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Socio-economic factors affecting spatial inequalities in pregnancy-related ambulance attendances in Greater London

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Exploring inequalities in ambulance and pre-hospital demand is important to improve service equity and reduce wider health inequalities. Maternity incidents amongst ambulance demand are a key area of focus because of the specialized care that is needed for patients, as well as the impact of wider determinants of health on pregnancy outcomes. Since there are spatial inequalities amongst pregnant patients who call for an ambulance, the aim of this study is to assess the underlying factors associated with pregnancy related ambulance complaints, to determine why maternity patients utilize the ambulance service. Local indicators of spatial autocorrelation were used to identify clusters of ambulance maternity demand within Greater London (UK). A negative binomial regression model was used to explore associations between socioeconomic, environmental, accessibility and demographic variables. Our results reveal that neighborhoods with low adult skills (i.e. qualifications/English language abilities) have a higher rate of demand. Moreover, our results imply that the demand for ambulance services may not be directly tied to health outcomes; rather, it might be more closely associated with patients' reasons for calling an ambulance, irrespective of the actual necessity. The benefits of identifying factors that drive demand in ambulance services are not just linked to improving equity, but also to reducing demand, ultimately relieving pressure on services if alternative options are identified or underlying causes addressed. Doing so can improve health inequalities by firstly, improving ambulance care equity by directly supporting a better allocation of resources within ambulance systems to target patterns in demand.

KEYWORDS

ambulance, inequality, maternity, pregnancy, pre-hospital, demand, equity, efficiency

1 Introduction

Ambulance services in England are facing increasing organizational pressures and challenging performance. This can be partially attributable to growing demand, staffing issues, handover and waiting times, and post-pandemic difficulties (1–3). The reasons for this are complex and vary, including factors such as population growth and an aging population (4, 5). Since 2010, public services in England have also faced increased pressure from a freeze or significant cuts to funding, resulting in reduced services across the country, with variable impacts depending on individuals' location and access to services (6, 7). This is often described as a postcode lottery, meaning that residential locations determine the level of available public services and care (8, 47),

with significant differences—or inequality—between services available to individuals (9–11, 48). With health services under pressure and severely lacking capacity, ambulance services have become increasingly viewed as the first, only, or last option available for many patients, and a reliable gateway into the healthcare system (12), which in turn increases pressure on ambulance services when other patient care options might be more appropriate (13, 46).

Maternity care services in England can often overlook ambulance services as a critical part of maternity care. Heys et al. (14) argued for increased training, research, and standardization for emergency pre-hospital maternity care provided. A common strand of ambulance and maternity services research focuses specifically on unplanned births or out of hospital births. Research on out of hospital births attended by ambulance services has found that socio-economic variables such as income, class, and ethnicity are associated with outsized demand of this type (15). Heys et al. (14) found that paramedics often have low clinical confidence when dealing with maternity patients if they have not received specialized maternity training or exposure to maternity incidents, as well as being unable to access expert maternity advice. Therefore, maternity care should be an important part of ambulance demand research but currently there is little literature focusing on the drivers of this demand type (15, 16). This study seeks to provide an overview of maternity ambulance incidents and identify inequalities and factors driving this type of demand.

While other metrics such as clinical quality indicators are published for ambulance trusts (17, 49), ambulance response times receive a significant amount of research focus, as the speed of pre-hospital response is often critical for patient outcomes (18). It is common for ambulance research to focus on increasing demand by optimizing ambulance resource systems with the goal to reduce response times. Incorporating equity measures into ambulance planning often focuses on equal resource distribution based on geography, rather than matching the needs of the population, whilst an approach that prioritizes an average level performance of service delivery can overlook the variations where inequities persist (19–21). This approach can categorize the understanding of equity as “horizontal,” rather than “vertical.” Horizontal equity refers to a focus on equal distribution everywhere, whilst vertical equity looks to balance and distribute resources accordingly to match existing health inequalities amongst different groups. Ambulance services and literature often have a high proportion of research and strategy focused on aging population, as this is a large and increasing share of emergency ambulance demand (4, 5, 17, 22). Complaint types with high acuity are commonly the focus of research on ambulance efficiency, as an improved response time can improve survival rates for these categories. These are often classed as category 1 incidents, where (in England) a response time of under 8 min is expected (17). However, for categories of incidents such as maternity cases that may be a small fraction of overall activity, and of lower acuity, there are still inequalities in the response to these incidents that warrant being addressed. This can be to the detriment of different incidents, where inequalities may persist, and where patient care can be improved. Within the London Ambulance Service (LAS) strategy, maternity incidents

have been identified as an area where specialized care can be provided to improve patient care and outcomes (17, 61). This specialized pre-hospital care is important as it can often provide a better alternative pathway for patients, where conveyance to an emergency department may not be the most appropriate outcome. Allen et al. (55) noted that the National Health Service (NHS) legal cost for maternity care is one of the highest proportions of all clinical types, and so improved care, efficiency, and equity can look to reduce this financial aspect across all NHS services. Furthermore, maternity services have often been the focus of independent investigations into failings of care (14, 23) therefore there is increased interest nationally in improving care within this field.

This study aims to uncover spatial inequalities present in maternity incident demand and assess the underlying factors associated with geographical variations in ambulance demand rates. Determining utilization patterns of ambulances can promote equitable resource allocation and exploring wider determinants can explore how broader policy interventions may help alleviate demand in frontline medical services and reduce health inequalities. Examining underlying socio-economic and environmental factors that characterize hotspot areas can help determine how demand for ambulance resources can be reduced whilst at the same time patient care and equity improved.

2 Materials and methods

2.1 Setting

The London Ambulance Service (LAS) NHS Trust is the emergency medical care service that covers all Greater London. It is the busiest ambulance service in the UK, attending over 1 million incidents a year (17, 62). The LAS is the only ambulance trust in England to cover an entirely urban area, with a dense population of 8.8 million residents and is the only pan-London NHS trust. Greater London can be divided into five Integrated Care Systems, which centralize health and care operations for those areas. Analyses were conducted at Lower-level Super Output Areas (LSOA) geography level (defined by the UK census). This scale of administrative area was chosen as it allowed for the smallest scale of geographic area that data was available for, whilst also allowing for analysis on geographical inequalities by determining differences within boroughs. This scale also ensured patient anonymity by grouping to populations of ~1,500 individuals. The study area included 4,345 LSOAs excluding only one Greater London area containing Heathrow Airport due to the high volume of incidents within this one LSOA that did not occur in residential areas.

