify a child as part of the 'popular' social group. This meaning is again, part of the appeal of the activity. Children, therefore, can capitalise on the different meanings of exposure to help them achieve their leisure time goals.

Different meanings of pedestrian exposure can also influence how likely children are to take risks in the road environment. Risk taking is similar to the concept of 'behaviour on roads' present in Figure 1.2. However, as my thinking on pedestrian injury risk has developed over the thesis, I felt it was important to be more specific. The element risk taking in Figure 8.1 is comprised of conscious and unconscious risks children take in the road environment. Theoretically, meanings of pedestrian exposure can influence aspects of risks such as how quickly or slowly children cross roads, whether children are likely to travel with others, and whether conscious risk taking is appealing (as suggested in appendix 7). Future research could explore how different meanings of pedestrian exposure influence risk taking.

Turning back to links between hazard levels and the meaning of pedestrian exposure, features of the road environment investigated in Chapter 3, such as traffic speeds and volumes, and pedestrian footpaths can influence the experience of walking, playing or 'hanging out' on a particular road and what it means to participate in those activities.

The level of deprivation in an area is also directly linked to the meaning of exposure. Walking through a deprived area can be a very different experience than walking through a more affluent area (Bostock 2001). For instance, associations between deprivation and crime may lead to "unsafe" feelings among child pedestrians. Alternatively, some children may use their presence as a pedestrian in a deprived area to bolster "brave" or neighbourhood specific identities. These associations between area deprivation and the meaning of exposure may change amounts of exposure and/or risk taking behaviour leading to differences in pedestrian injury risk.

Another pathway links area deprivation to the distance children must travel to access goods and services including school, shops, and other services. If children living in deprived areas must travel further than children in more affluent areas to access services, then area deprivation may well lead to greater amounts of pedestrian exposure. Chapter 4 found no evidence that children living in deprived areas walk further or longer than children from more affluent area, so I have again included this pathway as a dotted line. Distances to goods and services may also influence availability of various leisure activities, which can in turn influence amounts of pedestrian exposure.

Ethnic density is another new element in Figure 8.1 motivated by findings in Chapter 7 which may link ethnicity and child pedestrian injury risk. Both structural and identity elements of ethnicity are linked to the ethnic density of an area. Structural elements such as poverty, experiences of racism or neighbourhood segregation more broadly may lead to high concentrations of ethnic minorities in particular areas. Alternatively, ethnic minorities may choose to live in areas with others with similar ethnic identities because of psychosocial benefits (such as shared values and social networks) or proximity to desired services. Findings from Chapter 7 confirmed that ethnic density is associated with pedestrian injury risk among 'Black' and to a lesser extent 'Asian' children but was unable to examine mechanisms linking ethnic density and pedestrian injury risk. As suggested in Figure 8.1, speculatively I believe ethnic density is linked to pedestrian injury risk in two ways: through access to goods and services and social norms. Children living in areas with greater proportions of people from a similar ethnic background may have to travel shorter distances to access culturally appropriate goods and services (such as churches or hairstylists) compared to children living in other areas, which may lead to lower levels of pedestrian exposure.

Ethnic density can also influence social norms, a new element to the causal diagram. I have used the element 'social norms' in Figure 8.1 to reconceptualise the inadequate catch all term "Culture" from Figure 1.2. In this diagram I have conceptualised social norms to be the unwritten rules that define appropriate beliefs, values, attitudes and behaviour in social groups. These social groups can include ethnic groups (indeed the bottom pathway in Figure 8.1 links ethnic identities to social norms at an individual level) but also other types of social groups (those defined by gender, income, religion, etc). I hypothesize that social norms are linked to ethnicity not only at the individual level but also linked to ethnic densities at the area level. For instance, the concentration of certain ethnic groups in an area can influence attitudes towards discrimination or people from different ethnic groups.

In this diagram I hypothesize that social norms can relate to pedestrian injury risk through two mechanisms: the meaning of pedestrian exposure and risk taking. Many different types of social norms can influence what it means to be a pedestrian. To give just a few examples, norms around appropriate hours for children to be on the streets can change the meaning of exposure during different types of the day. Social attitudes towards different schools can change the meaning of being a pedestrian dressed in a particular school uniform (Appendix 7). Social values around different transport modes can affect whether walking is a low-status mode of travel (compared to say cars) which can alter the experience of walking. As discussed above the meaning of pedestrian exposure can be linked to pedestrian injury through leisure activities, amounts of pedestrian exposure and risk taking. Future research could explore how social norms are linked to the experience of beings a pedestrian.

The bottom pathway in Figure 8.1 links social norms to risk taking. As suggested in Chapter 1 attitudes towards risk, parental norms around child protection practices, or peer norms around walking, playing or hanging out can lead to different levels of risk taking in the road environment and therefore pedestrian injury. Notably, the natural environment has been omitted from my revised causal diagram as Chapter 5 provided no evidence that ethnic differences in risk are related to light levels.

Figure 8.1 is necessarily intricate reflecting that the pathways linking ethnicity to pedestrian injury risk are multiple and complex. Elements along the causal pathways may interact or counteract each other in ways that influence injury risk, which may present real challenges for research. The next two sections highlight some of these challenges and provide a focus for future research,

8.6.2 Individual casual mechanisms

This thesis investigated a number of individual causal mechanisms linking 'Black' ethnicity to higher pedestrian injury rates. And while I was able to rule out certain factors as the likely culprit -- such as skin colour -- I was not able to uncover conclusive evidence to definitively explain higher injury risk among "Black' children. This may in part be due to the imperfect way 'ethnicity' was operationalised in this thesis, which was largely constrained by ethnicity definitions in quantitative data sets. Findings were further hampered by difficulties in measuring 'exposure'. But perhaps the most salient limitation of this thesis was that investigations were unable to examine ways that mechanisms might be inter-related.

Chapter 7, for example, outlined the difficulties in disentangling the relative contributions to injury risk of the road environment, exposure levels and behaviour. This limitation is not unique to this thesis. Other work which addresses explanations for ethnic inequalities in injury risk also tends to focus on one particular mechanism in isolation [see for instance work by Roberts and colleagues (1996) on quantities of pedestrian exposure and work by Chen and colleagues (2012) on ethnic differences in individual risk behaviour]. Empirical investigations of mechanisms are exacerbated by the well documented difficulties in conceptualising and measuring ethnicity, the 'hazardousness' of local roads, 'exposure' and behaviour, leading researchers to use imperfect proxies. However, even if these challenges could be adequately addressed, the complexities of these relationships (as outlined in Figure 8.1) and the ways in which mechanisms are inter-related arguably suggest that investigating individual mechanisms may produce diminishing returns.

As suggested in Chapter 7, a broader focus on the 'system' may prove more fruitful than investigations of individual causal pathways. System approaches advocate that health patterns emerge from dynamic inter-related components operating at different levels of influence. Systems can be complex, with heterogeneous and inter-dependent components, non-linear associations, balancing and reinforcing feedback mechanisms, and emergent properties (Galea, Riddle, and Kaplan 2010, Koopman and Lynch 1999). There have been increasing calls for public health to adopt system approaches particularly in the area of health disparities (Diez Roux 2011, Homer and Hirsch 2006). Diez Roux (2011) notes that in system approaches "because the effect of a given input depends on other conditions in the system, emphasis shifts from isolating the casual effect of a single factor to comprehending the functioning of the system as a whole" (Diez Roux 2011: p1627).

In the case of inequalities in child pedestrian injury, Figure 8.1 provides a useful first step in taking a 'systems' approach to inequalities in risk. However, now the focus must shift from quantifying ethnic differences in risk (i.e. the left-most and right-most parts of Figure 8.1), to exploring how different elements of Figure 8.1 interact at different levels of influence to link ethnicity and injury risk (i.e. how the middle part of the diagram works). Thinking more explicitly about these dynamic processes has the potential for a step change in our understandings of pedestrian injury risk. The next section highlights the case for future qualitative work to contribute to this approach.

8.6.3 The role of qualitative work

Many, if not most, of the pathways outlined in Figure 8.1 were necessarily speculative. Much more work is needed to unpick the mechanisms suggested in Figure 8.1. Based on the findings of this thesis, I believe qualitative research has an important role to play in furthering understandings. For instance, this thesis was unable to explore mechanisms linking ethnicity to leisure activities. As detailed earlier quantitative examinations are not possible with current methodological tools (Appendix 7). However, even if quantitative analyses were able estimate (say) the number of minutes children from different ethnic groups spend playing or 'hanging out' in the road environment, they would not be able to give any information about why differences occur. Qualitative work could play a useful role in identifying the mechanisms linking ethnicity to leisure activities.

In addition, while Chapter 7 was able to identify a 'group density' effect on 'Black' child pedestrian injuries, quantitative explorations were unable to identify how 'group density' mechanisms work to reduce injury. Here too, qualitative work is needed to unpack how psychosocial factors such as stigma and social integration affect not only exposure levels of minority ethnic children but also the meaning of being exposed in different environments.

Indeed, given that this thesis suggests that the meaning of pedestrian exposure is a key mechanism linking structural and identity elements of ethnicity to pedestrian injury risk, exploring both the social meaning of exposure and how it feels to be a pedestrian in different social and physical environments are a research priority. This could help shed light on the hypothesised pathways linking the meaning of pedestrian exposure to social norms, risk taking and amounts of pedestrian exposure. More broadly, using qualitative research to inform a 'systems' approach may help shake up current thinking about how ethnicity relates to injury risk.

In summary, findings from this thesis have a number of implications for research (Box 8.1). The work presented in Chapters 3-8 have led me to conceptualise links between ethnicity and pedestrian injury risk in a new way (Figure 8.1) suggesting complex and inter-related casual pathways. Quantitative explorations of individual mechanisms are unlikely to illuminate pathways linking ethnicity to injury risk. In this new conceptualisation the meaning of exposure emerged as a crucial mechanism linking ethnicity to pedestrian exposure and pedestrian injury. The meaning of exposure, however, has been relatively unexplored in pedestrian research. Therefore, more research is needed to understand the social meanings and affective experiences of being a pedestrian in different social and physical environments.

Box 8.1: Implications for research:

- Mechanisms linking ethnicity, pedestrian exposure and pedestrian injury are complex and inter-related.
- Quantitative investigations of individual casual mechanisms in isolation may produce diminishing returns.
- A broader focus on the 'system' and ways in which elements and mechanisms interact may prove more fruitful.
- Qualitative work has an important role to play in unpicking mechanisms, with explorations of social meanings and affective experiences of being a pedestrian as a priority.

8.7 IMPLICATIONS FOR POLICY

Apart from suggesting a new approach to explore ethnic inequalities in child pedestrian injury risk, findings from this thesis also have a number of implications for injury prevention policies. At the outset, it is useful to acknowledge the presence of tensions between strategies to prevent pedestrian injuries and other public health goals. Findings from this thesis (Chapter 4 and Appendix 7) indicate that pedestrian exposure is an important mediator of injury risk. Strategies to lessen pedestrian exposure, such as car-pools or restrictions on leisure activities, may well reduce pedestrian injuries. However, walking, playing and 'hanging out' in the road environment also have real health benefits in terms of physical activity and mental well-being.

Tensions between these health goals have engendered some creative strategies. For example, walking school buses (WSBs), where adults chaperone children to school imparting road safety knowledge, have become a popular strategy to increase physical activity and extend children's geographies while maintaining their safety in the road environment (Kingham and Ussher 2007). While these strategies do appear to address these public health aims, they also have some disadvantages. WSBs characterise walking as an inherently dangerous activity that children need to do ‘correctly’ to avoid injury, and road environments as inherently dangerous locations where motor vehicles have priority. This may make walking, playing or ‘hanging out’ in these environments less attractive, which argues that young people may miss out on the health and well-being benefits of these activities. Critics of WSBs have suggested that upstream interventions that challenge the hegemony of motor vehicles by making environments more pleasurable and less hazardous for children are a more useful way of addressing these tensions (Kearns, Collins, and Neuwelt 2003). Especially pertinent to this discussion is the research from Chapter 3, which found that the quality of the road environment is an important mediator of injury risk. The findings suggest that interventions which seek to make road environments less hazardous may be successful in reducing child pedestrian injuries without harming health and well-being goals. Findings from Appendix 7, which indicate that young people are exposed to injury in various ways during their leisure time, underscore the importance of interventions to make road environments less hazardous in areas where children are likely to play and ‘hang out’.

There is good evidence from London (Grundy et al. 2009) and many countries around the world (Bunn et al. 2009) that physical measures to slow traffic speeds to 20 mph can reduce road traffic injuries. Not only can these types of interventions reduce injuries overall, there is some evidence that they address inequalities in injuries when targeted at deprived areas (Steinbach et al. 2011). As ‘Black’ children disproportionately live in deprived areas, reducing hazard levels in deprived areas may also help to reduce ethnic inequalities in injury.

While interventions that address the road environment seem capable of preventing injuries and potentially reducing injury inequalities, interventions targeting the behaviour of young people in the road environment are less promising. Young people (sometimes purposefully) expose themselves to road hazards during their leisure time as a way of both expressing their identities and resisting overly structured lives imposed on them by adults (Appendix 7). It seems unlikely then, that educational campaigns, which seek to make young people aware of the road hazard risks they face, will effectively reduce injury. If challenging ‘what they are supposed to do’ is what young people are tacitly trying to accomplish by creating mobility related risks in the road environment, then imposing more ‘structure’ on how they should behave in public is unlikely to deter them from creating these risks. Indeed, as detailed in a systematic review, research has been unable to detect a discernible impact of educational campaigns on road injury risk (Duperrex, Bunn, and Roberts 2002).Further, unlike physical measures, targeting behaviour-related interventions to those at highest risk poses genuine concerns. There may be some benefits in raising awareness of child pedestrian injury as a problem in some communities. But targeting education strategies at, for instance, ‘Black’ children may potentially blame the victims and frame child pedestrian injury as 'their problem' (Steinbach et al. 2007). Work examining other injury related safety practices has suggested that intervention strategies targeted at deprived areas may not be able to successfully reduce inequalities among 'Black' and ethnic minority families perhaps due to differences in risk perceptions, supervisory practices, or the 'learning value' of injuries (Kendrick, Mulvaney, and Watson 2009). This suggests that interventions to reduce inequalities in injury would need to be culturally appropriate. Given that the mechanisms linking, for instance, 'Black' ethnicity to pedestrian injury remain poorly understood, it is difficult to conceptualise how to devise programmes to appropriately address 'Black' children.

Box 8.2: Implications for policy and practice:

- Pedestrian exposure has real health benefits in terms of physical activity and mental well-being.
- Interventions which reduce pedestrian exposure may reduce injury but will also reduce the health and well-being benefits of walking, playing or 'hanging out'.
- Interventions which seek to make road environments less hazardous may be successful in reducing child pedestrian injuries without harming health and well-being goals.
- Targeting interventions which address the road environment at deprived areas may help to reduce socioeconomic inequalities in pedestrian injury risk.
- As 'Black' children disproportionately live in deprived areas, reducing hazard levels in deprived areas may also help to reduce ethnic inequalities in injury.
- Educational strategies are unlikely to reduce injury, and targeting these at ethnic minority groups is victim blaming and should be avoided

Implications for policy and practice emerging from this thesis are summarised in Box 8.2. Rather than restrict children's activities or introduce more rules on how they should behave, the findings from this thesis suggest that interventions which aim to make exposure less hazardous have the potential to reduce both inequalities in child pedestrian injury and injuries overall. Interventions in the environment that restrict the movement of vehicles, rather than the movement of pedestrians, arguably put the burden of reducing injuries where it belongs: on the cause rather than the recipient of harm.

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APPENDIX 1: 'RACE' OR PLACE? EXPLAINING ETHNIC VARIATIONS IN CHILDHOOD PEDESTRIAN INJURY RATES IN LONDON

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COVER SHEET FOR EACH 'RESEARCH PAPER' INCLUDED IN A RESEARCH THESIS

1. For a 'research paper' already published

1.1. Where was the work published? **Health & Place**

1.2. When was the work published? **2010**

1.2.1. If the work was published prior to registration for your research degree, give a brief rationale for its inclusion**: this article provides useful background information on ethnic inequalities in injury rates. Because it was completed prior to registration it is included in an Appendix.**

1.3. Was the work subject to academic peer review? **Yes**

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I designed the study with Judith Green, Phil Edwards and Chris Grundy. I formatted data for analysis, analysed the data and drafted the manuscript. I revised the manuscript based on comments from Judith Green, Phil Edwards, and Chris Grundy.

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SUPERVISOR'S SIGNATURE: P Edwards

'RACE' OR PLACE? EXPLAINING ETHNIC VARIATIONS IN CHILDHOOD PEDESTRIAN INJURY RATES IN LONDON

ABSTRACT

There is a substantial literature on socio-economic inequalities in injury rates, but less on ethnic differences. Using police records of road injuries to examine the relationships between pedestrian injury, area deprivation and ethnicity we found that, in London, children categorised as 'Black' had higher injury rates than those categorised as 'White' or 'Asian', and that living in less deprived areas did not protect 'Black' children from higher risk. Ethnic differences in injury rates cannot be explained by minority ethnic status or area deprivation, but are likely to result from the complex ways in which ethnicity shapes local experiences of exposure to injury risk.

Word Count: 103 words

INTRODUCTION

Despite declines in rates of injury over the last twenty years, road traffic injuries remain a major contributor to childhood mortality and morbidity in high income countries (WHO, 2004). This burden is not distributed equally, with studies in a number of countries documenting persisting inequalities in the risk of injury and death (Laflamme and Diderichsen, 2000; Reimers and Laflamme, 2005; Rivera and Barber, 1985; Edwards et al, 2008). In the United Kingdom (UK), local and national studies have identified higher pedestrian injury rates in areas characterised by high levels of deprivation (Grayling et al, 2002; Lyons et al, 2003; Edwards et al, 2008). Analysis of injury mortality data (Edwards et al, 2006) suggests that there are particularly steep socio-economic gradients for child pedestrians.

