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How do resilient communities protect people with severe mental illnesses from death?

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How do resilient communities protect people with severe mental illnesses from death?

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This thesis is submitted for the degree of Doctor of Philosophy

December 2023

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and Professor Craig Morgan

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Contribution statement

Conceptualisation, funding acquisition for the PhD studentship which led to this thesis was conducted by supervisors (JD, TW). Acquisition of linked data between the South London and Maudsley (SLaM) NHS Foundation Trust Clinical Record Interactive Search (CRIS) and the Office for National Statistics mortality dataset was supported by JD. Additional data linkages with datasets containing data for the urban built and social environment exposure variables using datasets supplied by the Ordnance Survey, Office for National Statistics and Department of Levelling Up, Housing & Communities was conducted by the CRIS Clinical Data Linkage Service with my input during consultations. Ethical, legal, and governance approvals for these data were obtained before the commencement of my PhD. CRIS data was supplied to me by CRIS informaticians, who wrote structured query language scripts based on plain English extraction requests of a previous study conducted by my supervisors.

I completed governance training and obtained the necessary permissions to access the data. I carried out the literature searches and formulated aims and objectives for all the studies detailed in this thesis, receiving support from my supervisors. I wrote all Stata and performed geospatial analyses using ArcGIS, seeking guidance from my supervisors and collaborators as necessary. I wrote this thesis and the systematic review manuscript arising from this work in collaboration with my supervisors and co-authors. I took the lead in submitting and revising the manuscript for a peer-reviewed journal.

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Abstract

Background:

People with severe mental illnesses (SMI), such as schizophrenia, experience an 10- to 20-year reduced life expectancy compared to the general population, primarily due to preventable physical causes. The contribution of neighbourhood-level characteristics, such as residing in areas with more green spaces, in influencing mortality risk in SMI remains uncertain. This thesis aims to address this knowledge gap.

Methods:

Study 1: I conducted a systematic review examining the association between area-level exposures and mortality in SMI.

Studies 2-4: Cohort data was extracted from the Clinical Records Interactive Search, a secondary mental healthcare case register containing de-identified patient records from the South London and Maudsley (SLaM) NHS Foundation Trust. SLaM is one of the largest European mental health providers covering a catchment area of 1.3 million residents. De-identified patient-level data linked to neighbourhood-level exposures at middle super output area-level (MSOA) (mean population: 7,000 people), were used.

In study 2, age and gender standardized mortality ratios (SMR) were calculated at the area level, visually mapped, and analysed for spatial autocorrelation using hot spot analyses. Area-level indicators assessed for associations with the SMRs included: (urban built environment) area deprivation, population density, green spaces and food retail outlets, and (urban social environment): social fragmentation, ethnic density and places of worship. Ecological regression analyses were also undertaken.

Studies 3 and 4 were cohort studies which used multilevel regression approaches to assess area-level associations with mortality in SMI. Study 3 assessed the overall availability of environmental features in the surrounding local area, whereas study 4 assessed the walking distance to the environmental features.

Results:

Study 1: Systematic review searches identified 3,353 abstracts. 7 studies from 4 countries were included in the synthesis - quality of the studies was moderately high. Consistent associations between residence in more deprived areas and increased risk of mortality outcomes in SMI, and evidence of an association between areas with higher proportions of

racialised minority groups and a reduced risk of mortality in SMI, was noted. No studies investigated the effect of the built environment on mortality outcomes.

Study 2: SMRs ranged from 1.28 to 6.84 in people with SMI across 148 MSOAs, in the catchment. Hot spot analyses revealed significant clustering of area-level exposures, while no significant clustering was observed for SMRs. Ecological analyses suggested that residence in areas with higher levels of deprivation and convenience stores were associated with higher SMRs. However, this association was attenuated in the fully adjusted models.

Studies 3 and 4: followed over 25,000 people until death or until the end of the study (study 3, n = 22,689 and study 4, n = 22,564). In a cohort study design, weak associations were observed between residence in areas with higher proportions of more walkable areas, convenience stores and population density with lowered risk of all-cause and natural-cause mortality at the MSA level. Associations were attenuated after adjusting for confounders.

Study 4: Weak associations were observed between residence in areas with increased distance to green spaces and fast-food outlets and higher risk of all-cause mortality.

Associations between increased distance to green space and all-cause mortality persisted after accounting for individual-level covariates. However, the association between fast-food outlets and risk of mortality was attenuated.

Conclusions:

Excess mortality remains a health inequality in SMI, with some associations observed between neighbourhood-level indicators and mortality. Limitations include the absence of rural areas in the dataset and a lack of information on comorbid physical health. The thesis concludes with discussions on future clinical, policy, and practice implications based on the findings.

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List of abbreviations

AHR	Adjusted Hazard Ratio
ARR	Adjusted Rate Ratio
CH	Companies House
CLDS	Clinical Data Linkage Service
CRIS	Clinical Record Interactive Search
CSDH	Committee on Social Determinants of Health
ESRI	Environmental Systems Research Institute
HR	Hazard Ratio
ICD-10	International Statistical Classification of Diseases and Related Health Problems - 10 th Revision
ICS	Integrated Care System
IMD	Index of Multiple Deprivation
IRR	Incidence Risk Ratio
LSOA	Lower Super Output Area
MLM	Multilevel modelling
MSOA	Middle Super Output Area
NHS	National Health Service
NIHR	National Institute for Health Research
NLP	Natural Language Processing
NOS	Newcastle-Ottawa Scale
OLS	Ordinary Least Squares regression
ONS	Office for National Statistics
OS	Ordnance Survey
POI	Points of Interest
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
SDH	Social determinants of health
SHR	Sub-hazard ratio

SLaM	South London and Maudsley NHS Foundation Trust
SMI	Severe mental illness
SMR	Standardized mortality ratio
VIF	Variance Inflation Factor
VPC	Variance Partition Coefficient
WHO	World Health Organization

Chapter 1. Introduction

Premature mortality among individuals with severe mental illnesses (SMI) is a complex, multi-faceted and global problem. Across low-, middle-, and high-income countries, findings consistently indicate a higher risk of mortality among individuals with SMI compared to those without such diagnoses in the general population (Hayes, Marston, Walters, King, & Osborn, 2017; Hjorthøj, Stürup, McGrath, & Nordentoft, 2017; Saha, Chant, & McGrath, 2007). Prior research has indicated that populations with SMI experience a 10 - 20 year reduction in life expectancy compared to the general population (Hjorthøj, Stürup, McGrath, & Nordentoft, 2017; Saha, Chant, & McGrath, 2007), mostly from preventable physical causes (Ilyas, Chesney, & Patel, 2017) including respiratory disease, cardiovascular disease and infections (Fekadu et al., 2015; Laursen, 2011). Although global efforts have successfully increased life expectancy in the general population, particularly in reducing mortality from chronic and infectious diseases (World Health Organization, 2020), these endeavours have not adequately addressed excess mortality that has been linked to physical health comorbidities and suicide in individuals with mental health conditions (Lee et al., 2018). Moreover, other research has indicated that this gap in life expectancy is continuing to increase over time (Olfson, Gerhard, Huang, Crystal, & Stroup, 2015; Saha et al., 2007).

The majority of research investigating the factors influencing risk of premature mortality in SMI have tended to focus on individual-level risk factors (Laursen, 2019). Consequently, interventions have tended to focus on risk factors such as smoking and dietary habits (Bambra et al., 2010). Whilst these individual-level interventions remain important in targeting these proximal risk factors for health complications, a gap in life expectancy continues to persist among people with SMI. Therefore, it is important to understand why this health inequality persists in people with SMI. By doing so, we can take the necessary steps to tackle this inequality.

1.1 Does mortality in severe mental illnesses vary by geography?

Other research has indicated that excess mortality among people with SMI may vary geographically. An international review indicated that the highest risk estimates for excess mortality in SMI were observed in Africa (Hjorthøj et al., 2017). However, it's important to note that only one study from the African continent was included in this review, so this finding should be interpreted with caution (Hjorthøj et al., 2017). Until the mid-2000s, it was assumed that people with schizophrenia had better prognoses and outcomes in low- and middle-income countries (Hopper & Wanderling, 2000) as inferred by reports from the World Health Organisation (WHO) studies (Jablensky & Sartorius, 2008). These studies

concluded that although the risk of mortality was higher in people living with SMI compared to general population samples across the international research sites, the mortality rates were higher in higher income countries. However, the WHO studies have methodological limitations which included the failure to account for higher attrition rates in low- to middle-income countries, limited analyses of the sociocultural variations in schizophrenia diagnoses and its impact on outcomes (Patel, Cohen, Thara, & Gureje, 2006), other unmeasured potential confounders (e.g. social support) (Jablensky & Sartorius, 2008) and no inclusion of environmental factors within analyses.

Towards a multifactorial understanding of mortality in severe mental illnesses

In the last two decades, investigators have reached a consensus on the understanding that the factors influencing the risk of mortality in SMI are likely multifactorial. These factors are likely interrelated and exert influence not only at the individual level but also within communities, neighbourhoods, institutions (e.g. health organisations) and the broader socio-political context (Liu et al., 2017; O'Connor et al., 2023; Solar & Irwin, 2010). Excess mortality in individuals with SMI is not solely attributed to a single factor; while those with SMI exhibit high rates of adverse health behaviours such as physical inactivity, substance misuse, smoking, and poor diet, other studies underscore the significance of factors beyond these individual-level risk factors (Liu et al., 2017).

While the role of social determinants in excess mortality is widely recognized, there have been limited research investigating the relationship between these factors and mortality in SMI. Prior research suggests that individual-level risk factors are exacerbated in the presence of adverse social determinants of health across the lifespan; these include economic recession, unemployment, residence in deprived neighbourhoods, lack of social support, limited access to employment, housing and education (Solar & Irwin, 2010; Liu et al., 2017). Limited access to financial resources and ongoing income inequality influence both physical and mental health (Lund et al., 2018). Individuals with mental illness are more likely to experience systemic social exclusion, encompassing factors such as discrimination and homelessness, all of which has been associated with the risk of mortality (Liu et al., 2017; Thornicroft et al., 2022).

1.2 Towards a place-based understanding of mortality in severe mental health conditions

There is a growing recognition within public health of the need to consider place-based approaches in addressing this health inequality in SMI (O'Connor et al., 2023).

Environmental factors, given their nature, affect large populations in shared living or working environments, which may potentially explain some of the spatial variation in broader health inequalities (National Research Council (US), 2013). Identified factors linked to increased risk of mortality in the general population include (but not limited to) residence in neighbourhoods with higher population densities (Carnegie, Inglis, Taylor, Bak-Klimek, & Okoye, 2022), higher levels of area-level deprivation (Office for National Statistics, 2019), increased access to fast-food outlets (Alter & Eny, 2005) and residence in socially fragmented areas (Mok et al., 2013). These associations persist after adjusting for individual factors, however their role in the association between SMI and mortality remains unclear.

Given the limited research investigating the role of environmental factors in premature mortality in SMI, this thesis intended to bridge this gap in the evidence base by investigating these aforementioned factors. This thesis will use quantitative methods to explore how the risk of mortality among individuals diagnosed with SMI varies geographically across urbanised and ethnically diverse neighbourhoods in southeast London. The thesis will also investigate which urban built and social environmental factors influence the risk of mortality among this population and quantify the extent to which variation in mortality outcomes are accounted for by differences between neighbourhoods using a multilevel modelling approach.

1.3 Aims

The overall aims of this thesis are:

1. To systematically review the existing literature on the association between mortality and urban built and social environment variables in SMI;
2. To explore whether there are geographical areas of higher mortality in SMI (relative to the general population), and identify the urban, built and environmental factors potentially associated with this
3. To assess associations between the urban built and social environment indicators and the mortality outcomes in the SMI cohort
4. To assess how much of the variation in the mortality outcomes is attributable to differences at both the neighbourhood and individual levels

1.4 Chapter overview in this thesis

In order to address the aims listed above, I undertook a systematic review of the literature. I then undertook a series of empirical investigations of large-scale health records from a well-defined catchment area in southeast London, to explore and understand whether urban built and social/ environmental factors at the neighbourhood level were associated with excess mortality in people living with severe mental illnesses.

In **Chapter 2**, I will provide an overview of the background for this investigation, and I will describe the theoretical framework used to conceptualise the relationship between the environment factors and risk of mortality in SMI. In **Chapter 3**, I will describe the rationale and findings of the systematic review on the current evidence base for the role of environmental factors in mortality in SMI. **Chapter 4** outlines the methods undertaken for empirical assessment and includes a description of the study design, data collection, measures, cohort and quantitative methods used. **Chapter 5** describes the rationale, procedure, findings and conclusions of the ecological and geospatial analyses conducted. **Chapters 6 - 7** describes the rationale, procedure, findings and conclusions of the multilevel modelling analyses which addresses the thesis aims 4 - 5. **Chapter 8** provides an overview of the findings from Studies 1 - 4, summarises the overall strengths and weaknesses of the studies, discusses the thesis findings within the wider research context, leading to a summary of implications of the findings for research, clinical practice and public health policy.

Chapter 2: Background and literature review

In this chapter, I will provide an overview of the evidence for excess mortality in populations with severe mental illnesses (SMI). I will then review the evidence for the association of several urban built and social environment indicators that will be investigated in the subsequent analyses in this thesis. I will also briefly describe the characteristics of the four South London boroughs included in the study catchment area. I will then outline the integrated framework, a theoretical model I used to conceptualise how the urban built and social environment indicators may influence the risk of premature mortality in people with SMI.

2.1 Premature mortality and severe mental illness

The global burden of mental illness has risen in recent years and is now the leading cause of lost disability-adjusted life years (Chesney, Goodwin, & Fazel, 2014). People diagnosed with severe mental illnesses (SMI) (defined as non-affective and affective psychoses, and bipolar disorder) experience a 10-20 year reduction in life expectancy compared with the general population (Hjorthøj, Stürup, McGrath, & Nordentoft, 2017; Saha, Chant, & McGrath, 2007). High mortality rates associated with unnatural causes of death (such as suicide) have been observed in people with SMI, but these are relatively uncommon, and most deaths in SMI are from natural causes (Hoang et al., 2013). Jayatilleke and colleagues (2017) reported that deaths from natural causes accounted for 78.6% and 79.2% of lost life years in men and women with SMI, respectively. Other UK-based cohort studies have also reported higher standardised mortality ratios for all-cause mortality among people with SMI compared to the general population (Hoang, Goldacre, & Stewart, 2013; John et al., 2018). Despite a vast body of research indicating excess mortality in SMI, the mortality gap has not reduced (Eaton, 2012; Hoang, Stewart, & Goldacre, 2011; Saha et al., 2007) and therefore highlights an urgency in needing to take action to address this health disparity.

Across low-, middle-, and high-income countries, findings consistently indicate a higher risk of mortality among individuals with SMI compared to those without these diagnoses in the general population (Hayes, Marston, Walters, King, & Osborn, 2017; Hjorthøj, Stürup, McGrath, & Nordentoft, 2017; Saha, Chant, & McGrath, 2007). A systematic review by Saha and colleagues (2007) revealed a 2.5-fold greater risk of death for individuals with schizophrenia compared to those without such diagnoses in the general population, pooling data from 37 studies conducted in 25 countries. Another review showed that schizophrenia was linked to a loss of 13-15 years of potential life, with men experiencing more years of

potential life lost than women in most analyses (Hjorthøj et al., 2017). An elevated risk of premature mortality has also been observed among individuals with bipolar disorder. In a review by Hayes and colleagues (2015) that included 26 studies, the pooled standardised mortality ratio for all-cause mortality in bipolar disorder was 2.05 (95% CI: 1.89 - 2.23). These reviews consistently indicate excess mortality in individuals with SMI, with disparities worsening over time and remaining a consistent trend across international contexts.

The World Health Organization (WHO) has categorised risk factors contributing to excess mortality in individuals with SMI into three distinct groups (Liu et al., 2017). Mortality in SMI is attributed to (1) individual factors, which can be disorder-specific (e.g., symptom severity, genetic factors, early age of onset) or behaviour-specific (e.g. physical inactivity, poor diet), (2) health system factors (e.g. limited accessibility of services, negative beliefs within the workforce, polypharmacy) and 3) social determinants of health (e.g. deprived neighbourhoods, societal stigmatisation and discrimination, unemployment, discriminatory public health policies) (Tiihonen et al., 2009).

The role of social determinants in excess mortality in SMI is widely recognised but compared to research on individual and health system factors, the pathways through which the social determinants operate have received less attention (O'Connor et al., 2023). The cumulative effect of adverse social determinants of health over the lifespan, which include (but not limited to) unemployment, residence in deprived neighbourhoods and limited access to social support, education, housing and job opportunities, foster an environment that amplifies individual-level risk factors (Oyesanya et al., 2015; Chang et al., 2019). Income inequality and restricted financial resources can directly affect both mental and physical well-being (Lund et al., 2018). Individuals with psychosis face approximately a sixfold higher likelihood of unemployment in comparison to the general population, with only 5% to 15% of individuals with psychosis estimated to be employed (NIHR, 2018). Those with SMI are more likely to reside in neighbourhoods characterized by higher levels of social deprivation and occupy lower socioeconomic positions (Eaton & Harrison, 2001; Werner et al., 2007). They are also more likely to experience social exclusion, including homelessness, which is likewise associated with premature mortality (Thornicroft et al., 2022). The role of area-level factors in excess mortality in SMI has also remained relatively understudied in this population.

Area level indicators and mortality in the general population

Within the last two decades there has been a renewed focus on the inclusion of area-level factors that can influence the course and distribution of health outcomes, largely within the general population (Diez Roux, 2016). Area-level factors, by their nature, can affect sizeable populations coexisting in shared residential or work environments, making them potential explanatory factors for observed geographic disparities in health outcomes (National Research Council, 2018). Several area-level features that have been found to be associated with an increased risk of mortality in the general population have been identified, which includes: reduced exposure to green spaces (Gascon et al., 2016), higher air pollution (Faustini et al., 2014), reduced ethnic density (Bécares et al., 2012), higher population density (Carnegie et al., 2022), access to fast food outlets (Alter & Eny, 2005) area-level deprivation (Office for National Statistics, 2019) and social fragmentation (Mok et al., 2013). These studies demonstrated that after accounting for individual-level factors (e.g. sex, ethnicity, socio-economic status), there remained a proportion of variance in the risk of mortality accounted for by environmental factors. However, the existence of these associations between area-level factors and premature mortality within SMI are yet to be clarified.

In summary, over the course of four decades, research has consistently demonstrated a heightened risk of mortality in individuals with SMI. However, interventions have primarily concentrated on individual-level risk factors, which have not proven effective in reducing the excess mortality in this population. There is a growing recognition within public health research of the need to consider place-based approaches in addressing this health disparity (O'Connor et al., 2023) nevertheless, research in this area is remains limited. Therefore, the present thesis aims to address this gap in empirical research by investigating the associations between mortality and area-level factors in SMI.

2.2 Built environment

Area-level factors that are typically investigated for their association with mortality and other health outcomes include indicators of the built environment. The “built environment” broadly refers to the human-made aspects of the surrounding physical space, including rural or urban buildings, facilities, infrastructures and open spaces (Roof & Oleru, 2008). It encompasses all structures and spaces that are created or modified by humans and serve as places for people to live, work, and engage in recreational activities (Travert et al., 2019). From nomadic primitive populations to urban dwellers of today, the environment, has been shaped and optimised to meet human needs (Renalds, et al., 2010). The built environment encompasses not only parks and green spaces but also includes traffic flow, cleanliness, pavement conditions, maintenance of public spaces, population density and land use mix (Renalds, et al., 2010). The following subsections will detail the current evidence base on several built environment indicators and their association with health and/or mortality outcomes which have been included in the quantitative analyses of this thesis.

2.2.1 Area-level deprivation and mortality

For over three decades, social inequalities have been a major focus in the UK's public health agenda. Social inequalities have been found to impact not only health but other areas such as education, crime, welfare and employment (Niggebrugge, Haynes, Jones, Lovett, & Harvey, 2005). The term socioeconomic deprivation refers to the disadvantage experienced by an individual or a social group in terms of access and control over material, economic or social opportunities and resources (Lamnisos, Lambrianidou, & Middleton, 2019). This disadvantage can occur at geographical-level, such as at community-level or at neighbourhood-level.

Individuals residing in deprived neighbourhoods experience considerably more adverse outcomes in terms of morbidity and mortality compared to those living in areas with lower levels of deprivation (Knies & Kumari, 2022; Mackenbach et al., 2008; Schiøtz, Stockmarr, Høst, Glümer, & Frølich, 2017) and within the UK, these health outcomes have been found to vary geographically, referred to as the “North-South divide” (Kontopantelis et al., 2018). The North of England experiences worse health outcomes which have been linked to higher levels of deprivation, when compared to the South. According to data from 2017 to 2019, people living in more affluent areas could expect to live almost two decades longer in good health compared to those residing in the most deprived areas (Williams, Buck, Babalola, & Maguire, 2022).

From 2018 to 2020, in the North East of England, both men and women's healthy life expectancy at birth¹ was 59.4 and 59.0 years respectively (Office for Health Improvements & Disparities, 2022). This corresponds to 6.9 and 5.9 years less than the healthy life expectancy observed in women and men based in the South East (Office for Health Improvements & Disparities, 2022). Even similarly deprived neighbourhoods in the North demonstrate worse health outcomes than those in the South (Kontopantelis et al., 2018). Furthermore, people with similar socioeconomic status tend to have poorer health in the North than in the South (Doran, Drever, & Whitehead, 2004). There are several factors that contribute to these regional health disparities, including environmental, occupational, migratory, epigenetic, lifestyle factors and long-standing inequalities in provision of resources and investment (Social Mobility Commission, 2017). The evidence in relation to area-level deprivation and mortality in SMI have been discussed in the systematic review in [Chapter 3](#). In general, the findings from the review align closely with research findings in the general population, showing that residence in deprived neighbourhoods is linked to an increased risk of mortality in individuals with SMI. However, the underlying mechanisms for the increased risk of mortality among individuals with SMI in deprived areas remain relatively unknown, making it an area in need of further research.

2.2.2 Neighbourhood walkability and mortality

The evidence base has consistently demonstrated a positive association between physical activity and risk of mortality in the general population. Even low-intensity exercise, such as walking, has been demonstrated to lower the risk of mortality among a cohort diagnosed with chronic heart disease and diabetes (Smith, Wingard, Smith, Kritz-Silverstein, & Barrett-Connor, 2007; Wannamethee, Shaper, & Walker, 2000). Conversely, physical inactivity compared to walking at less than the recommended thresholds, has been linked to greater risk of all-cause mortality (Patel et al., 2018). Walking has also been positively associated with a lower risk of mortality from cancer and respiratory conditions (Hakim et al., 1998; Ikeda et al., 2020). A meta-analysis indicated that individuals with cancer diagnoses who engaged in regular exercise were at reduced risk of cancer-related mortality compared to those who did not exercise as regularly (Cormie, Zopf, Zhang, & Schmitz, 2017). However, it

¹ Healthy life expectancy at birth: the average number of years a person would expect to live in good health, rather than with a disability or in poor health. See [Office for Health Improvement & Disparities Indicator Definitions](#).

remains unclear whether there is an association between features of the built environment and risk of mortality.