2.2. Ambulance demand data

Ambulance data comprising of “see and treat” incidents categorized with the primary complaint as “pregnancy, childbirth, miscarriage” from the London Ambulance Service (LAS) was used for this cross-sectional analysis. LAS demand data categorizes incidents into Chief Complaint groups. These are clinical groupings

that help provide information to staff dealing with an incident. The largest chief complaint group is NHS 111 “Transfers,” whilst “Falls and Breathing Problems” are large categories; there is also a large group of incidents with an “unknown” chief complaint. This is worth acknowledging whilst using chief complaint categorization, as NHS 111 “Transfers” and “Unknown,” do not provide any clinical information for analysis, and there may be many maternity related incidents that were not categorized under the pregnancy chief complaint. Furthermore, incidents may not be accurately categorized by call handlers, and the true nature of an incident may change once patients are treated in person. Pregnancy incidents from 2010 to 2022 dispatch data were collated to LSOAs, and incident rates per 1,000 population were calculated for LSOAs across Greater London. Residential population levels from the 2021 Census were used to calculate incident rates, which includes all people registered at a household in an area.

2.3. Independent variables

Independent variables used for analysis were of four categories: demographic, socioeconomic, infrastructure/accessibility, and environmental. The variables chosen for this study came from multiple sources. Data on locations of NHS hospitals with maternity facilities in Greater London was provided by LAS. The number of patients registered at General Practitioners (GP) practices was taken from NHS Digital with GP practices aggregated to LSOAs. This does not account for patients that may be registered at GP practices in one LSOA but live in another, as well as other accuracy issues such as ghost patients, list inflation, or over coverage (66). Variables categorized into socioeconomic, environmental, and accessibility were taken from the Index of Multiple Deprivation (IMD): indicators calculated and categorized into sub-domain scores of deprivation. Variables, including IMD sub-domains, were chosen based on a review of literature on ambulance demand studies and pregnancy related health outcomes (16) using sub-domains to allow effects beyond the overall deprivation score to be explored, whilst controlling for multicollinearity (the chosen variables are summarized in Table 1).

This study focused on three demographic variables derived from Census 2021 data. While age is generally associated with higher ambulance demand, it was not included in the modeling due to its low correlation with maternity ambulance incidents. The limited availability of data at this scale suggests that the relationship between older pregnant patients and ambulance incident rates is likely more discernible at the individual patient record level rather than through ecological analysis.

Ethnic disparities in healthcare access and maternity health outcomes, particularly among black women, have been emphasized in several studies (24–26, 52). To capture a comprehensive understanding of racial impacts amongst all ethnic census groups, our study incorporated the three main non-white census groups: (i) Black/African/Caribbean, (ii) Mixed Ethnic, (iii) Asian. Including these three categories also allows for accounting for the proportion of white to non-white demographics, allowing a more nuanced examination of the intersectional dynamics at

play. Moreover, it acknowledges the heterogeneity within non-white populations, which is essential for developing targeted interventions and policies.

Sub-domains taken from the Index of Multiple Deprivation were reviewed and selected based on previous literature (50). For example, a score of Adult Skills (which combine both rates of education and English language proficiency) was considered, as there are several studies regarding adult education, language skills, and their effect on healthcare accessibility and health outcomes (24, 27, 65). This is applicable to maternity health outcomes too and relevant for emergency ambulance incidents as whether a patient needs an ambulance can be influenced by whether they sought alternative care, or if they delayed care until it became an emergency.

The number of households with lone parents was included as a measure to examine the effect of maternity patients living alone. Previous research indicates that lone mothers have a different experience of pregnancy as well as a lack of social network (28, 29), but their association with ambulance utilization is not as clear.

Low socioeconomic status has shown links to inequalities in adverse pregnancy outcomes. Factors such as professional occupations, were included because of association between professional work occupations, good health behaviors, and well-informed decisions. Furthermore, associations with physical stresses, risky behaviors, and poorer outcomes in pregnancy led us to include this factor (25, 30).

Foreign born percentages in neighborhoods have been included due to previous literature associating foreign patients with poorer pregnancy outcomes, due to difficulty accessing healthcare services, or reluctance to connect due to fears of immigration status (14, 56, 74).

This study focuses on three accessibility factors as potential determinants of ambulance incident rates, considering their relevance to patients' decisions to call for an ambulance. These were: (i) distance to nearest maternity hospital, (ii) percentage of residents registered to a GP, and (iii) the percentage of households without access to a car. We theorize that the distance from the nearest maternity hospital could impact patients' choices to use ambulances for accessing care, drawing on insights from previous research discussing how distance influences accessibility to healthcare resources (31, 32).

The inclusion of the proportion of households with access to a car reflects its potential impact on patients' decisions regarding ambulance use. Individuals with access to a car might choose to directly seek care at an Emergency Department (ED). Furthermore, residents registered with General Practitioners (GPs) may play a role in influencing patient choices toward alternative care, potentially reducing reliance on ambulance services (5, 13). The accessibility of other primary care resources is also a crucial factor in shaping the utilization patterns of emergency medical services (33). An understanding of these diverse accessibility factors contributes to a more nuanced assessment of the dynamics influencing ambulance use across various scenarios.

Environmental factors are included primarily based on their influence on health outcomes amongst pregnancy related incidents. These factors include housing conditions, air quality, crime rates,

TABLE 1 Summary of variables chosen.

Category	Variables considered	Assumptions	References	Source
Demographic	Age % Black/African/Caribbean % Mixed Ethnic % Asian	Worse health outcomes depending on group Racial inequalities and health disparities within groups. Accessing healthcare, prenatal options	Agyemang et al., (54), Jardine et al. (25)	Census 2021
Socioeconomic Status	Adult Skills* - Adults with no or low qualifications - English language proficiency	Affect whether populations have awareness of alternative NHS Healthcare resources healthcare resources. Patient pathways. May hesitate and delay care until medical emergencies arise	Agyemang et al., (54), Schempf et al., (70), Hong et al., (60), Jardine et al., (25), Rayment-Jones et al., (35)	IMD 2019
	% Foreign born	More difficult time accessing healthcare resources. Relying on fall back of ambulance	Vik et al., (74), Urquia et al., (73), Rayment-Jones et al., (69)	Census 2021
	% Professional occupations	Private healthcare resources	Gluck et al., (57)	Census 2021
	% Households one person	Pregnant patients living alone may be more likely to utilize ambulances than those living with a partner or shared accommodation	Hadebe et al., (58)	Census 2021
Infrastructure and accessibility	Distance from maternity hospital % Households no cars (51)	Affects decision making to utilize an ambulance Households with a car might travel to hospitals without waiting for an ambulance. More accessible and easier alternative	Miranda et al., (64), Pinchbeck, (68)	LAS, Census 2021
	% Population registered to GP (51)	GP practices might be an alternative resource for pregnant patients. Patients may fall back on ambulance utilization if they cannot access or are not registered	Miranda et al., (64)	NHS Digital 2022
Environmental factors	Wider barriers to housing and services* - Household overcrowding - Homelessness - Housing affordability	Difficulty with access to housing and stability in housing can affect health outcomes for maternity patients, including higher rates of preterm births and emergency department visits	Agyemang et al., (54), Pantell et al., (67)	IMD 2019
	Indoors living environment* - Poor housing conditions - Houses without central heating	Complications or poorer outcomes for pregnancy. Increase chance of utilizing ambulance Stress and mental health concerns. Increase risk of illness with pregnancy complications	Agyemang et al., (54), Miranda et al., (64)	IMD 2019
	Air Quality Indices (CO ₂ NOx PM2.5 PM10)	Pregnancy complications	Hannam et al. (38), Miranda et al., (64)	LAEI, 2019
	Crime* Violence, Burglary, theft, Criminal Damage	Increased stress Domestic violence—violence against women Health behaviors—Risky behaviors e.g., substance abuse, CHAOTIC lives	Miranda et al., (64), Schempf et al., (70)	IMD 2019

*English Indices of Deprivation 2019 subdomain categories – Noble et al. (75).

housing access, and overcrowding. These factors therefore are considered for ambulance utilization.