To date, there has been far less epidemiological research on ethnicity and road injury risk, and the findings are less clear cut than those on deprivation. Although many international studies suggest that minority ethnic groups are at higher risk than the majority population (Schiff and Becker, 1996; Campos-Outcalt et al, 2002; Stevens and Dellinger, 2002; Cecarelli and Knuiman, 2002; Braver, 2003; Stirbu et al, 2006; Savitsky et al, 2007), others have identified some minority groups at lower risk (Campous-Outcalt et al, 2003). Within the UK, one case control study found 'non-white' children at higher risk (Christie, 1995), and one local study found 'Asian', but not other ethnic minority, children at higher risk of road traffic injury (Lawson and Edwards, 1991). There are a number of national and regional policy incentives for examining whether there is evidence for ethnic inequalities in injury in the UK, with statutory agencies charged with reducing inequality in health outcomes by targeting those at highest risk and working with communities to develop appropriate services (Department of Health, 2003; Mayor of London, 2008). Nearly half of all non-white ethnic minorities in the UK live in London, and more than one in three London residents belong to a minority ethnic group (Bains and Klodawski, 2006). Transport for London, the body responsible for delivering the Mayor of London's transport strategy (Mayor of London, 2001) commissioned this study in response to concerns about whether road safety gains were being shared equally across London's diverse population.

Research on the relationships between ethnicity and health outcomes presents conceptual, methodological and practical challenges. There is now a growing body of evidence documenting ethnic differences in health outcomes in the UK (Marmot et al, 1984; Davey Smith et al, 2000; Nazroo, 2001; Erens et al, 2001) but, as Bhopal (1997) has cautioned, there is a real risk of 'black box epidemiology' if we merely document 'differences' between poorly defined and conceptualised groupings. To be useful for policy and practice in addressing inequalities in health, research needs to be directed at not only documenting inequalities, but unpacking the mechanisms which potentially link components of ethnicity with particular health outcomes. This is a challenge on a number of levels. First, a priori assumptions of ethnic differences may bias research efforts towards looking at how minority ethnic groups compare (poorly) to majority populations and, as Bradby (2003) notes, acknowledging discrimination whilst not perpetuating it is difficult. Second, as an epidemiological variable, ethnicity is inherently problematic. Ethnicity, referring to 'the identification with a social group … on the basis of shared values, beliefs, customs, language and lifestyle' (Nazroo, 2004: 13), includes components related to nationality, skin colour, country of origin of self and ancestors, and religion. As a multidimensional and fluid concept, with meanings influenced by both historical value systems and the current social and political context (Bradby, 2003), ethnic identities are of course time and place specific. The ways in which ethnicity potentially influences health outcomes theoretically relate to these aspects of identity, but also (more plausibly, for many health outcomes) to ethnicity as 'structure' (Karlsen and Nazroo, 2002), including components such as associations with socio-economic factors and experiences of racism.

A MODEL OF POTENTIAL LINKS BETWEEN ETHNICITY AND CHILD PEDESTRIAN INJURY RISK

In terms of conceptualising how ethnicity might relate to pedestrian injury as an outcome, there are a number of potential causal pathways relating to ethnicity as both 'structure' and 'identity'. The determinants of the relative risk of being injured as a pedestrian include three factors: the road environment (how many roads and junctions, the volume and speed of traffic); an individual's exposure to that environment (how often they are on or near the road as a pedestrian); and their behaviour on or near roads. These three factors are inter-related, in that behaviour and levels of exposure are to some extent determined by the perceived dangerousness of the road environment. Figure 1 summarises some of pathways by which ethnicity might influence these variables.

[Figure 1 about here]

First, ethnicity is often associated with deprivation, both at area level and individually, at household level. A long standing debate in research on ethnicity and health has been the extent to which observed differences reflect socio-economic inequalities (Nazroo, 1998, 2001; Davey

Smith, 2000; Ahmad and Bradby, 2007). At an area level, given the known associations between injury and area deprivation (Edwards et al, 2008), and the fact that ethnic minorities tend to live in more deprived areas in the UK (Prime Ministers Strategy Unit, 2005), with particularly steep gradients in London (Table 1), any differences found in pedestrian injury by ethnicity might simply be a reflection of area effects relating to local road environments. Evidence suggests that a higher density of major roads, high vehicle speeds, high junction density, the presence of parked cars, the presence of bus stops, low minor road density, high employment density, and low residential population density are associated with increased pedestrian injury risk (Noland and Quddus, 2005; Grayling et al, 2002; Agran et al, 1996; Roberts et al, 1995). Thus ethnicity may be merely a proxy for the area effects of 'place', if minority ethnic communities live in areas more likely to have these road environments.

However, it is also known that injury risk is associated independently with individual, or household, socio-economic deprivation as well as area effects (Reading et al, 1999; Haynes et al, 2003). At the household level, associations with injury risk have been found for both number of parents in the household (Haynes et al, 2003) and employment status (Edwards et al, 2006). These variables are also likely to vary across ethnic groups. Pedestrian exposure is likely to be an important mediator of relationships between deprivation and risk, with Sonkin et al (2006) finding, for instance, higher levels of walking in households with unemployed adults, in rented rather than owner-occupied accommodation and in households with no access to a car. Within the UK, there are large ethnic differences in household car availability, with the National Travel Survey (Department for Transport 2006) identifying highest rates of car ownership in those of Indian and White British background (86 and 82 per cent respectively) and lowest in those of African or Caribbean background (54 and 62 per cent respectively).

Other candidate explanations relate to causal pathways that link cultural components of ethnicity to risk. 'Culture' is a rather inadequate catch-all term for those aspects of lifestyle that might be shared within ethnic groups, but it could be hypothesised that for instance, different ethnic identities may be associated with factors that directly influence injury risk, such as different attitudes to risk taking (which might influence road crossing behaviour) (see for example, Factor et al, 2008), or different preferences for leisure activities (such as those centred on outdoor, public space exposed to traffic risk). These 'cultural' factors may of course be mediators of deprivation effects, in that differential access to indoor space or private gardens may shape preferences for outdoor activity, and structural factors may make risk taking behaviour more prevalent. From a policy perspective, candidate explanations which relate to behaviour or cultural preferences are perhaps less interesting, for two reasons. First, they often relate to factors that are less amenable to social intervention, given the limited evidence for the effectiveness of educational interventions directed at changing behaviour compared with interventions addressing the road environment (Duperrex et al, 2002; Bunn et al, 2003). Second, even if interventions were effective in changing behaviour, it might well be inappropriate to do so. A higher propensity to enjoy outdoor activity, for instance, is likely to bring health benefits as well as health risks. The challenge is to provide an environment in which such activities can be done without incurring additional risk, rather than to reduce children's use of outdoor space.

The aims of this study were driven to a large extent by policy needs. There was a desire to identify whether there were ethnic inequalities in outcomes, and the first aim was therefore to identify whether it was possible, using available data sets, to identify credible evidence of differences in pedestrian injury rates by ethnicity. Second, given that there is a considerable amount of evidence that interventions addressing the road environment are the most effective for reducing injuries (Bunn et al, 2003; Morrison et al, 2003) we aimed to identify how far any differences by ethnicity could be explained by area deprivation. If area deprivation accounted for any differences found across ethnic groups, inequalities could potentially be ameliorated through policies to prioritise deprived neighbourhoods for traffic interventions.

MEASURES OF ETHNICITY

A major challenge to such a study is that the problems of inadequate conceptualisation of ethnicity lead directly to difficulties in operationalisation for empirical research. Population denominator data come from self-identified fixed response categories used in the decennial census, which reflect the multiple ways in which British minority ethnic groups are differentiated (by skin colour, ethnic identity, religion and nationality, for instance). This strategy is subject to limitations given that fixed response census categories can neither reflect the contextual nature of claims to particular ethnic identities, nor adequately capture mixed ethnic identities. A more significant practical challenge is that few routine data sets in the UK utilise the same categories. The most comprehensive data source for health care use, Hospital Episode Statistics (HES), which records admissions to National Health Service hospitals, only utilised comparable codes to those of the Census from 2001, and there are wide variations in terms of completeness of coding and historically a high proportion of missing ethnic codes (around 36%) for under 15 year olds (HES Online, 2004).

An alternative for examining road traffic injuries is STATS19 data, from police records of road collisions. STATS19 is the official dataset of personal injury road collisions and resulting casualties that occur on the public highway in the UK. Although data on the ethnicity of persons involved in road traffic collisions is not available for most of the UK, London Metropolitan police officers have recorded the ethnicity of casualties since 1995. Initially, these data appear of limited value. The measure of ethnicity used is the six-category Police National Computer 'Identity Code', which is designed for description for crime detection and prevention, rather than monitoring, purposes (ACPO, 2001). The categories (Table 2) rely on observer identification of physical attributes, rather than on self-identification, as in the census. It is unknown how, in practice, London's police officers do distinguish people as, for instance, 'Dark skinned European' or 'Arab'. These categories certainly do not reflect how most people would define their own ethnicity, and there are no population level data that use them. Despite these weaknesses, STATS19 data do have a number of advantages compared with HES data. They have a reasonable coverage of ethnicity, and may be less subject to the selection bias inherent in HES from differences in help-seeking behaviour, which are associated with distance to hospital, deprivation and ethnicity. Given the availability and coverage of STATS19, we were interested to see whether these data could be used to examine the relationships between ethnicity, area deprivation and road environments.

METHODS

We obtained an extract of STATS19 data from the London Road Safety Unit that included all reported casualties and collisions occurring in London during 1996–2006. Where possible, we removed non-London residents (e.g. visitors) using their postcode of residence. Casualties were included in the analysis if aged 0 to 15 years and injured as pedestrians. Each casualty was assigned to a lower super output area (LSOA) based on the Ordnance Survey grid reference of the location where the collision occurred. LSOAs are geographic areas containing an average of 1,500 people, defined by the Office of National Statistics using measures of population size, mutual proximity and homogeneity. There are 4,765 LSOAs in London, within 33 boroughs. Collision location was used in the analysis due to the low levels of completeness of recording home postcodes in some boroughs, and because children are known to be injured as pedestrians close to home (Edwards et al, 2007). LSOAs in the City of London were excluded from the analysis as this borough tends to have a large day-time population and a small resident population. The level of deprivation of each LSOA was scored using the Index of Multiple

Deprivation 2004 (IMD) (Noble et al, 2004). LSOAs were ranked according to IMD score and divided into deciles (1 least deprived to 10 most deprived).

POPULATION ESTIMATES AND RATES

To derive population rates, we first mapped the majority of the STATS19 categories pragmatically to aggregated groupings used by the Greater London Authority, which are drawn from the 2001 Census categories that are most common in London (Table 2) (Bains and Klodawski, 2006). We then derived three broad categories of ethnicity, which we have called 'White', 'Black, and 'Asian', based on these mappings of STATS19 codes to aggregated census categories. We also conducted a sensitivity analysis to compare the results from alternative mappings of STATS19 codes to census categories. Age specific population data are not available at LSOA level by ethnic group, so the population of 'White', 'Black', and 'Asian' children in each LSOA was estimated by multiplying the numbers of children resident in each LSOA by the percentages of residents of all ages that are 'White', 'Black', or 'Asian' (both from the 2001 Census). The estimates of LSOA-level ethnic group child populations were then scaled to sum to the available borough level totals, to allow for ethnic differences in family size.

ROAD ENVIRONMENT AND AREA CHARACTERISTIC VARIABLES

Based on evidence from the literature, we selected available road environment and area characteristic variables with known associations with injury risk. These included: density of road junctions, A roads and minor roads in the LSOA, the proportion of postcodes in an LSOA characterized as business, and the area (in square metres) of an LSOA. Information on vehicle speeds and traffic flows is only available at borough level and is unlikely to reflect accurately the road environment in each individual LSOA. These borough level variables were not therefore included in the main model, but were included in a sensitivity analysis. To create variables describing the road environment in an LSOA, and in adjacent LSOAs, current road network information from the Integrated Transport Network (ITN) supplied by Ordnance Survey was overlaid with LSOA boundaries provided by the census in ArcView GIS. Borough-level estimates of traffic flow and traffic speeds were provided by Road Network Monitoring, Transport for London.

STATISTICAL ANALYSIS

Negative binomial multivariable regression was used to estimate models of the number of children of each ethnic group injured as pedestrians in each LSOA. We estimated injury rate ratios, with 95% confidence intervals, comparing rates in each decile of LSOAs with the rate in the least deprived decile, adjusting for road environment and area characteristic variables (*see statistical appendix for details of model specification*). Robust standard errors were used to allow for within-borough correlations in LSOA injury rates. Finally, a likelihood ratio test of two Poisson regression models of pedestrian injury risk, one including a term for interaction between deprivation and ethnicity, and the other excluding the interaction term, was used to assess whether the relationship between deprivation and injury was similar across ethnic groups. Approval for the study was obtained from the London School of Hygiene & Tropical Medicine Research Ethics Committee.

RESULTS

Between 1996 and 2006 there were 22,121 pedestrian causalities aged 0–15 years recorded in London (excluding City of London), with 11,206 identified as 'White', 5,400 as 'Black', 2,511 as 'Asian' and 477 as either 'Arab' or 'Oriental'. A total of 2,527 (11%) casualties had missing ethnicity codes. Based on our initial pragmatic mapping, average annual pedestrian injury rates were higher in 'Black' children (176 per 100,000 children; 95% confidence interval 172 to 181), than in either 'White' children (118 per 100,000 children; 95% CI 116 to 121) or in 'Asian' children (91 per 100,000 children; 95% CI 88 to 95).

The size of these ethnic differences was changed using alternative groupings of STATS19 codes and census derived categories. For example: when the STATS19 category 'Dark Skinned European' was excluded from the 'White' group, the rate decreased to 109 (95% CI 107 to 111) per 100,000 children; when 'Arab' and 'Oriental' were included in the 'Asian' group, the rate increased to 109 (95% CI 105 to 113) per 100,000; when 'Dark-skinned European' was included in the 'Asian' group, the rate increased to 124 (95% CI 120-128) per 100,000. However, rates in the 'Black' group remained higher than all other ethnic groupings in all except one mapping. When records with missing ethnicity codes were included in the 'Asian' group, the rates in the 'Asian' group, 184 (95% CI 179-189) per 100,000, became equivalent to that in the 'Black' group, 176 (95% CI 172-181) per 100, 000.

[Full details are available from the web].

THE RELATIONSHIP BETWEEN INJURY RISK AND DEPRIVATION FOR EACH ETHNIC GROUPING

Based on our pragmatic grouping of ethnicity categories, Figure 2 shows pedestrian injury rates by deprivation decile separately for each ethnic group, unadjusted for road environment variables. In least deprived deciles, 'Black' child pedestrian injury rates were highest, and in the two most deprived deciles 'Black' and 'White' child pedestrian injury rates were similar. The pedestrian injury rates in 'Asian' children were lower than in either 'Black' or 'White' children across all deprivation deciles.

After adjusting for road environment and area characteristic variables, we looked separately at the relative risks for pedestrian injury across deprivation deciles for each ethnic grouping (Figure 3). For 'White' pedestrians, there was a linear relationship between deprivation and injury rates, with the rate in the most deprived decile 2.90 (95% CI 2.53 to 3.32) times higher than that in the least deprived decile. For 'Asian' child pedestrians, there was a similar relationship between deprivation and injury risk, with the rate in the most deprived decile 2.34 (95% CI 1.70 to 3.21) times that in the least deprived decile. However, for 'Black' children, no relationship was observed between deprivation and injury rates, with no evidence for a difference in rates between the most deprived and least deprived deciles (rate ratio 1.01; 95% CI 0.75 to 1.37).

The relationship between child pedestrian injury and deprivation in the 'White' and 'Asian' groups was not substantially changed when using alternative mappings of the STATS19 ethnic codes. There was good evidence, from the test for interaction, that the relationship between level of area deprivation and injury rates differs by ethnic group ($p<0.001$). There was a reasonably good fit of our model to the data for 'White' child pedestrian injury (Pearson chi-squared=4921, residual degrees of freedom=4745). The fit for 'Black' child pedestrian injury and 'Asian' pedestrians was less good (Pearson chi-squared=5720 and 5740, with 4730 and 4738 residual degrees of freedom, respectively).

THE EFFECT OF ROAD ENVIRONMENT AND AREA CHARACTERISTICS

Table 3 shows the effect of the road environment variables and area characteristics on child pedestrian injury independently of area level deprivation for the three ethnic groupings. The results indicate some evidence that density of A roads in LSOAs (i.e. kilometres of A roads per hectare) was associated with increased injury rates, whereas the density of minor roads was associated with decreased injury risk for all three ethnic groupings. An increase in the proportion of postcodes in an LSOA characterized as 'business' was associated with higher injury rates in children from all three ethnic groups. There was good evidence that higher junction density was associated with higher injury rates in 'White' children. Including borough level data on morning speeds of A roads and traffic flow in the models did not change the model coefficients; that is, relationships between injury and deprivation, road and area variables were unchanged. There was weak evidence that higher speed was associated with increased injury risk in 'White' and 'Asian' children, but decreased injury risk in 'Black' children (results not shown).