Since the late 1990s, there has been an increasing interest in the influence of the built environment on obesogenic behaviours (e.g. physical inactivity, diet) (Ewing & Cervero, 2010; Ferdinand, Sen, Rahurkar, Engler, & Menachemi, 2012; Sallis, Bauman, & Pratt, 1998). This includes features of the built environment that support human physical activity such as walking, known as neighbourhood walkability (Freeman et al., 2013). 'Neighbourhood walkability' is typically conceptualised as a combination of the following environmental features: (1) land-use mix, (2) residential density and (3) street connectivity (Frank & Engelke, 2005a; Ribeiro & Hoffmann, 2018).

Land use mix

Land use mix is a measure of the number of different land use types (e.g. residential areas, commercial land use) within a neighbourhood (Frank, Andresen, & Schmid, 2004). The potential benefits of neighbourhoods with greater levels of mixed land use are two-fold. Firstly, neighbourhoods with higher levels of mixed land uses and are pedestrian-orientated may facilitate or promote social relationships or community connections, foster trust and reciprocity among community members and improve access to information and services, known as social capital (Leyden, 2003). It has been suggested that mixed-use, pedestrian-oriented neighbourhoods boost social capital by facilitating interactions between residents. This includes (but not limited to) chance encounters with neighbours at a local park, general 'chitchats' and planned social gatherings at a community centre, all of which help to foster a sense of connection and trust between individuals and the neighbourhood they live in (Leyden, 2003).

However, other researchers have posited that mixed land use can have detrimental effects on social capital and mental health. Baum and colleagues (1978) reported that shopping sites located at the end of residential streets were linked to frequent occurrences of unwanted social contact and perceived lack of control over spaces due to strangers using spaces that were typically used by residents. As a result, residents indicated experiencing higher levels of stress and a tendency to withdraw from neighbourhood interactions (Baum et al., 1978). Similar findings have also been reported among older men, who were at higher odds of developing depression in neighbourhoods with higher levels of land use mix compared to living in neighbourhoods with lower levels of land use mix (Saarloos, Alfonso, Giles-Corti, Middleton, & Almeida, 2011). The authors connected these findings to the

tendency of amenities and services, particularly retail establishments, to draw more unfamiliar individuals to a neighbourhood. This increased influx of people can result in heightened traffic flow, ultimately leading to reduced social interactions among residents and an associated increase in stress levels (Saarloos et al., 2011; Halpern, 1995; Glass & Balfour, 2003).

Secondly, neighbourhoods with greater land use mix are thought to promote physical activity because they contain a large number of services or amenities (e.g. eateries, local bars, places of worship, pharmacies) that residents may wish to access (Stevenson et al., 2016). The availability and close proximity of these services and amenities to residential locations are suggested to promote physical activity (e.g. walking) among residents (Grasser, Van Dyck, Titze, & Stronegger, 2013; McCormack & Shiell, 2011) by enabling them to carry out their daily activities (e.g. transporting their children to school, grocery shopping) without having to rely on a car (Leyden, 2003). The findings of a UK-based cohort study indicated reduced risk of all-cause mortality among participants aged between 80 and 84 who lived in neighbourhoods with higher land use mix (adjusted hazard ratio: 0.60, 95% CI 0.37 – 0.98) (Wu et al., 2016). This finding was associated with the increased opportunities for physical activity owing to improved access to services and amenities in areas with higher land use mix, thus reducing the risk of physical health comorbidities that are linked to mortality. However, the associations among slightly younger participants (aged 75 to 79) were mediated by self-reported comorbid conditions.

However, the current evidence base related to the health benefits of land use mix are inconsistent - while the findings of several investigations indicate that higher land use mix is related to increased physical activity, others suggest null associations (Grasser et al., 2013; Hajna, Dasgupta, Joseph, & Ross, 2014; McCormack & Shiell, 2011). The inconsistencies in findings could be attributed to differences in how the built environment and physical activity were measured (Brownson, Hoehner, Day, Forsyth, & Sallis, 2009; Inoue et al., 2010). The relationship between land use mix and physical activity is typically quantified using entropy indexes (Bordoloi, Mote, Sarkar, & Mallikarjuna, 2013; Saelens & Handy, 2008), which demonstrate how varied (or mixed) the distribution of land uses is - higher entropy scores indicate a higher (more diverse) mix of land uses. Land use categories that may encourage or hinder physical activity are chosen for inclusion. Moreover, it remains unclear how different types of land use mix influence the relationship between neighbourhood design and specific walking behaviours (such as walking for transportation or recreation), as well as whether changes in the combination and/or composition of land

use categories influences these relationships (Christian et al., 2011). Additionally, there have been no further investigations among younger age groups with SMI.

Street connectivity

Other studies have investigated the associations between the density of junctions (i.e. intersections that connect three or more streets) and how well streets connect to each other, known as street connectivity (Mecredy, Pickett, & Janssen, 2011). Neighbourhoods with a well-connected street network are characterised as having streets with many short connections and intersections and few cul-de-sacs and dead ends (Tressider, 2005). Higher levels of street connectivity are hypothesised to enable ease of transportation via walking or cycling by the provision of short and direct routes between origin locations (e.g. home) and destination locations (e.g. supermarket) and by providing alternative route options (Berrigan, Pickle, & Dill, 2010; Koohsari, Sugiyama, Lamb, Villanueva, & Owen, 2014; Mecredy et al., 2011). Several studies have reported positive associations between high levels of street connectivity and walking for transport (Bentley et al., 2018; Molaei, Tang, & Hardie, 2021; Sugiyama, Neuhaus, Cole, Giles-Corti, & Owen, 2012).

However other investigations suggest that the link between street connectivity and walking may be mediated by availability of destinations. Koohsari and colleagues (2014) reported that availability of destinations accounted for 16% of the association between street connectivity and walking. Thus, street connectivity may encourage walking among residents but this is not solely due to how the streets are set up, but also because there are places (e.g. shops, restaurants) residents can walk to. Other possible links between street connectivity and walking include pedestrian infrastructure (the quality and availability of footpaths), enhanced public transport, problems with car parking, car ownership, and area-level deprivation (Ball, Lamb, Travaglini, & Ellaway, 2012; Koohsari et al., 2014). Other researchers have reported that street connectivity may be linked to traffic safety and actual and perceived crime, which may discourage walking among residents (Johnson & Bowers, 2010; Rifaat, Tay, & De Barros, 2010).

Residential density

The number of dwellings per square kilometre (or other geometric) of residential land area is referred to as residential (or housing) density (Adams et al., 2014). Neighbourhoods with higher residential densities are generally perceived to enhance pedestrian infrastructure (e.g. footpaths) since higher population density in these neighbourhoods means a greater demand for services and other amenities (Hajna et al., 2015). It has also been suggested

that neighbourhoods with high residential density enhance walking for transportation since crowding and traffic congestion are likely to be higher in these areas and would therefore encourage individuals to walk or take the bus rather than drive to selected destinations (Forsyth, Oakes, Schmitz, & Hearst, 2007). Prior research suggests that areas with high residential density are likely to increase levels of cycling and walking activity (Inoue et al., 2010; Witten et al., 2012). Moreover, individuals living in neighbourhoods with lower residential density were less active than those living in neighbourhoods with higher residential density (Frank, Schmid, Sallis, Chapman, & Saelens, 2005b; Saelens, Sallis, Black, & Chen, 2003). However, these studies did not adjust for the effects of area-level deprivation and there have been no studies investigating associations between residential density and mortality in SMI.

Neighbourhood walkability

Land use mix, street connectivity and residential density are strongly correlated (Frank et al., 2005b). Thus, researchers tend to combine these three measures into an index that measures the walkability of a neighbourhoods (Frank et al., 2005b; Leslie et al., 2007). Living in walkable neighbourhoods has been linked to increased physical activity (Rundle et al., 2016; Sallis et al., 2016) and lower risks of obesity (Creatore et al., 2016; Hirsch et al., 2014; Koh, Sekine, Yamada, Fujimura, & Tatsuse, 2022), diabetes (Booth et al., 2019; Creatore et al., 2016), and cardiometabolic disease (Chandrabose et al., 2019; Sarkar, Webster, & Gallacher, 2018).

To date there are limited studies that have investigated the link between neighbourhood walkability and mortality in the general population. These investigations tend to render inconsistent findings. One cohort study reported a 9% and 1% reduction in the risk of cardiovascular- and non-accidental mortality among individuals living in neighbourhoods with high walkability compared to those in neighbourhoods with lower levels of walkability respectively (Lang et al., 2022). Individuals with lower incomes and educational attainment, and those who lived in the most deprived neighbourhoods were observed to benefit the most from these walkable environments (Lang et al., 2022). Similar protective effects of neighbourhood walkability and mortality outcomes were also reported among women living in the most walkable neighbourhoods in the US - hazard ratios were 0.72 (95% CI = 0.62–0.85) for obesity-related cancer mortality 0.91 (95% CI = 0.86–0.97) for obesity-related disease and 0.96 (95% confidence intervals [CI] = 0.93–0.99) for all-cause mortality respectively, after adjusting for individual- and neighbourhood-level confounders (India-Aldana et al., 2021). Two ecological investigations indicated an inverse association between

the walkability index and cardiovascular-related mortality, particularly among women, but only in statistical models that did not adjust for socioeconomic status and other demographic variables (Gaglioti et al., 2018; Sánchez-Villegas, Cabrera-León, & Gil García, 2021). However, most of these studies have been conducted in the US and Canada using general population samples. Therefore, it is difficult to generalise these findings to the UK context and within populations diagnosed with SMI.

2.2.3 Population density and mortality

Population density is a geographical term referring to the number of individuals in a specified area of land (Carnegie et al., 2022). It is also used as a measure of urbanicity which refers the degree of pressure on natural resources and reflects the level of human activity within a particular geographical region (Montgomery et al., 2003; Agovino et al., 2018). Researchers have proposed that living in densely populated neighbourhoods can have both advantages and disadvantages for population health (Yu et al., 2022). They suggest the existence of a non-linear relationship between population density and health outcomes, where positive health outcomes tend to increase as population density rises, primarily due to close proximity and improved access to neighbourhood services. However, this trend may reach a threshold where further increases in population density lead to overcrowding, resulting in constraints on services and infrastructure (Sarkar & Webster, 2017). Furthermore, densely populated areas may introduce additional health risk factors. These areas often have elevated levels of traffic-related air pollution, and they tend to concentrate bars and retailers selling unhealthy products (Meijer et al., 2012).

In studies on psychosis, population density is typically used as a proxy for urbanicity when investigating associations between urbanicity and incidence of psychosis (Heinz et al., 2013). A systematic review showed that increases in urbanicity (as measured by population density) were associated with increased incidence of schizophrenia and non-affective psychosis (Heinz et al., 2013). Another review also found consistent associations between increased urbanicity and higher incidence of schizophrenia (Castillejos et al., 2018). Notably, most of these studies were carried out in high-income countries (as observed in the Heinz et al., 2013 review), and the limited research conducted in low- to middle-income settings, in India and Kenya, did not find associations between urbanicity and schizophrenia (Castillejos et al., 2018).

Research conducted in the general population on population density and mortality has predominantly identified an elevated risk of mortality in densely populated neighbourhoods. A recent systematic review that included 54 studies revealed a link

between residing in highly populous neighbourhoods and a higher risk of variety of non-communicable diseases, including cardiovascular disease, cancer, and respiratory diseases in developed countries (Carnegie et al., 2022). Furthermore, the findings from studies that accounted for socioeconomic status indicated that high population density is linked to increased rates of overall mortality, COPD- and cardiovascular-related mortality (Carnegie et al., 2022).

Despite evidence of an association between mortality and population density in the general population, there have been limited studies investigating this association in SMI. The evidence in relation to population density and mortality in SMI have been discussed in the systematic review in [Chapter 3](#). Based on the limited number of research studies included in the review, the findings indicated mixed evidence of an association between population density and mortality in SMI.

2.2.4 Food environment and mortality

Nutrition and dietary factors have been identified as one of the leading causes of global disability, illness and death; in 2017 dietary factors were associated with 1 in 5 deaths and 255 million disability adjusted life years (Afshin et al., 2019). In recent decades, economic development, globalization, technological improvements, and changes in agricultural systems have drastically transformed diets around the world (Turner et al., 2018). These factors have resulted in a shift away from regular consumption of staple vegetables, fruits, grains and legumes and towards dietary patterns that include more refined carbohydrates, animal source foods, processed foods, sugar-sweetened beverages and edible oils (Popkin, 2015; Popkin, Adair, & Ng, 2012). The physical, socio-cultural, economic and political contexts that are likely to influence dietary choices, health and nutrition are collectively known as the ‘food environment’ (Swinburn et al., 2013).

Daniel and colleagues (2010) posit that dietary behaviours and adverse health outcomes may be influenced by poor quality food environments characterised by an abundance of fast-food outlets that outnumber outlets selling fresh produce (known as ‘food swamps’) or in places where access to fresh produce or other minimally processed foods is limited or non-existent (known as ‘food deserts’). These food environments are more commonly found in middle- and high-income nations where urbanization, greater industrialised food production, and individual-level lifestyle changes have all contributed to a rise in consumption of foods with high calorific value, high fat, sugar, and salt content, which are lacking in essential minerals and vitamins (Victor et al., 2023). Several investigations conducted in the US have demonstrated an association between these poor-quality food

environments and cardiovascular diseases in the general population (Kelli et al., 2019; Morris et al., 2019; Testa, Jackson, Semenza, & Vaughn, 2021). These food groups have also been linked to an increased prevalence of obesity and diet-related illnesses like cardiovascular disease in various population subgroups (Cooksey Stowers, Jiang, Atoloye, Lucan, & Gans, 2020; Morris et al., 2019; Rezende et al., 2016).

2.2.4.a Fast food outlets

Other studies have investigated associations between specific characteristics of the food environment, health outcomes and dietary behaviours. Fast food outlets are one of the most typically investigated physical characteristic of the food environment and are defined as regionally or internationally recognised franchised restaurants that sell low-cost, quick-service food such as pizza and fried chicken (Lamichhane et al., 2013). Fast-food availability has grown dramatically worldwide. For example, in the last decade, the number of McDonald's restaurants has increased by over 22% globally between 2010 and 2021 (Statistica, 2022). One UK study in a general population sample, found that the odds of obesity were 51% higher in participants living in areas with the highest exposure to fast food outlets compared to those living in areas with lower exposure and greater odds were observed in participants jointly classified in the lowest income bracket and exposed to higher numbers of fast food outlets (OR = 2.43, 95% CI: 2.09 - 2.84) (Burgoine, Sarkar, Webster, & Monsivais, 2018). Similar associations have been reported between fast food outlets and cardiovascular disease risk (Malambo, Kengne, De Villiers, Lambert, & Puoane, 2016) and engagement in unhealthy dietary behaviours in the general population (Bahadoran, Mirmiran, & Azizi, 2015; Burgoine et al., 2016; Burgoine, Forouhi, Griffin, Wareham, & Monsivais, 2014).

However, these findings have not been consistently replicated in other investigations in the general population. A systematic review found predominantly null associations between fast food outlets and obesity (Cobb et al., 2015). Differences in study methodologies may account for the inconsistencies in findings. For example, many of the studies included in Cobb and colleagues' (2015) review typically used non-validated food outlet directories and self-reported obesity measures which may increase the likelihood of null associations. Additionally, a social gradient in obesity and dietary habits has been observed across markers of socioeconomic status such as income, education (Mills et al., 2018), and occupation (McLaren, 2007) and may be contributing to inequalities in the risk of non-communicable diseases (Cooper, 2001; Moody et al, 2016) in the general population. Potential explanations include a reduced awareness of healthy eating practices and fewer

culinary skills (Parmenter et al., 2000; Lang et al, 1999), as well as limited time for home cooking among socially disadvantaged populations (Adams & White, 2015). However, many of these studies have been conducted in the US within the general population and it is unclear whether similar trends would be observed among people with severe mental illnesses (SMI) in the UK.

2.2.4.b Supermarkets

Another physical characteristic of the food environment that has received attention are supermarkets and grocery stores. Supermarkets are defined as: food stores that sell groceries such as fresh produce and meat, that tend to be used as a proxy for access to healthier dietary options (Lamichhane et al., 2013). The evidence base for the association between supermarkets and health outcomes within the general population are largely inconsistent. One systematic review reported an inverse association between areas with high densities of supermarkets and low blood pressure (Malambo et al., 2016) whilst another review found predominantly null associations between supermarkets and obesity measures in the general population, although some of the included studies showed a inverse association between increased supermarket availability and lower obesity (Cobb et al., 2015). Inclusion of studies whose aims were not to specifically investigate the link between health outcomes and supermarkets may partially explain the null associations were observed in the review (Cobb et al., 2015). Also, given the numerous possible causes of obesity, the influence of any single cause, including the food environment, is likely to be small, which may increase likelihood of null associations in studies with small sample sizes.

2.2.4.c Convenience stores

Convenience stores are retail businesses that sell a variety of everyday products from groceries to toiletries (Goossensen, Garcia, Garcia-Sierra, Calvet-Mir, & Domene, 2023). These stores have been suggested to increase alcohol consumption and the cultivate unhealthy dietary habits by providing affordable, energy-dense, and nutritionally deficient foods (e.g. crisps, chocolate) (Cannuscio, Weiss, & Asch, 2010; Dai & Wang, 2011; Ruff, Akhund, Adjoian, & Kansagra, 2014; Yang, Wang, & Qiu, 2019). A large portion of studies investigating the link between convenience stores and health outcomes have been carried out in the US. This research has predominantly concentrated on the socio-spatial discrepancies in the accessibility of unhealthy food retailers, revealing that people residing in deprived neighbourhoods tend to have increased access to convenience stores (Dai & Wang, 2011; Ruff et al., 2014). Other studies have highlighted the higher prevalence of obesity among low-income and racially minoritized communities, a phenomenon linked to

their constrained access to nutritious food options (Baker, Schootman, Barnidge, & Kelly, 2006; Hilmers, Hilmers, & Dave, 2012; Zenk et al., 2006) and the elevated concentration of fast-food establishments and convenience stores in their neighbourhoods (Bodor, Ulmer, Futrell Dunaway, Farley, & Rose, 2010; Drewnowski, 2009). However, given the dearth of research in countries other than the US (Martin et al., 2014), it remains unclear whether similar associations exist between convenience stores and adverse health outcomes in an urbanised context in the UK and among individuals with SMI.

Research investigating associations between the food environment and mortality outcomes are limited. Two ecological studies have indicated negative associations between areas with high exposure to fast food outlets and all-cause mortality (Alter & Eny, 2005) and between areas with high supply of ultra processed foods and cardiovascular-related mortality (Victor et al., 2023). A cohort study also reported a 12% and 16% increase in the risk of colorectal- and breast cancer-related mortality in those living in food deserts (Fong, Lafaro, Ituarte, & Fong, 2021) in the general population. In contrast, other cohort studies have found no associations between food desert residence and myocardial infarction mortality (sub-hazard ratio: 1.05; 95% CI: 0.80 - 1.38), all-cause mortality (Hazard Ratio [HR]: 0.99; 95% CI = 0.87- 1.14) (Kelli et al., 2019) and between healthy food outlets and cardiovascular mortality (HR: 1.03; 95% CI 1.00 - 1.07) in the general population (Lovasi et al., 2021).

Among the studies that found an association between the food environment and mortality outcomes, several explanations have been suggested which include: (1) high prevalence of poor quality diets among residents in food swamps (Kelli et al., 2017), (2) greater likelihood of socioeconomic deprivation among residents in food swamps compared to those who do not reside in these areas (Testa et al., 2021) (3) residents in food swamps may have to travel longer distances to purchase healthier foods which leaves little time for leisure or physical activities (Sierra, Cordova, Chen, & Rajadhyaksha, 2015) and (4) living in food swamps may inadvertently promote unhealthy lifestyle choices such as smoking (Saluja, Davies, Oldmeadow, & Boyle, 2021). Other investigations suggest that associations between food environment variables and mortality are mediated by income. Access to healthy food may be influenced by income and the ability to acquire healthy food, regardless of whether healthy food options are available locally. Kelli and colleagues (2019) found that participants living in a high-income neighbourhood experienced lower frequencies of cardiovascular-related outcomes. Thus, the relative cost of high-quality food may play a bigger role in preventing access to healthy food compared to accessibility of healthy food. However, the

existence of these associations between the food environment and mortality in SMI are yet to be explored.

2.2.4.d Off-licences

Off-licences (also referred to as alcohol outlets) are retail outlets that primarily sell alcoholic beverages – the licencing for these outlets mean that alcohol can only be purchased and not consumed on the premises (Morleo et al., 2009). The availability of alcohol outlets can potentially shape local consumption habits and affect health outcomes through several pathways. Higher density of alcohol outlets and heightened visibility of their advertising and promotions can contribute to greater availability of alcohol, lower prices for alcohol products due to local competition between retailers and can create and reinforce local attitudes and norms regarding drinking behaviours (Livingston, Chikritzhs, & Room, 2007; Pasch, Hearst, Nelson, Forsyth, & Lytle, 2009).

Systematic reviews have shown that extended trading hours for off-licences are associated with population-level increases in alcohol-related injuries, while restricted trading hours are linked to decreases in alcohol-related injuries (Popova, Giesbrecht, Bekmuradov, & Patra, 2009; Sherk et al., 2018; Wilkinson, Livingston, & Room, 2016). In terms of mortality, a Swiss cohort study indicated that the risk of alcohol-related mortality decreased as the number of alcohol outlets in the vicinity of one's residence decreased among both men and women (Spoerri et al., 2013). Reductions in the number of outlets were also associated with a reduction in the risk of mortality from mental and behavioural causes and from lung cancer (Spoerri et al., 2013). Similarly, findings from a Scottish ecological study demonstrated significantly higher alcohol-related deaths in neighbourhoods with a greater number of alcohol outlets (Richardson, Hill, Mitchell, Pearce, & Shortt, 2015). In summary, these studies have explored associations between the risk of mortality and availability of alcohol outlets among the general population however there have been no research exploring these associations among individuals with SMI.

2.2.5 Green spaces and mortality

The concept of green spaces being beneficial to population health became widely accepted as early as the 1800s (Twohig-Bennett & Jones, 2018). Since this time, various London-based organisations such as the National Health Society and Commons Preservation Society have advocated for the creation, accessibility and creation of parks and open spaces within densely populated residential areas, referring to them as the 'lungs' of these urbanised areas (Hickman, 2013).

Green space typically refers to open and undeveloped land with natural vegetation (Centers for Disease Control and Prevention, 2013), although it also exists in a variety of other forms, including public open spaces, urban parks and other greenery. Within the health sector, the benefits of green space exposure have been recognised - Oxford-based general practitioner, William Bird, developed the UK's first health walk scheme at his clinic in 1995 which resulted in the establishment of the English Walking for Health programme (Walking for Health, 2016). Collaborations between local nature partnerships and health care providers are becoming more common in the UK (Bloomfield, 2014; Kent Nature Partnership, 2021; Natural Cambridgeshire, 2021) with the goal of increasing exposure to features of the natural environment that are linked to better health among the population (Natural Cambridgeshire, 2021). However, ensuring access to green spaces among those who stand to benefit the most may prove challenging to policymakers (Twohig-Bennett & Jones, 2018).