Crime IMD deprivation scores are included as measure of societal risk, where women who are often living or experiencing higher social risk may be less likely to access preventative healthcare and therefore require emergency care more often. Highly deprived areas with high crime rates are an indicator representing areas of high stress, uncertainty, and chaotic lives, which can increase social risk (34, 35). Housing Insecurity, measuring by wider barriers to housing from the IMD, was included because of previous links between housing insecurity and maternity outcomes (36, 37). This is similar for air quality indicators, with previous literature indicating that poor air quality

can be linked to poorer health outcomes amongst maternity patients (38, 39) and therefore more likely to utilize emergency pre-hospital care.

2.4. Statistical analysis

2.4.1. Spatial autocorrelation

Spatial autocorrelation is a branch of statistics that consists in an extension of autocorrelation methods through a second spatial dimension. Whilst autocorrelation measures the strength of relationship between values of residuals along a regression line, spatial autocorrelation involves the relationship between

neighboring values. Neighboring values that are closely related would indicate a strong spatial autocorrelation and systematic variation. Values that would appear to be arranged randomly across space would show a weak spatial autocorrelation; complete spatial randomness is the complete random arrangement of values across an area. The I value is calculated alongside a p -value to ensure its statistical significance. Results where $p < 0.05$ would allow us to assume that spatial autocorrelation exists. A Moran's I value of zero would indicate complete spatial randomness. A positive Moran's I value indicates positive spatial autocorrelation and clustering while negative values would indicate neighboring values are not similar (40, 41).

Local Indicators of Spatial Autocorrelation were used to identify clusters of similar rates within the study area. The local Moran's I value for a local spatial object is calculated using the formula:

$$I_i = \frac{x_i - \bar{X}}{m_2} \sum_j w_{ij}(x_j - \bar{X}) \tag{1}$$

$$m_2 = \frac{\sum_i (x_i - \bar{X})^2}{n - 1} \tag{2}$$

Where m_2 is a constant for locations, w_{ij} is the spatial weight of observation i and j , \bar{X} is the attribute mean. n is the number of observations. Using local spatial scores can allow a nuanced understanding of where high or low clusters are within the region and to also identify spatial outliers, such as high areas amongst low values and low areas amongst high. Areas that were significant hotspots (p -value < 0.05), alongside borough variation, are used to examine differences in regression models compared to global results.

2.4.2. Negative binomial regression

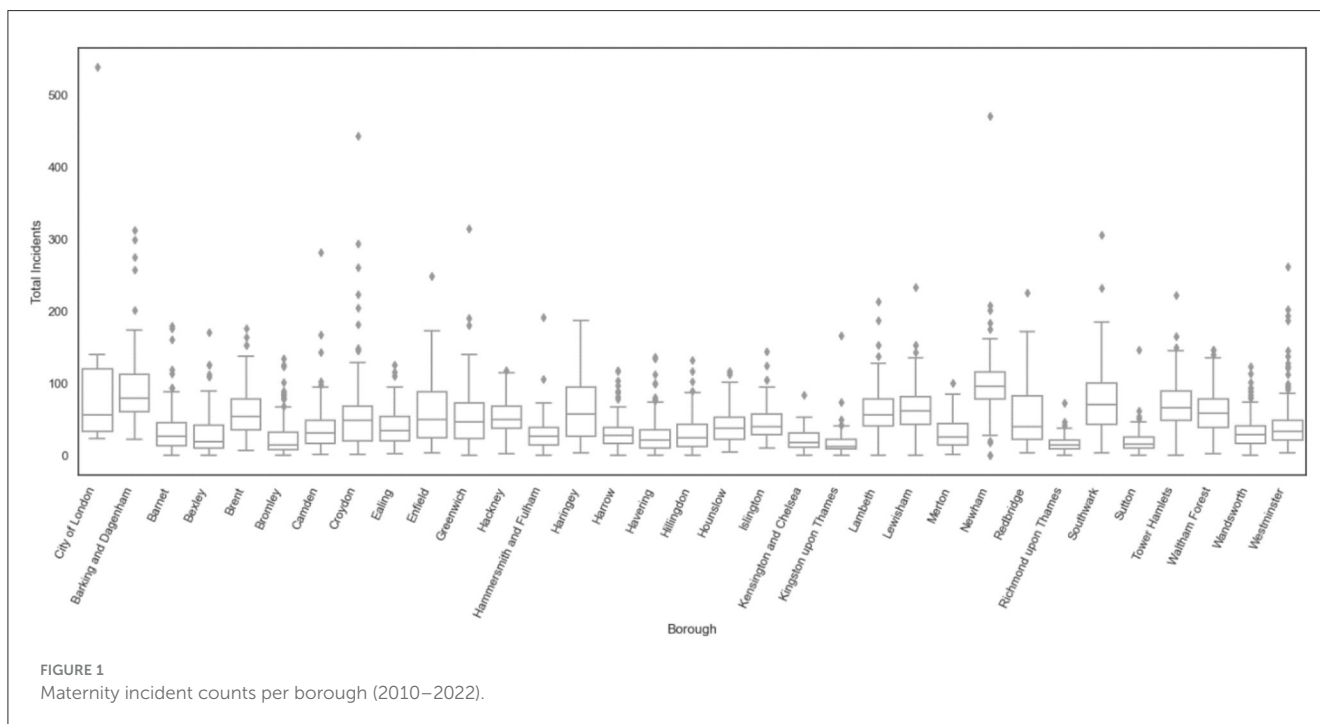
A negative binomial regression model was used, as it allows for overdispersion by adding an extra parameter to the model that estimates the extra variation in the count data beyond what is explained by the mean. Negative binomial regression equation is commonly represented as:

$$\log \log \lambda_i = \beta_0 + \beta_1 x_{i1} + \beta_2 x_{i2} + \dots + \beta_k x_{ik} + \sigma \varepsilon_i \tag{3}$$