DISCUSSION

We have used STATS19 data first to estimate the rates of pedestrian injury for three broad ethnic groupings of children in London and then to examine the relationship between deprivation and injury risk separately for each ethnic grouping. A common threat to validity in research on ethnicity is numerator-denominator bias, given the reliance in most studies on data from different recording systems for numerators and denominators. Much of the evidence on mortality and ethnicity from the United States, for instance, uses coroner recorded ethnic and race categories, (see for instance Stevens and Dellinger, 2002; Campos-Outcalt et al, 2002; Campos-Outcalt et al, 2003; Braver, 2003), with known problems in reliability when assessed against self-report data for many ethnic groups (Briggs et al, 2005). Even where the same classification systems are used, it is not known how far self-reported ethnicity is reliable over different locations (such as health care facilities and census completion). Given that our denominators were from census population estimates and numerators were derived from police-assigned classifications of what is essentially a measure of observed 'race' rather than ethnicity, and there are no data on how police decisions might relate to self-identified ethnic identity, numerator-denominator bias is a particular threat in this study. We addressed this possible limitation by first deriving a pragmatic mapping of STATS19 ethnic codes to census derived categories, and then testing the robustness of our results by using alternative mappings. These alternatives were more conservative in terms of potentially over-estimating the apparently high rate of 'Black' casualties or under-estimating the lower rates of 'White' and 'Asian' groups. The results suggest that caution is required when comparing the rates of 'White' and 'Asian' child injuries. This is perhaps unsurprising given the difficulty of identifying ethnic identities from observed physical characteristics in ways that are likely to correspond to self-defined ethnicity. However, the alternative mappings do not appear to substantively change the inferences about either the higher 'Black' rates or the differential effect of deprivation on relative risks across the ethnic groups. For some ethnic groupings, there may be a large enough degree of overlap between self and observer identified categories to derive reasonably reliable population rates at a crude level of aggregation. We can therefore be fairly confident that we have identified a higher rate of pedestrian injury in 'Black' children in London compared with others. Alternative mappings also did not substantively change the findings that pedestrian injury rates increase with area deprivation in 'White' and 'Asian' but not 'Black' children, and that these relationships remain after controlling for those features of the road environment that we could measure.

A further cause of numerator-denominator bias might be due to assigning casualties to the LSOAs in which they were injured, rather than to those in which they live (a necessary step due to incomplete postcodes). Although location of collision is a reasonable proxy for location of residence for children in general (Edwards et al, 2007), there may of course be ethnic differences in typical distances travelled by children. If, for instance, 'Black' children who live in deprived areas are more likely to attend schools further away from home than are their 'White' or 'Asian' neighbours, this could partially explain why we observed higher 'Black' child pedestrian injury rates than expected in less deprived areas.

A second potential threat to reliability is data completeness. It is estimated that 30% of London's road traffic injuries go unreported, and that across the UK 20% of traffic injuries are unrecorded in STATS19 (Ward et al, 2006). If there are between-group differences in the reporting of traffic injuries, this may affect the overall relative differences by ethnicity. However, this under-reporting and under-recording of injuries in STATS19 will only affect our analysis of the relationships between area deprivation, ethnicity and risk if the within-ethnic group propensity to report or record an injury differs by area deprivation. To account for the different patterns of association between deprivation and injury risk in the 'Black' and other ethnic groupings, this would entail injuries to 'Black' child pedestrians (compared to other groups) being relatively over-reported if they occur in the least deprived areas, and relatively under-reported in the most deprived areas. As this may be an unlikely, but not impossible, scenario, we conducted a sensitivity analysis including only those children killed or seriously injured, where reporting biases are less likely to be a threat. The relationship between deprivation and serious injury risk was found to be similar to that using all injuries among 'White' and 'Black' children. There were not enough killed or seriously injured 'Asian' child pedestrians to make similar comparisons.

The most plausible mediators of area effects on injury risk are those relating to the local road environment, and this was confirmed by our study. Our model included those variables known to be related to road injury risk, including the density of A roads (on which the majority of injuries in London occur), density of minor roads, density of road junctions, a measure of residential status and a measure of population density. We found similar results to previous studies: a higher density of A roads, a higher density of road junctions, and more businesses in an area were associated with higher pedestrian injury risk, while a higher density of minor roads was associated with lower injury risk.

There is evidence from broader studies of health and ethnicity that the measure of deprivation chosen makes a significant difference to the level of 'ethnic difference' found (Kaufman et al, 1997; Davey Smith, 2000; Braveman et al, 2001) and that area measures may underestimate the standard of living of minority groups (Davey Smith et al, 2000). The measure of area deprivation used in this study, IMD, may well be prone to these weaknesses, and it is possible that it discriminates less well for 'Black' than other ethnic groups if, for instance, there is less variability between the individual 'Black' households located across different LSOAs than for other groups. Qualitative evidence from studies of housing and social class in London certainly suggests that the relationship between residence and affluence may operate differently across different ethnic groups. Butler and Robson (2003), for instance, in their study of gentrification in Inner London, found few minority ethnic households in the rapidly gentrifying areas they studied, even when located near multi-cultural areas, and Watt (2005) found individual 'marginal professionals' in social housing who may be more affluent, or have different cultural capital, than the majority of residents locally.

WHAT THIS STUDY ADDS

Few studies have examined ethnic differences in pedestrian injury, and the majority of research on ethnicity and transport injury has used mortality data (Schiff and Becker, 1996; Stevens et al, 2002; Campos-Outcalt et al, 2002; Campos-Outcalt et al, 2003; Braver et al, 2003; Stirbu et al, 2006). Deaths are rare, and may be atypical of all injury. Compared with other studies of childhood pedestrian injury, our findings are consistent with a Dutch study (Stirbu et al, 2006) that found that minority ethnic children were at higher risk of pedestrian injury mortality, and an Israeli study that identified a higher risk of road traffic injuries for non-Jewish children but interestingly (as in this study) that this higher relative risk disappeared in areas with lower socio-economic status (Savitsky et al, 2007). There is little literature from the UK. One study from

Birmingham found that Asian children under 10 years were at higher risk as pedestrians, although this difference was not found for other modes of transport, or at other ages (Lawson and Edwards, 1991), suggesting that exposure differences may have explained some of the increased risk. Another UK case-control study compared school children injured as pedestrians with those not injured and found that 'non-white' minority ethnic children were over-represented in the 'injured' group, but was not able to identify the contribution of socio-economic factors to this difference (Christie, 1995). By using police data which included an accurate record of the injury location, we were able to both limit the problem of identifying appropriate population denominators, and to avoid bias from potential population differences in health service use. We have been able to estimate reasonably robust population rates for broad ethnic groupings in London and to examine the contribution of area level deprivation, at the level of LSOA, on the relationship between ethnicity and injury risk.

POSSIBLE MECHANISMS

Our study concurs with most international and UK findings that some ethnic minority children are at greater risk of pedestrian injury. However, there is no consensus about precisely who is at risk. The study from Birmingham, for instance, found Asian but not other minority group children to be at increased risk of pedestrian injury (Lawson and Edwards, 1991) whereas our findings suggest that 'Asian' children in London are at relatively low risk and 'Black' children face an increased risk. This suggests that there is nothing fundamental about belonging to a minority ethnic group *per se* or even to a *particular* minority ethnic group that increases risk of pedestrian injury. However, our results suggest that the high rate for 'Black' children in London is unlikely to be completely explained by artefacts of inadequate measures of ethnicity or by the association between ethnicity and area deprivation. It is perhaps surprising that whereas lower area deprivation appears to protect 'Asian' and 'White' children from injury risk, it has no similar effect for 'Black' children. There are likely to be complex causal pathways that link belonging to particular ethnic groups living in particular environments and higher child injury rates. Further research is needed on the mechanisms that link ethnicity to road injury risk. Household level deprivation, which might vary in ways that are not reflected in area level deprivation measures, could theoretically influence variables such as mode of transport used, or length of time spent travelling to school or leisure activities. Thus differential exposure is one potential mechanism through which either individual deprivation or cultural factors could influence ethnic differences in risk. There is some suggestion in the road environment analysis for the importance of exposure, given the density of A roads was associated with increased injury risk, as these are likely to have higher traffic flows than either B roads or minor roads, creating more opportunities for car-pedestrian collisions. Existing empirical evidence on the relative amount of pedestrian exposure to roads across different ethnic groups in the UK is mixed (Bly et al, 2006). However, if transport mode, amount of time spent travelling and distance travelled do differ by ethnicity and deprivation, different levels of pedestrian exposure may help to explain our results.

IS IT USEFUL TO LOOK AT 'ETHNICITY' AS A VARIABLE?

We have already suggested that our measure of ethnicity is problematic for a study of pedestrian injury risk. Inevitably, in an epidemiological study, the need to aggregate fine-grained choices that could reflect the complexity of ethnicity into broad categories such as 'Black', 'White', or 'Asian' risks masking considerable within-group differences and emphasizing between-group differences. All the broad aggregations we derived collapse a number of population groups that are theoretically very different in terms of likely risks. For instance, rates of car ownership vary across those from Indian, Pakistani and 'Other Asian' backgrounds (Department of Transport, 2006), and the 'White' group includes both UK born individuals and those more recently arrived migrants who may have very different transport mode use. Identifying a high rate of injury among those classified as 'Black' does not identify particular communities which might have disproportionately high rates of injury. Further, without more detailed data on exposure, we have no way of knowing whether this increased risk is the result of greater time exposed as pedestrians, or of behavioural factors. In terms of developing road safety policies that do not exacerbate inequalities in childhood, the aim should be to provide road environments that are safe for the most vulnerable of road users. It is difficult to identify evidence-based interventions which could address such poorly defined groupings as 'Black' children. The implications of the results of this and other studies is that injury risk for particular population groups is unlikely to be generalisable beyond local areas: 'Black' children have been identified as at higher risk in London over the period 1996-2006 but not, for instance, in Birmingham a decade previously (Lawson and Edwards, 1991). Given that area deprivation does increase risk for most population groups, and that the majority of 'Black' child pedestrian injuries do occur in the most deprived areas (simply because this is where most 'Black' children live, as shown in Table 1), road environment improvements that prioritise the most deprived areas are still likely to be the most efficient in terms of strategies to address inequalities. In our dataset, for instance, 36% of 'White' casualties, 48% of 'Asian' casualties and 57% of 'Black' casualties occurred within the three most deprived deciles of LSOAs. However, in terms of understanding the mechanisms that might put some children at greater risk of injury, this analysis by ethnicity is interesting in terms of raising questions for further research that could explore in more detail how exposure to risk might be shaped by ethnicity and place. The key policy challenge remains that of providing safer environments that reduce the risk to vulnerable road users, however often they are exposed to that risk.

CONCLUSION

It is clearly not membership of a minority ethnic group *per se* that puts children at higher risk of being injured, given the different results for different minority groups within this study and compared with others. Furthermore, for those who are at higher risk, it is unlikely to be 'place' of residence that fully explains that additional risk. We cannot, from this secondary analysis, identify what it is about being classified as 'Black' in London that appears to put children at higher risk of road traffic injury than their peers in other ethnic groups, or why living in a less deprived area does not appear to protect them. To do so, we would need more sophisticated understanding of how different components of ethnicity and other structural factors (such as individual deprivation) inter-relate in different places in order to make exposure to injury risk more or less likely for some groups. The measure of ethnicity used in this study was inevitably crude, and not capable of capturing the multiple ways in which ethnic identity is experienced by individuals or communities. Certainly, the aggregations 'Black', 'Asian' and 'White' do not represent any real communities in London, and all three groupings obscure real differences likely to relate to injury risk. However, the overall findings relating to those children identified as 'Black' appeared to be robust. First, 'Black' children appear to be at higher risk than those identified as 'White' or 'Asian'. Second, the well-documented relationship between area deprivation and risk did not hold for the 'Black' children: they do not appear to be protected from pedestrian injury risk by living in less deprived areas.

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COMPETING INTERESTS

None declared.

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Table 1 Average percentages of Lower Super Output Area populations that are 'Black' and 'Asian' by deciles of deprivation (Edwards et al, 2007).

Deprivation deciles	Percentage 'Black' (Standard Deviation)	Percentage 'Asian' (Standard Deviation)
1	1.5 (1)	6.6 (7)
2	2.7 (2)	7.8 (9)
3	4.8 (5)	11.7 (13)
4	6.8 (6)	12.8 (13)
5	9.2 (7)	14.5 (15)
6	11.1 (7)	12.5 (15)
7	13.2 (8)	12.7 (14)
8	16.0 (10)	13.0 (17)
9	20.8 (12)	12.2 (14)
10	23.2 (12)	15.6 (17)

Table 2 Derivations of ethnic groups from mapping of STATS19 ethnicity categories to Greater London Authority (GLA) aggregations of census ethnic group codes

This study	STATS19	GLA (Aggregated Ethnic Group)	Census 2001
'White'	White-skinned European	White	British
	Dark-skinned European		Irish
			Other White
'Black'	Afro-Caribbean	Black Caribbean	Caribbean
		Black African	African
		Other Black	Other Black
			Mixed-White & Black Caribbean
			Mixed-White & Black African
'Asian'	Asian	Indian	Indian
		Pakistani	Pakistani
		Bangladeshi	Bangladeshi
		Other Asian	Other Asian
			Mixed-White & Asian
(excluded from main analysis)	Oriental	Chinese	Chinese
	Arab	Other	Other
		Other Mixed	Mixed-Other

Table 3 Rate ratios showing changes in injury rates associated with road environment and area characteristics of LSOAs

	'White'			'Black'			'Asian'		
Variable	RR	(95% CI)	p- value	RR	(95% CI)	p-value	RR	(95% CI)	p-value
Density† of A roads	1.004	(1.002 – 1.006)	<0.001	1.008	(1.006 – 1.010)	<0.001	1.003	(1.002 – 1.005)	<0.001
Density† of minor roads	0.996	(0.995 – 0.998)	<0.001	0.998	(0.996 – 0.999)	<0.001	0.998	(0.996 – 0.999)	0.002
Density†† of road junctions	1.074	(1.014 – 1.138)	0.015	1.046	(0.977 – 1.120)	0.194	1.013	(0.962 – 1.067)	0.629
Proportion of postcodes characterized as business	1.043	(1.035 – 1.051)	<0.001	1.047	(1.037 – 1.056)	<0.001	1.040	(1.031 –1.049)	<0.001
Area (m^2)	1.000	(0.999 – 1.000)	0.292	1.000	(0.999 – 1.000)	0.346	0.999	(0.998 – 1.000)	0.258

Rate ratios adjusted for area level deprivation (deciles of IMD) and the other variables shown in the table.

† Density measured as kilometres of road per hectare

†† Density measured as number of road junctions per hectare

STATISTICAL APPENDIX

We assumed that counts of road traffic injuries at lower super output area (LSOA) level are generated by a Poisson-like process. As variation in injury counts was found to be greater than a Poisson, we selected a negative binomial regression model to incorporate an overdispersion parameter. In this model the number of child pedestrians injured y_i in LSOA i is defined as follows:

$$y_i \sim Poisson(\mu_i)$$

where

$$\mu_i = \exp(\mathbf{ß}\underline{x}_i + \mathrm{offset}_i + u_i)$$

and

$$e^{ui} \sim gamma(1/a,\ 1/a)$$

Here **ß** are the coefficients of the effect on child pedestrian injuries of the road environment and area characteristics $\underline{x}_i$ in LSOA i, 'offset$_i$' is the population exposed (i.e. the resident child population) in LSOA i, and α is the overdispersion parameter. Robust standard errors were obtained using the 'cluster' command, clustering on borough (n=32), which assumes that child pedestrian injuries are independent across boroughs but not necessarily within boroughs.

Figure 1 A model of causal pathways linking ethnicity to pedestrian injury risk

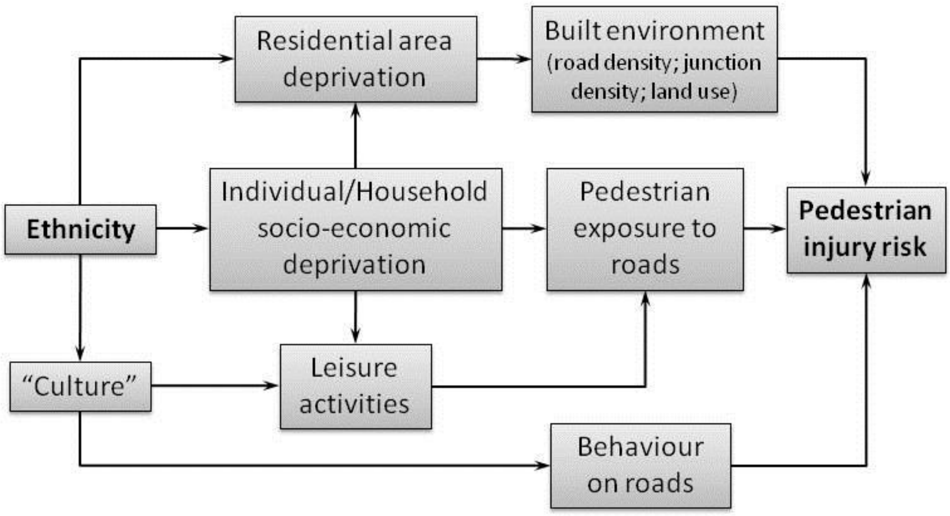


Figure 2 Pedestrian injury rates per 100,000 children by deprivation decile for each ethnic group (unadjusted for road environment variables)