Researchers and policymakers have continued to focus on health inequalities associated with socioeconomic factors, with indications that inequalities are continuing to increase (Pearce, Mitchell, & Shortt, 2015). Environmental factors are one of several possible explanations for their occurrence. (World Health Organization, 2019). Prior research has indicated that deprived neighbourhoods tend to have less green spaces (Mitchell, Astell-Burt, & Richardson, 2011) and that residents in these neighbourhoods are less likely to utilise the green spaces that do exist (Jones, Hillsdon, & Coombes, 2009). Conversely, residents of more affluent neighbourhoods have been observed to visit parks more frequently and to visit higher quality parks (Beck, 2009; Leslie, Cerin, & Kremer, 2010). Other evidence suggests positive associations between exposure to green space and health outcomes (Gascon et al., 2015; Van den Berg et al., 2015) and that neighbourhoods with higher proportions of green spaces have less health inequalities related to income deprivation (Mitchell & Popham, 2008). Green spaces have been observed to have many health-related benefits however these benefits tend to be overlooked as potential part of a multifaceted approach in addressing existing health inequalities (Twohig-Bennett & Jones, 2018).

Positive health outcomes have been linked to regular visitation of and residence near to green spaces (Rojas-Rueda, Nieuwenhuijsen, Gascon, Perez-Leon, & Mudu, 2019; Twohig-Bennett & Jones, 2018). Several explanations for the mechanism linking green space exposure and health outcomes have been proffered. Firstly, exposure to green spaces have been linked to improved physical health. Several studies in the general population have found that those who live in neighbourhoods with higher proportions of green spaces had

higher self-perceived general health (Astell-Burt & Feng, 2019; Maas, Verheij, Groenewegen, de Vries, & Spreeuwenberg, 2006). Significant reductions in morbidity have also been observed, including musculoskeletal, respiratory, cardiovascular and neurological health problems (Liu et al., 2022; Maas et al., 2009; Rojas-Rueda et al., 2019). Other research indicates lower risk of mortality (Villeneuve et al., 2012). The mechanism underlying this link could be that the availability of green areas encourages increased levels of physical activity among residents which in turn may lower the risk of health conditions like diabetes and obesity (De la Fuente et al., 2021).

Secondly, both measured and self-reported nature exposure has been connected to improved mental health status. Individuals who live in areas with higher proportions of green spaces reported better mental health than those who lived in areas with less green spaces (Alcock, White, Wheeler, Fleming, & Depledge, 2014; Astell-Burt & Feng, 2019). Reduced incidence of common mental health disorders (Maas et al., 2009) and reduced levels of self-reported stress (Fan, Das, & Chen, 2011) have also been observed in areas with more green spaces. Both mental health conditions and stress have been linked to higher risk of mortality (Russ et al., 2012) and therefore an indirect mechanism may be operating between green spaces and mortality.

According to the stress reduction theory, green spaces induce stress recovery through exposure to associated features of green spaces which include (but not limited to), aesthetically pleasing flora, presence of water and spatial openness (Dadvand & Nieuwenhuijsen, 2019). This helps to reduce help reduce negative thoughts and states of stress arousal via psychophysiological pathways (Ulrich, 1984). For example, changes in cardiovascular physiology have been associated with acute psychological stress which is linked to transitory myocardial ischaemia even in the absence of illness (Brotman, Golden, & Wittstein, 2007). Previous research suggests that psychological stress is linked to dysregulation of involuntary bodily processes controlled by the autonomic nervous system, such as blood pressure, heart rate, and respiration (Kubzansky & Kawachi, 2000) which may increase the risk of premature mortality (Robinson, McBeth, & Macfarlane, 2004).

Alternatively, psychological stress may increase the risk of excessive activation of a hormonal response system known as the hypothalamic-pituitary-adrenal (HPA) axis. The HPA axis regulates bodily stress responses (e.g. sweating, increased heart rate) and thus dysregulation of this system may lead to greater likelihood of an individual engaging in unhealthy behaviours (e.g., smoking, increased alcohol intake) to cope with their stress responses (Kubzansky & Kawachi, 2000).

Studies investigating green spaces and mortality have largely found reductions in the risk of mortality among the general population. Several systematic reviews have indicated inverse associations between green spaces and risk of all-cause mortality (Kua & Lee, 2021) and mortality due to several health conditions which include cancer (Kua & Lee, 2021), cardiometabolic illnesses (Kua & Lee, 2021; Meo, Al-Khlaiwi, & Aqil, 2022; Twohig-Bennett & Jones, 2018) and stroke (Yuan, Huang, Lin, Zhu, & Zhu, 2021). However, several limitations should be taken into account when interpreting the current evidence base. Firstly, the heterogeneity in green space measures across these studies increases the difficulties in combining coefficients to determine pooled effects of the green spaces on the risk of mortality (Rojas-Rueda et al., 2019). Secondly, the quantitative measures of green spaces such as the normalized difference vegetation index does not measure the quality or accessibility of these spaces, both of which may impact the association between green spaces and health (Mendoza et al., 2023). Thirdly, the majority of studies investigating the benefits of green spaces comes from cross-sectional and ecological studies, with minimal data from longitudinal investigations (Bauwelink et al., 2021; Chen et al., 2020; Rodriguez-Loureiro et al., 2022; Rojas-Rueda et al., 2019) and are therefore limited in determining causal associations. Lastly, there are currently no studies that have investigated the influence of green spaces on risk of mortality in SMI.

2.3 Social environment

The social environment typically refers to aspects of the environment that influence societal norms, enforce patterns of social control, impact stress levels, offer or limit opportunities for specific behaviours, and impose restrictions on individual choices (Institute of Medicine [US], 2002). At the area-level this typically includes (but not limited to) social cohesion and social networks (Hernandez & Blazer, 2006). These social environment factors have been measured through area-level indicators like social fragmentation (Collings et al., 2009) and the proportions of different ethnic minority communities coexisting in specific geographic locations (Faris & Dunham, 1939; Halpern, 1993). The following subsections will discuss the current evidence base on the social environment indicators and their association with health and/or mortality outcomes which have been included in the statistical analysis portions of this thesis.

2.3.1 Social fragmentation and mortality

'Social fragmentation' is a concept rooted in Emile Durkheim's work, and it has been loosely categorized alongside other social attributes of groups and neighbourhoods, including social cohesion and collective social functioning (Stjärne et al., 2004). Durkheim theorised that,

social groups or 'societies' differ in the degree of their cohesiveness or, conversely, the extent to which they are fragmented, which affects their ability to offer balanced levels of regulation and integration for their members (Durkheim, 1951). Durkheim proposed that a social group that is either excessively fragmented or overly cohesive would struggle to provide optimal levels of support - a theory he explored by analysing suicide rates in various social groups (Taylor & Ashworth, 1987; Durkheim, 1951), albeit with varying degrees of success.

Social cohesion refers to the extent of connectedness and solidarity among groups in society and characterised by the levels of **community integration** and **regulation** within social groups (Kawachi & Berkman, 2000). Community integration is defined as the degree to which individuals feel accepted by or connected to a group or society (Zhang, 2016). Integration is formed from the creation and maintenance of social relationships that are embedded in larger networks such as communities and other social groups - this includes ties to families, neighbourhoods and communities (Mueller, Abrutyn, Pescosolido, & Diefendorf, 2021). The core elements of these social relationships are reciprocity and trust, both of which feed into a system of expectations and obligations among group members (Hawe & Shiell, 2000; Putnam, 1993). Trust between group members allows group members to share privileged knowledge, call on favours and get better access to services and opportunities in the community, known as **social capital** (Hawe & Shiell, 2000; Kawachi, Subramanian, & Kim, 2008; Portes, 1998). It is theorised that social capital facilitates the dissemination of health information (e.g., information about medical treatments and new health services) and reduces barriers to accessing health services (e.g. residents offering transportation to health services) in the general population (Kawachi, Kennedy, & Glass, 1999; Yang, Lei, & Kurtulus, 2018).

Community regulation refers to the extent to which a group's social values, rules and norms controls and coordinates the attitudes and behaviours of group members (Collings et al., 2009; Mueller & Abrutyn, 2016). Durkheim envisaged people as having innate and insatiable desires that are typically regulated by the norms, values and rules of the society in which the person lives in (Clegg, Cunha, & Rego, 2016). It is suggested that without regulation, the desires of the individual would be both uncontrollable and unsatisfying, leading to feelings of disappointment and powerlessness. Individuals in such instances have impracticable expectations, and when these are not satisfied, the person feels disconnected from societal norms, leading to unhappiness and feelings of meaninglessness and hopelessness, known as **anomie** (Clegg et al., 2016). Anomie is theorised to arise during phases of major political,

social or economic turmoil (e.g. global pandemic, financial recession) or by a change in socioeconomic status of the individual (e.g. job loss) (Hossen, 2022; Mueller et al., 2021) which is suggested to increase the risk of ‘anomic’ suicide. Prior studies in the general population have also demonstrated increased risk of suicide in the wake of economic recession (Oyesanya et al., 2015) and austerity measures (Stuckler, Reeves, Loopstra, Karanikolos, & McKee, 2017).

It has been proposed that there is a U-shaped relationship between the levels of regulation and integration and individual-level well-being. In this context, a highly fragmented neighbourhood may lead individuals to experience isolation and a reduced access to supportive levels of integration and regulation (Ivory et al., 2012). Conversely, an excessively cohesive social environment could overwhelm and subsume individuals (Kushner and Sterk, 2005), hindering their ability to act in their own best interests. Therefore, in neighbourhoods characterized by high levels of social fragmentation, it is theorized that community integration and social capital levels are likely to be diminished (Ivory et al., 2012). As a result, individuals residing in such neighbourhoods may face an elevated risk of experiencing adverse mental health outcomes (Ku et al., 2021; Ivory et al., 2011) and an increased risk of suicide (Zhang, 2016).

Building on Durkheim’s work, Congdon (1996) sought to create a metric which could account for the distribution of suicide in London better than existing deprivation measures. This led to the development of an index of social fragmentation based on proportions of single-person households, private rental accommodation, married couples and population turnover (residential mobility) derived from census data (Evans, Middleton, & Gunnell, 2004). This index predicted suicide rates in the local authority districts of London more effectively than pre-existing area-level deprivation measures (Evans et al., 2004). Several ecological investigations using general population samples have since reported associations between higher scores on the neighbourhood-level social fragmentation index and increased risk of suicide within the UK (Congdon, 2012; Evans et al., 2004; Middleton et al., 2004; Mok et al., 2013; Smith, Whitley, Dorling, & Gunnell, 2001), China (Hsu, Chang, Lee, & Yip, 2015; Li, Xu, Zhang, & Liu, 2016; Yeung, Men, Caine, & Yip, 2022), Japan (Yoshioka, Hanley, Sato, & Saijo, 2022) and Taiwan (Lin, Hsu, Gunnell, Chen, & Chang, 2019). Associations between social fragmentation and suicide have also been observed among females compared to males (Congdon, 1996; Congdon, 2012; Lin et al., 2019). However, the ecological design of these studies increases the difficulty in drawing causal associations between social fragmentation and suicide.

Studies investigating associations between social fragmentation and mortality outcomes have reported relatively mixed findings in general population samples. One Dutch cohort study found that men and women who moved to less socially fragmented neighbourhoods had a 18% and 22% lower risk of suicide respectively compared to those remaining in highly fragmented neighbourhoods (Hagedoorn & Helbich, 2022). Another cohort study also found that after controlling for individual-level covariates, a higher risk of suicide was observed in individuals residing in neighbourhoods with higher levels of social fragmentation (Jakobsen et al., 2022). Other studies have also reported stronger associations between area-level deprivation and natural-cause mortality and suicide when compared to associations between social fragmentation and natural-cause mortality (O'Farrell, Corcoran, & Perry, 2016; Smith et al., 2001; Whitley, Gunnell, Dorling, & Smith, 1999; Yeung et al., 2022). One possible reason for weaker associations between the social fragmentation index and natural cause mortality is that the Congdon index was originally created to identify geographic locations with substantial instability and population turnover and to be utilised in research on suicide (Stjärne et al., 2004). Hence, it is likely that the social fragmentation index has a weaker association with the causal pathways for natural-cause mortality. Despite this, little is known about whether similar associations between neighbourhood-level social fragmentation and mortality outcomes exist in SMI given that most studies have been conducted in the general population.

The evidence in relation to the association between social fragmentation and mortality in SMI are scant and has been reviewed in [Chapter 3](#). The review identified only one study had investigated this association. Das-Munshi and colleagues' (2019) cohort study included 18,201 people with SMI, followed up using de-identified electronic health registers that were linked with mortality data from the Office for National Statistics dataset. The median follow-up period was 6.36 years and the study was conducted in an ethnically diverse location in south London. No associations were observed between social fragmentation and the mortality outcomes in the study cohort (adjusted rate ratio 0.98, 95% CI = 0.94 - 1.03). Furthermore, other neighbourhood-level characteristics that could serve as a marker social cohesiveness or as a buffer against detrimental social factors (e.g. discrimination) have yet to be investigated within this population, as elaborated upon in the upcoming subsections.

2.3.2 Ethnic density and mortality

Prior research suggests that individuals from racialised minority groups experience better health outcomes when they reside in neighbourhoods with greater concentrations of people that identify as belonging to the same ethnic group (i.e. co-ethnics) - referred to as the

ethnic density effect (Faris & Dunham, 1939; Halpern, 1993). Several mechanisms have been proffered as to how neighbourhoods with high densities of racialised minority groups form, primarily based on research conducted in the US. This includes (but is not limited to) the need for protection against discrimination and racial harassment, a desire to bond over shared cultural, language, and religious beliefs and traditions, develop and maintain social connections and employment opportunities in a neighbourhood, government policies that increase the likelihood of ethnic segregation and historical housing arrangements that have limited racialised minority groups to low-quality dwellings due to private landlords and public housing allocation (Krieger et al., 2014; Peach & Byron, 1994). This physical segregation of wealthier White groups and socio-economically disadvantaged racially minoritized groups results in the latter group residing in more deprived neighbourhoods; one of several factors that has been linked to higher risk of all-cause mortality and morbidity in general population samples from European countries (Mackenbach et al., 2008; Schiøtz, Stockmarr, Høst, Glümer, & Frølich, 2017) and adverse health behaviours (Fone, Farewell, White, Lyons, & Dunstan, 2013; Office for National Statistics, 2023).

A couple of pathways have been posited that link neighbourhood-level ethnic density to public health. Firstly, neighbourhoods with higher levels of ethnic density may encourage more social interactions between members of the same ethnic group, which in turn facilitates supportive levels of community integration and regulation (Ivory et al., 2012) and increased access to social capital (Bourdieu, 1986; Kawachi, Subramanian, & Kim, 2008; Mollica, Gray, & Trevino, 2003). These social processes may help to form tight knit racially minoritized communities which may influence the wellbeing of its group members because of the higher levels of social cohesion between its members (Uphoff et al., 2013).

The hypothesized higher levels of social cohesion within neighbourhoods with higher proportions of racially minoritized communities may influence the health behaviours of individual group members. Increased levels of social cohesion, feelings of belonging to a social group and social control have been reported among racially minoritized residents living in areas with higher co-ethnic densities (Sampson, Raudenbush, & Earls, 1997). These factors strengthen social norms which consequently affect health behaviours among individuals. People with higher levels of social connectedness and social relationships are expected to adhere to social norms because failure to do so would result in collective sanctions (Portes, 1997). Bécares and colleagues (2011) found that increased area-level ethnic density was associated with lower odds of self-reported current drinking habits among all racialized minority groups. Another study reported reduced odds of smoking

among most ethnic groups living in neighbourhoods with higher co-ethnic densities - null associations were reported for Black Caribbean women (Mathur et al., 2017). Consequently, neighbourhoods with higher ethnic densities may exhibit higher levels of social control, which may encourage residents to engage in specific health behaviours, such as physical exercise and healthier diets (Yang et al., 2018).

Residence in neighbourhoods with higher levels of co-ethnic density may provide protective or buffering effects against discrimination and other forms of racial harassment (Bécares, Nazroo, & Stafford, 2009; Pickett & Wilkinson, 2008). Discrimination can be a source of stress for racialized minority communities (Whitley, Prince, McKenzie, & Stewart, 2006). Individuals who live in close proximity to members of their own ethnic group are less likely to experience negative consequences of discrimination than those who live in neighbourhoods with reduced levels of co-ethnic density, as the latter are subject to more discrimination while receiving less support (Yang et al., 2018). It is reasoned that in areas with a higher ethnic density, racialized minority groups may be subjected to less discrimination and thus less stress, making them less vulnerable to engaging in risky health behaviours used to cope with stress, such as drug and alcohol abuse (Bécares et al., 2011). Lower prevalence of mental health difficulties have also been documented in areas with higher levels of ethnic density which may be attributable to the elevated levels of social support and social networks embedded within racialised minority communities (Bécares, Dewey, & Das-Munshi, 2018; Das-Munshi et al., 2012; Das-Munshi, Becares, Dewey, Stansfeld, & Prince, 2010).

Evidence in relation to the link between area-level ethnic density and mortality are inconsistent in the general population. The findings of a systematic review indicated that areas with higher proportions of Black residents were associated with increased risk of all-cause and cause-specific mortality (Bécares et al., 2012). However, other studies included in the review indicated a protective effect of area-level ethnic density for the risk of mortality in individuals aged 65 and older and in areas where there were higher levels of social capital in general population samples (Bécares et al., 2012). Another systematic review indicated that neighbourhoods with a greater proportion of Black residents exhibited an elevated risk of cancer-related mortality (Fang & Tseng, 2018). However, there were mixed findings for the association between the risk of cancer mortality in neighbourhoods with higher proportions of Hispanic residents (Fang & Tseng, 2018).

The evidence in relation to the association between area-level ethnic density and mortality in SMI are scant and has been reviewed in [Chapter 3](#). The review identified only one study had investigated this association and found a protective effect of area-level ethnic density and mortality among racialised minority individuals with SMI (Das-Munshi et al., 2019). Das-Munshi and colleagues' (2019) found that all-cause mortality was elevated for racialised minority groups in the least ethnically dense areas (adjusted rate ratio [aRR] 0.96, 95% CI: 0.71 - 1.29) compared with racialized minority groups in the most ethnically dense areas (aRR: 0.52, 95% CI: 0.38 - 0.71), relative to their white British counterparts with similar SMI diagnoses. For racialized minority individuals with SMI, residing in areas with higher ethnic density may act as a protective factor against social isolation or could be linked to exposure to stronger health-promoting social norms that may contribute to a reduced risk of premature mortality in SMI (Das-Munshi et al., 2019; Susser & Kirkbride, 2019). However, there have been no subsequent investigations exploring this association in SMI.

2.3.3 Places of worship and mortality

Some of the earliest work investigating the effect of religion on health came from sociologist, Emile Durkheim. Durkheim's (1952) ecological study explored variations in suicide rates between Catholics and Protestants, revealing lower rates of suicide among the Catholic population. Durkheim suggested that the lower rates of suicide were associated with greater social control and social integration among Catholics. However, other researchers have contested Durkheim's interpretation, suggesting that the findings of his study, being a product of its time, may have been influenced by contextual factors. For example, during Durkheim's era, the Catholic Church imposed stricter sanctions against suicide than many Protestant groups (Stark et al., 1983). A review also indicated inconsistent evidence of differences in the rates of suicide between these two faith groups (Stack, 2000) whilst other reviews have reported protective effects of religion in general on mental and physical health outcomes in the general population (AbdAleati, Mohd & Mydin, 2016; Lawrence et al., 2016).

A couple of mechanisms have been posited for the link between religion and health. Firstly, religion may foster social cohesion among practicing group members in two ways. Religion provides a group-level regulatory function (Idler & Kasl, 1997). Many religions provide rules that are considered binding by their followers, encompassing not only religious and ethical matters but also extending to other basic human needs including (but not limited to) dietary choices and intimate relationships (McCullough & Smith, 2003). Secondly, religion has been

suggested to provide a social integration function (Idler & Kasl, 1997). Members of religious organisations share a set of beliefs, hold regular meetings, impart and impose a framework for appropriate behaviour, maintain the day-to-day functioning of the group via contributions and voluntary activities and share a commitment to support other members in need (Musick et al., 2004). In this sense, members of religious communities may benefit from having tangible and meaningful connections to other people which in turn increases access to resources provided via social connections within this community, known as religious social capital (Maselko, Hughes, & Cheney, 2011).

Moreover, religion can play a more indirect role in social integration by facilitating the creation of new institutions like clinics, after-school clubs, and shelters, or by revitalizing existing ones such as safer neighbourhood initiatives outcomes (McCullough & Smith, 2003). This can help create environments that are more favourable for achieving positive health outcomes (McCullough & Smith, 2003). Therefore, these social connections not only provide followers with a subjective sense of belonging to a group and the perception that they are cared for by other people, but they can also put people who lack resources (e.g. housing, food, clothing) into contact with people who are willing and able to assist them in obtaining these resources (McCullough & Smith, 2003).

Several longitudinal studies have found evidence of a link between religiosity and mortality outcomes in general population samples. One systematic review found that 82 cohort studies reported positive associations between religiosity and longer lifespans compared with six studies which found shorter lifespans with increased religiosity (Koenig, 2012). Another investigation reported that those who attended religious services on a monthly basis had a 10% reduced risk of mortality compared with those who seldom attended services after adjustment for age, sex, education and ethnicity (Doolittle, McGinnis, Ransome, Fiellin, & Justice, 2021). Nonetheless, it is important to note that most of these studies were conducted in the US, it would be difficult to assume that similar associations exist in the UK and among people with SMI. Secondly, these studies have generally investigated the presence of religious and/or spiritual beliefs and religious service attendance and their association with mortality - no studies have investigated the availability and proximity of places of worship at the neighbourhood level and how this potentially influences the risk of mortality among people with SMI.

2.4 Study catchment area

The National Health Service (NHS) provides state-wide universal healthcare in the UK and in some geographic areas the NHS have near exclusive provision of mental health services. The South London and Maudsley NHS Foundation Trust (SLaM) provides comprehensive secondary mental healthcare to approximately 1.36 million people in four London boroughs (Lewisham, Lambeth, Southwark, and Croydon). The current investigation will use an anonymised electronic health record provided by the SLaM NHS trust. Consequently, the geographical context for all subsequent analyses is confined to these four boroughs served by the SLaM NHS trust. I will, therefore, offer an overview of the characteristics of each of these boroughs relative to the mid-point of the study observation period (i.e. 2011).

2.4.1 Croydon

Croydon is an outer London borough that borders the county of Surrey to the south and Southwark, Lambeth and Lewisham to the north. In 1086, Croydon was recorded as a small market town with a population of 335 residents. Since then, it has grown to be the fifth largest borough in London at 8,700 hectares and home to one of London's largest retail and business districts with well-developed transportation links (tram, road and rail) (Croydon Observatory, 2012). It is also home to some of London's wealthiest neighbourhoods and has over 3,000 acres of countryside, parkland and open spaces (Office for Health Improvement & Disparities, 2012). 14.6% of the population reported having long-term health condition compared with 17.6% nationally as reported in the 2011 Census. Croydon contains pockets of significant deprivation, with one small area ranking as the third most deprived area in London (out of 4,642 small areas) and around 10,000 residents living in neighbourhoods that are among the 10% most deprived in England (Croydon Council, 2021). In Croydon, areas with the highest levels of deprivation have been associated with lower life expectancies; at the mid-point of the study observation period (i.e. 2012), males and females born in these areas had life expectancies that were 9.5 and 5.8 years lower than those born in areas with the least deprivation respectively (Office for Health Improvement & Disparities, 2012).