Where the expected value for the outcome variable y_i is represented as λ_i , β_k is the regression coefficient for the corresponding variable x_k . The error term $\sigma \varepsilon_i$ is included for negative binomial regressions and accounts for the overdispersion, differing from regular Poisson regression types (53). The full model used for this study can be represented as:

$$\begin{aligned} \ln(\text{Incidents per 1,000}) = & \beta_0 + \beta_1 x_{\text{pctBlack,African,Caribbean}} \\ & + \beta_2 x_{\text{pctAsian}} + \beta_3 x_{\text{pctAdultSkills}} \\ & + \beta_4 x_{\text{ProfessionalOccupationFemale}} + \beta_5 x_{\text{LoneParentHousehold}} \\ & + \beta_6 x_{\text{NearestHospitalDist}} + \beta_7 x_{\text{pctHouseNoCars}} \\ & + \beta_8 x_{\text{pctGPRegistered}} + \beta_9 x_{\text{WiderHousingBarriers}} \\ & + \beta_{10} x_{\text{HousingDeprivation}} + \beta_{10} x_{\text{CrimeDeprivation}} \end{aligned} \tag{4}$$

Results are presented as Incident Rate Ratios (IRR). Two levels of regression models were implemented: one for the overall Greater London area, and another was applied to each of the 33 London boroughs to unveil the spatial differences.