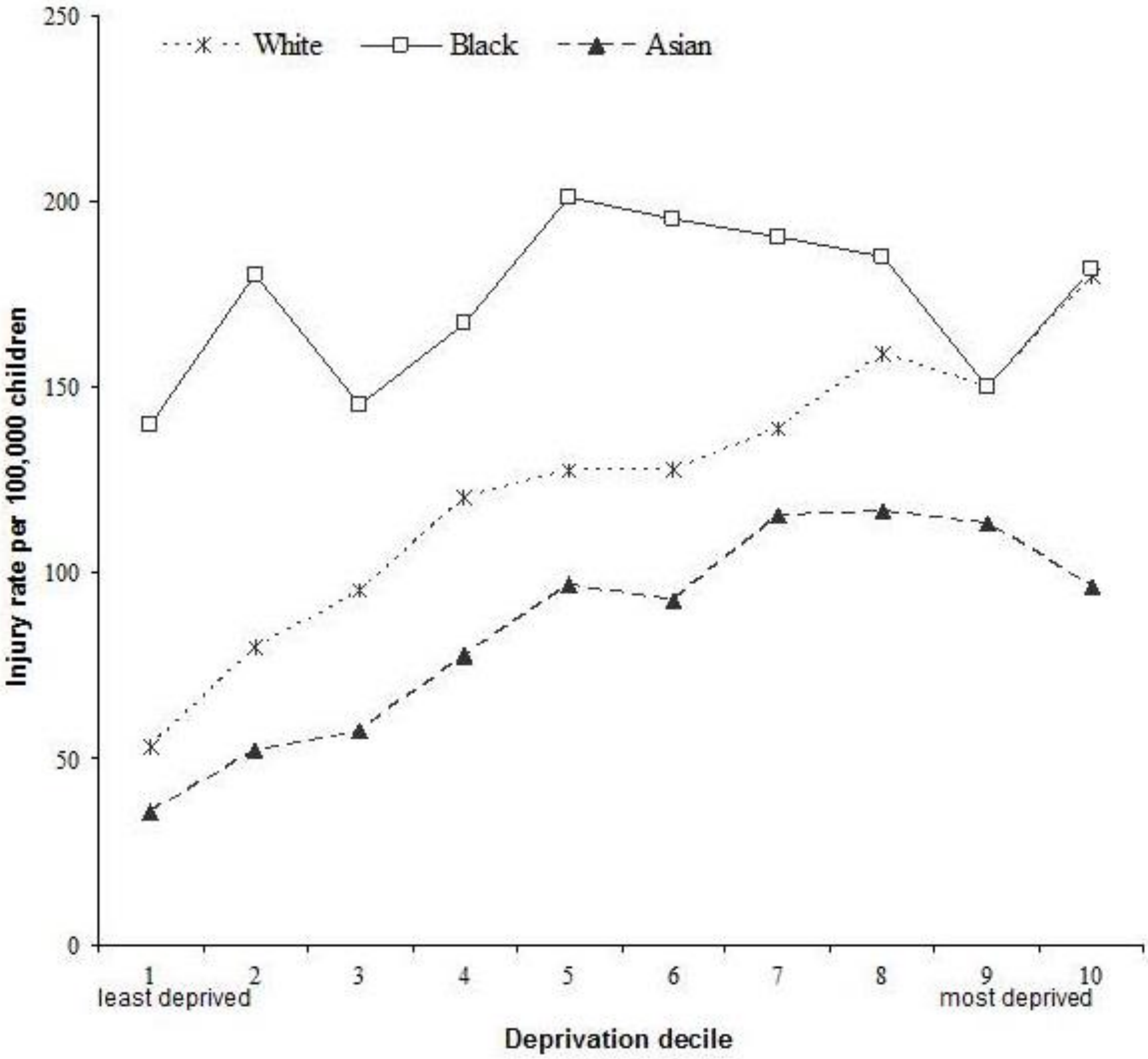
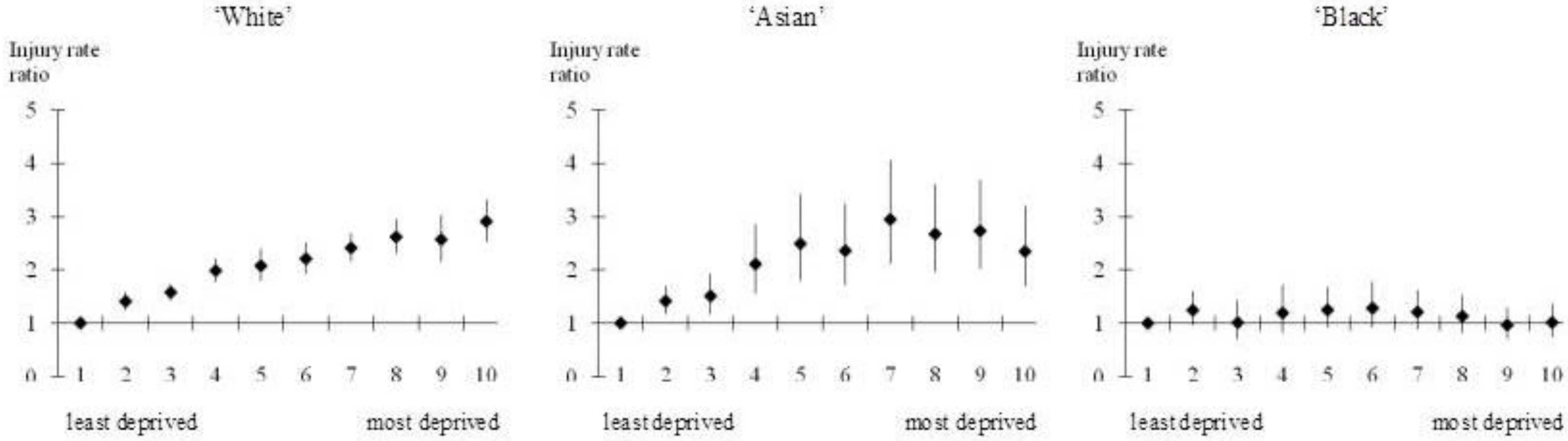


Figure 3 Injury rate ratios comparing pedestrian injury rates by decile of deprivation with that in the least deprived decile (adjusted for road environment variables).



APPENDIX 2: CASUALTY ETHNICITY AND INJURY SEVERITY IN THE STATS19

The STATS19 data set contains information on 438,038 casualties between 2000-2012. Of those casualties, 30,329 (7%) were missing information on age and a further 128 (<1%) were missing data on road user type. Table 1 presents counts of child pedestrian (0-15) casualties by the ethnicity variable, 'identity code' for each year from 2000-2012. Overall, 16% of child pedestrian casualties were missing an identity code. There is some indication that the percentage of child pedestrian casualties missing an identity code is increasing over time.

Table A2.1 Child pedestrian casualties (aged 0-15) 2000-2012 by Identity Code

	White-skinned Europeans		Dark-skinned Europeans		Afro-Caribbean		Asian		Arab		Oriental		Missing		Total
year	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**
2000	1,058	46	105	5	547	24	262	11	27	1	30	1	285	12	2,314
2001	1,055	46	88	4	550	24	249	11	22	1	34	1	299	13	2,297
2002	749	41	82	4	505	28	199	11	23	1	19	1	248	14	1,825
2003	643	39	74	5	457	28	198	12	25	2	14	1	219	13	1,630
2004	636	43	50	3	404	27	173	12	19	1	14	1	197	13	1,493
2005	543	39	53	4	390	28	147	11	14	1	18	1	218	16	1,383
2006	483	39	46	4	318	26	158	13	14	1	12	1	201	16	1,232
2007	435	37	40	3	295	25	134	11	15	1	16	1	250	21	1,185
2008	380	35	46	4	280	26	153	14	8	1	9	1	216	20	1,092
2009	349	33	56	5	297	28	143	14	9	1	13	1	190	18	1,057
2010	383	32	64	5	336	28	155	13	15	1	17	1	238	20	1,208
2011	361	31	38	3	345	29	148	13	12	1	9	1	268	23	1,181
2012	311	30	38	4	274	26	130	12	15	1	26	2	251	24	1,045
Total	7,386	39	780	4	4,998	26	2,249	12	218	1	231	1	3,080	16	18,942

In Stats19 data police record each casualty as a fatal, serious or slight injury. Guidance on collection of STATS 19 data (Department for Transport 2004)indicate that:

- Fatal injuries are casualties who die on the scene of a collision or up to 30 days as a result of the collision.
- Serious injuries are casualties require who require detention in hospital as an 'in patient" either immediately or later, or casualties who sustain one of the following: fracture, internal injury, severe cuts, crushing, severe burns (excluding frictions burns), concussion, severe general shock requiring hospital treatment. Casualties who die more than 30 days as a result of injuries sustained in the collision.

- Slight casualties are casualties that do not fit into the fatal or serious categories. Injuries may include: sprains (not necessarily requiring medical treatment), neck whiplash injury, bruises, slight cuts, slight shock requiring roadside attention.

A recent study has examined how, in practice, police officers do distinguish casualties as fatal, serious and slight (Ward et al. 2010). Findings suggest that when a paramedic is present, officers ask for their judgement when filling out the Stats19 report. In the absence of a paramedic, police officers use previous experience to assess the injury.

Tables A2.2-A2.5 display the number of fatal, serious, and slight child (0-15) pedestrian injuries from 2000-2012 overall and by ethnic group. The distribution of slight, serious and fatal injuries appears relatively similar over time and across ethnic groups.

Table A2.2 Number and percentage of recorded child pedestrian injuries by severity 2000-2012, all ethnicities

	Fatal		**Serious**		**Slight**		**Total**
Year	**n**	**%**	**n**	**%**	**n**	**%**	**n**
2000	16	1%	443	19%	1,855	80%	2,314
2001	14	1%	468	20%	1,815	79%	2,297
2002	11	1%	384	21%	1,430	78%	1,825
2003	7	0%	314	19%	1,309	80%	1,630
2004	8	1%	293	20%	1,192	80%	1,493
2005	11	1%	230	17%	1,142	83%	1,383
2006	11	1%	256	21%	965	78%	1,232
2007	8	1%	243	21%	934	79%	1,185
2008	13	1%	213	20%	866	79%	1,092
2009	4	0%	170	16%	883	84%	1,057
2010	8	1%	181	15%	1,019	84%	1,208
2011	5	0%	170	14%	1,006	85%	1,181
2012	2	0%	209	20%	834	80%	1,045
Total	118	1%	3574	19%	15,250	81%	18,942

Table A2.3 Number and percentage of recorded child pedestrian injuries by severity 2000-2012, 'White' children

	Fatal		Serious		Slight		Total
Year	n	%	n	%	n	%	n
2000	10	1%	242	21%	911	78%	1,163
2001	5	0%	243	21%	895	78%	1,143
2002	4	0%	184	22%	643	77%	831
2003	3	0%	138	19%	576	80%	717
2004	4	1%	138	20%	544	79%	686
2005	3	1%	99	17%	494	83%	596
2006	4	1%	119	22%	406	77%	529
2007	3	1%	105	22%	367	77%	475
2008	6	1%	77	18%	343	81%	426
2009	2	0%	60	15%	343	85%	405
2010	0	0%	72	16%	375	84%	447
2011	1	0%	69	17%	329	82%	399
2012	0	0%	72	21%	277	79%	349
Total	45	1%	1618	20%	6,503	80%	8,166

Table A2.4 Number and percentage of recorded child pedestrian injuries by severity 2000-2012, 'Black' children

	Fatal		Serious		Slight		Total
Year	n	%	n	%	n	%	n
2000	4	1%	100	18%	443	81%	547
2001	3	1%	118	21%	429	78%	550
2002	2	0%	94	19%	409	81%	505
2003	2	0%	91	20%	364	80%	457
2004	0	0%	86	21%	318	79%	404
2005	2	1%	63	16%	325	83%	390
2006	2	1%	65	20%	251	79%	318
2007	1	0%	52	18%	242	82%	295
2008	1	0%	55	20%	224	80%	280
2009	1	0%	52	18%	244	82%	297
2010	4	1%	47	14%	285	85%	336
2011	0	0%	33	10%	312	90%	345
2012	1	0%	47	17%	226	82%	274
Total	23	0%	903	18%	4,072	81%	4,998

Table A2.5 Number and percentage of recorded child pedestrian injuries by severity 2000-2012, 'Asian' children

	Fatal		Serious		Slight		Total
Year	**n**	**%**	**n**	**%**	**n**	**%**	**n**
2000	2	1%	40	15%	220	84%	262
2001	4	2%	48	19%	197	79%	249
2002	3	2%	44	22%	152	76%	199
2003	1	1%	41	21%	156	79%	198
2004	2	1%	33	19%	138	80%	173
2005	2	1%	25	17%	120	82%	147
2006	3	2%	38	24%	117	74%	158
2007	0	0%	26	19%	108	81%	134
2008	2	1%	33	22%	118	77%	153
2009	0	0%	23	16%	120	84%	143
2010	2	1%	17	11%	136	88%	155
2011	0	0%	20	14%	128	86%	148
2012	0	0%	24	18%	106	82%	130
Total	21	1%	412	18%	1,816	81%	2,249

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Appendix 3: How many child pedestrians are injured in the same LSOA in which they live?

Between 2000-2009, 15,508 children aged between 0-15 were injured as pedestrians on London's roads. Of those, 6,469 (42%) were missing information on their location of residence. Table A3.1 illustrates the number and percentage of children who are injured in the same LSOA in which they live (for those with valid information on location of residence). The LSOAs used in this table are based on 2001 census boundaries. There were 4,765 LSOAs in London.

Approximately 70% of 'White', 'Black' and 'Asian' children who were injured within 200 metres of their home were injured in the same LSOA in which they live. However, very few 'White', 'Black' and 'Asian' children that were injured more than 200m from their home were injured in the same LSOA in which they live. Overall, 23% of 'White' children, 20% of 'Black' children and 27% of 'Asian' children were injured in the same LSOA in which they live.

Table A3.2 shows the number of children injured in and LSOA of a similar deprivation level in which they live. For this table I scored levels of deprivation using the 2010 English Index of Multiple Deprivation. The 4,765 LSOAs in London were ranked according to IMD score and divided into quantiles. Levels of deprivation of a child's LSOA of collision and LSOA of residence were considered to be the same if the IMD scores were within the same quantile.

More than half of 'White', 'Black' and 'Asian' children were injured in an area with a similar deprivation level to the one in which they live.

Table A3.1: Child pedestrian injuries (aged 0-15) by LSOA of collision and LSOA of residence, 2000-2009

	'White'				'Black'				'Asian'			
crash distance (metres)	**LSOA of collision and residence are the same**		**LSOA of collision and residence are different**		**LSOA of collision and residence are the same**		**LSOA of collision and residence are different**		**LSOA of collision and residence are the same**		**LSOA of collision and residence are different**	
	n	%	n	%	n	%	n	%	n	%	n	%
<200m	733	70%	309	30%	381	69%	172	31%	230	70%	99	30%
200m-670m	203	20%	826	80%	103	17%	499	83%	46	18%	205	82%
670m-2120m	8	1%	1,056	99%	3	1%	571	99%	1	0%	234	100%
> 2120m	0	0%	1,001	100%	0	0%	649	100%	0	0%	213	100%
any distance	**944**	**23%**	**3192**	**77%**	**487**	**20%**	**1891**	**80%**	**277**	**27%**	**751**	**73%**

Table A3.2: Child pedestrian injuries (aged 0-15) by deprivation level (IMD quantile) LSOA of collision and LSOA of residence, 2000-2009

	'White'				'Black'				'Asian'			
crash distance (metres)	**Deprivation level of LSOA of collision and residence are the same**		**Deprivation level of collision and residence are different**		**Deprivation level of LSOA of collision and residence are the same**		**Deprivation level of collision and residence are different**		**Deprivation level of LSOA of collision and residence are the same**		**Deprivation level of collision and residence are different**	
	n	%	n	%	n	%	n	%	n	%	n	%
<200m	867	83%	175	17%	464	84%	89	16%	280	85%	49	15%
200m-670m	557	54%	472	46%	336	56%	266	44%	139	55%	112	45%
670m-2120m	384	36%	680	64%	203	35%	371	65%	102	43%	133	57%
> 2120m	261	26%	737	74%	206	32%	443	68%	69	32%	144	68%
any distance	2069	50%	2064	50%	1209	51%	1169	49%	590	57%	438	43%

Note: 3 children who had a LSOA of residence in Wales are excluded from this table as deprivation levels in Wales are not directly comparable to deprivation levels in England.

APPENDIX 4: SEARCH STRATEGY FOR LITERATURE REVIEW ON BUILT ENVIRONMENTAL CORRELATES OF PEDESTRIAN INJURY

Medline (via OVID) 1990-June 2010 (Found 258)

1. environment adj20 (physical or traffic or road or built or urban or characteristic$ or feature$ or geograph$)
2. road adj50 (danger or safety)
3. variation adj50 (geographic$ or spatial)
4. or /1-3
5. injur$
6. accident$
7. crash$
8. collision$
9. casual$
10. or/14-17
11. 4 and 10
12. Walk$
13. Pedestrian$
14. Or/12-13
15. 11 and 14

Embase (via OVID) 1990-June 2010 (Found 164)

1. environment adj20 (physical or traffic or road or built or urban or characteristic$ or feature$ or geograph$)
2. road adj50 (danger or safety)
3. variation adj50 (geographic$ or spatial)
4. or /1-3
5. injur$
6. accident$
7. crash$
8. collision$
9. casual$
10. or/14-17
11. 4 and 10
12. Walk$
13. Pedestrian$
14. Or/12-13
15. 11 and 14

Web of Science (Found 582)

1. environment near/20 (physical or traffic or road or built or urban or characteristic* or feature* or geograph*)
2. road near/50 (danger or safety)

3. variation near/50 (geographic$ or spatial)
4. or /1-3
5. injur$
6. accident$
7. crash$
8. collision$
9. casual$
10. or/14-17
11. 4 and 10
12. Walk$
13. Pedestrian$
14. Or/12-13
15. 11 and 14

International Bibliography of the Social Sciences (1990-June 2010) (Found 119)

1. physical environment
2. traffic environment
3. road environment
4. built environment
5. urban environment
6. road characteristics
7. physical characteristics
8. environment characteristics
9. road danger
10. road safety
11. spatial variation
12. geographic$ variation
13. or/ 1-12
14. injur*
15. accident*
16. crash*
17. collision*
18. casualt*
19. or/14-18
20. 13 and 19

APPENDIX 5 CHARACTERISTICS OF EXCLUDED STUDIES

In the literature review of road environmental correlates of pedestrian injury, I excluded 118 studies after retrieving the full text of each paper. Table A4.1 presents a selection of excluded studies and reasons for exclusion.