2.4.2 Lambeth

Lambeth is an inner London borough bordered to the north by the River Thames, Southwark to the east, Wandsworth to the west and Croydon to the south. It is the ninth smallest London borough and is in the top 20% of the most deprived local authorities in England (Public Health England, 2020a) with a fast-expanding population that is expected to grow by 9% over the next ten years (Lambeth Clinical Commissioning Group, 2013). Lambeth has

slightly younger age profile when compared with the rest of the country, with roughly 52% of the population aged 20-44 years, compared with 34% nationally (Lambeth Clinical Commissioning Group, 2013). Lambeth is classified as a London Cosmopolitan area in the 2011 Census. According to this categorization, Lambeth has a diverse range of ethnic and cultural traditions that have established themselves in specific town centre districts and quarters – around 130 languages are spoken by residents in this borough (Lambeth Clinical Commissioning Group, 2013). Since the mass migration of people from the West Indies during the 1940s and 1950s, Lambeth has served as a significant hub for the Black Caribbean community and is home to sizable populations of African diaspora and Portuguese speakers (Lambeth Council, 2012). Similar to Croydon, life expectancy in its most deprived neighbourhoods is 5.3 years lower for males and 3.8 years lower for women than in the least deprived areas (Office for Health Improvement & Disparities, 2012).

2.4.3 Lewisham

Lewisham is the 13th smallest borough in London and is in the top 20% of the most deprived local authorities in England (Public Health England, 2020b). Similar to Lambeth, Lewisham has a younger demographic than the rest of England; children and young people aged 0-19 years account for 24.5% of population, compared with 22.4% in inner London and 23.8% nationally (Lewisham Council, 2017). It is the country's 15th most ethnically diverse borough - according to the 2011 Census, 46.4% of Lewisham's residents identify as Black, Asian, or other racially minoritized group and 14.4% of residents reported having a long-term health condition, compared with 17.6% in England. Life expectancy in Lewisham's most deprived neighbourhoods was 6.8 years lower for males and 4.6 years lower for females compared with the least deprived neighbourhoods (Office for Health Improvement & Disparities, 2012).

2.4.4 Southwark

Southwark is an inner London borough on the south bank of the River Thames, bordered to the east by Lewisham and to the west by Lambeth. It is the ninth most densely populated local authority at 9,988 residents per square kilometre (Southwark Council, 2021). According to the 2011 Census, its population density is higher than the London average of 5,199 people per square kilometre and the national average 407 people per square kilometre. It has a slightly younger age profile compared with the rest of England – young people aged 25-29 accounted for 12% of the population compared with 7% nationally (Southwark Council, 2014). Almost half of Southwark's residents (46%) identify as members of racially minoritized communities. The 2011 Census also indicate that just under 40% of areas in

Southwark are in the top 5% of deprived areas nationally. Life expectancy in Southwark's most deprived neighbourhoods was 10.4 years lower for males and 8.6 years lower for females compared in the least deprived neighbourhoods (Office for Health Improvement & Disparities, 2012).

2.5 Summary of literature review

Area-level deprivation

Findings from studies conducted both with individuals with and without SMI, have consistently reported that residence in deprived neighbourhoods are associated with more adverse outcomes in terms of morbidity and mortality outcomes compared with those living in less deprived neighbourhoods.

Neighbourhood walkability

There are limited studies that have investigated the link between neighbourhood walkability and mortality. These investigations have rendered inconsistent findings. Some studies have indicated positive effect of increased levels of walkability on lowering the risk of all-cause mortality as well as the risk of other cause-specific mortality (e.g. cardiovascular- and obesity-related mortality). However, other studies have shown attenuation of the association of neighbourhood walkability with health outcomes after adjusting for socioeconomic status and other demographic variables. Additionally, these associations have not been explored in cohorts with SMI.

Population density

Research on population density and mortality has predominantly identified an elevated risk of mortality in densely populated neighbourhoods. However, this association has been less consistently observed in cohorts with SMI.

Food environment

Research on the association between the food environment and mortality outcomes is limited. Some studies have found a negative effect of increased exposure to unhealthy food outlets (e.g. fast food retailers) and all-cause and cardiovascular-related mortality. However, other studies have reported null associations between residence in areas with lowered access to healthy foods and all-cause and cause-specific and mortality. Moreover, there have been no studies investigating these association in SMI.

Green spaces

Studies investigating associations between green spaces and mortality have largely found reductions in the risk of mortality among the general population. However, this link has yet to be explored among populations with SMI.

Social fragmentation

Studies investigating associations between social fragmentation and health outcomes have reported inconsistent findings. Some investigations indicated small effects or null associations between highly fragmented neighbourhoods and natural-cause mortality after adjusting for area-level deprivation. Other studies have noted a lower risk of suicide in neighbourhoods with lower levels social fragmentation however this finding is not consistent among other studies. Research investigating this association among individuals with SMI are limited – only one study was identified in the systematic review (see [Chapter 3](#)) which indicated no evidence of a link between social fragmentation and risk of mortality in SMI.

Ethnic density

Evidence in relation to the link between area-level ethnic density and mortality are inconsistent. The findings of two systematic reviews indicate both adverse and protective effects in areas with higher proportions of racialised minority groups in relation to the risk of mortality among individuals without SMI. The evidence in relation to the association between area-level ethnic density and mortality in SMI are scant – only one study had investigated this association in SMI (as discussed in the systematic review - [Chapter 3](#)). Das-Munshi and colleagues' (2019) cohort study included 18,201 people with SMI, followed up using de-identified electronic health registers that were linked with mortality data from the Office for National Statistics dataset. All-cause mortality was elevated for racialised minority groups in the least ethnically dense areas (adjusted rate ratio [aRR] 0.96, 95% CI: 0.71 - 1.29) compared with racialized minority groups in the most ethnically dense areas (aRR: 0.52, 95% CI: 0.38 - 0.71), relative to their white British counterparts with similar SMI diagnoses. For racialized minority individuals with SMI, residing in areas with higher ethnic density may act as a protective factor against social isolation or could be linked to exposure to stronger health-promoting social norms that may contribute to a reduced risk of premature mortality in SMI (Das-Munshi et al., 2019; Susser & Kirkbride, 2019).

Places of worship

Several longitudinal studies have found evidence of a positive effect of religion and lowered risk of mortality outcomes. However, most studies have been conducted in the US and there have been no studies investigating the whether the proportion or proximity of places of worship influence the risk of mortality in SMI. Therefore it remains unclear whether similar associations exist in urbanised contexts in the UK and among populations with SMI.

Methodological limitations of reviewed studies

Firstly, many of the studies investigating associations between the neighbourhood-level variables and health outcomes conducted analyses using samples from the general population. Therefore, the ability to extrapolate these findings to populations with SMI are limited.

Secondly, the inconsistency in findings among some of the studies included in the literature review may be due to discrepancies in methodologies between the studies identified in the literature review, such as the characterization and measurement of environmental exposure variables (e.g. fast food outlets, green spaces). For example, systematic reviews investigating the association between green spaces and health outcomes have highlighted the heterogeneity in measurements of green spaces which ranged from the use of normalised difference vegetation index to proportions of green spaces aggregated to census tract areas (Twohig-Bennett & Jones, 2018). These differences in exposure measurements can make it difficult to draw overall summaries of the strength and direction of the association between neighbourhood-level indicators and the risk of mortality.

Thirdly, the different geographical boundaries / units used in the research increase difficulties in comparing findings and the geographical area units chosen may also have an impact on summary values (e.g. population density, mortality rates), which vary depending on the shape and scale of the geographical unit (Arcaya et al., 2016). This is referred to as the Modifiable Areal Unit Problem.

Furthermore, few studies considered the inherent clustered nature of the data by employing statistical techniques such as multilevel modelling (MLM). Traditional regression analyses typically assume that all observed data points are independent of one another. However, in many of these studies, the clustering of individuals within neighbourhoods was not properly addressed using appropriate frameworks, such as MLM or other applicable methods. Multilevel modelling offers advantages over conventional regression models as it allows for the partitioning of total variance into components between neighbourhoods and

within neighbourhoods. This can result in more accurate estimations of these effects and a deeper understanding of the geographical factors influencing health outcomes, as demonstrated by the work of Merlo and colleagues in 2005(a).

2.6 Integrated framework for social determinants associated with mortality in populations with severe mental illnesses

For this project, an integrated approach was chosen to conceptualise the association between neighbourhood-level factors and the risk of premature mortality in SMI by amalgamating two frameworks: (1) the World Health Organisation (WHO) Committee on Social Determinants of Health (CSDH) conceptual framework (Solar & Irwin, 2010) and (2) ecosocial theory of disease distribution proposed by Krieger (2001; 2012). The CSDH framework was used to categorise neighbourhood-level factors and conceptualise their association with mortality outcomes in SMI, and ecosocial theory was used to conceptualise these mechanisms from a life course and spatiotemporal perspective. This amalgamated model provides a conceptual framework for understanding how factors measured at the neighbourhood-level affect the risk of mortality among individuals diagnosed with SMI (see [Figure 2.6.3](#) for model diagram).

The CSDH conceptual framework is an action-oriented framework created to address social determinants of health inequalities and promoting change (see [figure 2.6.1](#)). Its objectives include identifying the social determinants of health, and clarifying the mechanisms that link the social determinants to these inequalities. The framework consists of three components: (1) socioeconomic and political context, (2) structural determinants and socioeconomic position, and (3) intermediary determinants. The socioeconomic-political context encompasses a wide range of societal factors that cannot be directly measured at the individual level. These factors include the education system, labour market and the welfare state. They are instrumental in creating, influencing, and maintaining social hierarchies. Government-level policies also have a broad-ranging impact on factors that influence the distribution and effects of the social determinants of health (SDH) across various population groups (Solar & Irwin, 2010).

Many individuals were affected by the government austerity measures and typically those on the lowest incomes (Duffy, 2013; Mattheys, 2015). Individuals with SMI are no exception and tend to be disproportionately represented within these lower socioeconomic groups (Werner, Malaspina, & Rabinowitz, 2007). A recent study showed that between April 2013 and October 2016, benefit claimants with a psychiatric condition were 2.4 times more likely than those with a non-psychiatric condition to lose their benefits following a reassessment for Personal Independence Payments (Iacobucci, 2019). Individuals with SMI are also more likely to face significant challenges in employment. For example, people with psychosis are around six times more likely to be unemployed compared with the general population with

only 5% to 15% of people with psychosis estimated to be in employment (NIHR, 2018). Additionally, people with SMI are more likely to reside in neighbourhoods characterized by higher social deprivation and occupy lower socioeconomic positions (Eaton & Harrison, 2001; Werner et al., 2007). Underlying mechanisms driving this inequality have been linked to mental health related stigma and discrimination (Social Exclusion Unit, 2004).

Limited levels of disposable income among individuals with SMI and stigma have an affect on their ability to access services and health-promoting resources within their neighbourhood (Perese, 2007). This intensifies financial hardship and makes it more difficult for them to meet basic needs, ultimately affecting health outcomes in this population (Loopstra & Lalor, 2017; Pybus, 2018). This interaction between the socioeconomic-political context, underlying structural/social mechanisms that contribute to the unequal distribution of factors influencing health and social stratification, along with the resulting socioeconomic status of individuals, is known as the structural determinants of health. This concept forms the second component of the CSDH framework.

The structural determinants of health operate through several factors that are theorised to be more proximal indicators of health outcomes. These factors are known as intermediary determinants and constitute the third component of this framework. Intermediary determinants considered in this project are material and social-environmental circumstances. Material circumstances are factors related to the physical environment that are likely significant for the health status of populations with SMI, particularly those occupying lower socioeconomic positions. For example, residence in neighbourhoods with an abundance of fast-food outlets may influence dietary behaviours that increase the likelihood of adverse health outcomes (Daniel, Paquet, Auger, Zang, & Kestens, 2010). This situation may be compounded by socioeconomic factors, such as limited access to disposable income (Power, Pybus, Pickett, & Doherty, 2021).

Social-environmental circumstances includes (but not limited to) stressful living conditions (e.g. high debt, residence in high crime areas) and the presence or absence of social support and coping strategies. It is theorised that different social groups encounter varying levels of exposure to challenging socioenvironmental circumstances that are difficult to cope with in their daily lives (Solar & Irwin, 2010). For example, neighbourhoods with lower levels of social connectedness and social cohesion (referred to as social fragmentation) may increase the risk of suicide (Congdon, 2012; Evans, Middleton, & Gunnell, 2004; Middleton et al., 2004). Neighbourhoods that are highly fragmented may be less able to provide appropriate

support to more vulnerable group members and this could lead to increased risk of suicide (Ivory et al., 2012). However, this association has received limited exploration in populations with SMI.

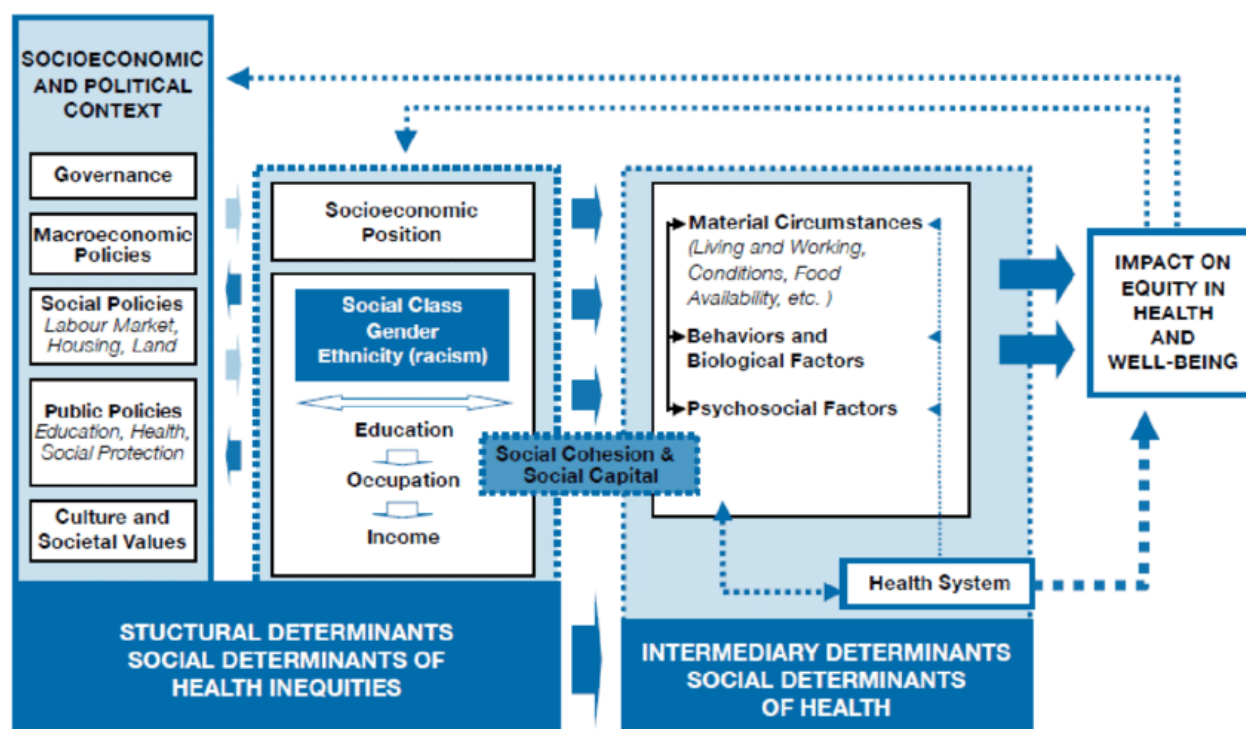


Fig. 2.6.1 Committee on Social Determinants of Health (CSDH) conceptual framework (Solar & Irwin, 2010)

Ecosocial theory is a multilevel framework developed to identify the factors that drive social inequalities in health (Krieger, 2001; Krieger, 2012; Palm, Schmitz, & Mangelsdorf, 2013) (see [Figure 2.6.2](#)). The central focus of ecosocial theory is on how individuals physically manifest exposures arising from societal and ecological contexts, resulting in distinct patterns in the distributions of health outcomes. Similar to the CSDH framework, this theory emphasises the interplay between socioeconomic and political contexts, underlying structural/social mechanisms, socioeconomic positions and intermediary determinants of health. However, there is more of an emphasis on the cumulative impact of these interactions across the life course and less of a focus on proximal and distal classifications of determinants. Furthermore, the theory encourages researchers to clarify spatiotemporal scales at which both the exposure and outcome variables have been measured at.

Both ecosocial theory (Krieger, 2001; 2012) and the CSDH framework (Solar & Irwin, 2010) offer insights into how social determinants affect the distribution of health outcomes at the population level. Krieger (2001; 2012) suggests that from conception to death, our bodies physically manifest the exposures originating from the social and material environment in

which we live. These embodied experiences are hypothesized to influence the rates and patterns of health outcomes within populations (Krieger, 2012). For example, exposures such as socioeconomic deprivation, insufficient healthcare, and excessive proximity to fast-food outlets can significantly impact our bodies. Disparities in health observed within the population may be explained by unequal exposure to these factors. This concept, known as 'embodiment,' stands as a central tenet in ecosocial theory (Krieger, 2001; 2012).

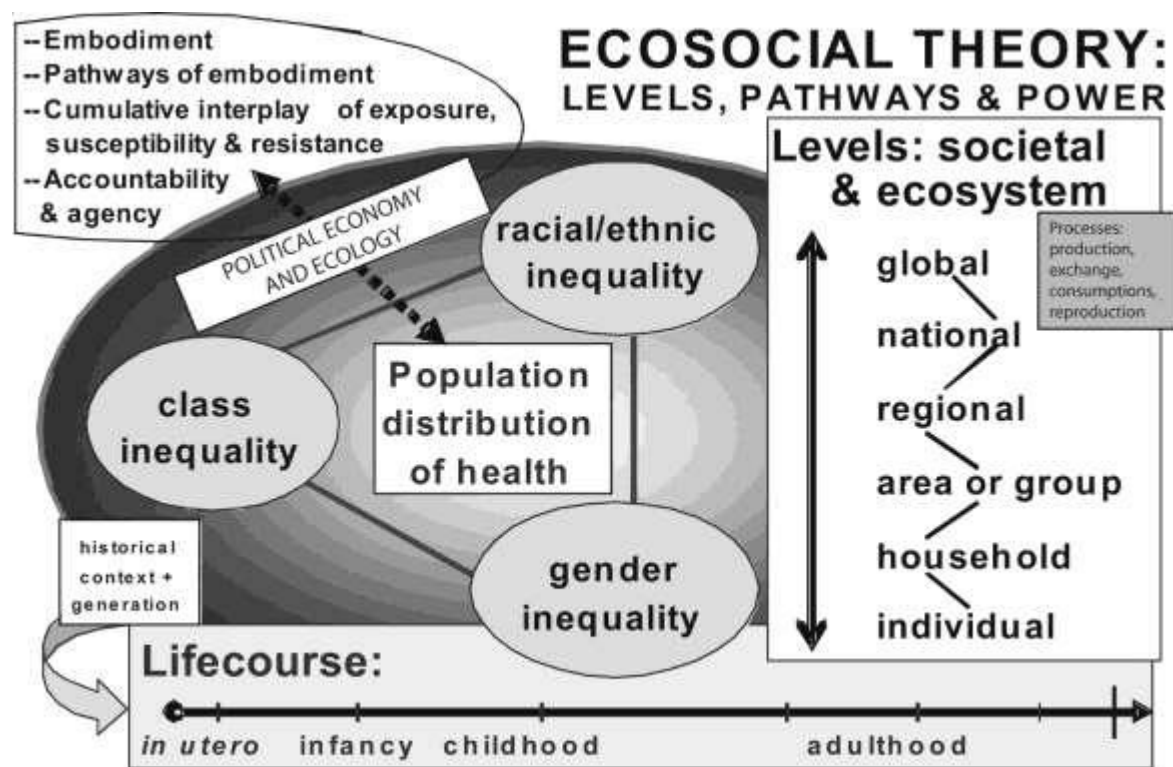


Fig. 2.6.2 Ecosocial theory (Krieger, 2012)

[Figure 2.6.3](#) positions the current project within the life course and the spatiotemporal scale at which the study was conducted. The amalgamated model in [figure 2.6.3](#) emphasises the interplay between the socioeconomic and political contexts, urban built and social environment variables and sociodemographic indicators and the resulting mortality outcome in SMI. The intermediate (distal) determinants of excess mortality in SMI have been conceptualised as the urban built (e.g. area-level deprivation, retail outlets) and social environment (e.g. social fragmentation, ethnic density) indicators that have been reviewed in the previous section. While the association of built and social environmental indicators with mortality is explored in the previous literature review sections, individual-level factors like substance misuse and mental health diagnosis could also influence an individual's access to these neighbourhood resources and therefore affect the risk of mortality in SMI.

Based on the literature review and the integrated framework, the aims of the thesis are:

- to systematically review the existing literature on the association between mortality and neighbourhood-level variables
- to compare the risk of mortality among the study cohort compared with the general population without SMI
- to explore the geographical patterning of mortality in the SMI cohort across the study catchment area
- to assess associations between the urban built and social environment indicators and the mortality outcomes in the cohort both at the individual-level and at the neighbourhood-level
- to assess how much of the variation in the mortality outcomes are attributable to differences at both the neighbourhood and individual levels

Based on the literature review and integrated framework, the hypotheses were:

- Individuals with SMI will have an elevated risk of mortality compared with the general population without these diagnoses.
- Neighbourhoods characterized by higher risk of mortality are more likely to be located near to other neighbourhoods that also have similarly elevated risk of mortality.