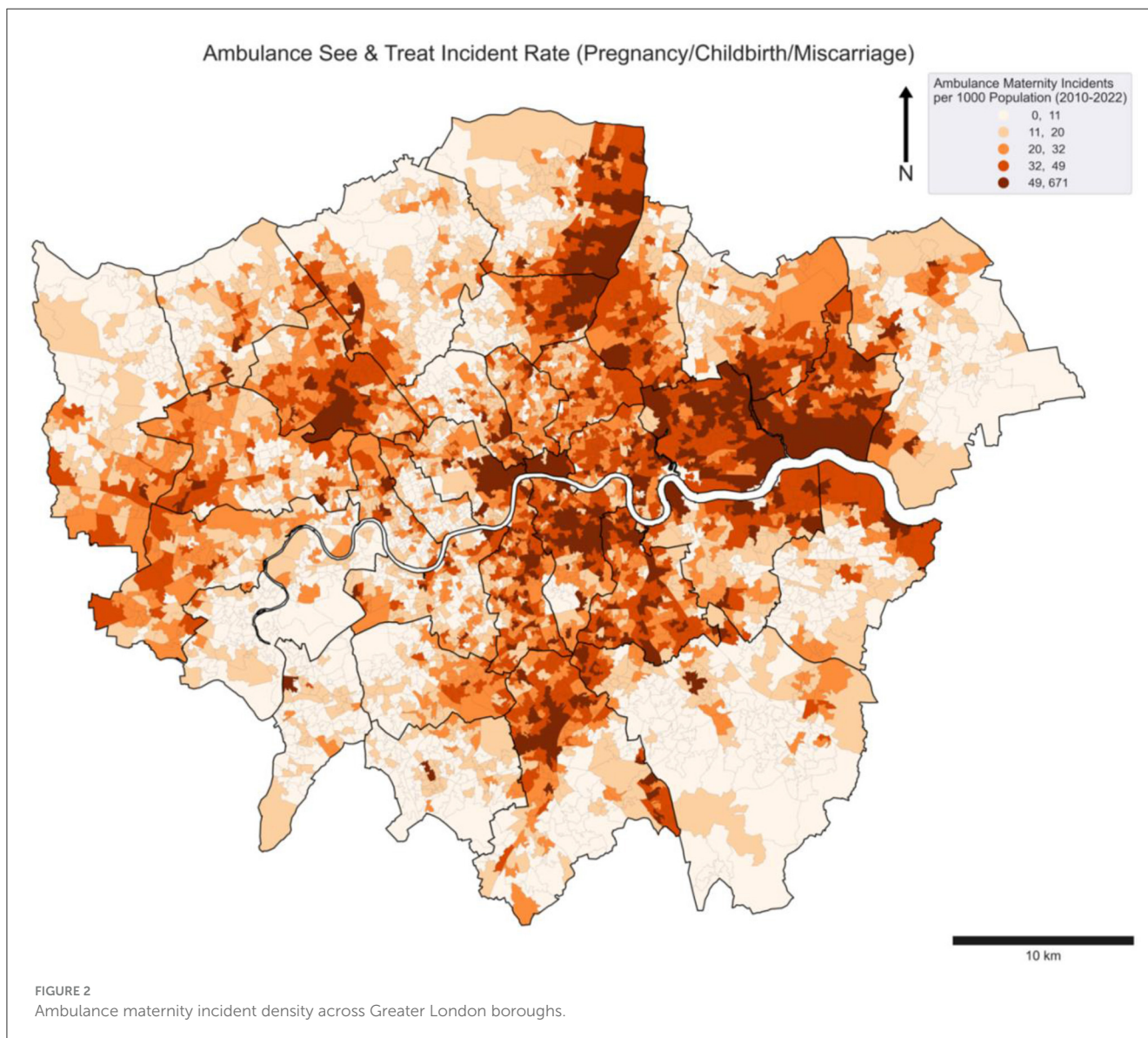
3 Results

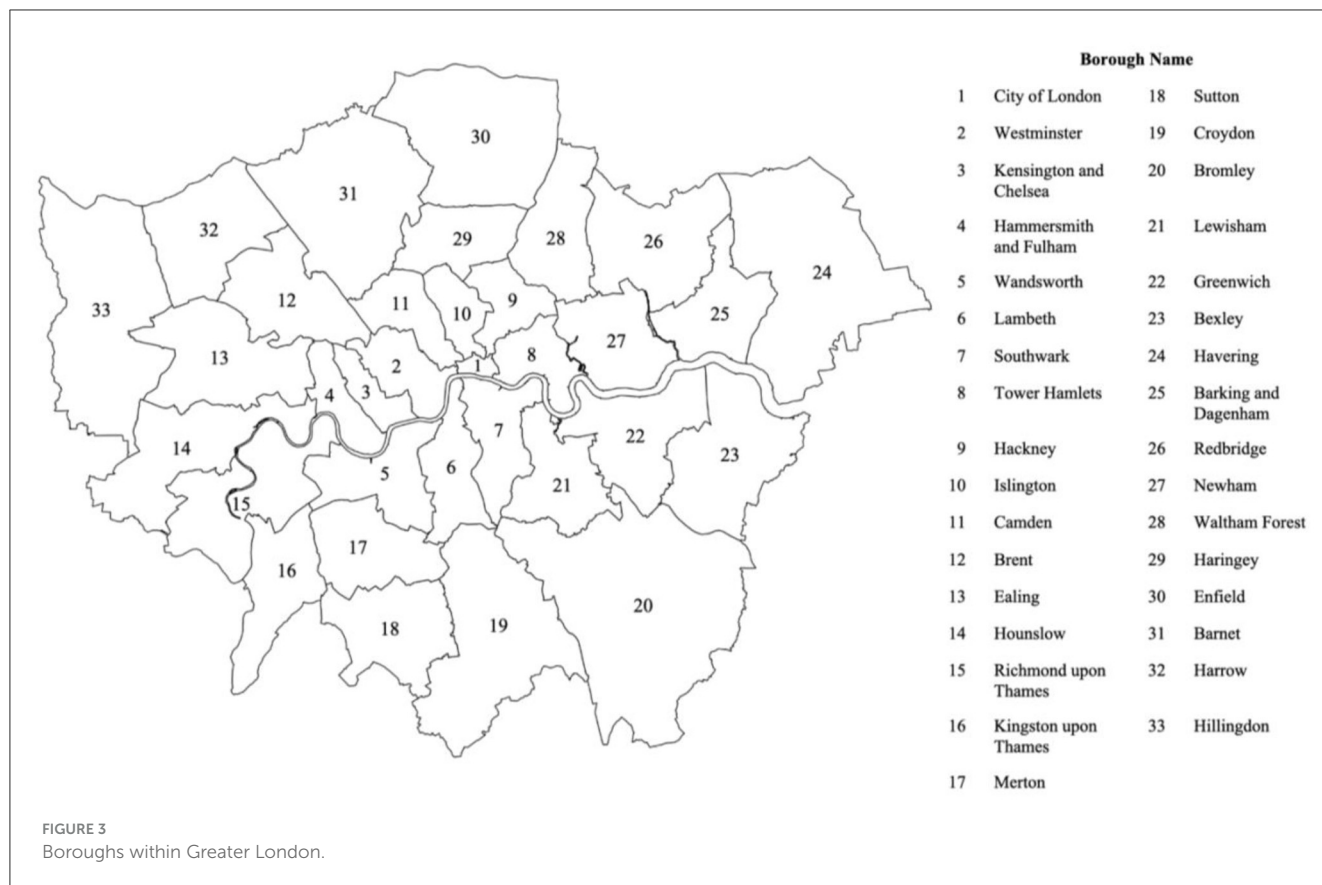
Between 2010–2022 there were 231,118 emergency ambulance incidents categorized as “Pregnancy, Childbirth, Miscarriage,” with the minimum per LSOA reported as 0 and the maximum 1,659 incidents. There were 22 LSOAs out of a total of 4,835 that had zero reported incidents. The median number of incidents per LSOA is 38 (Figure 1). Incidents per 1,000 people (Figure 2) show the distribution of incident rates across Greater London. This indicates that rates are not consistent with population levels. Across Greater London the incident rate pattern shows boroughs that have higher rates, such as London Borough of Newham, which has the highest median of incident rates per LSOA, excluding the City of London (Figure 3). Some boroughs have significant LSOA outliers such as Croydon, Greenwich, Southwark, and Westminster with areas of relatively high incident rates, relative to their surrounding neighborhoods. This reflects areas of traditionally high deprivation amongst boroughs where there

is a large range of deprivation. Figure 4 shows the deprivation rates from the IMD 2019 for comparison with ambulance incident rates.

Spearman rank correlation coefficient results suggest a high range of correlation deprivation scores (between -0.30 and 0.79), indicating that deprivation sub-domains may better reflect the relationship with demand rates. Other chosen variables ranged from 0.77 (% Black/African/Caribbean) to 0.20 (air quality pm 2.5). These results were used to inform the feature selection for regression analysis.

LISA hotspots (Figure 5) show significant variation between east and west, as well as north and south. This suggests that rates of pregnancy complaints are clustered in specific areas within London neighborhoods (i.e. Newham and Barking and Dagenham have the highest number of hotspots per borough: the largest proportion of hotspots falls within North East London Integrated Care System). This ranges considerably between boroughs from Newham containing 140 LSOA hotspots to 3 boroughs containing





only 1. This suggests a substantial level of demand inequality within this clinical complaint type.

Our regression results (Table 2) show that neighborhoods with low rates amongst the Adult Skills IMD subdomain have an IRR of 1.39 (1.30–1.48), indicating a 39% higher rate of demand in neighborhoods with low adult skills. Low adult skills can contribute to a lack of understanding of alternative care pathways, early issue recognition and patient self-efficacy, the ability for a patient to seek appropriate healthcare services earlier. Other deprivation scores of wider barriers to housing and indoor housing conditions have scores of 1.18 (1.12–1.24) and 1.13 (1.1–1.16) respectively. This indicates that neighborhoods with a poorer housing quality have a 13% higher rate of pregnancy ambulance incidents.

Other meaningful associations are rates of households with no cars and distance of neighborhoods to a maternity hospital. These factors indicate that accessibility for patients to alternative local services may have an influence on a patient’s decision to use ambulance services or seek alternative care before their circumstances become an emergency. Alternative/easier routes to a hospital rather than through ambulance use could also explain this strong relationship as patients may not wish to wait for an ambulance to arrive.