Table A5.1 Characteristics of Excluded Studies

Study	**Reason for exclusion**
(Abdel-Aty, Chundi, and Lee 2007)	Reports of pedestrian and cyclist crashes together, does not estimate correlates of pedestrian injury separately
(Bunn et al. 2009)	Literature review
(Damsere-Derry et al. 2010)	Reports driver and pedestrian characteristics only; does not estimate environmental correlates
(Gomes et al. 2008)	Lit review, no new results
(Nakahara et al. 2004)	Reports on traffic mortality in general, does not examine pedestrian mortality separately
(Petch and Henson 2000)	Reports of pedestrian and cyclist crashes together, does not estimate correlates of pedestrian injury separately
(von Kries et al. 1998)	Reports of pedestrian and cyclist crashes together, does not estimate correlates of pedestrian injury separately
(Wong, Sze, and Li 2007)	Reports of traffic crashes generally, does not examine pedestrian injury separately

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Bunn, F., T. Collier, C. Frost, K. Ker, R. Steinbach, I. Roberts, and R. Wentz. 2009. "Area-wide traffic calming for preventing traffic related injuries." *The Cochrane Database of Systematic Reviews* (4).

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Gomes, S. Vieira, C. Carvalheira, J. Cardoso, and L. Picado Santos. 2008. "Accident prediction models in urban areas: Lisbon case study." In *Urban Transport Xiv: Urban Transport and the Environment in the 21st Century*, edited by C. A. Brebbia, 619-627.

Joly, Marie-France, Peter M. Foggin, and I. Barry Pless. 1991. "Geographical and socio-ecological variations of traffic accidents among children." *Social Science & Medicine* no. 33 (7):765-769.

Nakahara, S., Y. Nakamura, M. Ichikawa, and S. Wakai. 2004. "Relation between increased numbers of safe playing areas and decreased vehicle related child mortality rates in Japan from 1970 to 1985: a trend analysis." *Journal of Epidemiology and Community Health* no. 58 (12):976-981. doi: 10.1136/jech.2003.018804.

Petch, R. O., and R. R. Henson. 2000. "Child road safety in the urban environment." *Journal of Transport Geography* no. 8 (3):197-211.

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Wong, S. C., N. N. Sze, and Y. C. Li. 2007. "Contributory factors to traffic crashes at signalized intersections in Hong Kong." *Accident Analysis and Prevention* no. 39 (6):1107-1113. doi: 10.1016/j.aap.2007.02.009.

APPENDIX 6: INDEX OF MULTIPLE DEPRIVATION

The Index of Multiple Deprivation (IMD) brings together more than 36 indicators across seven domains of deprivation into an overall score for each geographical area. The seven domains of deprivation are: Income, Employment, Health and disability, Education, skills and training, Barriers to housing and services, Living environment, and Crime. Low scores indicate less deprived areas while higher score indicate higher levels of deprivation.

IMD has been calculated by the Department for Communities and Local Government in various forms since the 1970s. This thesis uses two iterations of IMD: IMD2004, IMD2010. There are slight changes to the way IMD is calculated in each iteration. Consequently, IMD scores within particular areas are not directly comparable over time. Therefore, for analyses in chapters 3 and 7 (and as a sensitivity analisys in chapter 8), I divide areas of London into deciles (or quintiles) of deprivation based on their IMD score. Cut-off points of IMD scores for 2004 and 2010 deciles of deprivation are available in Table A6.1.

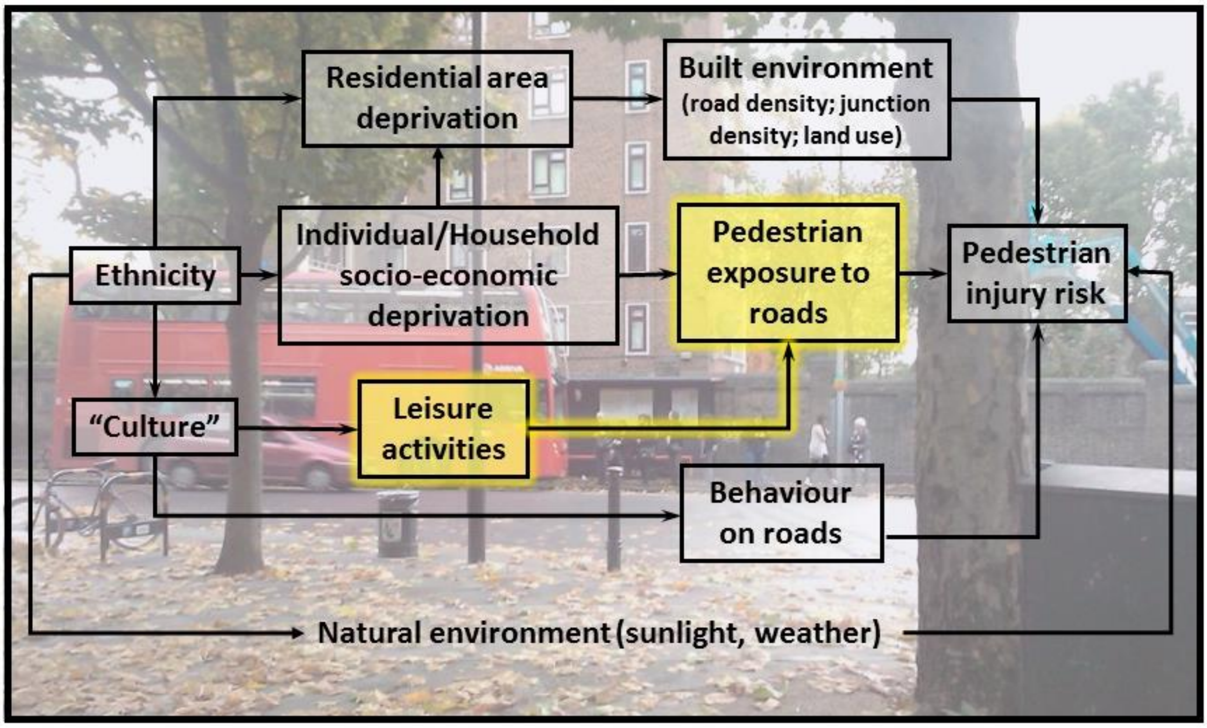
Table A6.1: IMD deciles

IMD decile	IMD 2004 score range	IMD 2010 score range
(least deprived) 1	1.70 – 8.10	1.70 – 8.85
2	8.20 – 11.87	8.86 – 12.38
3	11.88 – 15.36	12.39 – 15.85
4	15.37 – 19.24	15.86 – 19.94
5	19.25 – 23.06	19.95 – 23.81
6	23.06 – 27.65	23.81 – 28.02
7	27.66 – 32.51	28.02 – 32.47
8	32.52 – 39.93	32.48 – 37.46
9	39.94 – 44.87	37.47 – 43.44
(most deprived) 10	44.88 – 76.78	43.44 – 66.21

APPENDIX 7 HOW AND WHY ARE YOUNG PEOPLE EXPOSED TO PEDESTRIAN INJURY DURING LEISURE TIME?

Chapter 4 investigated the role of travel time exposure in explaining ethnic patterns of child pedestrian injury in London. It explored whether or not higher injury rates for 'Black' children are due to more time spent walking to or from school or other places compared to other children. The conclusion was that differences in walking during travel time are unlikely to explain the higher rates of pedestrian injury among 'Black' children, or why area affluence does not protect 'Black' children from injury. Differences in such walking behaviour may, however, help explain the comparatively lower injury rates among 'Asian' children. However, walking to or from school or other places is not the only activity in which children are likely to be exposed to pedestrian injury risk. Children may also be exposed to road hazards during leisure activities, such as playing or 'hanging out', if they occur in or near the road environment. This type of exposure is not captured in travel diaries like the London Travel Demand survey but still may represent a significant proportion of children's exposure to road hazards. Research from an urban hospital in the United States found that nearly 30% of all child pedestrians casualties were injured while engaged in playing or 'hanging out' activities as opposed to travelling (Posner, 2002). This appendix explores whether exposure during leisure activities can help explain ethnic differences in child pedestrian injury in London (highlighted in Figure A7.1).

Figure A7.1: Hypothesized model of links between ethnicity and pedestrian injury risk



The leisure time exposure hypothesis theorises that ethnic differences in the amount of time spent playing or 'hanging out' in the road environment can help explain observed ethnic differences in pedestrian injury risk. As noted in the introduction, it is plausible that a child's ethnicity influences their leisure pursuits and, specifically, how much they may be exposed to road hazards. For example, structural associations between ethnicity and socio-economic disadvantage may limit the indoor leisure spaces available to minority ethnic children, leading them to spend more time 'hanging out' or playing outdoors, in or near the street. Conversely, experiences of racism may make some minority children opt to stay indoors out of fear of racially charged incidents. Cultural traditions may influence how children spend their free hours, including how much time they devote to leisure activities.

It is, however, difficult to find a data source that would allow a calculation of time exposed to road hazards (or distances travelled in the road environment) during leisure activities for 'White', 'Black' and 'Asian' children. I investigated a number of potential data sources on children's leisure time exposure to road hazards, including global-positioning system (GPS) data on children's movement (such as UCL's CAPABLE project (Mackett et al., 2007)), time diaries (such as the Time Use Survey (Lader et al., 2006)), and surveys of leisure activities (such as Well London Study (Well London Research Team, 2014) and Taking Part: The National Survey of Culture, Leisure and Sport (Department for Culture Media and Sport, 2011)).

These sources all have considerable methodological limitations for the measurement of leisure time exposure to road hazards. GPS units, for instance, can theoretically provide rich data on how much and where children move. While useful for measuring physical activity they are not yet accurate enough to determine time spent exposed to road hazards, particularly in London where tall buildings obstruct views of the sky.

Time diaries and surveys of leisure activities present other challenges for measuring leisure time exposure to road hazards. Unlike travel time exposure, which involves one activity- i.e. travelling from A to B - leisure time exposure is made up of a variety of different micro-activities. These may include, for instance, anything from informal sports to socialising with friends to taking in the spectacle of the city. In order to use time diaries or leisure activity surveys, I would need to identify which activities may expose children to road hazards. I searched the published literature to see if any studies have investigated which types of leisure activities occur in the road environment.

I was unable to find any studies that have mapped the range of micro-activities that may expose children to road hazards during their leisure time. Consequently, I concluded that before children's leisure time exposure to road hazards in London can be measured, some exploratory work on how young people interact with(in) the road environment during their leisure activities was needed. Until a measure of leisure time exposure to road hazards has been developed, quantitative explorations of ethnic or socio-economic differences in leisure time exposure are not possible.

This appendix, therefore, provides the first step in developing an understanding of leisure time exposure, by focusing on how, and why, children are exposed to road hazards during their leisure activities. This is a rather broad research question to investigate empirically. To narrow down the question into a more manageable one, I chose to focus on 'hanging out' practices in London. I chose to concentrate on 'hanging out' rather than playing for two reasons. First, 'hanging out' is an activity that increases as children get older, suggesting that 'hanging out' is less likely than playing to be supervised by adults. Most research postulates that unsupervised exposure to hazards is associated with increased injury risk. However, measurement of supervision also has distinct methodological challenges, therefore direct evidence on associations between supervision and injury is limited (Morrongiello, 2005).

Secondly, compared to playing, which is generally described as an activity that brings physical and mental health benefits to children (Ginsburg et al., 2007), 'hanging out' is a more controversial social practice. Some argue that 'hanging out' brings developmental benefits (Thomas, 2005), while others class 'hanging out' as anti-social behaviour (Walker et al., 2009). These divergent understandings of 'hanging out' make an in-depth exploration of how and why young people 'hang out' an attractive topic for research. Unlike the previous chapters of this thesis, which quantitatively examine ethnic differences in the quality of exposure and quantity of travel time exposure, how young people interact with(in) the road environment during their 'hanging out' practices is a topic where a qualitative exploration is more appropriate.

There are number of ways to explore what children do when they 'hang out', and specifically, whether those activities could potentially expose them to injury. Perhaps the most straightforward is to ask young people directly which of their leisure time pursuits expose them to pedestrian injury risk. This method, however, is unlikely to provide useful data. They way young people understand risk may differ from adults (Green, 1997). In this case young people may have different views about what types of activities expose them to injury risk. Furthermore, asking about 'risk' may not resonate well with young people's everyday understandings of their leisure activities (Green, 2009). Taking an alternative approach, I chose to explore young peoples' own descriptions of their leisure activities and travel experiences. My aim was to find out what London's young people were explicitly and implicitly trying to accomplish by 'hanging out' and how movement (which when it occurs in the road environment exposes young people to road hazards) can help contribute to those goals. To do this, I opportunistically drew on qualitative data generated from the 'On the Buses' study.

A7.1 The 'On the Buses' Study

The data used in following Research Paper come from the 'On the Buses' (OTB) study, which evaluated the introduction of free bus travel for young people in London. In 2005, Transport for London (TfL) gave all young people under 16 in London free access to bus and tram travel. In 2006, TfL extended the policy to anyone under 18 in full time education or training. The National Institute for Health Research (NIHR) commissioned the mixed methods 'On the Buses' study to explore the health impacts of introducing free bus travel for young people in London. The study ran from 2010-2012 and included a large qualitative component, which explored the pathways linking free bus travel to social inclusion, future car dependence and the effects of the scheme on the well-being of young people. The qualitative component generated data from individual and small group interviews and focus groups with young people aged 12–18 years in London. The following Research Paper draws on these data.

Young people were purposively sampled from one of four London boroughs, which differed in terms of area deprivation and transport availability: Hammersmith and Fulham, Islington, Sutton, and Havering. The study aimed to recruit a maximum variation sample in terms of age, gender and ethnicity. Young people were recruited through secondary schools, local community youth clubs, a local authority youth parliament, LSHTM's young scientist programme, and settings such as a pupil referral unit and an 'alternative provisions' facility to include those young people who struggled in or were excluded from conventional schools and colleges. Additionally, some participants were snowballed from personal contacts. Sampling continued until saturation was reached (i.e. until new data no longer contributed to understandings of the links between free bus travel and health).

In total the OTB study included 119 participants: 53 participants were interviewed in 40 individual and small group (2-3 people) interviews and 66 participants were interviewed in 16 focus groups of 4-8 people. Table 5.1 presents a demographic breakdown of all interviewed participants. Interviews took place between February 2010 and April 2012 in schools and colleges and were conducted by one or two members of the OTB qualitative team: Judith Green, Helen Roberts, Alasdair Jones, Anna Goodman and myself. I was involved in collecting data from 42 participants. Before the interviews began, all participants were presented with an information sheet about the OTB study and gave written consent to participate (See Appendix 7). Ethnical approval for the study was granted by the London School of Hygiene and Tropical Medicine's Ethnics committee (Application no. 5635).

Table 5.1 On the Buses interviewees by age, gender and ethnicity (N=119) (Green et al., 2014)

Gender	Female	63
	Male	56
Age Range	Under 13	27
	14-15	61
	16-17	21
	>=18	10
Ethnicity*	White British	52
	White Other	8
	Black/Black British	22
	Asian/Asian British	15
	Mixed	18
	Other	3
	Not Answered	1

*These are indicative groupings based on self-report.

Interviews were semi-structured with interviewers encouraging story-telling and loosely following a topic guide. Questions focused on how young people travel, the activities they engaged in after school and on the weekends, their commutes to school, work and other activities, and the types of places they visit in London. The research team has published a number of journal articles using this data (Goodman et al., 2013, Jones et al., 2013, Jones et al., 2012).

These data, which were already being collected for a funded project, appeared to be a useful opportunity to collect stories on young people's leisure activities. Pilot interviews from the OTB study suggested that 'hanging out' was a fundamental leisure activity for young people in London and bus travel played a key role in 'hanging out' practices. Bus travel offered young people the opportunity to move between leisure activity spaces. Furthermore, buses themselves provided a social space for 'hanging out' activities (Jones et al., 2012). The OTB research team therefore identified leisure activities in general, and 'hanging out' in particular, as an important topic for further exploration. This focus fitted well with the objectives of my thesis. Therefore, in the further OTB interviews, I was able to add a number of questions specifically addressing young people's leisure activities in the topic guide. Details on analysis are available in the following Research Paper, but briefly, I analysed the qualitative data thematically as it was collected. My role as a Research Fellow and data collector on the OTB project allowed me to return to the field to test emerging hypothesis and gather more detailed data where necessary. The Research Paper presented in the next section (A7.2) uses the OTB data to broadly examine the role of mobility in 'hanging out' practices in London. Section A7.3 discusses what these findings suggest about how 'hanging out' exposes young people to road hazards in London and whether this exposure can be measured. Finally Section A7.4 examines the implications of the findings in Sections A7.2 and A7.3 for the leisure time hypothesis in explaining ethnic differences in injury risk in London.

A7.2 'JUST WANDERING': MOBILITY, 'HANGING OUT', AND RISK

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Status: Prepared for submission in *Health, Risk & Society*

COVER SHEET FOR EACH 'RESEARCH PAPER' INCLUDED IN A RESEARCH THESIS

1. For a 'research paper' already published

1.1. Where was the work published? **N/A**

1.2. When was the work published? **N/A**

1.2.1. If the work was published prior to registration for your research degree, give a brief rationale for its inclusion**: N/A**

1.3. Was the work subject to academic peer review? **N/A**

1.4. Have you retained the copyright for the work? **N/A**

If yes, please attach evidence of retention.

If no, or if the work is being included in its published format, please attach evidence of permission from copyright holder (publisher or other author) to include work

2. For a 'research paper' prepared for publication but not yet published

2.1. Where is the work intended to be published? **Health, Risk & Society**

2.2. Please list the paper's authors in the intended authorship order
Rebecca Steinbach, the 'On the Buses' Research team

2.3. Stage of publication – **Not yet submitted** / Submitted / Undergoing revision from peer reviewers' comments / In press

3. For multi-authored work, give full details of your role in the research included in the paper and in the preparation of the paper. (Attach a further sheet if necessary)
I designed the study with input from the 'On the Buses' (OTB) research team. I collected the data with other members of the OTB team. I analysed the data, discussing themes with the rest of the research team. I drafted the manuscript.