The following hypotheses relate to the urban **built environment indicators**:

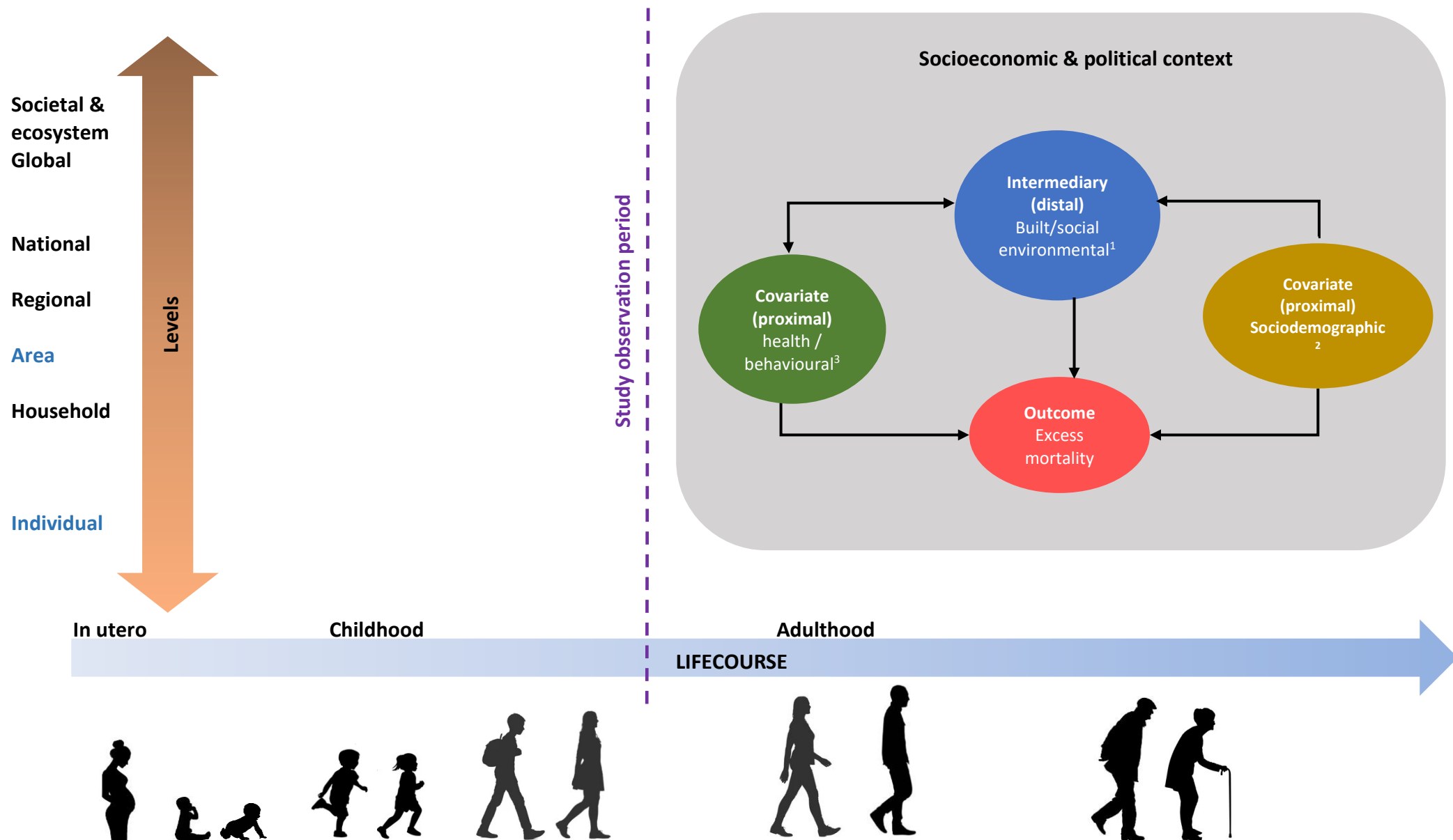
- Individuals with SMI living in deprived neighbourhoods will have an elevated risk of mortality in the cohort with SMI.
- Individuals with SMI will have an elevated risk of mortality if residing in neighbourhoods with higher proportions of the following urban built environment indicators:
 - Convenience stores
 - Fast food outlets
 - Off-licences
- Individuals with SMI will have a lower risk of mortality if residing in neighbourhoods with higher proportions of the following urban built environment indicators:
 - Green spaces

- Supermarkets

The following hypotheses relate to the urban **social environment indicators** which measure the level of social cohesion in neighbourhoods:

- Individuals with SMI residing in socially fragmented neighbourhoods will have an elevated risk of unnatural-cause mortality.
- Individuals with SMI will have lower risk of mortality if residing in neighbourhoods with higher proportions of the following social environment indicators:
 - Racialised minority residents
 - Places of worship

Fig. 2.6.3 Conceptual model based on the CDSH Social Determinants of Health framework and Ecosocial Theory



¹Intermediary - material and socioenvironmental factors measured at the area level: deprivation, population density, neighbourhood walkability, green spaces, retail outlets, social fragmentation, ethnic density, places of worship

²Covariates - intermediary sociodemographic factors measured at the individual level: includes age, sex, ethnicity and marital status

³Covariates - intermediary health / behavioural factors: substance misuse and SMI diagnosis

Chapter 3: Study 1 - Systematic review

In this section, I will detail the method, findings and conclusions of the systematic review. The systematic review is currently under review with the Schizophrenia Research journal for publication:

Laporte, D., Chilman, N., Morgan, C., Schofield, P., Wykes, T., Das-Munshi, J. (Manuscript submitted for publication). The association between area-level factors and mortality in severe mental illnesses: A systematic review. Schizophrenia Research

Please refer to [Appendix 1](#) for draft manuscript.

The systematic review aimed to evaluate the existing evidence on the relationship between social and built area-level factors and mortality risk in the population with SMI. The aim was to identify area-level factors that may affect the risk of premature mortality in people diagnosed with SMI aged 15 and older. To my knowledge, this is the first review to focus on the association between environmental factors at the area-level, and mortality in SMI.

3.1 Method

Search strategy and inclusion criteria

Titles and abstracts in the following databases from their earliest date, including Embase (1947), MEDLINE (1946), PsycINFO (1806), Social Policy and Practice (1890), and Web of Science Core Collection (1900). Searches were conducted in May 2020 and repeated in December 2021. To align with the current guidelines on updating reviews (Cumpston & Chandler, 2022) and to account for any potentially overlooked studies in previous searches, additional search terms were incorporated when the searches were updated in June 2023 (see [Figure 3.2.1](#) for PRISMA flow chart and [Appendix 2](#) for search terms). Grey literature was searched using the OpenGrey database (<http://www.opengrey.eu/>). No time or language restrictions were imposed. The search terms were developed through prior literature searches and in consultation with the King's College London library service. The search strategy was developed to achieve a balance between sensitivity and specificity. The objective was to encompass a wide scope of relevant studies while minimizing the inclusion of irrelevant studies.

Studies were included if they:

- a) reported results on the relationship between area-level factors (e.g. area deprivation, urbanicity, ethnic density, social fragmentation and other features of the urban built and social environment) and mortality outcomes .
- b) included participants aged 15 and older

- c) included participants with a diagnosis of SMI (defined here as schizophreniform disorders, non-organic psychotic disorders and bipolar disorder)
- d) used case-control, cross-sectional, prospective or retrospective cohort designs and (e) were available in full-text.

I excluded studies that were reviews, editorials, research protocols and letters and ecological studies.

Authors of included studies were contacted to identify additional studies. The reference lists of all included studies were hand-searched by me for further articles that could be eligible for inclusion. After removing duplicates, the papers were screened and a random sample (17%) were reviewed by another PhD student (initials: NC, see [Acknowledgements](#) section).

Agreement was 100% between the two raters.

The search terms used for SMI were: 'schizophrenia,' OR 'psychoses,' OR 'psychosis,' OR 'bipolar disorder', OR 'severe mental illne*', OR 'serious mental disorde*', ' OR 'schiz*.' These SMI terms were paired with search terms for mortality, (e.g. 'mortality,' OR 'all cause mortality,' OR 'mortality risk,' OR 'premature mortality,' OR 'death') and area-level factors measuring aspects of the built environment (e.g., 'area-level deprivation,' OR 'urbanicity,' OR 'green spaces,' 'pollution,' OR 'population density') or the social environment (e.g., 'ethnic density,' OR 'social fragmentation,' OR 'social cohesion,' OR 'social networks,' OR 'social capital'). 'Built environment', 'natural environment', 'social environment', 'food environment' and 'environment' were included as search terms to identify all potential environmental factors that have been measured at the area-level, across both the social and built environment spectrum. These terms were utilized as a broader search term to capture studies that might have employed area-level indicators not covered by the more specific search terms. (see [Appendix 2](#) for the full electronic search strategy).

Data extraction and quality assessment

I extracted data from eligible studies according to the following fields: study design, country, sample size and characteristics (age, ethnicity, mental health diagnoses), follow-up period, mortality outcomes, area-level exposures, study measures, statistical analyses, covariates/ confounders, and findings. Authors were contacted for information that could not be found in the articles. Results from a single dataset presented in more than one published paper were considered to be from the same study.

The heterogeneity of measures used to assess area-level exposures, omission of effect sizes for some area-level variables and the differences in confounders adjusted across different studies, meant that a meta-analysis was not feasible, hence a narrative synthesis and tabulated presentations of the results was conducted. DL and NC independently conducted a risk of bias assessment using the Newcastle Ottawa Scale (NOS) (Wells et al., 2012). Agreement between the reviewers was 80%. The remaining proportion of disagreements were discussed and agreed upon with a third reviewer (initials: JD - see [Acknowledgements](#) section).

The protocol for this narrative review and was registered to the PROSPERO website (registration number: CRD42019155447) and follows the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (see [Appendix 3](#)).

3.2 Results

[Figure 3.2.1](#) displays the PRISMA flow diagram with reasons for exclusion. A total of eight studies were initially identified, however two of them utilized the same dataset. Therefore, the results from these two studies were combined, resulting in a total of seven studies included in the review. Table 3.2.1 provides an overview of characteristics of included studies. All included studies were cohort studies. Just over a quarter of studies reported geographical measures relating to the areas under investigation; however, these largely related to population density, as a measure for urbanicity, only. The follow-up period for the cohort studies ranged between 3 years and 15 years. SMI sample sizes ranged from 307 to 46,136 participants. Two studies recruited cohorts from clinical populations only. Four studies were conducted in the UK while three studies were conducted in China Ethiopia and Spain respectively. Lastly, none of the studies included a measure of the built environment (e.g. green spaces, food take-away outlets).

Fig. 3.2.1 PRISMA flow diagram

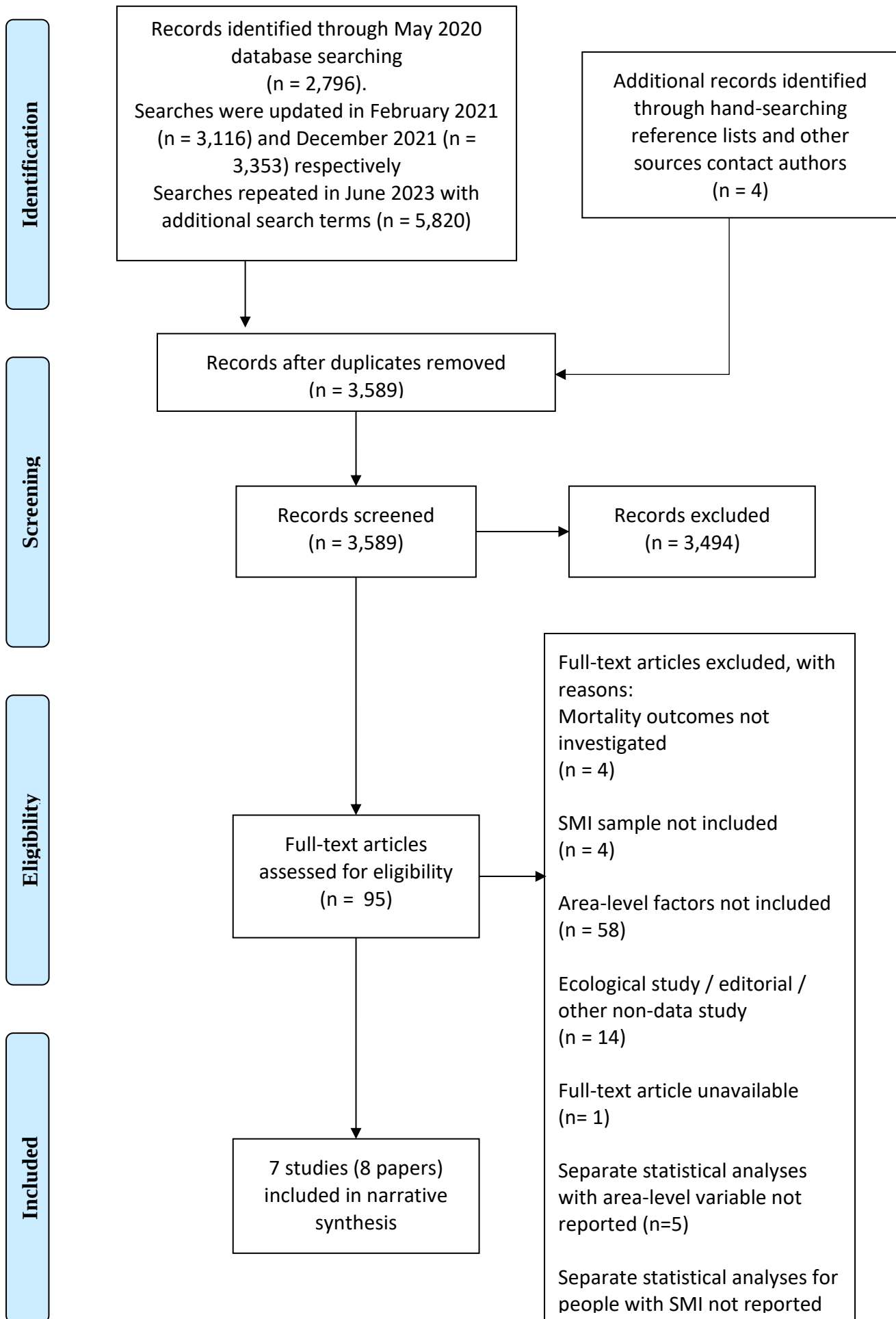


Table 3.2.1 Demographic overview of included studies

Study characteristics	No. of studies (n = 7)	%
Country		
UK	4	57.1
China	1	14.3
Ethiopia	1	14.3
Spain	1	14.3
Population		
Clinical	2	28.6
Population-based	5	71.4
Sample age		
≥15	4	57.1
≥18	3	42.9
SMI		
Bipolar disorder and schizophreniform disorders	5	71.4
Schizophreniform disorders only	2	28.6
Area-level exposures		
Area-level deprivation	4	57.1
Rural / urbanised areas	3	42.9
Population density (urbanicity)	1	14.3
Ethnic density	1	14.3
Social fragmentation	1	14.3
Geographical area measure		
Not specified	5	71.4
Census derived LSOA and MSOA (average 1,500 and 7,200 residents per area respectively)	2	28.6
Mortality outcome		
All-cause mortality	5	71.4
Unnatural mortality, including suicide	2	28.6
Natural mortality	1	14.3
Follow-up period		
3 years	1	14.3
4 years	1	14.3
5 years	1	14.3
7 years	1	14.3
>10 years	2	28.6
Individual-level covariates		
Age	6	85.7
Sex	5	71.4
Marital status	4	57.4
Psychiatric diagnosis	2	28.6
Ethnicity	2	28.6
Education/ employment status	3	42.9
Substance / alcohol misuse	2	28.6
Calendar period	1	14.3
Physical health comorbidity	1	14.3
Smoking status	1	14.3
Other	5	71.4

Abbreviations: MSOA = Middle Super Output Area, LSOA = Lower Super Output Area, SMI = Severe Mental Illness

3.2.1. Effect of area-level exposures on mortality outcomes

An overview of the findings from the included studies is presented in [table 3.2.2](#) and [table 3.2.3](#).

3.2.1.a Urban-rural factors and all-cause mortality

Four studies investigated the influence of urbanicity on the risk of all-cause mortality; one study¹ used a measure of population density, with higher population density taken to indicate more urbanised areas. Two studies^{5,7} mentioned the use of rural-urban classification variables and one study³ used the ratio of non-agricultural population to total population (%). However, no further information relating to area-level characteristics were reported on how the rural-urban variables were created and defined. Two studies^{1,5} were conducted in high income countries and these investigations found no association between urban areas and mortality in SMI. One Chinese study³ also found no statistically significant association between urbanicity and mortality. Whereas an Ethiopian study⁷ reported that residency in urban areas was associated with a higher mortality risk in people with SMI, investigators of three other studies, all from high income settings, did not find an association between urbanicity and excess mortality in SMI.

3.2.1.b Deprivation and all-cause mortality

Five studies^{1,2,4-6} investigated the association between area-level deprivation and mortality in SMI - all investigations were conducted in high income countries. Most studies^{1,2,4,6} included measures of relative deprivation that have been generated from individual-level variables, these include the English Index of Multiple Deprivation (IMD)^{1,2}, the Carstairs Index⁶ and the Scottish IMD⁴. These measures of deprivation relate to how people live and are typically derived from census variables (e.g. housing facilities, health, employment, income) which are combined to generate a score that indicates the overall level of deprivation individuals experience living in an area.

Three studies^{4,6,5} reported an association between increasing levels of deprivation and increases in mortality outcomes. One UK study⁴ found higher proportions of deaths in the SMI cohort compared with the general Scottish population who lived in the most deprived areas. One Spanish study⁵ reported a higher risk for all-cause mortality risk in participants with SMI living in deprived urban areas compared with those with similar diagnoses who resided in non-deprived urban areas. However, two studies^{1,2} conducted primarily in deprived geographical areas in south-east London found no association between mortality outcomes and area-level deprivation.

3.2.1.c Deprivation and cause-specific mortality

Two UK-based studies^{4,6} reported associations between cause-specific mortality in areas with both lower and higher levels of deprivation. One study⁴ reported lowered proportions of cancer- and alcohol-related deaths among people with SMI living in the most deprived areas compared with

both the local Glaswegian and wider Scottish populations without SMI living in similarly deprived areas. The second study⁶ found lowered suicide-related mortality among people with SMI living in the most deprived areas compared with people with SMI living in the least deprived areas. They also reported higher risk of suicide mortality in the most deprived areas among people with SMI compared with the control group living in similarly deprived areas⁶.

3.2.1.d Other area-level factors and all-cause mortality

One UK study¹ investigated the association between mortality and two area-level factors: (1) social fragmentation (a measure of social cohesion within communities) and (2) ethnic density (proportion of the population within a geographic area in racially minoritized groups). The social fragmentation measure was derived from four UK Census variables: (1) numbers of privately rented households, (2) single-person households, (3) unmarried individuals or individuals not in cohabiting relationships and (4) mobility in the previous year.

The study¹ reported elevated levels of mortality outcomes among people with SMI compared with the general population although they found no association between area-level social fragmentation and mortality outcomes among people with SMI living in south-east London. However, the same study¹ found that residency in areas with higher ethnic density was associated with a lowered risk of all-cause and natural-cause mortality among racially minoritized groups with SMI compared with their White counterparts living in the same areas.

Table 3.2.2 Longitudinal studies included in the review

No.	Author(s), Year, Country	Sample, Follow up period	Area-level exposure/s	Mortality outcome	Statistical analysis	Individual-level covariates	Findings
1	Das-Munshi et al., 2019 and Das-Munshi et al., 2017 England	Sample age: ≥15 Clinical population N = 18,201 (diagnosed with schizophrenia-spectrum disorders or bipolar disorders) FU: 7 years	2019 study: <i>Deprivation</i> Assessed using IMD <i>Social fragmentation</i> Assessed using Congdon Index <i>Urbanicity</i> Assessed using persons per hectare of land <i>Ethnic density</i> Percentage of the total population accounted for by each racialised minority group resident in the area at the time of the 2011 Census 2017 study: <i>Deprivation</i> Assessed using IMD	All-cause	2019 study: SMR Poisson regression 2017 study: Cox regression	Age, sex, ethnicity, diagnosis (ICD-10), marital status, substance use disorders	2019 study: Lowered all-cause mortality rate ratios for racially minoritized participants with SMI living in areas of higher ethnic density compared to their White British counterparts after adjusting for other covariates (aRR 0.52, 95% CI 0.38 - 0.71, p <.0001). No associations reported for other area-level exposures. 2017 study No association reported between area-level deprivation and mortality in this cohort (aHR = 0.98, 95% CI = 0.85 - 1.14, p =.080).
2	Hayes et al., 2012 England	Sample age: 15 - 94 Clinical population N = 6,880 (diagnosed with schizophreniform disorders or bipolar disorder) FU: 4 years	<i>Deprivation</i> Assessed using IMD	All-cause	Cox regression	Age, sex, ethnicity, diagnosis (ICD-10), marital status, no. of face-to-face mental health contacts Problem drinking / drug taking, problematic social relationships, employment, non-accidental self-injury, physical illness or disability, depressed mood, daily life functioning, sub-optimal living conditions assessed by HoNOS	No significant associations were observed in the hazard ratios between the deprivation tertiles and mortality in the SMI cohort.

No.	Author(s), Year, Country	Sample, Follow up period	Area-level exposure/s	Mortality outcome	Statistical analysis	Individual-level covariates	Findings
3	Luo et al., 2021 China	Sample age: ≥ 18 Population-based cohort N = 2,071 (diagnosed with schizophrenia) N = 1,909,205 (controls) FU: 3 years	<i>Urbanicity</i> Assessed using the ratio of non-agricultural population to total population (%)	All-cause	Cox regression	Age, sex, marital status, residence, household size, education, household income per capita, employment status	No significant association indicated between increasing urbanicity and all-cause mortality (aHR, 0.63, 95% CI 0.25–1.58; $p > .05$)
4	Martin et al., 2014 Scotland	Sample age: 18 - 65 Population-based cohort N = 230 (deaths among those diagnosed with bipolar disorder or schizophrenia) N = 8,094 (deaths in local Glaswegian population) N = 24,590 (deaths in wider Scottish population) FU: 5 years	<i>Deprivation</i> Assessed using SIMD	All-cause Natural-cause Unnatural-cause	Descriptive statistics Chi square	N/A	Elevated all-cause mortality reported among people with SMI living in the most deprived quintiles relative to the general Scottish population (46.1% vs 31.9%, $p < .001$). Conversely, lower proportion of deaths were observed in the SMI cohort compared to the local Glaswegian population living in the most deprived areas (46.1% vs 66.3%, $p < .001$). Elevated drug-related deaths observed in the SMI cohort living in the most deprived areas compared to the local Glaswegian (12.3% vs. 5.9%, $p = < 0.001$) and wider Scottish population (12.3% vs. 5.1%, $p = < 0.001$). Differences observed in suicide-related deaths between the SMI cohort and (1) the local Glaswegian population (12.3% vs 6.9%, $p = .054$) and (2) the wider Scottish population (12.33% vs 6.9%, $p = .05$) living in the most deprived quintiles were significant. Lower cancer- and alcohol-related deaths observed in the SMI cohort compared to the local Glaswegian (12.3% vs. 25.1%, $p = .013$) and the wider Scottish population (12.3% vs. 26.3%, $p = .008$) living in the most deprived quintiles.

No.	Author(s), Year, Country	Sample, Follow up period	Area-level exposure/s	Mortality outcome	Statistical analysis	Individual-level covariates	Findings
5	Moreno-Küstner et al., (2020) Spain	Sample age: ≥15 Population-based cohort N = 1,418 (diagnosed with schizophrenia-spectrum disorders or non-organic psychoses) FU: 13 years	<i>Area of residence:</i> - Non-deprived urban - Deprived urban - Rural No measure specified	All-cause	SMR YLL Cox regression	Age, sex, civil (marital) status, education, type of living arrangement, employment, psychiatric diagnosis (ICD-10)	Reported higher risk for all-cause mortality risk in participants with SMI living in deprived urban areas compared to those with similar diagnoses residing in non-deprived urban areas (aHR, 1.46, 95% CI 1.04–2.05; p = 0.028). No association for risk of all-cause mortality between participants with SMI living in rural areas and compared to those with similar diagnoses who lived in non-deprived urban areas (aHR, 0.74, 95% CI 0.45–1.24; p = 0.055).
6	Osborn et al., 2008 England	Sample age: ≥18 Population-based cohort N = 46,136 (diagnosed with bipolar disorder, schizophrenia or delusional disorder) N = 300,426 (control) FU: 15 years	<i>Deprivation</i> Assessed with Carstairs Index	Suicide	Cox regression PAR	Age, calendar period, antidepressant prescription in last 6 months and smoking	Elevated risk of suicide mortality observed in cohort diagnosed with SMI who lived in the most deprived areas compared to the control group living in similarly deprived areas (adjusted HR 5.30, 95% CI 2.77 - 10.15). Elevated risk of suicide mortality for the SMI cohort living in the least deprived quintiles compared to the control group living in similarly deprived quintiles (aHR 10.52, 95% CI 4.25 - 26.05). Lowered risk of suicide mortality for people with SMI living in the most deprived quintile compared to people with similar SMI diagnoses living in the least deprived quintiles (aHR 0.54, 95% CI 0.30 - 0.99)
7	Teferra et al., 2011 Ethiopia	Sample age: ≥15 Population-based cohort N = 307 (diagnosed with schizophrenia) FU: 5 years	<i>Rural and urban areas</i> No measure specified	All-cause	Cox regression Years of life lost	Age, sex, marital status, education, age of illness onset, duration of illness, speed of onset of mental illness, schizophrenia diagnosis (ICD-10, CIDI and SCAN), medication	Reported lowered risk for all-cause mortality in participants living in rural areas compared to those who resided in urban areas (aHR, 0.34, 95% CI 0.14 - 0.80; p = 0.014).