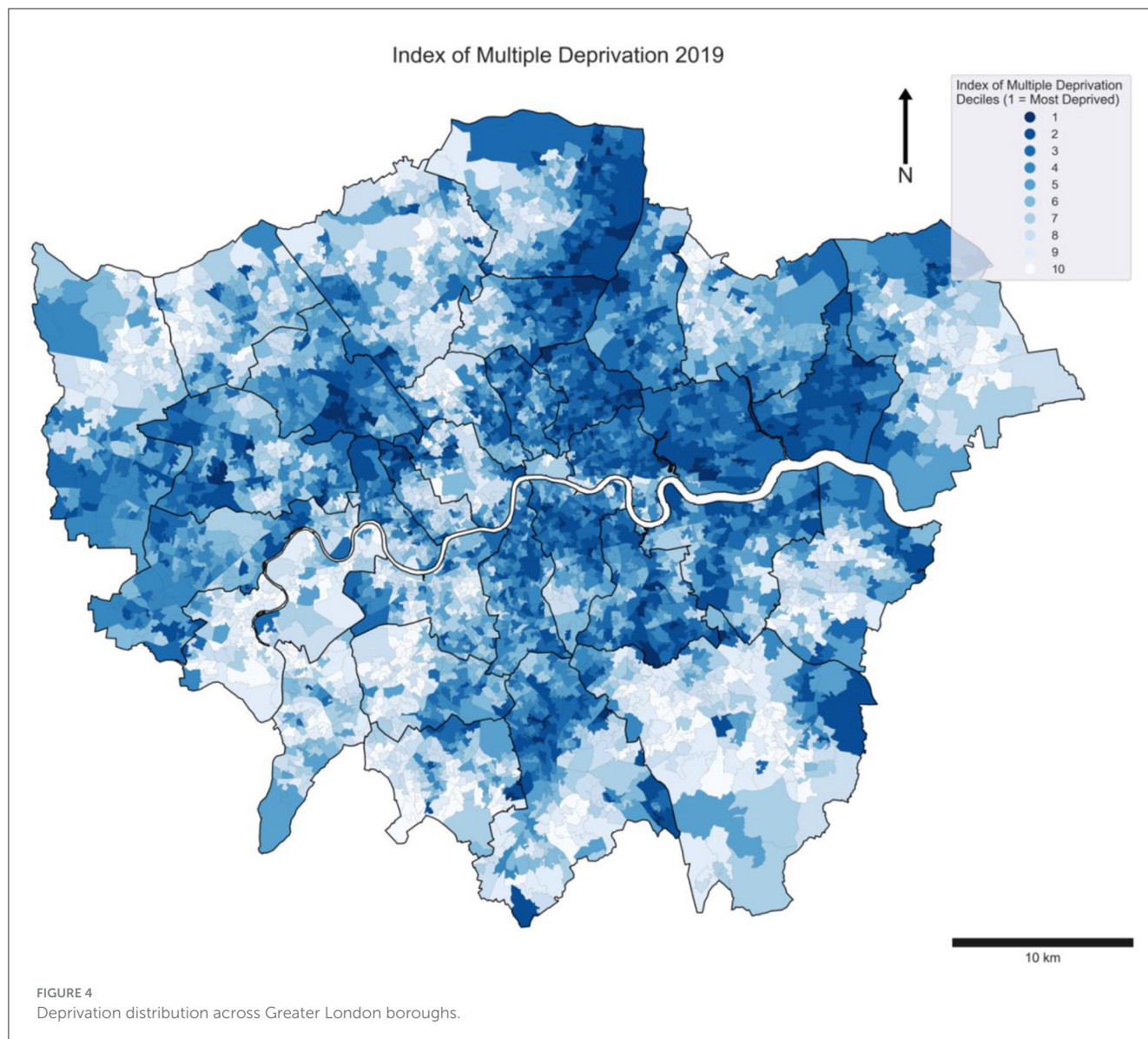
For the local regression results, some factors, including the percentage of residents with black ethnicity, have a consistent effect (IRR) across London boroughs. Other factors, such as Adult Skills, have a large distribution from borough to borough, with a difference in adult skills IRR values of 0.86 in Camden and 1.58 in Barking and Dagenham (Figure 6). This suggests that the effect of

low adult skills varies across boroughs where healthcare services are delivered through different systems.

4 Discussion

Ambulance services are a small part of the NHS maternity care pathway. Many pregnant people will never need to use this service during their pregnancy; however, for those who do, it can be an important and crucial step in this pathway. One assumption made in this research is that high ambulance demand can be an indicator that maternity patients have poor health outcomes, as previous literature suggests this is the case for births that require emergency ambulance assistance (15, 63, 71, 72). Alternatively, another assumption that can explain factors associated with this demand is that patients have utilized ambulance services when an alternative option was more appropriate. Factors associated with high demand in this study can fall into one of these two categories.

Adult Skills, which include language abilities and qualification levels, have the strongest association of all the factors considered in this study. We argue that adult skills are a strong driver because this factor can fall into both categories of demand usage, poor health outcomes, and poor decision making. Poor health outcomes in many clinical fields have already been associated with lower rates of qualifications amongst populations. This can influence maternity demand as pregnant patients delayed seeking health services earlier in their care. This delay could turn an issue that may be treated elsewhere, or prevented, into a potential emergency that requires