NAME IN FULL (Block Capitals) REBECCA STEINBACH

STUDENT ID NO: 262437

CANDIDATE'S SIGNATURE: Date: 01/08/2014

SUPERVISOR'S SIGNATURE:

‘JUST WANDERING’: MOBILITY, ‘HANGING OUT’, AND RISK

BACKGROUND

Public discourse often depicts youth as being simultaneously ‘at-risk’ and ‘as-risk’ (Turnbull and Spence 2011), particularly in discussions around their mobility. Both not enough and too much mobility are considered risky. For example, young people are considered increasingly ‘at risk’ for a number of ‘chronic’ or ‘non-communicable’ diseases due to increasingly sedentary lifestyles in their daily lives (Hill and Melanson 1999). Further, children’s physical and emotional well-being is also thought to be jeopardized by hazardous road environments and fear of ‘stranger danger’ which ‘imprison’ youth in their homes (Hillman, Adams, and Whitelegg 1990). Even as the risks they face continue to grow (Furedi 2006), however, young people are simultaneously portrayed as presenting risks toward others. They’re construed not just as victims, but also as perpetrators of crime and anti-social behaviour, and as perpetrators whose poor behavioural decisions may pose a financial burden to society in the future.

These ‘risks to’ and ‘risks of’ young people are not shared equally across populations. In terms of ‘risks to’ young people, research suggests differences in both the risks of being mobile and the risks of being sedentary by age, sex, socioeconomic status and ethnicity in the UK. For example, mobility puts boys, relatively disadvantaged children and children from some ethnic minority backgrounds at higher risk of pedestrian injury compared to their counterparts (Wazana et al. 1997). In terms of sedentary behaviour girls, older children, relatively disadvantaged children, and children from ethnic minority backgrounds tend to have higher levels (Coombs et al. 2013, Brodersen et al. 2007).

Public discourse tends to characterise ‘risks of’ young people in terms of who is perceived as a risk to society. Here too, certain groups are considered more risky than others. For instance, members of youth subcultures such as “chavs” and “hoodies” are highlighted as especially menacing (Marsh and Melville 2011).

The inter-related framings of youth ‘at risk’ and youth ‘as risk’ have led to a public health context of ‘monitoring’ of young people’s mobility and ‘prevention’ of mobility related risks. A large literature tracking young people’s movements has emerged (Dollman et al. 2009, Fjørtoft, Kristoffersen, and Sageie 2009, Krenn et al. 2011). Studies are increasingly using advanced technology to understand how much, and where, young people move. For instance, the CAPABLE project collected data on children’s spatial activity patterns using questionnaires, 4-day time diaries, global positioning systems equipment, and accelerometers (Mackett et al. 2007).

Studies like this and the PEACH project, which used similar methods of data collection, have been able to illuminate links between young people's independent mobility and their amount of physical activity (Page et al. 2009, Brown et al. 2008). These types of studies tend to focus on quantitative measures of mobility and physical activity; scholars have paid relatively less attention to *why* young people move or the meaning of that movement [for a notable exception see Lesley Murray's work on emotions and mobility during the school commute (Murray 2009, Murray and Mand 2013)].

Public health researchers have capitalised on this increased surveillance of children's mobility to identify a range of strategies to both increase levels of children's physical activity and to prevent mobility related risks. Strategies to promote physical activity include school-based interventions, media campaigns, family-based interventions and policies to promote active travel (Heath et al. 2012). Strategies to prevent road traffic injuries include school-based pedestrian training, video and internet training, pedestrian crossing guards, and walking school buses (Schwebel, Davis, and O'Neal 2012). There can be tensions between physical activity and risk reduction strategies. For instance, campaigns to increase active travel to school aim to increase amounts of young people's physical activity and reduce risks of obesity. However, increasing the amount of walking children engage in also increases their exposure to road danger, and thereby their risks of road traffic injury.

Most of these strategies address mobility during structured time (e.g., at school or after-school activities) or while commuting. Less attention has been paid to young people's mobility during leisure time, when they are just 'hanging out.' There are, perhaps, good reasons why time spent 'hanging out' has been overlooked by the public health community. 'Hanging out' is a social practice that has long been problematised within a risk framing of youth. Unlike structured activities which bring health and well being benefits (Mahoney and Stattin 2000), 'hanging out' is typically represented as idle, inactive, or unproductive behaviour (Bartko and Eccles 2003). Academic discourse has linked behavioural risks for alcohol and drug abuse, teenage pregnancy, delinquency and drop out rates to 'hanging out' (Agnew and Petersen 1989). Reflecting concerns about youth 'as risk' to others, the British Crime Survey characterizes teenagers hanging around the streets as, in itself, 'anti-social behaviour'. The British population appears to agree; 30% of those surveyed reported this as a problem in their neighbourhood (Walker et al. 2009). 'Hanging out', then brings together framings of young people 'at risk' (from sedentary behaviour) and 'as risk' (anti-social behaviour) making this social practice inherently threatening.

But recently a number of studies have begun to challenge the conception of 'hanging out' as an idle practice. For example, in the education literature, Scott (2009) argues that rather than being a mentally inactive activity, the effortless nature of 'hanging out' can create useful dialogue between young people, allow for deep thought and foster creativity. Mathews and colleagues (2000) have argued that rather than being a stationary practice, 'hanging out' actually consists of a panoply of activities, such as talking and chatting with friends, informal sports, playing and shopping. Some of these 'micro-activities' may even be productive from a societal standpoint. For instance, browsing in shopping malls can be read as 'preparing' young people for adult consumer roles (Kato 2009).

'Hanging out', then, may therefore be seen as an activity that is slowly beginning to be viewed more positively in academic (though not necessarily popular) discourse. This is largely driven by urban geographers who have studied how young people interact with "place" during while 'hanging out', particularly in the public realm. Urban geographers have suggested that young people are spatially excluded and congregate in public spaces because they have nowhere else to go (Lieberg 1995). But rather than being an anti-social behaviour (as suggested by the British Crime Survey), some have argued that young people use these public spaces in socially productive ways. Thomas, for instance, has suggested that presence in public space helps young people to form, display and negotiate their identities (Thomas 2005).

This (mainly) geographic literature, however, generally focuses on the static spaces where children spend time such as shopping malls and parks. Less attention has been paid to movement within and between different spaces. What kinds of mobilities are enacted while 'hanging out'? How do those mobilities impact on young people and the larger public?

To address these questions, we examine how mobility and 'hanging out' interrelate among young people in London to shed light on the meaning of mobility, the potential mobility-related risks young people might face or create, and the public health opportunities that may result.

METHODS

This paper draws on qualitative data generated during the 'On the Buses' study (Green et al. 2014), which assessed the impact of a free bus travel scheme for young people introduced in 2005 on the public health of Londoners. Between February 2010 and August 2011 we recruited 119 young Londoners (aged 12-18 years) living in, or attending school, in four areas of London which varied in terms of transport accessibility and area deprivation (N=97) or doing work experience at the London School of Hygiene and Tropical Medicine (N=22). Young people were purposively sampled to generate a diverse sample in terms of age, gender, ethnicity and area deprivation and were interviewed individually, in small groups (2-3 people) or in focus groups. Interviewers asked young people about the activities they engaged in after school and on the weekends, their commutes to school, work and other activities, and the types of places they visited in London. Informed consent was sought from each participant. A full description of the data and data collection processes can be found elsewhere (Green et al. 2014).

While the qualitative data was not generated to specifically address the role of mobility in 'hanging out' practices, we were able to include a number of questions in the topic guide, which allowed the research team to collect data that specifically addressed leisure time activities among young people. The authors were all involved in data collection, providing contextual access and allowing us to generate tacit insights about young people's leisure activities. Finally, the analysis of qualitative data for this paper and the 'On the Buses' project occurred concurrently, allowing us to return to the field to test some emerging hypotheses.

ANALYSIS

All interviews and focus groups were recorded and transcribed. We analysed data thematically as it was collected. After familiarising ourselves with each transcript we initially coded themes related to the micro-activities young people undertook during their leisure time and the spaces they used for these activities. From this exercise, it was clear that young people's primary leisure activity was 'hanging out' and that mobility in and between different spaces played a key role in 'hanging out'. We then compared accounts of the micro-activities of 'hanging out' (and the locations where in which these took place) to begin to consider what young people were explicitly and tacitly trying to accomplish with their 'hanging out' practices, paying particular attention to deviant cases. We were able to return to the field to gather more detailed information on specific themes. We began to build a list of what young people were seeking to accomplish while 'hanging out' and then re-examined how mobility contributed to these 'accomplishments'. Participants are referred to by pseudonyms in all interview extracts.

FINDINGS

An initial challenge of this research was trying to capture children's activities. Initial questions on what they did or preferred activities were met with brief, unengaged and unelaborated responses:

> Nadia: We just like hang out and stuff.
>
> Interviewer: So what sort of stuff would you get up to?

> Jack: Nothing...
> Emily: Just going out for the day.
> Charlie: Just doing whatever.

Such comments were common across the data set, from all ages and genders. Young people tended to use vague language when describing these 'hanging out' activities in response to direct questions. Such 'closing down' responses are not uncommon when young people interact with an adult interviewer in an interview or focus group format designed to elicit data about their behaviour. Given that young people are aware that adults in the larger society consider their 'hanging out' behaviour as risky or unhealthy (Spencer 2013), perhaps it is not surprising that few discussed risks in answers to direct questions. Indeed, some youth in our study reflected this knowledge in the words they used to describe their 'hanging out' activities.

> Freya: a group of us from school ... we went to London Bridge and just *wasted some time* there. (emphasis added)

Youth, therefore, may use the vagueness of 'doing nothing' as a way of avoiding conflict in an environment where expressions of pleasurable activity are often met with unhealthy risk discourses.

In practice, of course, young people aren't really just 'hanging out' "doing nothing". Like previous work (Mathews 2000), our data suggested that the term 'hanging out' encompassed a variety of activities. Young people reported socialising with friends, shopping, visiting London attractions, playing sports, listening to music, and watching TV. If responses to direct questions suggested an absence of activity, then detailed stories elsewhere in the interviews and discussions provided a rich description of 'hanging out' activities. It appears that the activities of young people are so routine within their daily lives that they do not consider them noteworthy. For example, like Nadia, Emily also uses the word "stuff" to describe her "normal" activities.

> Emily: It's just a normal day, apart from obviously you have the youth club to come to, so yeah, it's just a normal day, watch a bit of TV and stuff.

MOBILITY

When youth were more explicit about their leisure time activities it was clear that, in London, the capacity to be mobile -- or more precisely the capacity to move to and through spaces using a chosen style of movement -- played an important role in 'hanging out' practices. Relative to adults, young people are less able to be mobile in their daily lives. They are formally restricted from moving through certain spaces (e.g. some public houses), from moving during certain times (e.g. through curfews), and from using some modes of travel (e.g. driving a car). More informally, young people are further restricted because of lack of money to travel, or limited ability to obtain lifts from parents. It is therefore, perhaps, not surprising that young people appeared to capitalize on their (limited) capacities to be mobile during their leisure time. Young people reported using many available forms of movement while 'hanging out'. Walking was the most common, but they also used other modes of mobility while 'hanging out', such as bicycles and public transport.

> Interviewer: And if you meet up, what would you do if you meet up before school? Would you just carry on walking in?
> Anton: Walk and talk and what not. And then we just
> Sophie: Just wander.

> Omar: I was with my friend for about two hours just hanging around, just, I don't know, just walking around basically.

Interestingly, as these quotes suggest, young people reported using their capacity to be mobile not just for travel purposes (i.e. to get from one point to another). 'Wandering' or walking around was a leisure activity in itself. Reasons why the capacity to be mobile appeared so important in children's 'hanging out' practices become clearer when we begin to look at the expressed and symbolic goals of 'hanging out'. Two were explicit and frequently mentioned by young people: to escape boredom, and to socialize with friends. In addition to these expressed goals, 'hanging out' also appeared to achieve more tacit symbolic goals. 'Hanging out' was a way to form and reproduce social identities, to disrupt the predictability of everyday life, to challenge the structures imposed by adults, and to learn citizenship skills. The expressed and symbolic goals were implicitly tied to the (often public) spaces in which 'hanging out' took place. The capacity to be mobile in and between these spaces played a key role in enhancing both the expressed and more symbolic goals of 'hanging out'.

ESCAPING BOREDOM

Young people reported that 'hanging out' was a strategy for escaping boredom, a universal plight in their lives. Nearly all of our participants mentioned suffering from boredom or a similar concept at some point throughout their day.

> Charlie: [I enjoy] hanging out … there's nothing to do when you get home, just sit there and watch the TV.

> Tristan: No, we're like sitting in the estate and talking and stuff, it just gets boring after a while, so we just, sometimes we just ride, ride our bikes and cruise.

> Tyra: I don't know, like we'll just be bored and we don't want to go home, so we'll just hop on a bus and we'll go anywhere. And sometimes it's buses we don't know and we'll just see where we end up.

However, like "doing nothing", "boredom" appeared to be a vague description for more complex emotions in our data. Boredom appeared to have multiple and inter-related meanings. Young people used the concept of "boredom" to represent both under-stimulation and the predictability of everyday life. In addition, the term 'boredom' was also used to express frustrations with mechanisms that constrained young people's independence. Young people used 'hanging out' practices to combat all of these meanings of boredom.

Traditionally boredom is thought of as a lack of stimulation, and it is easy to conceive how 'hanging out' (and its variety of activities) would help provide amusement. The young people in our study often reported escaping boredom by 'hanging out' in public spaces such as parks or high streets. The many attractions of being a voyeur in the city have long been a topic of literature (Shaya 2004), and the young people in our study reported being seduced by the spectacle of everyday urban life. Moving through the city, by walking (de Certeau 1984) or other modes was able to enhance the enjoyment of being a flâneur (a casual observer of society).

> Nadia: So yeah when it's sunny we get out on the high street, roam around, it's fun. There's a lot of crowd and everything and there's a lot happening.

Young people reported enjoying roaming around London, experiencing different spaces and the stimulation of society. By utilising their capacities to be mobile, young people were able to take in more of urban life, but interestingly mobility was also sometimes described as the primary purpose of young people's leisure activity.

> Naomi: It's fun going around to different places, different means of transport, sometimes train, bus. And then normally getting lost.
> Interviewer: Oh yeah?

Naomi: We normally take a map with us.
Interviewer: You do?
Naomi: If we're going somewhere like central London or something, because we don't really know where we're going.

The young people in our data appeared to crave new experiences; techniques such as "getting lost" were ways to disrupt normal routines and encounter novel situations. This suggests for young people "boredom" not only encapsulates under-stimulation but also predictability. Escaping "boredom" by engendering these new situations also helped young people achieve more symbolic goals. Roaming around the city helped them to learn important citizenship skills, including geographical knowledge of London and how to negotiate the sometimes challenging public transport system (Goodman et al. 2013, Jones et al. 2012).

As Naomi suggests in her discussion of the "fun" of getting lost, 'hanging out' also entailed creating risks using young people's capacities to be mobile. "Fun" was universally described as the opposite of boredom in our data, and young people described many different ways they could use their capacity to be mobile to create "fun" uncertainty. In addition to using transport to "get lost", this group of girls create uncertainty by running from bus to bus.

Donna: Or because it's fun, yeah.
[Laughter]
Interviewer: It's fun changing buses?
Donna: Yeah, just the running after the next one just so you can get on it because you ...
Nora: And even if, even before
Interviewer: So you'll do that if you see behind the ones then?
Nora: We just ...
Donna: If there's a packed bus and there's an empty bus we go to the empty bus.
Tamika: Yeah, but it's risky because most buses come, drive past you.

These girls viewed the possibility of missing the next bus or getting lost as alluring. This suggests that young people are striving to disrupt the certainty of everyday life by using their capacity to be mobile in their 'hanging out' practices. Throughout our data descriptions of 'fun' often contained an element of surprise while 'boredom' was used to represent routine. For instance, Fatima blamed "boredom" as the reason she no longer participates in a structured afterschool activity.

Interviewer: Are there any other activities you do on a regular basis?
Fatima: I used to go, I used to do... dance club. (But) dance club got boring because the teacher was boring... (Now) I just like sitting at home on the computer talking to random people online, it's quite fun going on chat rooms and things.

Like others in our data, she highlights the randomness of her preferred activity as part of the appeal. The way she blames the teacher for making the dance class boring is suggestive of another way young people use 'hanging out' to escape boredom. One way to interpret this girl's reasoning behind quitting dance club is her dissatisfaction with the adult leadership, which she has reframed as 'boring'. Her preferred activity of chatting online is both unstructured and largely unsupervised, providing respite from adult structure and authority.

Indeed, young people's desire for uncertainty or surprise is arguably the result of over-structured, routine lives. Taking risks while 'hanging out' offered relief from these structures. Stories of some of the more dramatic risks in our data suggested that young people used 'hanging out' as a way to rebel against these structures. For example, Johnny explicitly capitalises on his capacity to be mobile to rebel against established risk discourses:

> Johnny: [Hanging out with] the bike is fun after all, and I do dangerous stuff with a bike, I don't really, I'm not scared.... Yeah, I go down the stairs and everything....Yeah, it's quite scary but when you do it, yeah, then you're going to think, oh, that was nothing, I could do it another three or four times.

The fact that Johnny acknowledges his actions are dangerous suggests that he is consciously challenging established risk discourses, thereby reclaiming some power from the adult hegemony. Taking risks and challenging established risk discourses is a key part of growing and forming social identities (Green and Singleton 2006). Taking risks and talking about taking risks are one way that young people refine their own views about appropriate social behaviour and map social relationships (Green 1997). In this way, movement related risks while 'hanging out' helped young people to negotiate their social identities and rebel against adult structure.

SOCIABILITY

As Anton discusses above, chatting with friends was another primary goal of 'hanging out'. Young people's friends could provide amusement and stimulation.