Abbreviations: aHR = Adjusted Hazard Ratio, aRR = Adjusted rate ratio, aHR = Adjusted hazard ratio, CHD = Coronary Heart Disease, CVD = cardiovascular mortality, CIDI = Composite International Diagnostic Interview, FU = Follow up period, HoNOS = Health of the Nation Outcome Scales, HR = Hazard ratio, ICD = International Classification of Diseases, IMD = Index of Multiple Deprivation, , PAR = Population Attributable Risk, SCAN = Schedules for Clinical Assessment in Neuropsychiatry, SIMD = Scottish Index of Multiple Deprivation, SMI = Severe mental illness, SMR = Standardised mortality ratio, YLL = potential years of life lost

Table 3.2.3 Direction of association between area-level exposures and all-cause and cause-specific mortality outcomes

All-cause mortality outcomes				
Author(s), Year	Area-level exposure			
	Increasing deprivation	Increasing ethnic density	Increasing urbanicity (ranging from more rural to more urban areas)	Increasing social fragmentation
Moreno-Küstner et al., 2020	X	-	X	-
Martin et al., 2014	X ²	-	-	-
Das-Munshi et al., 2019; 2017	X	X	X	X
Teferra et al., 2011	-	-	X	-
Hayes et al., 2012	X	-	-	-
Luo et al 2021			X	
Cause-specific mortality outcomes				
	Mortality outcome	Area-level exposure		
		Increasing deprivation		
Osborn et al., 2008	Suicide	X ⁴	X ⁵	
	Suicide	X		
Martin et al., 2014	Drug-related	X		
	Cancer	X		
	Alcohol-related	X		

Key:

	No association between area-level exposure and mortality outcome
	Association between area-level exposure and an increase in mortality outcome
	Association between area-level exposure and a decrease in mortality outcome

² Compared to the general Scottish population living in similarly deprived areas

³ Compared to the local Glaswegian population living in similarly deprived areas

⁴ Compared to the control group without SMI diagnoses living in similarly deprived areas

⁵ Compared to group with SMI living in the least deprived areas

3.2.2 Risk of bias

The NOS ratings ranged for the cohort studies ranged between 6 and 8 (see [Table 3.2.4](#)). Despite these relatively high NOS quality ratings many studies did not provide detailed information on the geographical areas included (e.g. population density of each geographical area) or operationalise terms such as “rural” or “urban”. A quarter of the studies used official Census data to define geographical areas. Most analyses adjusted for age and sex and all cohort studies implemented a follow-up period of >1 year bar one study⁴. One study⁶ reported wide confidence intervals for the association between area-level factors and mortality. This may be due to a limited number of mortality events within the samples which may make it more difficult to estimate the true effect of the area-level variable. One study⁷ used verbal autopsy with close family members of the deceased to identify links with the cause of death. However, this method was not supplemented with official mortality records and relied on the relatives’ recall which may be affected by recall bias.

3.2.3 Geographical measures

Around three quarters of included studies did not report or reported incomplete information about the geographical measurements of the areas included in their investigation. Two studies^{1, 2} provided geographical area measurements using the UK census derived Lower and Middle Super Output Areas (LSOA and MSOA).

3.2.4 Individual-level covariates

Most studies^{1-4, 6-8} controlled for participants’ age and sex within subsequent statistical analyses and a quarter of the studies^{1,2} included ethnicity variables. No investigation provided comprehensive statistical models adjusting for all significant covariates.

3.2.5 Mortality outcomes

Most studies^{1-5, 7} investigated all-cause mortality outcomes. Most studies¹⁻⁶ derived the mortality variable from official datasets bar one study⁷ which used a verbal autopsy method. Mortality in the SMI cohorts ranged from 0.3 %⁶ to 12.4%⁷.

Table 3.2.4 Risk of bias for cohort studies - Newcastle-Ottawa Scale

	Selection (maximum 4)				Comparability of cohorts (maximum 2)	Outcome (maximum 3)			
Author(s), Year	Representativeness of exposed cohort (0-1)	Selection of the non-exposed cohort (0-1)	Ascertainment of area-level exposure using standardised measure or other measurement instrument (0-1)	Outcome not present at start of study (0-1)	Controls for age and sex (0-1) Controls for any other additional factor (0-1)	Assessment of outcome through report clinical records or other official databases (0-1)	Follow-up long enough for outcome to occur (>1 year) (0-1)	Follow-up complete, or unlikely to introduce bias (<20% lost or attrition described and accounted for in analysis) (0-1)	Quality rating (Max = 9)
Hayes et al., 2012	*	*	*	-	**	*	*	*	8
Das-Munshi et al., 2019; 2017	*	*	*	-	**	*	*	*	8
Luo et al., 2021	*	*	*	-	**	*	*	-	7
Osborn et al., 2008	*	*	*	-	**	*	*	*	8
Moreno-Küstner et al., (2020)	*	*	-	-	**	*	*	*	7
Teferra et al., 2011	*	*	-	*	**	-	*	*	7
Martin et al., 2014	*	*	*	-	-	*	*	*	6

3.3 Discussion

This review is, to my knowledge, the first to provide a synthesis of the current evidence base in relation to area-level factors and mortality in SMI using systematic inclusion criteria across many databases (including a grey literature database). The review revealed limited studies investigating this association which made it difficult to draw firm conclusions. Of the studies identified, most were conducted in the UK, with other studies conducted in Spain and Ethiopia, therefore the findings may be less generalisable to populations outside of these settings.

I identified only 7 studies (8 papers) exploring the association between mortality and area level factors which highlights the dearth of literature on this topic. Our findings suggest research to date is inconclusive on the nature and magnitude, if any, of associations between area-level factors and risk of mortality in people with SMI. For those studies that adjusted for an urbanicity variable in their statistical models, no consistent associations were reported between residence in either rural / urban areas and mortality in SMI. There was no evidence of an association between mortality and other area-level factors which included social fragmentation. However, one study suggested a protective effect of area-level ethnic density and mortality in an ethnically diverse SMI cohort (Das-Munshi et al., 2019). None of the included studies investigated built environment attributes such as green and blue spaces and pollution.

Three studies reported an association between increasing area-level deprivation and an increased risk of mortality in SMI. The two UK-based studies which found an association between deprivation and suicide-related mortality may suggest that areas of high deprivation confer additional risk factors for people with SMI in the form of socio-economic disadvantages (e.g. unemployment, poor housing conditions, limited access to resources) that may exacerbate this risk. This finding is consistent with other investigations conducted using samples from the general population (Office for National Statistics, 2019).

Interestingly, additional analyses conducted by Osborn and colleagues (2008) using data from the UK, revealed a lower risk of suicide mortality among people with SMI living in areas of high deprivation compared with those with the same diagnoses living in the least deprived areas. The difficulties in interpreting this finding arise from the lack of individual level information provided by the study. For example, this study did not control for individual-level socio-economic status and therefore it is difficult to determine the extent to which the study findings are linked to contextual or individual level factors. However, these

findings may indicate a non-linear association between deprivation and suicide mortality in SMI which may warrant further investigation.

Two studies reported no association between all-cause mortality and deprivation. These findings may reflect underlying contextual factors related to the areas sampled within the investigations. For example, two studies were conducted almost primarily in areas with high levels of deprivation relative to other areas in England (Das-Munshi et al., 2019; Hayes et al., 2012). Therefore, it may have been more difficult to detect differences in mortality by area-level deprivation compared with other studies which found associations between deprivation and mortality outcomes that included a more diverse range of areas with both higher and lower levels of deprivation (Martin et al., 2014; Osborn, Levy, Nazareth, & King, 2008). Given the mixed findings, it is important to bear in mind the variation in measures used to derive the deprivation variables. These measures included the English and Scottish Indexes of Multiple Deprivation (IMD) and the Carstairs index which measure deprivation using different domains and are weighted differently. Hence, comparison of findings between studies using different measures may increase the difficulty of making comparisons.

One study found a positive association between ethnic density and mortality in SMI in England. The study reported that racially minoritized participants with SMI living in areas with higher proportions of other resident racially minoritized groups had lowered risk of mortality compared with White British participants with similar diagnoses. This finding is similar to those found in previous investigations looking at the link between ethnic density and mental health (Bécares, Dewey, & Das-Munshi, 2018). Racially minoritized groups with SMI may accrue benefits by living in areas with higher ethnic density potentially through social mechanisms (e.g. increased levels of social support and being less likely to be socially isolated) that may be associated with a reduced risk of mortality (Das-Munshi et al., 2019). However, this finding has not been replicated and therefore it would be beneficial to investigate this in more depth.

Although these studies lay the groundwork for more detailed follow-up investigations, there are several limitations which should be taken into consideration. Firstly, the lack of consistency in findings may reflect differences in study methodologies including the definition and measurement of environmental exposure variables (e.g. “urban” and “rural” areas). The varied geographical boundaries / units used within the studies prevents comparative analysis between studies and the geographical area units chosen may have had an impact on summary values (e.g. population density, mortality rates) which vary according

to the shape and scale of the geographical unit (Arcaya et al., 2016). This is known as the Modifiable Areal Unit Problem (MAUP). Although the use of census-defined geographical areas is a favourable method for reducing the risk of MAUP, a potential difficulty is that these areas may not accurately represent the participants' experiences of their neighbourhoods. Participants' views of their neighbourhood (including the boundaries) may differ from the official measures and therefore crucial information about their travel and access to neighbourhood features that may be associated with their health may be missed due to using only census-defined geographical boundaries.

Secondly, few studies accounted for the clustered nature of the data using appropriate approaches such as multilevel modelling (MLM) methods. In traditional regression analyses, it is assumed that all observational data are independent of each other. Many of the studies did not account for clustering of individuals within neighbourhoods using appropriate frameworks such as multilevel modelling or other approaches. MLM has an advantage over traditional regression models in that the total variance can be partitioned between variances observed both between neighbourhoods and within neighbourhoods which can lead to more accurate estimation of these effects and may enable better understanding of the geographical contexts which affect health outcomes (Merlo, Chaix, Yang, Lynch, & Råstam, 2005). Hence, future research could benefit from inclusion of these statistical methods within studies investigating these associations.

Some studies tended to include area-level deprivation variables as the only area-level exposure variable - these deprivation measures are a composite measure of aggregated properties of individuals (e.g. unemployment, income, education, and training) from censuses and other population surveys which means that area-level factors that appear to be relevant may be an artefact of area indices acting as a proxy for individual-level factors not included in the statistical analyses (e.g. individual-level socioeconomic status vs area-level deprivation). Moreover, given the aggregated properties (i.e. individual-level factors) of these measures, this may not be the best indicator of the quantity and quality of other physical/built features within neighbourhoods (e.g. green spaces, access to transport) that may influence mortality in SMI.

Another limitation is that over two thirds of included studies investigated all-cause mortality as the only mortality outcome. Recent reviews of research conducted with the general population have found weak to moderate associations between various area-level factors and cause-specific mortality outcomes (Gascon et al., 2016; Hoek et al., 2013) which enables researchers to develop more targeted hypotheses about the mechanisms underlying these

associations. Therefore, future research conducted with SMI cohorts could benefit from inclusion of similar investigations into associations between cause-specific mortality outcomes and area-level factors.

The majority of included studies were conducted in high income settings and did not support an association between residing in increasingly urbanised locations and higher mortality risks in people with SMI. One Ethiopian study provided evidence of an association between residence in urban areas and a higher risk of all-cause mortality within an SMI cohort (Teferra et al., 2011). Future investigations could benefit from further exploration of the role of area-level factors in mortality among people with SMI, which may also differ according to whether the setting is a high- or low- or middle-income country.

Strengths and limitations of the review

To my knowledge, this is the first review to investigate the relationship between area-level factors and the risk of mortality in SMI. While previous reviews have primarily focused on examining geographic disparities in mortality among individuals with SMI (Patel et al., 2006) and the widening mortality gap (Hjorthøj et al., 2017; Hayes et al., 2017), the specific aim of this review was to explore the impact of environmental factors at the area level on mortality risk in this population. The findings of this narrative review highlight a significant research gap in this particular area, which future studies should address. Due to the small number of studies identified and heterogeneity of the included studies, which include differing approaches to the measurement of area-level exposures and adjustment of confounders, conducting a meta-analysis was not feasible. Furthermore, the review did not provide a comparison of the risk of mortality between affective and non-affective disorders since the included studies did not report separate statistical analyses for these subgroups. I adhered to the criteria outlined in the risk of bias measure (Newcastle-Ottawa Scale), which stipulated that cohort studies should have a minimum follow-up period of 1 year for a 'high' quality rating. I recognize that the latency period for mortality outcomes could extend beyond this specified criterion. However, all studies in this review had a follow up period exceeding one year (ranging from 3-15 years) and most studies (with the exception of one study) utilised methods (e.g. deriving rate of death over time) which are insensitive to the period of follow up, and assume rate is constant over time, or take into account non-proportional hazards over time. A further strength is that we developed search terms in this review from existing literature, with expert input from a librarian. The search terms were kept broad to enable identification of potentially suitable studies.

3.4 Conclusion

In conclusion, across all studies the association between deprivation and mortality in SMI was most consistently demonstrated when compared with other investigated associations and is also consistent with research conducted within the general population. One study suggested a link between urbanicity and mortality in SMI in a low to middle income setting - other studies conducted in high income countries have not found similar associations with urbanicity variables. Another study suggested a protective effect of area-level ethnic density on mortality in SMI within high income settings which covered an urbanised area with ethnically diverse populations. Lastly, none of the included studies included built/physical environment variables (e.g. green spaces, pollution) and therefore the association between these factors and mortality could not be ascertained in this review. The extent to which the included studies offer hypotheses regarding potential factors and mechanisms driving previously reported geographical variations in the risk of mortality in SMI (Hjorthøj et al., 2017) are limited due to methodological limitations.

Currently, a large proportion of interventions tend to focus on individual-level factors as informed by the existing evidence base that have linked these factors to premature mortality in SMI. However, despite the implementation of these interventions there remains a significant gap in life expectancy between the general population and the SMI population (Hjorthøj et al., 2017) which indicates that solely targeting individual-level factors may not be the most effective way to reduce excess mortality in this population. In future, research in this area would benefit from more targeted analyses of area-level factors (particularly physical environment factors) and cause-specific mortality outcomes. The findings could inform interventions with SMI in terms of multilevel frameworks that take into account both individual- and area-level factors. Also, future investigations could benefit from investigating these associations in low- and middle-income countries to enable future comparative analyses between different countries and contexts. Premature mortality remains a pervasive health inequality in SMI and given more recent reports of an increasing gap in life expectancy, it is of the utmost importance to address this inequality in order to improve the quality of life for this population.

Chapter 4: Quantitative methods

4.1 Introduction

In the previous chapter, a review of the literature highlighted the absence of empirical evidence investigating links between aspects of the social and built environment relating to mortality in severe mental illness (SMI). This evidence gap is notable, considering the increasing recognition within public health to consider place-based approaches to address health inequalities in SMI (O'Connor et al., 2023). The integrated frameworks in Chapter 2 suggest that an understanding of these processes could shed light on approaches to understand and tackle premature mortality in SMI. Therefore, I set out to address this gap in knowledge through a series of empirical studies using large scale and linked quantitative data from a well-defined catchment of a secondary mental health Trust in southeast London. The methods underpinning this are explained in this chapter with results chapters (5-7).

This methods chapter will cover the methods for the ecological and geospatial analyses in chapter 5 and the multilevel modelling analyses in chapters 6 and 7. The studies presented in these chapters share some characteristics as they come from the same local catchment area with similar data sources. However, there were key differences in terms of the analyses, cohort numbers, exposure measures and statistical analyses used which will be summarised in the table 4.1 below.

Table 4.1 Characteristics of studies 2 - 4

Chapter	Chapter 5	Chapter 6	Chapter 7
Study	Study 2	Study 3	Study 4
Study design	Ecological	Cohort	Cohort
Sample			
SLaM NHS deidentified clinical dataset	✓	✓	✓
Sample size (n)	22,689	22,689	22,564*
Outcome measure	SMR [†]	Individual-level mortality	Individual-level mortality
Exposure measures			
Proportion of urban environment features per MSOA [‡]	✓	✓	✗
Distance to nearest urban environment feature from residential post code	✗	✗	✓
Statistical analyses			
OLS regression	✓	✗	✗
Geospatial analyses	✓	✗	✗
Multilevel modelling	✗	✓	✓
Competing risks regression	✗	✓	✓

*125 cohort members were missing residential location information and therefore were not included in the analyses for study 4 only; [†]SMR = Age and sex standardised mortality ratios (calculated at the middle super output area level); [‡]MSOA = middle super output area

The next section will provide more information on the methods used in across these studies.

4.2 Study design, participants and setting

All studies listed above used de-identified clinical health record data from the South London and Maudsley (SLaM) NHS Foundation Trust. SLaM is one of the largest mental health providers in Europe, offering comprehensive secondary mental healthcare to approximately 1.3 million residents across four ethnically diverse boroughs in southeast London (Southwark, Croydon, Lewisham, and Lambeth). Their service provision includes all aspects of secondary mental healthcare for people of all ages, ranging from community and inpatient care to drug and alcohol and forensic services. Since 2006, SLaM has implemented electronic clinical records across all its services, and in 2008, the [Clinical Record Interactive Search \(CRIS\) system](#) was developed with the support of the NIHR Specialist Biomedical Research Centre for Mental Health. The CRIS system allows for efficient searching and retrieval of anonymized clinical records by researchers, with over 400,000 cases currently represented in the system (Perera et al., 2016). A detailed description of the protocol for CRIS is available in open-access publications (Stewart et al., 2009, Perera et al 2016).

SLaM clinical teams are mandated to provide mental disorder diagnoses for all service users (Stewart et al., 2009). These diagnoses are recorded in structured fields in the electronic health record. As a result of regular audits, the rates of completion for diagnostic fields are high (Stewart et al., 2009). For the purposes of this study, information from these fields were used to identify individuals with the following ICD-10 diagnostic categories for subsequent analyses: mania, and bipolar affective disorder (F30, F31) and schizophreniform disorders (F20– F29). Individuals with these SMI diagnoses were identified by searching the CRIS-structured fields, complemented by a Natural Language Processing (NLP) application created with Generalised Architecture for Text Engineering. This application extracts diagnostic statements from the free text fields of clinical case notes and other relevant clinical correspondence (Perera et al., 2016). A recent assessment of the performance of these NLP algorithms for clinical diagnoses revealed precision (positive predictive value) ranging from 0.97 to 1.00 across diagnoses at both annotation and patient levels (Das-Munshi et al., 2021).

Individuals were eligible for inclusion if they met the following criteria: (1) aged 15 and over at the time of diagnosis when they received a diagnosis of either schizophrenia spectrum

disorder (ICD-10 codes: F20-F29) or bipolar disorder (ICD-10 codes: F30 and F31) between 1st January 2007 and 31st December 2018 and (2) were recorded as living in either Croydon, Lambeth, Lewisham or Southwark at the time of their diagnosis. Individuals were excluded if they received a comorbid diagnosis of dementia before a diagnosis for schizophrenia spectrum disorder or bipolar disorder. This was done to ensure that only non-organic psychosis cases were included in the study. Individuals who were not resident in any of the four south London boroughs at the time of diagnosis, were also excluded from the sample.

4.3 Mortality outcome

The objective of this study was to investigate all-cause, natural- and unnatural-cause mortality outcomes among individuals with SMI during the study observation period of between 1st January 2007 and 31st December 2018. The identification of deaths within the sample involved accessing the UK Office of National Statistics (ONS) database which provided information on the deaths of patients who had received care from SLaM. This information from the ONS was then linked to their health records using unique patient identifiers. This linkage allowed us to obtain information about the cause and date of death according to ICD-10 for individuals who had died during the observation period. Deaths were classified as either from all causes (A00-R99; U00-Y89), unnatural causes (including deaths linked to suicide and external causes) (U509, V01-Y89) or natural causes (A00-Q99). Deaths categorized as ill-defined or unclassified (R00-R99) were included in the assessment of all-cause mortality but not included in the analysis using cause-specific mortality outcomes.

4.4 Measures

4.4.1 Exposure variables

4.4.1a Area-level deprivation

The 2015 Index of Multiple Deprivation (IMD) is England's official measure of relative deprivation for small regions (or neighbourhoods) (Department for Communities and Local Government, 2015a). It is an overall measure of multiple deprivation experienced by residents of a given neighbourhood, and it is derived for each Lower Super Output Area (LSOA), or neighbourhood, nationally. The mean population of an LSOA in England and Wales on 27th March 2011 was 1,614 with 95% of LSOAs having a population of between 1,157 and 2,354 (Office for National Statistics, 2012a). Each neighbourhood is ranked on its level of deprivation in comparison to other neighbourhoods. The IMD (2015) is based on 37 separate indicators that are organised across seven domains which are: employment, income, education, employment, health, crime barriers to housing and services and the

living environment. These indicators are integrated with the appropriate weights to construct the IMD.

The IMD has undergone multiple updates since its inception in 2004. The IMDs for 2004, 2007, and 2010 were based on the 2001 LSOA boundary codes. These codes were designed to include roughly equal numbers of private residential households and census populations and were derived from the 2001 Census data. In 2015, the fourth version of IMD was created to reflect changes in LSOA boundaries resulting from the 2011 Census. Changes in the LSOA boundaries were associated with one of the following reasons: (1) to enhance social homogeneity of the output area, (2) better align with local authority boundaries, or (3) accommodate substantial shifts in population size, such as when an LSOA's population fell below 1,000 people or 400 households (ONS, 2012b). Since the study midpoint observation period was in December 2012, relying on data collected in the 2001 census posed a risk of outdated information and may not accurately capture population characteristics in 2012. Furthermore, the data extraction from the CRIS database included 2011 MSOA codes for the residential locations of cohort members. As a result, it would present practical challenges to map the 2011 MSOA codes to the 2001 codes used by the 2010 IMD measure due to the changes in the MSOA geographical boundaries between these two time points. For example, if an MSOA was divided into three separate MSOAs in 2001 and later merged back into a single MSOA in 2011, it becomes challenging to determine which specific 2001 MSOA the cohort member resided in prior to the boundary changes. Therefore, the 2015 IMD was selected for this study because it used data collated from the 2011 Census. Data for the 2015 IMD was collated from the Ministry of Housing Communities & Local Government (2015).

For the purposes of the statistical analyses, the Lower Super Output Area (LSOA) IMD (2015) score was aggregated to the larger geographical area, the Middle Super Output Area (MSOA) using the suggested method from the IMD (2015) Research Report (Department for Communities and Local Government, 2015b). This approach was used since using LSOAs to specify the neighbourhoods included in the investigation resulted in some LSOAs being found to have no mortality outcomes recorded. Therefore, aggregating LSOA IMD (2015) scores to the MSOA level ensures compliance with the privacy agreement with SlaM NHS, which prohibits the disclosure of geographical areas with fewer than 10 deaths. The IMD scores were averaged for each MSOA by summing the population-weighted scores (see [Appendix 4](#) for worked example).

4.4.1.b Neighbourhood walkability

Neighbourhood walkability refers to the degree to which a neighbourhood encourages and facilitates active modes of transportation, particularly walking. This measure is typically comprised of the following environmental features: (1) land-use mix, (2) residential density and (3) street intersection density (Frank & Engelke, 2005a; Ribeiro & Hoffmann, 2018) (Hajna et al., 2015). The relationship of land use mix, residential density and street intersections was previously described in the literature review (see [Section 2.2.2](#)).