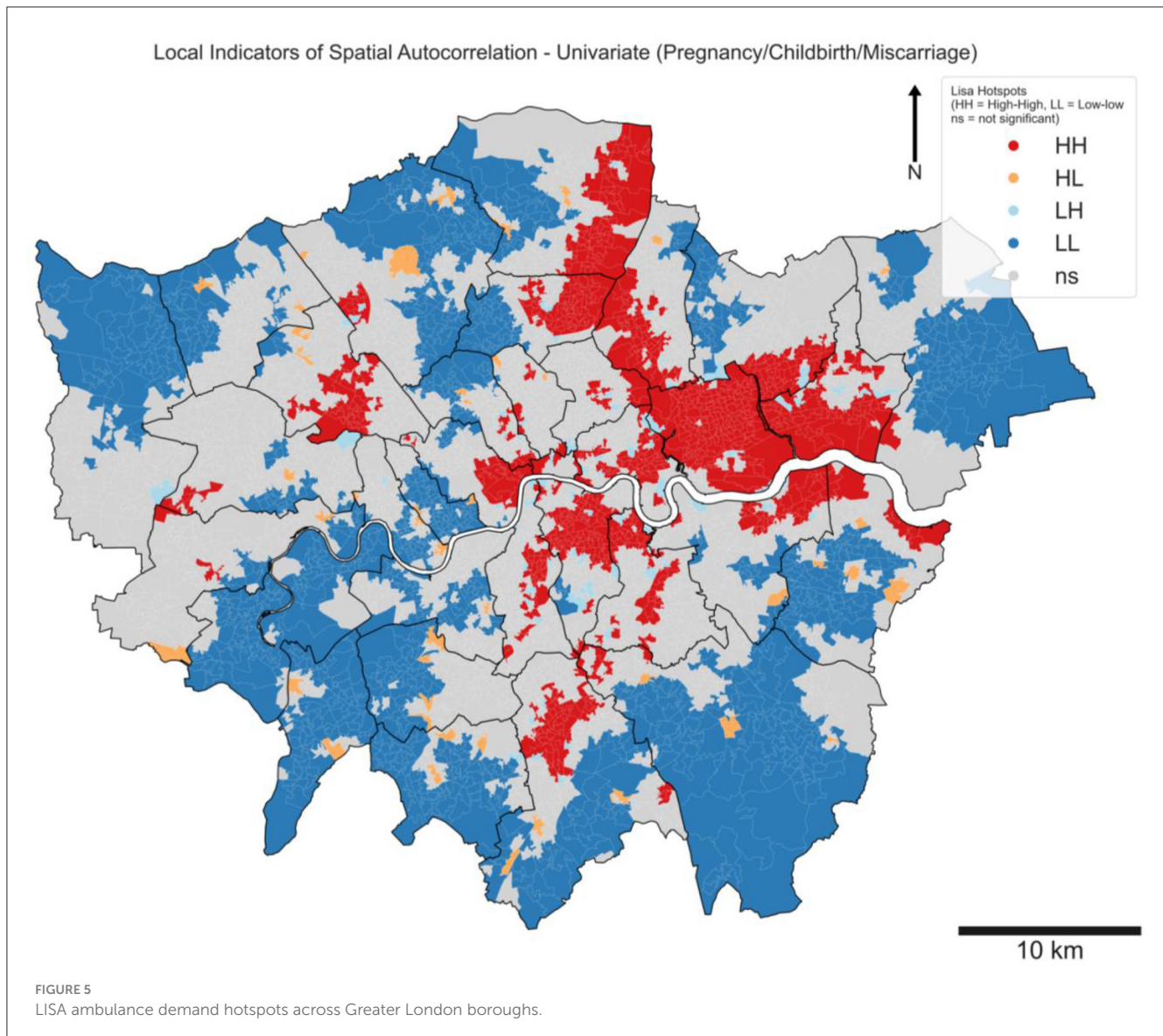


an ambulance. Areas where populations have higher qualifications may seek treatment either through GP appointments, or through a maternity hospital or midwife service provided, therefore avoiding ambulance service use. Adult Skill levels can also suggest how well patients can navigate the NHS care system. Poor language skills have been linked with poor pregnancy outcomes, as well as difficulty for patients to access healthcare services (59). Often it can be due to lack of understanding that patients can disengage with care or struggle to attend the consistent care and appointments that maternity patients require. Poor language skills are linked with maternity services being contacted later into pregnancies (27, 72). Our findings suggest that these associations will persist further into patients care and resolve with patients with these poorer language skills relying more heavily on emergency care during their pregnancy.

The strong associations between poor Adult Skills and higher ambulance demand can partially be explained through the lack of understanding of care pathways for pregnant patients and

the utilization of ambulance services when this may not be the most appropriate outcome. Many NHS trusts' maternity units provide 24-h services for pregnant patients to call with concerns. Nevertheless, patients who utilize ambulances as an option may not have exhausted other alternative care pathways (13). A possible explanation of this association could be through poor adult skill levels in neighborhoods where ambulance calls are frequent but perhaps not necessary. Further exploration of this could be researched through individual ambulance patient records, or through data where the outcomes for patients, if they are treated at home or conveyed to an emergency department or other facility, indicate whether the call was necessary.

Housing quality deprivation, measured through both indoor living environments and wider barriers to housing, shows a strong association with ambulance maternity rates. Areas with high deprivation scores in wider barriers to housing (Table 1) were 18% more likely to have emergency incidents, while poorer indoor living environments had 11% higher rates. These associations can be



linked to poor health outcomes in pregnancy, rather than whether patients utilize ambulances inappropriately. Previous links between health conditions and poor housing conditions indicate that this relationship is known (42), and these results show that this can manifest itself with higher demand on emergency ambulance care. Wider barriers to housing can again be linked through poorer maternity health outcomes, with stable access to housing having specific links to better pregnancy outcomes (36, 37). This study suggests that patients may resort to ambulance services as a response to these challenges.

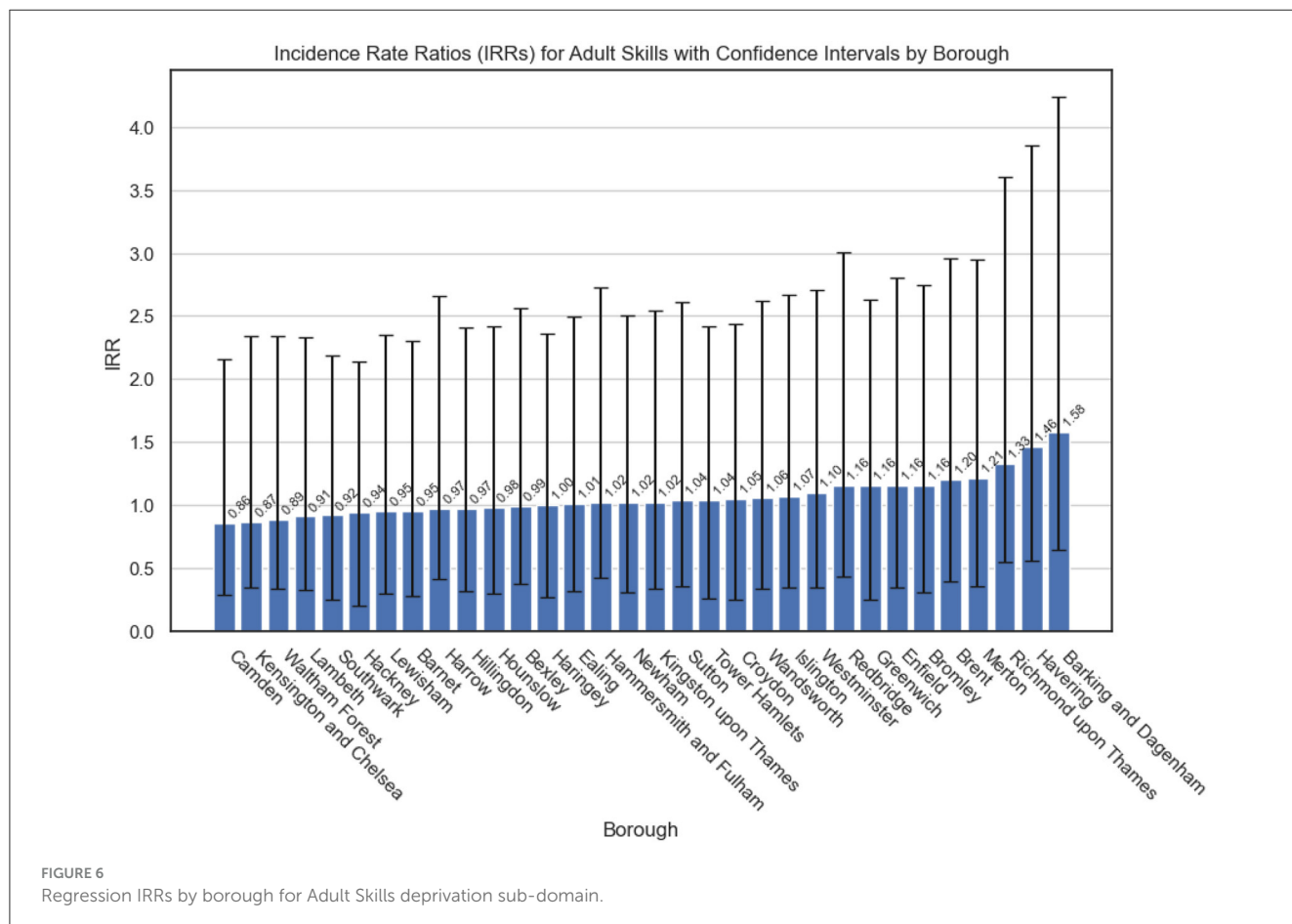
The findings regarding ethnicity and its association with ambulance demand seemingly run contrary to previous literature regarding health outcomes, which consistently highlights a strong connection with pregnancy outcomes, particularly amongst the black ethnic category (24, 25). This implies that while ethnicity can indeed influence pregnancy results, this influence doesn't necessarily translate into heightened emergency ambulance utilization. It suggests a scenario where some patients might forego

ambulance services even when essential, potentially leading to an underestimation of actual healthcare needs. Moreover, the study implies that the demand for ambulance services may not be directly tied to health outcomes; rather, it might be more closely associated with patients' reasons for calling an ambulance, irrespective of the actual necessity.