> Rasheed: Yeah, it's boring by yourself.... (If you are with your friends) then at least you can talk.

But more than just relieving under-stimulation, socialising could also help young people achieve more symbolic goals such as negotiating different identities and challenging adult control. The young people in our data reported two types of socialising while 'hanging out': bonding with close friends and large group interactions. Both types of socialising were explicitly tied to the spaces where these activities took place. The capacity to be mobile in and between these spaces was important in both carving out spaces for socialising and achieving some of the more symbolic goals 'hanging out'.

For many, there were real challenges in finding spaces in which to be social in London. Socially constrained at school, while under the supervision of teachers and subject to school rules (e.g. not allowed to use mobile phones), they also had difficulty socialising at home, especially for older age groups.

> Johnny: Well it's boring in the house, I'm not used to it anymore. I used to like it once upon a time but now it's boring... I'd rather be out having some fresh air and everything without me being in a stuffed house... [the presence of parents means] we can't actually shout and talk and laugh out loud.

Escaping the "adult gaze" (Matthews and Limb 1999) and having private space in what Lieberg (1995) has deemed 'places of retreat' in order to socialize was an important aspect of some 'hanging out' among young people, particularly in relation to very close friends. The street could provide such a venue.

> Daniel: Our streets are not packed at all. It's just like actually and there's literally only me and my friend walking down it. It's a medium sort of street, it's not that long and it's not that short and we just say whatever we want. We can literally shout it and no one would hear, and so it's much more free and you can be more open about what you're saying, where your eyes go, what you see and it's with a friend, so you feel much more comfortable.

A lack of space in congested urban areas may be one of the reasons young people so often used the capacity to be mobile during their 'hanging out' practices in London. Particularly in outdoor locations, being mobile created more "private" spaces to socialise.

Arguably, young people's colonization of informal spaces such as the street (Moore 1986), can be viewed as an expression of power (Sibley 1995) and, as Valentine (1996) suggests, as one way to challenge the spatial hegemony. Young people's presence in these spaces can disrupt adults' normality and lead to hostility (Valentine 1996). Indeed young people could be quite explicit about the tensions they felt with adults:

> Patricia: I know some people, I know some people can be intimidated, but some people just pre judge people before you, they even like, like if I'm walking down the street, like someone won't say excuse me, they'll rather just cross the road. Like if you said excuse me I'm a civilised human being and I'll move out the way for you like, I don't like that.

Interestingly, being mobile while 'hanging out' could actually help diffuse territorial tensions between young people and adults in public spaces, because young people need not occupy any particular space for very long.

Private bonding with close friends is not the only aim of 'hanging out'. Young people also sought to 'hang out' in "places of interaction" (Lieberg 1995) where they could maintain presence in social networks, gather information of interest (Pavis and Cunningham-Burley 1999) and widen those networks. These networks were often multiple including for example, sets of friends from school, former schools, and neighbourhoods

> Dominic: because that's where ... the popular people go and hang around and get known, get noticed so that you can start competitions. Because when you go there like the chicken and chips shop I used to go to is really packed, you see people you see in school, you see your friends from different schools, people get friends there. So apart from eating you just meet people, it's like a social hangout there.

Apart from just meeting different friends, these places could provide opportunities for young people to test out their identities and display them to their peers (and society at large). For instance, starting 'competitions ', as Dominic described, was one way young people could negotiate their place in the social order of the hangout they chose. The choice of hangout could also help convey identify traits with peers. For example, the Dominic's hangout is the one where the 'popular' people go, and presence there could help identify you as 'popular'.

These 'places of interaction' where young people could hang out in larger groups were relatively difficult for young people to find. Popular spaces for 'hanging out' included chip shops, coffee shops, sweet shops and cinemas. Adults appeared to tolerate these places for young people to 'hang out' in London; young people in our study did not report tensions with adults over these territories as they sometimes did in other more public spaces. Interestingly though, these spaces all require young people to spend money, even if relatively small amounts, to in essence "rent out" social space. Young people, to some extent, seemed to recognize that money gave them legitimacy in different spaces.

> Charlie: you just go wherever if you have any money.

As this quote implies, money was often a scarce resource among young people. So the participants in our study often reported preferences for 'hanging out' in outdoor locations. Parks and public spaces were popular often for logistical reasons like proximity and ability to accommodate large groups.

> Archie: Like if you're with one friend often there's a limit, like at their house there's a limit to how many people can be there and things like that. Whereas if you're going to Leicester Square you can have 10, 12 friends.

> Liam: Sometimes we just go over the park, because there's a park just opposite our school, go there for a bit, just chill and then go, get on a bus and go home, or walk through the park.

As many geographers have noted, public spaces are ascribed certain cultural meanings (Cattell et al. 2008). Young people may choose hang out in these spaces to display different aspects of their identities to friends and the world at large. For example, this young man hung out during a specific time (after dark) and in a particular space (local park) to display maturity and (arguably gendered) bravery:

> Omar: Yeah, just hanging about... outside....Yeah, because we're not scared of the dark, we're older now, so. ..

Public spaces also provided a convenient venue for young people to express themselves through mobility itself. They might choose a particular public place, walking gaits or other styles of movement to display their identity to a diverse audience. While identity expression was largely a tacit goal of 'hanging out', the young people in our study reported an awareness of their physical selves while 'hanging out' with friends.

> Dominic: When you're with your friends you're not the same person when you're alone. I think you try to look a bit more cooler with your friends

Looking cool was a key motive for 'hanging out' for many young people. Interestingly, young people also used the cultural meanings associated with different mobility modes (Steinbach et al. 2011) to display both 'cool' and other identities. For instance, this female focus group participant describes one way in which young people publically convey status to their peers:

> Tyra: Most of the time teenage boys they hang out in their parents' cars acting like they can drive or they'll just go around the block going, yeah, that's practically all they do.

Indeed, among our interviewees, moving independently in a car conferred special status:

> Trevor: Do you know how many girls you can get with cars bruv? You just honk at them.

But other modes of mobility could also display different aspects of young people's identities: These focus group participants describe travelling by train as an opportunity to to test out mature adult identities.

> Claire: Yeah I love... catching the train.
> Freya: It's nice...

> Claire: And you feel like a working person.
> Freya: Yeah.
> Claire: You feel like you're part of the working people, so yeah. Makes you feel more grown up.

In summary, a key symbolic goal of 'hanging out' in public spaces among young people was to negotiate and display their identities. Young people could express themselves by their presence in and movement between spaces with different cultural meanings; through different styles of movement and through the cultural connotations of different forms of mobility.

In addition to outdoor public spaces, the indoor public space of the bus emerged as a socially important informal space for young people (Jones et al. 2012), explicitly tying mobility to 'hanging out' practices. In London, where young people have had access to free bus travel since 2005, the bus was one of the few free indoor spaces with relatively little accessibility constraints. As Murray and Mand (2013) suggest, buses are more than merely a mode a transport for young people, but a "a social gathering, with young people moving around, mingling, sharing stories, looking at books and magazines, listening to music, eating and performing". Buses provided a venue for young people to achieve their expressed goal of socialising with friends and displaying their identities to both their peers and other bus passengers such as commuters, tourists and older citizens. As Jones and colleagues (2012) have suggested elsewhere, in addition to socialising and identity expression goals, everyday interactions on the bus such as negotiating responsibilities to give up a seat to an older or less able bus user helped young people learn civic ways of interacting in public.

Sometimes, young people were uncomfortable with the identities they were putting on display in public places. This often came up in discussions around school uniforms, which young people reported could mark you with undesirable character traits stereotyped to a particular school. When young people were uncomfortable with the identities they felt they were displaying for whatever reason they tended to avoid public spaces of interaction. For instance this young man disliked being seen with his mum's shopping on the 'public' bus.

> Andre: I don't like getting on the bus with shopping. Yeah. Yeah, I hate that as well because the way people just start staring at you....Yeah, only time I would get in a bus with shopping is if I have one of them expensive bags, otherwise no.

He preferred to walk or ride his bicycle to avoid interacting with his peers, retreating to the more 'private' space of the street. A few other participants in our study also reported taking to the streets to avoid particular people or the general "peer gaze". Therefore, in addition to social space, young could use their mobility to turn the street into 'private' space.

DISCUSSION

These findings contribute to the growing literature critiquing the conception of 'hanging out' as idle, inactive behaviour. We found that 'hanging out' to be a dynamic practice, encompassing a variety of activities and achieving a number of socially productive goals. The prominence of mobility in 'hanging out' in our data also suggests that this practice can include physical activities for young people.

Young people use mobility in a variety of ways to enhance the goals of 'hanging out'. Mobility helps young people to create social and 'private' spaces; it helps them physically and figuratively to express their identities; and it provides opportunities for pleasure both through the joy of movement itself and allowing young people the experience the 'spectacle of the city'. Particular modes of mobility offer opportunities for private bonding with close friends (walking), social gatherings (buses), and cultural associations of particular modes could facilitate identity displays.

We did find evidence in our data that young people create 'risks' using their mobility. Risks could be physical in ways that exposed young people to injury (like running from bus to bus) or more locational in exposing young people to violence in areas they were unfamiliar with (like purposefully getting lost). These risks are ways of negotiating identities, but also of creating uncertainty in overly structured lives and rebelling against adult risk discourses. Young people are able to engage with risk and learn important skills from their mistakes (Christensen and Mikkelsen 2008). In addition, they use their mobility to help them refine their own constructions of risk, which some have noted can differ from the way adult's perceive risk (Green 1997).

'Hanging out' is one of the few opportunities in their daily lives that young people have to develop their risk landscapes. Zeiher (2003) argues that young people are shuttled in between 'islands of childhood' like school and structured leisure activities which provide insulation from the risks of everyday life (Zeiher 2003). Mobile space, the space in between these islands of childhood, is a respite from this structure, "a place where power hierarchies can be challenged" (Murray and Mand 2013). In her work on the emotional aspects of the journey to school, Murray (2009) found that mobile space is an area where it's possible to be both subversive and liberated. Similarly we found young people use mobility during their 'hanging out' practices to challenge power hierarchies and develop risk landscapes.

Social factors may influence how young people use their leisure time mobility to create risk. Our study wasn't designed to compare population groups, however it is easy to see how the different accomplishments of mobility related risks may be more or less salient for different groups. Risk framing and risk taking is deeply gendered (Green and Singleton 2006). For instance, negotiating a 'male' identity may involve more dramatic physical risks, like the ones described by Johnny on his bike. Risks that young women create may also need to account for social and cultural discourses around female respectability (Green and Singleton 2006), which may suggest they are more likely to occur in groups or places of interaction. One's own socio-economic status may change the meaning of 'getting lost' in areas with differing levels of socioeconomic disadvantage. Young people from different ethnic backgrounds may have more or less 'structure' imposed on their daily lives, and therefore different levels of motivation to rebel against structure.

Overall, the way young people used mobility while 'hanging out' suggests that the framings of both youth 'at risk' and 'as risk' are problematic. A focus on protecting young people from risk has led to strong ideas about what they "should" be doing, led by expertise, promising certainty in an age of "manufactured uncertainty" (Kelly 2000). Young people experience their lives as over-structured, routinesed and under constant surveillance (Turnbull and Spence 2011). 'Hanging out', which subverts the sanctioned and acceptable ways for young people to spend time, was one way they could rebel against the adult hegemony. The 'risks' that young people created using their mobility during their 'hanging out' practices can be seen as productive from a societal standpoint as they helped young people negotiate identities and refine their own risk landscapes.

A focus on young people 'as risk' to others is also problematic, reflecting "a society that fears its own future" (Turnbull and Spence 2011p956) and turns youth into a risk management project. As Mcara and Mcvie warn treating youth as 'permanent suspects' may serve to maintain or reproduce the very problems which institutions are aiming to control (2005).

From public health perspective (which aims to maximise physical and emotional well-being among young people), 'hanging out' practices are a not only crucial to social development, in an urban environment where space is at a premium, these practices can be physically active. While perhaps agreeing that what is needed is less surveillance of young people rather than more, it is interesting to note that the physical activity benefits of 'hanging out' are not typically captured using current methods of surveillance such as travel or time diaries. If public health does insist on monitoring young people's mobility, our findings suggest that movement during 'hanging out' should not be neglected. Echoing calls from urban geographers, our findings also suggest that rather than curtailing 'hanging out' practices, public health should focus on creating more conducive environments for children's unstructured activities to stimulate the physical and emotional benefits of 'hanging out'.

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A7.3 How does 'hanging out' expose young people to road hazards?

The previous Research Paper described a number of ways in which 'hanging out' exposes young people to road hazards. While young people tended to describe their 'hanging out' practices in vague terms such as 'doing nothing', detailed stories suggested that they actually participated in a wide range of micro-activities which accomplished a number of 'goals'. Young people used 'hanging out' to: escape boredom, socialize with friends, form and reproduce social identities, learn citizenship skills, disrupt the predictability of everyday life, and challenge structures imposed by adults. Many of these 'goals' were enhanced by movement in outdoor locations that may expose young people to road hazards. Findings suggested that outdoor locations were popular spaces for 'hanging out' as they did not require money, could accommodate large(r) groups and avoided parental supervision.

Findings from the Research Paper in section A7.2 detailed a number of micro-activities that appear to leave young people particularly vulnerable to road hazards as pedestrians including: purposefully creating mobility related risks, traveling to unknown locations, and 'wandering around' the streets. Nora, Donna and Tamika, for instance, describe that they were able to disrupt the certainty of everyday life by creating a game involving running between buses. This game will necessarily involve crossing streets, and therefore will obviously expose these girls to road hazards. Worryingly, children may very well be distracted while engaging in this type activity, which may make exposure more hazardous.

Traveling to and from unknown locations emerged as another popular micro-activity in 'hanging out' practices. Tyra and Naomi describe using the bus for these adventures. While young people are unlikely to be exposed to road hazards while on the bus, walking to and from bus stops will involve some exposure. Similarly 'wandering around' in the road environment will expose children to injury risk. However, not all 'wandering around' carries the same level of exposure to road hazards. For instance, Daniel and Andre reported 'wandering around' the street to create private space to bond with friends (Daniel) and avoid the gaze of their peers (Andre). This type of 'wandering around' purposefully takes place on what Daniel describes as quiet streets, where "it's just like literally only me and my friends walking on it." This type of 'wandering around' is, then, unlikely to expose young people to high levels of road hazards. On the other hand, Nadia and Archie described 'wandering around' to enjoy the spectacle of the city and socialise with large groups of friends. This type of 'wandering around' necessarily takes place in busier locations such as high streets and London landmarks because those spaces have "a lot of crowd and everything and there is a lot happening"

(Nadia). Results from the literature review of environmental correlates of pedestrian injury (section 3.2) suggest that levels of hazards in those types of areas may be relatively high.

Taken together, findings from the Research Paper in Section A7.2 imply that young people have substantial and complex exposure to road hazards while 'hanging out', but there will be genuine challenges in measuring leisure time exposure quantitatively. The vagueness with which children described 'hanging out' suggests that they see these activities as routine and non-noteworthy, making them difficult to capture in surveys or time diaries. Through examining young people's stories, Research Paper in section A7.2 found that young people creatively used their mobility while 'hanging out' to craft a number of games, such as running from bus to bus (Donna, Nora and Tamika) or riding bicycles down stairs (Johnny). It does not seem feasible to capture all these types of activities in, for instance, a questionnaire to measure leisure time exposure, as they are likely to be constantly evolving. Additionally, interviews and focus groups revealed wide differences in the how hazardous similar 'micro-activities' are likely to be, especially 'wandering around'. This suggests that quantitative measures need to capture the context of micro-activities, as well as the time spent in the activity itself. Problematically, Research Paper in section A7.2 indicated that many of the 'goals' of 'hanging out' were not explicitly expressed, making it particularly tricky to design variables to describe the context of 'hanging out' activities.

Consequently, it does not seem feasible to develop quantitative measures of leisure time exposure to road hazards using self-administered methods such as surveys or time diaries. In the future, as technological advances improve GPS accuracy and mobile phone tracking accuracy, these methods may be more suitable to capture the context and amount of young people's leisure time exposure to road hazards. However, while findings suggest that quantitative exploration of ethnic differences in leisure time exposure will not be possible, the qualitative exploration of 'hanging out' in Research Paper 3 does have some implications for the role of the leisure time exposure hypothesis in explaining ethnic differences in risk in London.

A&.4 IMPLICATIONS OF FINDINGS FOR THE ROLE OF THE LEISURE TIME HYPOTHESIS IN EXPLAINING ETHNIC DIFFERENCES IN CHILD PEDESTRIAN INJURY.

Findings from the Research Paper in section A7.2 suggest that socio-economic factors may influence levels of exposure to road hazards during young people's leisure time. The paper found, for example, that young people routinely seek private spaces to socialize with their friends, away from their parents and other adults. Children from disadvantaged households may have less access to private space at home and may be less able to 'rent out' private space from popular 'hang out' spots such as cinemas, cafes or sweet shops. With fewer options, these young people may well seek out ‘private space’ on the street (as described by Daniel), thus increasing their exposure to road hazards.

Does the leisure time exposure hypothesis help explain ethnic differences in injury risk in London? Unfortunately, any conclusions drawn from the Research Paper in section A7.2 can only be speculative. Hypothetically, structural associations with low-socio-economic status could well mean that ‘Black’ children are more likely to socialise with friends in outdoor locations, increasing their road hazard risks. This may help to explain the relatively higher injury risks of ‘Black’ children. On the other hand, the same structural associations between ethnicity and low socio-economic status hold for many ‘Asian’ children. Theses minority ethnic groups, however, have relatively lower pedestrian injury risk. There may of course be other factors that influence ‘Asian’ children’s preferences for socialising indoors. As Kelly and colleagues (2013) suggest experiences or perceptions of racism in local areas may lead to young people spending less time outside the home environment. Our previous work suggested that concerns about racially charged confrontations were particularly salient for ‘Asian’ children in London (Steinbach et al., 2007).