1. **Land use mix**, defined as the diversity of land uses (e.g. residential areas, commercial sites) within a neighbourhood. The 2018 National Land use Database was obtained from the Department of Levelling Up, Housing & Communities and used to derive the land use mix variable. The entropy index was used to quantify land use and is one of the more commonly used and accepted measures for describing land use mix (Bordoloi, Mote, Sarkar, & Mallikarjuna, 2013). The index measures the uniformity of land use in a neighbourhood and the calculation is expressed as:

$$\text{Entropy} = \sum_j P_j \times \frac{\ln(P_j)}{\ln(J)}$$

P_j = the proportion of total land area occupied by the j^{th} land-use type found in the neighbourhood under consideration

J = total number of land uses in the neighbourhood

The entropy is normalised using the natural logarithm of the number of land uses, its value ranges from 0 to 1, with 0 representing homogeneous land use and 1 indicating that the neighbourhood is evenly distributed across all land use types (Bordoloi et al., 2013).

2. **Residential density** refers to number of dwellings per square kilometre (or other geometric) of residential land area is referred to as residential (or housing) density (Adams et al., 2014). This variable was created using data from the 2011 Census via the NOMIS website and calculated for each MSOA. The calculation (Frank et al., 2010) for this variable is as follows:

$$\text{number of residential dwelling units} \div \text{residential land area}$$

3. **Street intersection density** defined as the number of junctions that connect 3 or more streets per area unit (Wang, Wen, & Xu, 2013). The street intersection density variable was created using the geographic software, ArcGIS Pro (version 2.8.7). The shapefile (for further explanation of shapefiles, see [Section 4.7](#) Geographical measures and coordinate systems) that contained the visual and geographic data of the streets located in and around the London area was downloaded from the Ordnance Survey website (Ordnance Survey, 2022b). The street shapefile was imported into ArcGIS Pro and superimposed on another existing shapefile representing the Middle Super Output Area (MSOA) (neighbourhoods) of interest. The original street shapefile contained visual and geographic data for a larger area that overlapped with the neighbourhoods under investigation. Therefore, the MSOA shapefile was used to prevent ArcGIS Pro from including street intersections located outside of the geographical boundaries of these neighbourhoods in the final calculations. Street intersection density was calculated for each MSOA using the suggested method from the Environmental Systems Research Institute (ESRI, 2012) and is as follows:

$$(\text{number of street intersection junctions per MSOA} \div \text{area (hectares) of the MSOA}) \times 100.$$

The neighbourhood walkability score was used in the studies reported in [Chapters 5](#) and [6](#). To create the neighbourhood walkability score, the values for land use mix, residential density, and street intersection density were normalized using z scores. A z score of '1' for land use mix indicates that the original value was one standard deviation above the average value for that specific variable. The z scores of each of these three measures were summed together to create the composite walkability score (Cerin et al., 2022).

4.4.1.c Green spaces

Two measures of green spaces were derived for the purposes of this investigation.

4.4.1.c (i) Green space as an extent (total proportions) in a surrounding area:

For the empirical studies reported in [Chapters 5](#) and [6](#), green spaces, defined as the percentage of land classified as green spaces that are accessible to the public, was used to determine the extent of green space within the neighbourhoods of interest. Green spaces consisted of the following classifications: play spaces, public parks or gardens, allotments, churchyards and golf courses (Ordnance Survey, 2021). The shapefile that contained the

visual and geographic data of the green spaces was downloaded from the Ordnance Survey website (Ordnance Survey, 2022b). Similar to the processes undertaken to derive the street intersection density variable, the open green spaces shapefile was superimposed on the existing shapefile representing the MSOAs of interest to ensure calculations of open green spaces were restricted to the MSOAs of interest. The variable was calculated as the percentage of land (in hectares) within each MSOA that was classified as open green space, a method used by other authors investigating similar associations (Lachowycz & Jones, 2014; Mitchell, Astell-Burt, & Richardson, 2011).

4.4.1.c (ii) Green space assessed as straight-line distance to access point (i.e. “as crow flies”)

The study presented in [Chapter 7](#), used the nearest distance to green space access point in the statistical analyses. Secondly, to determine the distance to the nearest green spaces, a new variable was created using Ordnance Survey (2022b) green space access points coordinates data. Creating distance measures for green spaces and other urban environment indicators was challenging. Access to the recorded residential postcodes of cohort members at the time of diagnosis was restricted due to confidentiality agreements related to the CRIS dataset. To overcome this limitation, a separate dataset was created to establish a data linkage with the CRIS dataset, using the steps as outlined below:

First, I created a dataset using publicly available data. Using ArcGIS, the green spaces access points were overlaid on the existing shapefile representing the MSOAs of interest to ensure that access points were limited to the specific MSOAs of interest. A separate postcode directory file, which is publicly available through the Office for National Statistics (ONS) (2020), was used to map the geographic coordinates of all postcodes within the MSOAs of interest within the study catchment area; this amounted to just over 40,000 postcodes. Then, using the NEAR function within ArcGIS, the distance in metres to the nearest green space access point was calculated for each postcode listed in the ONS directory. Distance was computed using the “as-the-crow-flies” method – this method computes the shortest straight-line distance between a specified residential postcode and the point location of a neighbourhood feature. The resulting dataset containing information about the nearest green space access points and their corresponding postcodes, derived from publicly available data sources were then passed the CRIS Clinical Data Linkage Service (CDLS). The CDLS then linked this dataset with the postcodes of each cohort member in the CRIS dataset. The green space distance variable created represented the distance to the nearest green space access point to the recorded residential postcode at the time of the cohort

member's primary diagnosis. The final dataset with identifiable information such as patient postcodes were removed and was then passed back to me and forms the basis for analyses presented in [Chapter 7](#).

Using ArcGIS, the green spaces access points were overlaid on the existing shapefile representing the MSOAs of interest to ensure that access points were limited to the specific MSOAs of interest. A separate postcode directory file provided by the Office for National Statistics (2020) was used to map the geographic coordinates of all postcodes within the MSOAs of interest – within the study catchment area, this amounted to just over 40,000 postcodes. Then, using the NEAR function within ArcGIS, the distance in metres to the nearest green space access point was calculated for each postcode listed in the directory. Distance was computed using the “as-the-crow-flies” method – this method computes the shortest straight-line distance between a specified residential postcode and the point location of a neighbourhood feature. The resulting dataset containing information about the nearest green space access points and their corresponding postcodes were merged with the postcodes of each cohort member by the CRIS admin team. The distance to the nearest green space access point to the recorded residential postcode at the time of the cohort member's primary diagnosis was created as a variable for subsequent analyses.

4.4.1.d Population density

Population density was used as a measure of urbanicity. It was created from the 2011 Census data and was calculated as the number of people per hectare of land for each MSOA. The relationship of population density to urbanicity was previously described in the literature review (see [Section 2.2.3](#)). This measure was used in the studies reported in [Chapters 5](#) and [6](#).

4.4.1.e Ethnic density

Ethnic density was defined as the percentage of the residential population that identified as belonging to a racialised minority group. The variable was derived from the 2011 Census data and used as an indicator of the buffering effect of area-level ethnic density against detrimental social factors (e.g. discrimination) documented in prior literature (Bécares, Dewey, & Das-Munshi, 2018). Ethnic density was calculated for each MSOA. This measure was used in the studies reported in [Chapters 5](#) and [6](#).

4.4.1.f Social fragmentation

Social fragmentation is a measure indicating poor levels of community integration in the neighbourhoods of interest. In line with previous research (Congdon, 2012), social fragmentation was measured as a composite index that combined four indicators from the 2011 Census: the number of privately rented households, the number of single person households, the number of adults (over 16 years) unmarried, and the number of people who lived at a different address a year ago for each MSOA. To create the composite social fragmentation score for each MSOA, the scores for each indicator were normalized using z-scores and then summed together. This method mirrors the approach taken in a previous investigation (Das-Munshi et al., 2019) discussed in the literature review (see [Section 2.3.1](#)). This measure was used in the studies reported in [Chapters 5](#) and [6](#)

4.4.1.g Retail outlets and places of worship exposure variables

1. Supermarkets

Supermarkets were defined as large retail chains that commanded a significant portion of the UK grocery market at the mid-point of the study observation period (Burgoiné, Gallis, Penney, Monsivais, & Benjamin-Neelon, 2017). These included, Sainsbury's, Tesco, Morrisons, Asda, Waitrose, Aldi, and the Co-operative (Kantar Worldpanel, 2012). Supermarkets typically offer a sizeable range of fresh produce compared with other smaller retailers. Supermarkets were identified using the Ordnance Survey (2021) classification system. This variable was used as a proxy for access to healthy dietary options (Lamichhane et al., 2013).

2. Convenience stores

Convenience stores refer to a smaller retail format when compared with supermarkets. It is usually comprised of the following characteristics: typically less than 3,000 square feet in size, known for its convenient access for pedestrians and the local community, exempt from opening hours restrictions of the Sunday Trading Act (1994) and provision a smaller range of fresh vegetables, fruits and frozen produce (Foss, Royston, Atkinson, & Hawkes, 2019; Wilkins, Morris, Radley, & Griffiths, 2019). Convenience stores were identified using the Ordnance Survey (2021) classification system. This variable was used as a proxy for access to unhealthy dietary options (Foss et al., 2019).

3. Food takeaway outlets

Food takeaway outlets were classified as regionally or internationally recognised franchised restaurants that sell low-cost, quick-service food such as pizza, and fried chicken. It was used as a proxy for access to unhealthy dietary options (Lamichhane et al., 2013).

4. Off-licences

Off-licences refer to retail outlets that predominantly sell alcoholic beverages with limited or no fresh food produce (Companies House, 2022; Wilkins et al., 2019). Off-licences were identified using the Ordnance Survey (2021) classification system. This variable was used as a proxy for access to unhealthy dietary options (Foss et al., 2019).

5. Places of worship

Places of worship were defined places of worship refer to physical locations where people assemble to practice or profess their faith (Kinney & Winter, 2006) which includes (but is not limited to) churches, temples, and mosques. Places of worship were identified using the Ordnance Survey (2021) classification system. Places of worship were used as a proxy for area-level social cohesion.

Quality checks for retail outlets/ place of worship variables

These five variables were derived initially from searches of the online business directory, the Yellow Pages (Yell.com). Yell.com is a prominent online business directory in the UK – the website was created in 1996 and since then, they have recorded information on more than three million companies, including names, addresses and phone numbers (Yell.com, 2021). Yell.com compiles information about businesses from several sources which include submissions to their website from business owners and through other public sources of information such as government records and business registrations. Searches were performed in August 2020 and the search terms “supermarkets”, “grocers”, “fast food restaurants”, “off-licences” and “places of worship”, (as per Yell.com’s existing classification terms) were used to identify relevant businesses and religious buildings located in the neighbourhoods of interests on the Yell.com website. Searches were restricted to the catchment area for the study.

ParseHub, an open-source data extraction software, was used to extract the names and addresses (including post codes) from the Yell.com search page results into an excel spreadsheet. After checking for duplicates, the excel spreadsheet extractions were imported into Stata to merge the appropriate MSOA code and geographical coordinates (i.e. northings

and eastings) where each retail outlet and place of worship were located. Using the Office for National Statistics (ONS, 2020) postcode directory dataset, corresponding MSOA codes, northing and easting coordinates were merged into the datasets using Stata. To enhance the reliability of the data, checks were carried out on the businesses identified in the initial Yell.com searches. The primary objective was to confirm whether these businesses were operational during the study observation period. The first round of checks involved cross-checking / comparing against the official government registration directory known as Companies House (CH). This entailed performing advanced hand searches on the CH website, incorporating advanced filters to refine search results. This involved setting the search dates to include companies that were registered before the midpoint of the study observation period (i.e. 31st December 2012). The CH search results were then downloaded and cross-referenced with the data for 2,420 retail outlets and places of worship obtained from Yell.com.

However, it was observed that in certain cases, businesses listed the addresses of their accountants instead of their operational locations as evidenced by several duplications of the same address and Google map searches of these addresses. Furthermore, the CH website did not possess data pertaining to Places of Worship. To overcome these challenges, a second round of checks was conducted using Google searches. Each retail outlet and place of worship was individually hand searched on Google, applying filters to ensure that only web pages that listed information about (1) the outlets and religious sites and (2) web pages that were published during the study observation period were included in the search results. This was accomplished by utilizing the “Tools” option located under the search bar and inputting the study observation dates (i.e. up to the midpoint of the study period). The Google searches were cross-referenced with entries from CH and Yell.com.

A third round of quality control / checks were made once the Ordnance Survey (2022c), Points of Interest (POI) 2012 dataset became available post-pandemic in November 2022 by Ordnance Survey, the national mapping agency for Great Britain, produces the POI dataset, which includes the locations of various businesses and amenities. The POI dataset is known for its geospatial accuracy. Additionally, accuracy of POI data is comparable to that of other datasets available in the UK, as demonstrated in research on food environments conducted by Wilkins and colleagues (2017) and Burgoine and Harrison (2013). Once permission had been granted by Ordnance Survey to access the 2012 POI dataset, searches were conducted using the POI numerical classifications for each retail outlet and religious site which are as

follows: supermarkets “09470819”, convenience store “09470699”, food takeaway outlets “01020018”, off-licences “09470671” and places of worship “06340459”. Final cross-checks were performed with the previous Yell.com data, with preference given to data obtained from the POI.

Deriving proportion of amenities per middle super output area (MSOA)

The studies presented in [Chapters 5](#) and [6](#) used the proportion of amenities per MSOA in the statistical analyses. The proportion of each retail outlet (i.e. supermarket, convenience store, off-licence and fast-food outlet) and place of worship were calculated as the number of outlets per 100,000 population for each MSOA. These measures were derived using the following calculation:

$$(\text{number of outlets per MSOA} \div \text{total population of MSOA}) \times 100,000$$

Deriving distance to nearest amenity using “as the crow flies” distances

The study in [Chapter 7](#) used the nearest distance to nearest amenity in the statistical analyses. The distances to each of these features was created, using the same procedure as implemented for the access to green spaces variable. This was done using the NEAR function within ArcGIS, calculated the distance in metres to the nearest retail outlet (i.e. supermarket, convenience store, off-licence, and takeaway outlet) and religious site point for each postcode listed in the ONS postcode directory. The resulting dataset containing information about each nearest retail outlet and place of worship and their corresponding postcodes were merged with the postcodes of each cohort member by the CRIS CDLS (as described in [Section 4.4.3.b](#)). One anonymous green space distance variable was created which represented the distance to the nearest green space access point to the recorded residential postcode at the time of the cohort member’s primary diagnosis.

6.5 Individual-level covariates

Individual-level covariates were derived from the anonymised electronic health records in the CRIS dataset. These variables included age (at diagnosis), sex, ethnicity (recorded as a binary variable: White British and racialised minority) marital status (cohabitating, married, single, divorced or widowed), substance misuse and diagnosis (coded as a binary variable for a diagnosis of either: (1) an affective disorder or (2) a non-affective disorder).

6.5 Population denominator

Population denominator data was derived from the ONS. The 2012 ONS mid-year population estimates, and registered death data were used to derive standardised mortality rates for the cohort.

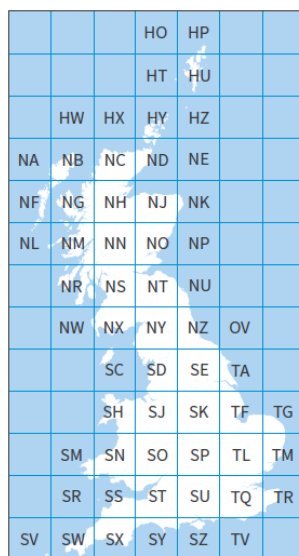
6.5 Geographical measures and coordinate systems

Middle super output areas (MSOA) are a group of contiguous output areas with an average population of 7,500 residents (ONS, 2012). There were 148 MSOAs located within the study catchment area and were used to investigate interactions between the exposure and outcome variables. The geospatial data for the MSOAs were represented by Ordnance Survey shapefiles. A shapefile is a widely used file format for geospatial data in Geographic Information System software. It is convenient for visually representing and analysing different types of features like landmarks, rivers, roads, boundaries, and parcels of land. The shapefiles were provided by Ordnance Survey and are covered by an Open Government Licence which allows users to copy, distribute and adapt the data.

The geographic coordinate system used to represent the locations of the variables for the built and social environment are called Northings and Eastings. This geographic coordinate system typically represents these locations on a two-dimensional plane. They are commonly used in mapping, surveying, and navigation in Britain (Ordnance Survey, 2020). In Britain, the recommended coordinate reference system is the British National Grid (Cabinet Office & Geospatial Commission, 2022). It is a flat coordinate system that eliminates the distortions caused by the Earth's curvature, enabling accurate measurements to be made based on geospatial data using this system (Cabinet Office & Geospatial Commission, 2022).

Northings, eastings, and the British National Grid work together to provide a standardized coordinate system for representing locations on maps and in spatial data in Britain. The British National Grid divides the entire country into a grid network of squares, each represented with two letters and measuring 100 kilometres across (see [Figure 4.1](#)) (Ordnance Survey, 2016). Within the British National Grid, each point or location is

identified by its specific northings and eastings values. Northings represent the vertical component, indicating the position relative to the origin in a northward direction and Eastings represent the horizontal component, indicating the position relative to the origin in an eastward direction. Together, they form a two-dimensional coordinate system. The origin point for the British National Grid is located south west of the Scilly Isles. It is assigned a northings value of 0 and an eastings value of 0. All other locations on the grid are measured in relation to this origin point (Ordnance Survey, 2020).



			HO	HP		
			HT	HU		
	HW	HX	HY	HZ		
NA	NB	NC	ND	NE		
NF	NG	NH	NJ	NK		
NL	NM	NN	NO	NP		
	NR	NS	NT	NU		
	NW	NX	NY	NZ	OV	
		SC	SD	SE	TA	
		SH	SJ	SK	TF	TG
	SM	SN	SO	SP	TL	TM
	SR	SS	ST	SU	TQ	TR
SV	SW	SX	SY	SZ	TV	

Fig. 4.1 Diagram of the British National Grid (Ordnance Survey, 2016)

4.8 Statistical methods for ecological and geospatial analyses (results presented in [Chapter 5](#))

4.8.1 Mapping methods

ArcGIS Pro was used to visually map MSOA boundaries using shapefiles downloaded from the Greater London Authority London Datastore website. All area-level and mortality variables were linked to the appropriate MSOA using either a georeferenced indicator (i.e. northings and eastings coordinates, MSOA codes) or by superimposing a secondary shapefile of the built environment variable onto the MSOA shapefile.

The SMRs for all-cause mortality were calculated for each MSOA (as described in the next section). ArcGIS Pro was used to visually map the SMRs alongside the exposure variables in order to identify initial trends between all-cause mortality and the area-level variables prior to further investigation using multilevel regression methods.

6.5.2 Deriving Standardised Mortality Ratios (SMRs)

Since the follow-up period for the study cohort varied based on the dates of diagnosis of cohort members within the 11-year observation window, weights were created to account for this time variation. This was done by determining the average observation time contributed by cohort members within each age and gender category. These weights were then multiplied by the number of recorded deaths in each corresponding age and gender category for the reference population (i.e. England and Wales) in 2012 (this year represented the mid-point of the study observation period). This process allowed the calculation of the expected numbers of deaths in the reference population should they have been followed up for the same amount of time as the cohort members. The expected number of deaths served as the denominators for calculating standardized mortality ratios (SMR) for the cohort. SMRs were subsequently computed for all-cause mortality, unnatural-cause mortality, and natural-cause mortality and for each (10-year) age band (i.e. 15-24, 25-34, 35-44, 45-54, 55-64, 65-74, 75-84, 85+).

6.5.2 Ecological and geospatial analyses

Tobler's First Law of Geography suggests that the similarity or relationship between two geographic phenomena decreases as the distance between them increases (Miller, 2004). In other words, neighbourhoods with higher numbers of mortality events are expected to be located close to neighbourhoods with similarly higher numbers of mortality events and vice versa, known as spatial autocorrelation. SMRs calculated for each MSOA, were assessed for the presence of spatial autocorrelation. This was carried out using the following analyses on ArcGIS Pro:

4.8.3.a Global Moran's I

The Global Moran's I test is a statistical test that assesses the presence of spatial autocorrelation within a dataset (ESRI, 2015b). This test assesses whether there is a significant spatial pattern of similarity, either positive or negative, among the values of a variable across the entire study area (i.e. all 148 MSOAs). It calculates a correlation coefficient known as Moran's I, which can range from -1 to +1. Values close to -1 indicate negative spatial autocorrelation, values close to +1 indicate positive spatial autocorrelation, and a value of 0 indicates no spatial autocorrelation. The purpose of the test is to determine whether the observed spatial pattern significantly deviates from what would be expected if the variable's values (i.e. for the standardised mortality ratios) were randomly distributed across space. If the calculated Moran's I coefficient significantly differs from 0, it suggests the presence of spatial autocorrelation. In other words, it indicates that the values of the

variable exhibit clustering rather than being randomly dispersed across the MSOAs (ESRI, 2015b).

4.8.3.b Getis-Ord G_i^* statistic

The Getis-Ord G_i^* statistic, is a metric used to detect localised spatial clustering patterns within a dataset (ESRI, 2015a). The Getis-Ord statistic aims to assess whether the observed clustering of high or low values of a variable is statistically significant within a spatial dataset. It compares the sum of values at a specific location with the sum of values in its surrounding neighbouring locations, taking into account the magnitude and spatial arrangement of these values. This test statistic differs from Global Moran's I , the latter statistic is designed to assess the overall spatial autocorrelation in the entire study area, whereas the former is designed to identify localised clustering patterns of high and low values.

The calculation of the Getis-Ord statistic involves computing a z-score for each location in the dataset, indicating the level of clustering. Positive z-scores indicate hotspots (clusters of high values), while negative z-scores indicate cold spots (clusters of low values). The magnitude of the z-score reflects the strength of the clustering, with larger absolute values representing stronger clustering. To determine the statistical significance of the clustering, the z-scores are compared to a critical value derived from a standard normal distribution (see [Figure 4.2](#) below). If the z-score surpasses the critical value, it indicates that the observed clustering is unlikely to occur solely by chance (ESRI, 2015a).

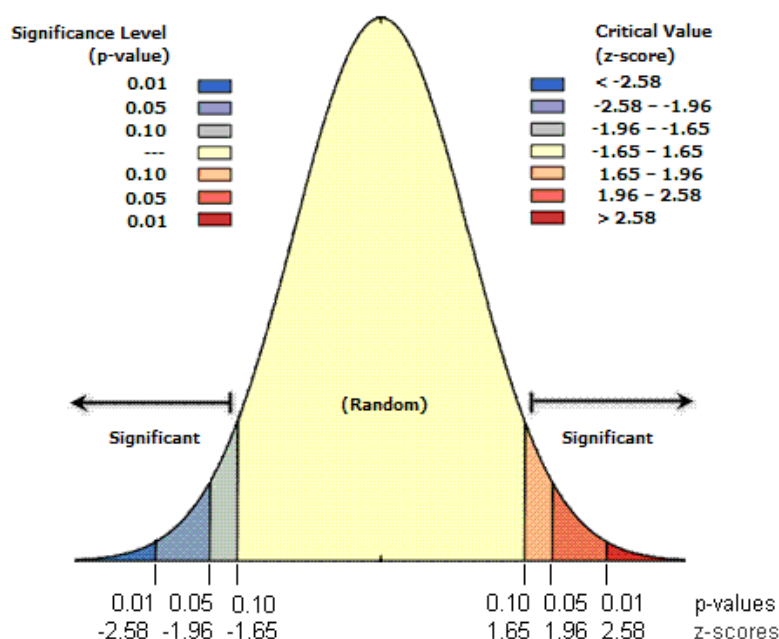


Fig. 4.2 Standardised normal distribution, critical values, z scores and p values (ArcGIS, 2009)

6.5.2 Univariable and Ordinary Least Squares (OLS) Regression analyses

Spearman's correlations were used to assess the initial associations between the SMRs and exposure variables measured at the MSOA level. OLS regression methods were used to model the ecological associations between the exposure variables and SMRs. Crude models and models adjusting for area-level deprivation were derived and adjusted r^2 values were reported for each model.