Another factor which supports that demand is linked to patient decision making is the distance of neighborhoods to a maternity hospital. Our findings suggest that the further an LSOA is from a maternity hospital the more likely it is that a patient may call an ambulance. An explanation for this could be that those who may live closer to maternity hospitals may forgo an ambulance to just travel directly to maternity facilities, which may be possible for many within a reasonable distance from a facility. This may be exasperated in more recent years as public perception of ambulance waiting times may lead to patients finding alternative ways to receive prompt appropriate healthcare.

TABLE 2 Negative binomial regression model results.

Variables	IRR	Std. Error	T-value	p-value	95% Conf interval
Pct Black/African	1.02	0.002	8.9	0.000	1.02–1.03
Pct Asian	1.02	0.001	13.05	0.000	1.00–1.02
Adult Skills	1.39	0.032	10.16	0.000	1.30–1.48
Professional occupation female	1.02	0.002	13.59	0.000	1.02–1.03
Lone parent household (pct)	1.03	0.005	5.98	0.000	1.02–1.04
Nearest Hospital Dist.	1.11	0.017	5.93	0.000	1.07–1.15
Household No Cars (pct)	1.02	0.001	13.69	0.000	1.01–1.02
GP registered (pct)	1.01	0.001	6.44	0.000	1.00–1.01
Wider barriers	1.18	0.027	6.25	0.001	1.12–1.24
Indoors	1.13	0.016	7.8	0.000	1.10–1.16
Crime	1.05	0.018	2.75	0.006	1.01–1.09
AIC	45,376.1		BIC	−39,337.96	
Pseudo R-square	0.3		No. Obs.	4,834	



Borough regression results indicate that for some factors the effects vary, while others have more consistent effects. The 'Black/Black British/Caribbean category shows a consistent effect across areas whilst for Adult Skills the effect is more varied. The links between borough differences can be linked to wider impacts

on ambulance utilization and can be tied back to the reasons why patients will or will not call for an ambulance.

It is important to acknowledge the potential of improving equity within demand through better service resources' allocations and strategy designs (43). In London, the LAS is the only pan

London NHS trust that operates in all 33 boroughs. This places it in the unique position to provide an equitable service across very distinct neighborhoods and help provide a continuity of care that other local NHS trusts may struggle to provide.

NHS England published a 3-year delivery plan for maternity and neonatal services, which sets out how trusts, Integrated Care Systems (ICS), and Integrated Care Board (ICB) can manage and improve maternity services and care in England. However, the strategy does not mention how joined pre-hospital services can be included as part of this care improvement. Ambulance trusts aren't mentioned at all within this plan (44). London Ambulance Trust describe providing specialized midwives as part of their strategy to provide specialized maternity care (17). These resources can be deployed to improve the outcomes for patients through a unique position of a continuity often across geographical areas that can span NHS trusts, as is the case within Greater London. This could improve care pathways where calls that do not require an emergency ambulance response are addressed with ambulance maternity resources and handed over to more appropriate maternity care locally, rather than conveyance to an emergency department (68). However, to understand the disparities between areas and target resources to reduce these inequalities, it is important to consider how other forms of healthcare at local levels are provided and their interaction and influence on ambulance utilization.

More widely, it is clear that ambulance demand can be influenced by healthcare services outside of emergency medical services. NHS local care framework is arranged through Integrated Care Systems (ICS) In London; this consists of five ICS, with boroughs divided into the five based on geography. The way that these care boards provide services have similarities, but also differences in funding priorities, staff levels, approaches to communications and outreach, resource distribution approaches, and can influence how patients may utilize healthcare services (45). Care provided by local NHS trusts and ICS can impact the outcomes of patients utilizing ambulance services either because of poor health outcomes or inappropriate usage. For example, the influence of poor Adult Skills on ambulance demand for maternity incidents could necessitate involving local NHS trusts to intervene and target communication to pregnant patients for healthcare access to reduce demand downstream. Clearer communication of local midwifery teams to emphasize that patients should call early and not wait for issues to become emergencies has the potential to reduce delays and patients requiring an ambulance.

Targeting the root causes of demand can also aim to decrease disparities in health. In regions like London, where social factors impact health and create vulnerable communities, addressing these issues can lead to improved population health outcomes, which in turn can alleviate pressure on health services such as ambulance services. For example, wider socio-economic policies that influence housing deprivation levels, if appropriately targeted for improvement, could also influence to reduce demand levels of ambulance services.

The benefits of identifying factors that drive demand in ambulance services are not just linked to improving equity, as specialized resources can be more effectively allocated, or overall

demand reduced, this has the potential to benefit the overall ambulance resource allocation efficiency, as resources can be used alternatively on other incident types. This is particularly beneficial for maternity incident reduction as this clinical incident type often results in lengthy response times.

5 Conclusion

This research has identified significant inequalities within ambulance demand, which are predominantly explained by a range of socio-economic, environmental, and accessibility factors. Addressing these inequalities requires both short and long-term strategies. In the short term, ambulance services can adapt resource allocation to better target local disparities. For instance, specialized resources and training, such as a dedicated midwife team, can be deployed to improve patient care in areas with high maternity incident rates.

In the long term, broader societal interventions are essential. These could include enhancing access to healthcare, improving socio-economic conditions, and addressing environmental factors that contribute to health disparities. Such interventions not only reduce the demand for emergency healthcare services but also mitigate the underlying health inequalities. For policymakers and healthcare providers, this research underscores the need for targeted and tailored approaches to resource allocation and service delivery. It also highlights the potential benefits of integrated care models and community-based health initiatives.

Future research should continue to explore inequalities across different clinical groupings within ambulance demand. Additionally, examining demand through other lenses, such as acuity categories (e.g., categories 1–4) and conveyance rates, could provide further insights into how best to allocate resources and reduce disparities. Expanding the scope of research to include these dimensions will enhance our understanding of ambulance demand patterns and support the development of more effective intervention strategies.

Data availability statement

The data analyzed in this study is subject to the following licenses/restrictions. London Ambulance Data needs to be approved by the NHS Trust Research Team if it is required to be shared. Requests to access these datasets should be directed to sam.murphy.20@ucl.ac.uk.

Author contributions

SM: Conceptualization, Investigation, Methodology, Writing – original draft, Writing – review & editing. CZ: Conceptualization, Supervision, Writing – review & editing. FL: Conceptualization, Writing – review & editing. LR: Data curation, Writing – review & editing. YG: Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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