Findings from the Research Paper in section A7.2 also suggested young people purposefully create mobility related risks while ‘hanging out’ in order to resist overly structured lives imposed on them by adults. Running from bus to bus and other similar rebellious activities obviously expose young people to road hazards. It is possible that ‘Black’ and ‘Asian’ children face even greater amounts of ‘structure’ in their lives as belonging to a minority ethnic group may restrict their choices and opportunities even further. Children from minority ethnic groups then, may have a greater urge to rebel against ‘structure’ and, in turn, more leisure time exposure to road hazards. If these speculations are true, the leisure time hypothesis may help explain greater pedestrian injury among ‘Black’ children but seems to contradict lower pedestrian injury among ‘Asian’ children. However, here too, the ways in which ‘Black’ and ‘Asian’ ethnicities are linked to ‘structure’ are likely to be different and complex, which may help to explain inconsistent findings.

Overall, findings from the Research Paper in section A7.2 indicate that young people ‘hang out’ in a variety of ways that expose them to injury. Findings hint that social factors such as ethnicity and socio-economic status may influence levels of exposure to road hazards during leisure time, but these results must be interpreted with care. Conclusions are limited by the research design of the Research Paper in section A7.2. The paper aimed to understand how young people used mobility in their hanging out practices, rather than compare practices between different population groups. More qualitative work exploring the ways in which structural and identity elements of ethnicity contribute to ‘hanging out’ practices would be useful. Indeed, as noted in section A7.3, quantitative work examining ethnic differences in leisure time exposure to road hazards is not currently possible. This makes qualitative explorations of how ethnicity is linked to leisure time exposure particularly judicious.

The Research Paper in section A7.2 has another limitation for examining the role of the leisure time exposure hypothesis in explaining reported ethnic differences in injury in London: the ages of the interviewees in the OTB data. The OTB data interviewed young people between the ages of 12 and 18. Ethnic differences in child pedestrian injury risk have been reported for children between 0 and 15. Compared to older children, whose 'hanging out' practices were captured in the Research Paper in section A7.2, younger children may play and 'hang out' in ways that expose them to injury differently. Qualitative work examining leisure activities among younger children - and especially how structural and identity elements of ethnicity contribute to these practices - would help to further illuminate the credibility of the leisure time exposure hypothesis.

Despite these weaknesses of the OTB data, I was able to opportunistically draw on this rich data source to examine how 'hanging out' exposes young people to road hazards in London and shed some light on the potential contribution of the leisure time hypothesis to ethnic differences in risk. Other research is needed to unpack how ethnicity and risk may interrelate.

In conclusion, young people are exposed to road hazards in a variety of ways during their leisure time. While ethnic differences in exposure levels cannot be measured, structural and identity elements of ethnicity may plausibly influence leisure time exposure. It is therefore possible that the leisure time hypothesis can help explain ethnic differences in injury risk in London, but more work is needed to examine links between ethnicity and leisure activities.

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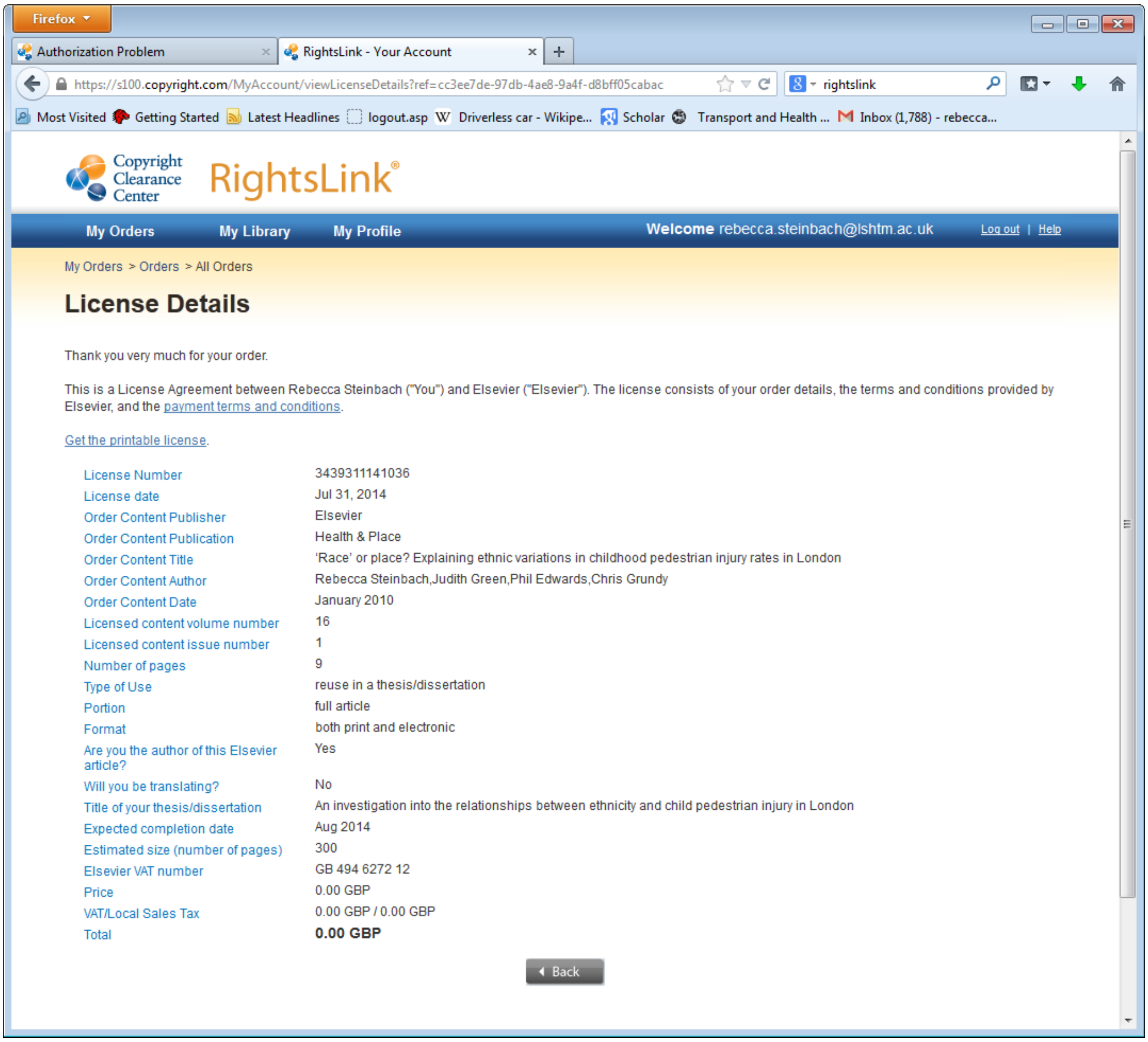

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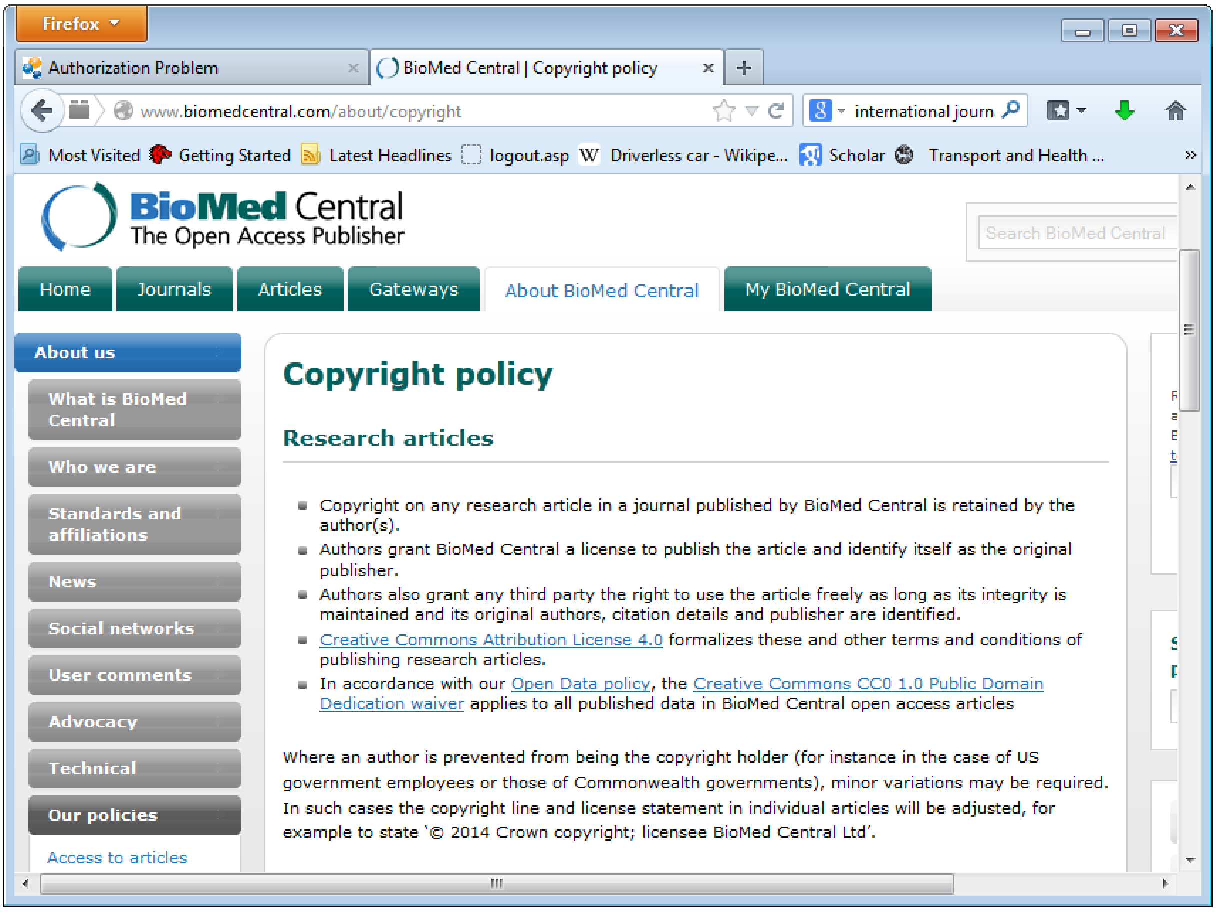

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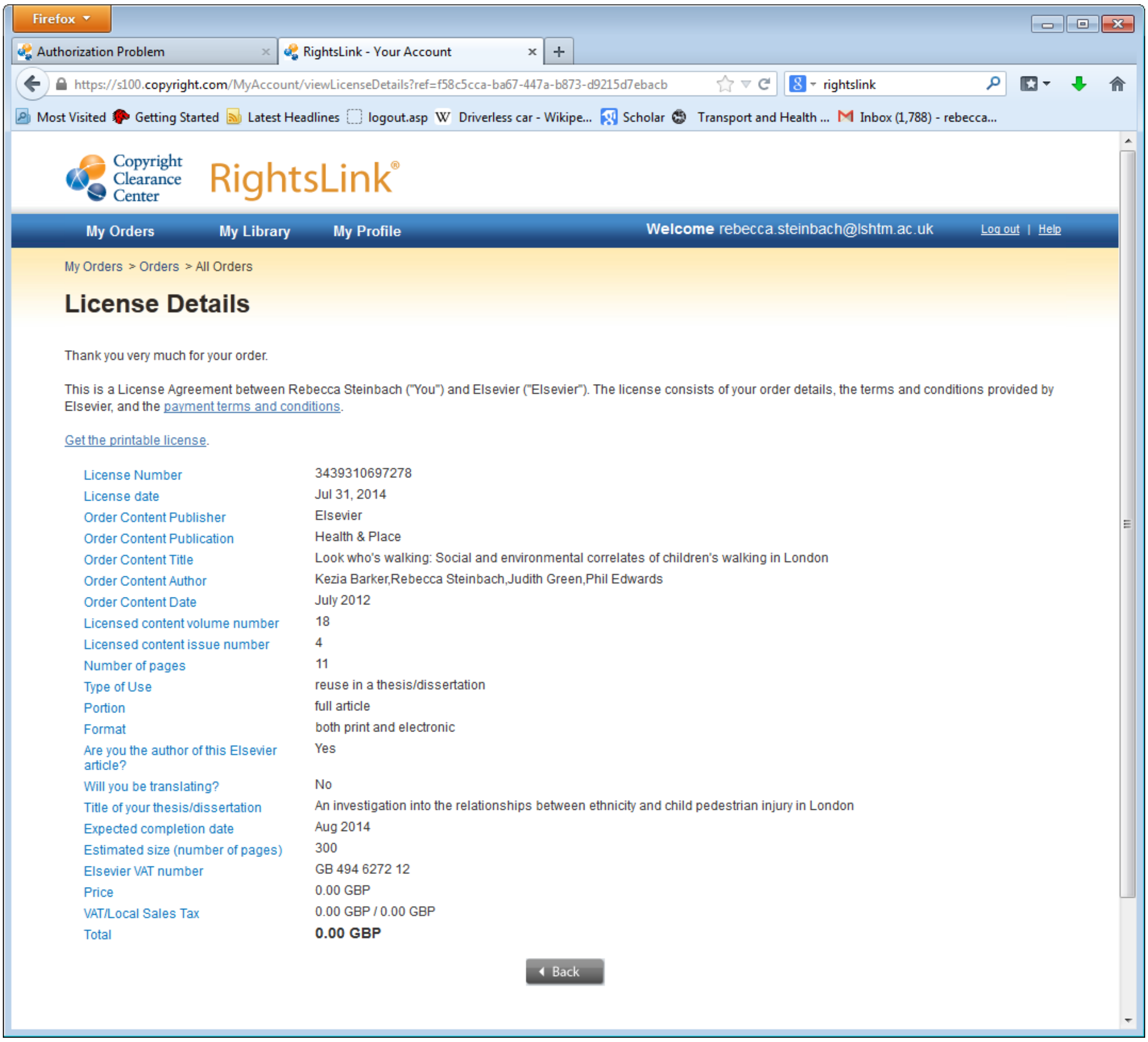

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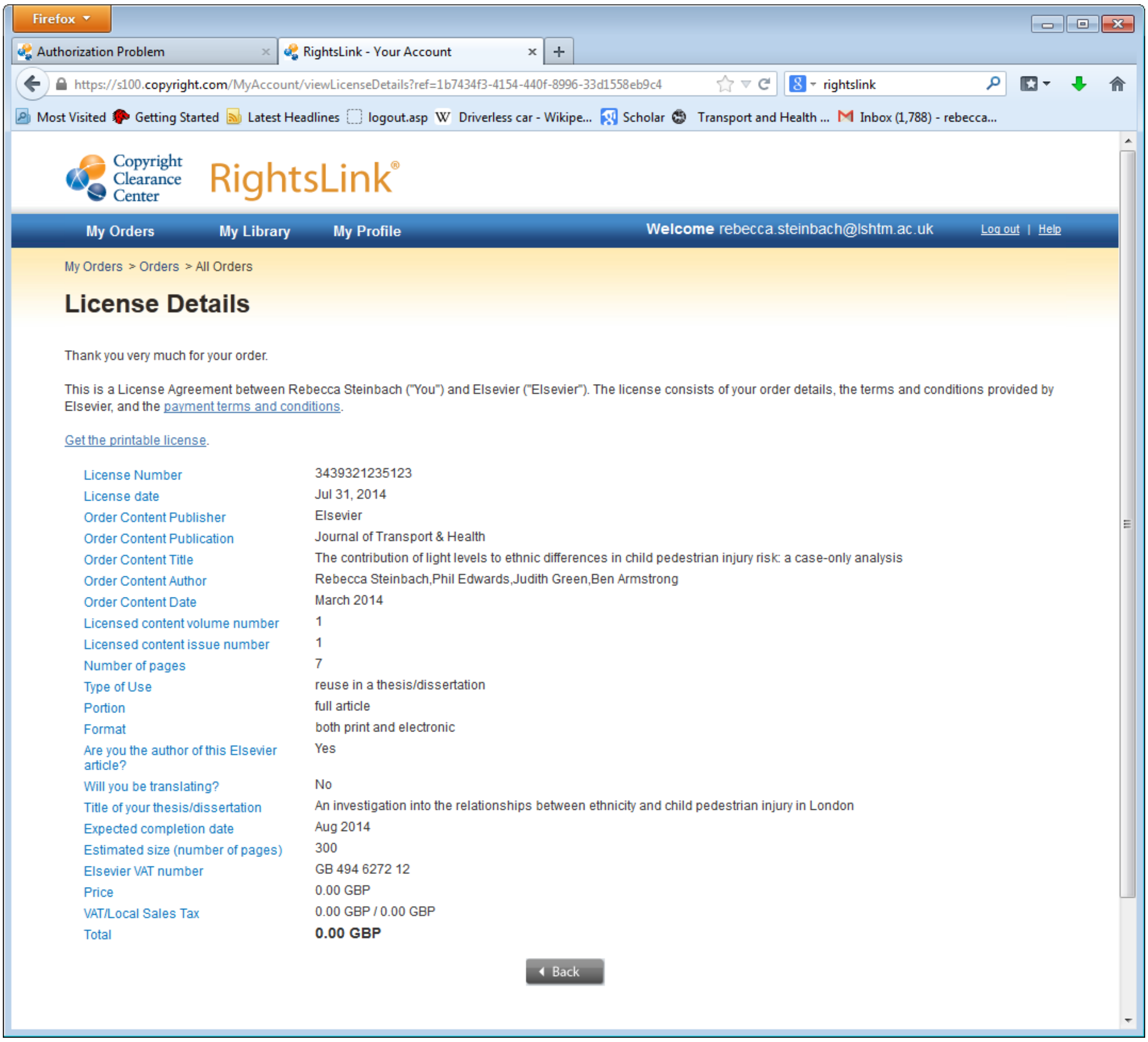

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