6.5 Statistical methods for multi-level modelling regression approaches, results presented in chapters [6](#) and [7](#)

6.5.2 Univariable and multilevel modelling analyses

Descriptive analyses

Descriptive statistics were conducted to provide information about the sociodemographic and clinical characteristics of the cohort as well as the distribution of the urban built and social environment variables. Individuals entered the cohort from the date of diagnosis and were followed up until death or until the end of the study observation period (i.e. 31st December 2018).

6.5.2 Multilevel modelling approaches

All-cause mortality (Poisson regression multi-levelling modelling approaches)

Many types of data, particularly observational data collected in epidemiological research have been documented to exhibit a hierarchical or clustered structure (Austin, Stryhn, Leckie, & Merlo, 2018). Cohort members who live in the same neighbourhood, for example, are more likely to share similar characteristics than cohort members who live in a different neighbourhood because of the level of exposure to various environmental factors (e.g. area-level deprivation) are likely to vary between the neighbourhoods which in turn may influence the outcome of interest (i.e. mortality). The hierarchical nature of this dataset would likely violate the assumptions of independence encompassed by other inferential statistical methods (e.g. linear regression), which infer that the observations in the sample are independent from one another and that the measurements for each cohort member are not influenced or related to the measurements of other members living in the same neighbourhood. Using statistical methods that assume independence in this context bias estimates of the association between neighbourhood-level variables by generating smaller

standard errors and P values and narrower confidence intervals (Kirkwood & Sterne, 2003).

To overcome these limitations, a multilevel Poisson regression approach was used to analyse associations between the exposure variables and all-cause mortality in the dataset. Poisson regression models are commonly employed in medical and public health research to directly predict risk for both common and rare events (Chen, Qian, Shi, & Franklin, 2018) and is preferred over other methods such as logistic regression models when the population is large or the outcome is rare (Centre for Multilevel Modelling, 2014). It is useful for datasets with a hierarchical structure because it enables simultaneous modelling of the fixed and random effects for variables measured at the individual level (e.g. age, sex) and at the neighbourhood level (e.g. open green spaces) which enables researchers to determine the proportion of the variance in the outcome variable that is accounted for by individual- and neighbourhood-level variables. This approach was used to model the rate of all-cause mortality among the cohort residing in each MSOA during the observation period using a 2-level random intercept model. The random intercept model assumes that, while the intercept or average outcome for individuals with a particular set of characteristics varies between neighbourhoods, the association between the outcome and exposure variables is consistent across all settings (Leyland & Groenewegen, 2020)¹. For each exposure variable, crude and adjusted incidence rate ratios were calculated using this approach, and goodness-of-fit between nested and complex models was tested using post-hoc likelihood ratio tests.

Inherent to MLM analyses is the importance of reporting the extent of clustering in the data. The extent of the clustering for each model was assessed by calculating the variance partition coefficients (VPCs; Goldstein, Browne, & Rasbash, 2002) which shows the proportion of the overall variation in the mortality outcome that can be attributed to (1) differences between the MSOAs and (2) differences between individual cohort members (Leckie et al., 2020; Merlo et al., 2006). The VPC was calculated using the formulae below. The total individual variance is made up of two parts: the variance in mortality outcomes between the MSOAs (V_m) and the variance between cohort members (V_i).

$$\text{VPC} = 100 \times \frac{V_m}{V_m + V_i}$$

Formula to calculate the between-MSOA variance

¹The random intercepts model assumes that the relationship between the exposure and outcome variable are consistent. However, another approach would be a random slopes model. The random slopes modelling assumes that the relationships between the exposure and outcome variables may vary between different groups (Centre for Multilevel Modelling, 2014). However, this approach was not taken because prior research largely conducted with general population samples, have not indicated that the urban built and social environment indicators have an inconsistent relationship with health outcomes.

The VPC is expressed as a percentage. Higher VPCs for the variance between MSOAs indicate significant variation in the mortality outcome that can be attributed to areas (MSOAs). On the other hand, smaller VPCs means that any differences between geographic areas are much smaller compared to the differences at individual-level within each area. The VPCs were calculated for each subsequent model iteratively as predictors and covariates were added to the model. Deviance statistics were also reported as a measure of goodness of fit of the models – lower values of the deviance statistic indicates better model fit.

Cause specific mortality outcomes using competing risks regression

A modified version of cox regression known as competing risks regression (Fine & Gray, 1999) analyses were used to model deaths from natural and unnatural causes using the *stcrreg* command in Stata. Classical survival analysis approaches are ineffective for analysing time-to-event data in a complex setting where an individual may die from different or competing causes. Competing risk regression aims to estimate the probability of an event in the context of competing events. Traditional methods to describe the survival process, such as Cox regression, are not tailored to handle the presence of competing causes for the same event (such as mortality). Consequently, they may yield inaccurate estimates when assessing the probability of cause-specific mortality events.

The competing risks regression approach (Fine & Gray, 1999) is based on the cumulative incidence function which refers to the probability of an event occurring before a specific time. Unlike Cox proportional hazards model, it does not ignore competing risks from other causes. This approach generates sub-distribution hazard ratios for the defined cause of interest that considers the risk of death from other causes. This approach was used to assess the association between the neighbourhood-level exposure variables and cause-specific mortality (i.e. natural- and unnatural mortality outcomes). This method would estimate sub-distribution hazard ratios for deaths resulting from a specific cause whilst taking into consideration the concurrent risk of dying from another cause during the observation period. Robust standard errors were used to account for clustering in the data.

Sensitivity analyses

In previous analyses of this dataset, out-migration from the catchment has been noted to be considerable (Das-Munshi et al., 2017). Therefore, sensitivity analyses were conducted to investigate the potential effect of attrition on the coefficients using competing risks regression approaches, to model the date at which participants emigrated out of the cohort against date of death from any cause using the cancelled cipher codes. The cancelled cipher

code is assigned to individuals who have not had a consultation with a general practitioner within a 3-year period if they are under 75 years old or within a 1-year period if they are 75 or older (Johnson & Blackwell, 2007). A letter is sent to their last known postal address and if no response is received within 6 months, their registration is cancelled (Johnson & Blackwell, 2007). The cancelled cipher includes two pieces of information: (1) the date of embarkation and (2) the reason for deregistration.

6.5 Ethics

Ethical approval to conduct secondary data analyses of CRIS was obtained by the Oxfordshire Research Ethics Committee C (reference 18/SC/0372). Applications to access to CRIS data and related data analyses are closely monitored and audited by the CRIS Oversight Committee. The Oversight Committee members consists of service users and members of the Maudsley Caldicott Guardian. The project was approved by this committee (project no: 20-002).

Chapter 5: Study 2 – Ecological and geospatial analyses

6.5 Introduction

Individuals with severe mental illnesses (SMI) experience a significant reduction in life expectancy compared to the general population, and the risk of mortality varies geographically. A systematic review ([Chapter 3](#)) has shown a consistent association between higher levels of area-level deprivation and increased risk of mortality in individuals with SMI. Additionally, there is evidence suggesting that racially minoritized populations who reside in areas of higher own-ethnic density may have a lower risk of death. However, research in this area is limited, particularly regarding the impact of other built environment variables such as fast-food outlets, availability of green spaces, and places of worship as highlighted by the review.

Previous research conducted with samples from the general population has indicated that residency in neighbourhoods with a higher proportion of green spaces, and better walkability is associated with a reduced risk of mortality. Conversely, people residing in neighbourhoods characterized by higher levels of deprivation, an abundance of convenience stores, fast-food outlets, and alcohol outlets tend to have poorer health outcomes. Importantly, critiques of these studies suggest that there is a high likelihood of a correlation between area-level deprivation and other area-level variables. This association arises from the fact that deprivation has been consistently linked to inequalities in access to services and amenities within neighbourhoods which may also impact public health outcomes.

To address these gaps, the present study adopted an ecological study design, informed by mapping approaches, to investigate the associations between area-level factors and all-cause mortality in individuals with SMI. The aim was to examine the extent to which these area-level factors contributed to mortality in individuals with SMI, residing in an urban location in southeast London.

Objectives

To address this gap in the literature, this study aims to investigate the ecological association between the built and social environment, and the risk of mortality in SMI within an urban and ethnically diverse location in south London. The ecological and mapping analyses addressed the first aims of this thesis which were:

- To map the standardised mortality ratios (SMR) of people with SMI across the study catchment area – specifically covering 148 middle super output area (MSOAs)

situated within the London boroughs of Lewisham, Lambeth, Croydon, and Southwark.

- To investigate whether the built and social environment variables were associated with an increased risk of mortality

The research questions were as follows:

- Do neighbourhood-level factors influence the risk of mortality in SMI?
- Are there spatial variations in area-level factors and risk of mortality in SMI?

Hypotheses:

Based on previous research, I hypothesized a higher risk of mortality among people with SMI compared to the general population associated with the following neighbourhood conditions:

- Neighbourhoods with higher rates of convenience stores, fast food outlets and area-level deprivation will be associated with higher age/ sex adjusted standardised mortality ratios.
- Neighbourhoods that are more densely populated and socially fragmented will be associated with higher standardised mortality ratios.

I hypothesised a lower risk of mortality among people with SMI compared to the general population associated with the following neighbourhood characteristics:

- Neighbourhoods with increased walkability, availability of green spaces and supermarkets will be associated with a lower risk of age and sex adjusted standardised mortality ratios.
- Neighbourhoods with higher percentages of resident racialised minority groups and higher rates of places of worship were expected to have a protective effect on the risk of all-cause mortality in SMI.

Additionally, associations between the built and social environment variables with standardised mortality ratios will be partially explained by area-level deprivation.

6.5 Summary of methods

In the previous sections I have described the ecological study design (see Section 4.2 and summary study design table), geographic measures and coordinate systems (see Section), exposure variables (see Section 4.4) and the statistical methods (see Section 4.8) used to

inform deriving standardised mortality ratios and subsequently mapping these through the package ArcGIS.

Data for each of the built and social environment variables were derived from several sources which included the Census 2011, the Greater London Authority Datastore website and the Department of Levelling Up, Housing & Communities (see [Methodology Chapter](#) for further details).

Conceptualization of spatial relationships is a fundamental aspect of spatial analysis and refers to how features in a geographic area are determined to interact and influence each other. The influence is determined by either a distance relative to the target feature (figure 5.1a), or by a shared boundary (figure 5.1b). In figure 5.1a features which are within a specified distance to a target feature are considered “neighbouring” features. In Figure 5.1b, features which share a boundary are considered neighbours.

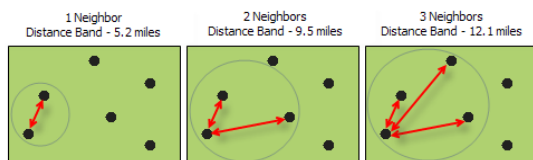


Fig. 5.1a Distance thresholds

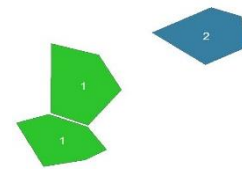


Fig. 5.1b Shared boundaries

For the purposes of this project, the specific feature of interest are the SMRs that have been calculated for each MSOA and the *zone of indifference* was used to conceptualise the spatial relationships between these SMRs at the MSOA level. This means that features located within a defined proximity of each other are considered neighbours. However, features that are located beyond this defined proximity are also considered neighbours, but their influence decreases progressively as the distance between them increases. To determine an appropriate distance between these SMR values, the Global Moran’s I analysis was conducted using 500 metre increments to determine the optimal distance between each feature to be used in the Getis-Ord GI* analyses. The results of this distance selection method are displayed in appendices 1 and 2 and the distance was selected according to the first peak in the graph as recommended by Environmental Systems Research Institute (ESRI, 2010).

For fuller details of methods used in this section please refer to the Methodology Chapter ([Chapter 4](#)).

6.5 Summary of analyses

Preliminary analyses involved assessing the distribution of SMRs and the exposure variables using histograms and qualitative maps created using ArcGIS Pro. As described previously (see [Section 4.8.3](#)), to assess the presence of spatial autocorrelation in the study catchment area, two statistical tests were employed: the Global Moran's I statistic and the Getis-Ord GI* statistic. These tests offer different perspectives on spatial autocorrelation. The Global Moran's I evaluates the overall spatial autocorrelation pattern across the entire study area, while the Getis-Ord GI* (also referred to as hot spot analyses) identifies localized patterns of spatial autocorrelation, such as clusters of MSOAs with high or low SMR values, that may not be captured by the Global Moran's I. To mitigate the risk of false positives obtained from the Getis-Ord GI* statistic, the false discovery rate (FDR) was applied. The FDR adjusts the p-value threshold (as shown in Table 5.1) to account for false positives.

Table 5.1 False discovery rate threshold for spatial autocorrelation (Environmental Systems Research Institute, 2021)

z-score (SD)	p-value	Confidence level
< -1.65 or > +1.65	< 0.10	90%
< -1.96 or > +1.96	< 0.05	95%
< -2.58 or > +2.58	< 0.01	99%

Spearman's correlation was used to investigate associations between the exposure and outcome variables. This statistical test was chosen because of the lack of normal distribution among the exposure and outcome variables as seen from the histograms.

Associations between the following area-level exposures and the SMR were estimated using ordinary least squares (OLS) regression. Two separate models were derived from this approach. The first model represented the built environment model and was comprised of the following variables: (1) area-level deprivation, (2) population density, (3) neighbourhood walkability, (4) rates of convenience stores, (5) supermarkets, (6) fast-food outlets and (7) off-licences (per 100,000 population).

The second model represented the social environment model and this led: (1) social fragmentation, (2) ethnic density and the rate of (3) places of worship (per 100,000

population). Each exposure variable were measured at the middle super output area (MSOA) level and created into quintiles for statistical analyses.

Unadjusted associations between each built and social environment variable and the SMR were modelled individually. The second model was adjusted for area-level deprivation and the final models included all the exposure variables. Distributions of SMR were checked using histograms to assess the level of normal distribution. Multicollinearity were assessed using variance inflation factor tests using Stata. Robust standard errors were used to adjust for heteroscedasticity in the mode

6.5 5.4 Results

Overview of sample

The analyses presented in this chapter included 148 middle super output areas (MSOAs), across the catchment area of the study, which covered the four south London boroughs of Croydon, Lambeth, Lewisham, and Southwark. A total of 2,911 deaths (12.8%) were observed within the cohort between 2007 and 2018. The number of deaths were similar between males (6.5%) and females (6.3%). Most decedents were aged between 75 and 84 at the time of their death (26.2%) followed by those aged between 65 and 74 (19%). [Table 5.2](#) provides descriptive characteristics of the MSOAs in the study catchment area. Based on descriptive analyses, the following observations were made regarding the study catchment area:

- Area-level deprivation:
 - Croydon had the most variability in the area-level deprivation rank scores. Just over one third of neighbourhoods in Southwark were classified as the most deprived in the study catchment area.
- Neighbourhood walkability:
 - 75% of neighbourhoods in Croydon and Lewisham were classified as having low walkability scores.
- Population density:
 - In Croydon, 25% of neighbourhoods were characterized as sparsely populated areas with 25% of areas having ≤ 33 persons per hectare.
- Green spaces:
 - Southwark exhibited more variation in the proportions of land identified as green spaces compared to other boroughs.
- Supermarkets:
 - Similar rates of supermarkets were observed across all four boroughs.
- Off-licences:
 - Lewisham displayed greater variability in the rates of off-licences. 25% of neighbourhoods in Lewisham had less than 1 off-licence per 100,000 population.

- Fast-food outlets:
 - Croydon exhibited more variability in fast-food outlets. 25% of neighbourhoods in Croydon had ≤ 20 fast food outlets per 100,000 population.
- Social fragmentation:
 - Croydon appeared to have the most socially fragmented neighbourhoods, with 75% of areas having a social fragmentation z-score of -6 and below.
- Ethnic density:
 - Croydon demonstrated greater variability in terms of area-level ethnic density, with over a 30% difference between the least and most ethnically dense neighbourhoods within the first and third quartiles.
- Places of worship:
 - Although the interquartile range for the rate of places of worship was similar across all boroughs, 25% of neighbourhoods in Lewisham had ≤ 15 places of worship per 100,000 population.
- SMR:
 - The interquartile ranges for age / sex standardised SMRs in people with SMI were relatively similar across all four boroughs.
- Study catchment area characteristics compared with national-level characteristics:
 - Compared with the rest of England, the study catchment area (i.e. Croydon, Lewisham, Southwark and Lambeth) exhibited elevated levels of area-level deprivation, greater population density, increased numbers of retail outlets per 100,000 (i.e. convenience stores, off-licences, and fast-food establishments), and higher proportions of resident racialized minority communities.
 - However, the study catchment area showed reduced numbers of supermarkets and religious establishments per 100,000 population when compared with the rest of England.

Table 5.2 Area-level characteristics and age- and sex-standardised mortality ratios in people with severe mental illness (SMI) across four south London boroughs

	London Borough				All Boroughs	National
	Croydon	Lambeth	Lewisham	Southwark		
MSOA ¹ (n)	44	35	36	33	148	6,791
	Median (IQR)	Median (IQR)	Median (IQR)	Median (IQR)	Median (IQR)	Median (IQR)
Built environment variables						
Area-level deprivation (rank score) ²	2,446 (1,520 , 4,152)	1,832 (1,208 , 2,426)	1,796 (1,155 , 2,687)	1,391 (1,002 , 2,409)	1,890 (1,173 , 2,813)	3,397 (1,698 , 5,094)
Walkability (z score) ³	-2.5 (-3.7 , 0.2)	0.8 (-1.1 , 2.9)	-1.3 (-2.3 , 0.4)	2.8 (0.5 , 4.8)	-0.1 (-2.5 , 2.2)	-
Population density ⁴	60 (33 , 87)	119 (95 , 145)	84 (69 , 101)	117 (96 , 147)	92 (66 , 117)	25 (7 , 45)
Green spaces (%) ⁵	11 (6 , 18)	6 (2 , 11)	9 (5 , 18)	8 (5 , 21)	9 (4 , 17)	-
Convenience stores †	72 (49 , 112)	105 (68 , 136)	95 (73 , 120)	107 (70 , 166)	91 (59 , 132)	63 (41 , 90)
Supermarkets †	0 (0 , 13)	0 (0 , 15)	0 (0 , 13)	0 (0 , 11)	0 (0 , 11)	12 (0 , 22)
Off-licences †	13 (10 , 23)	22 (12 , 32)	13 (0 , 26)	22 (13 , 34)	15 (11 , 25)	9 (0 , 16)
Fast-food outlets †	71 (20 , 138)	83 (25 , 116)	97 (42 , 132)	79 (67 , 125)	83 (35 , 125)	35 (14 , 74)
Social environment variables						
Social fragmentation (z score) ⁶	-2.0 (-6.0 , -0.3)	2.1 (0.3 , 4.1)	-1.1 (-2.8 , 0.7)	0.5 (-1.0 , 2.5)	-0.3 (-2.1 , 2.1)	-0.8 (-2.2 - 1.2)
Ethnic density (%) ⁷	42 (26 , 63)	41 (37 , 50)	44 (40 , 54)	43 (36 , 56)	43 (36 , 55)	5 (2 , 17)
Places of worship †	32 (24 , 56)	51 (32 , 62)	33 (15 , 50)	45 (25 , 57)	38 (24 , 55)	54 (31 , 92)
Mortality						
SMR ⁸	2.9 (2.4 , 3.5)	2.8 (2.5 , 3.3)	2.7 (2.2 , 3.8)	2.9 (2.4 , 3.4)	2.8 (2.4 , 3.4)	-

¹Middle Super Output Area; ²lower rank scores represent more deprived areas; ³higher scores indicate higher walkability; ⁴Persons per hectare; ⁵percentage of green spaces per hectare; ⁶higher scores indicates areas with higher social fragmentation; ⁷percentage of residential population that identify as a racialised minority; †retail outlets and services per 100,000 population.

Neighbourhood-level characteristics of MSOAs that exhibit the highest and lowest standardized mortality ratio values

In [Table 5.3](#), SMRs are presented for ten MSOAs located within the study catchment area, reflecting both the top 5 areas with the highest SMRs and the bottom 5 areas with the lowest SMRs. Forestdale in Croydon exhibited the lowest SMR, while Beckenham Hill in Lewisham had the highest SMR. There were some similarities observed in the built and social environment of areas with the highest and lowest SMRs. However, the areas with the lowest SMRs exhibited lower levels of walkability and a higher rate of fast-food outlets (per 100,000 population) when compared to areas with higher SMRs. Conversely, areas with higher SMRs had no supermarkets compared to areas with lower SMRs.

Table 5.3 Age and sex standardised mortality ratios (SMR) within MSOAs with the top 5 highest and bottom 5 lowest SMRs

					Built environment exposures								Social environment exposures		
	Deaths (N)	Expected	SMR	95% CI	IMD Rank	Walk ¹	Pop. dens. ²	Green spaces ³ (%)	Fast food ⁴ ‡	Conv. stores ⁵ ‡	Smkts ⁶ ‡	Off-licence ^{7‡}	Social frag ⁸ ‡	Ethnic dens. ⁹ (%)	PW ^{10‡}
MSOAs with the highest SMRs															
Beckenham Hill (Lewisham)	16	2.34	6.84	3.91 - 11.1	728	2.0	85	13.5	100	125	0	25	-3.3	66	50
Deptford North (Lewisham)	32	5.15	6.21	4.25 - 8.77	680	2.0	120	26.1	77	166	0	0	-.6	51	38
Burgess Park West & John Ruskin Street (Southwark)	25	4.04	6.19	4.01 - 9.14	1,161	-0.6	99	4.7	48	48	0	12	-.4	39	36
Brockley East & St John's (Lewisham)	28	4.81	5.82	3.87 - 8.41	2,157	-1.2	60	9.7	64	116	0	51	3.0	32	39
Purley North (Croydon)	14	2.54	5.50	3.01 - 9.23	3,406	-3.5	25	23.9	9	25	0	17	-1.4	20	26
MSOAs with the lowest SMRs															
Forestdale (Croydon)	10	7.82	1.28	0.61 - 2.35	3,204	1.3	117	39.9	132	96	0	36	.2	64	48
Burgess Park (Southwark)	<10	6.10	1.31	0.57 - 2.58	832	-4.1	77	28.6	109	95	12	0	-1.9	41	54
Downham East (Lewisham)	<10	4.50	1.33	0.49 - 2.90	870	-2.1	66	0.3	104	119	14	45	-4.1	34	45
Telegraph Hill (Lewisham)	15	9.50	1.58	0.88 - 2.60	3,345	-1.3	107	6.3	94	59	0	12	-3.4	44	47
Lee (Lewisham)	10	6.33	1.58	0.76 - 2.91	1,979	2.0	85	13.5	100	125	0	25	1.3	66	50

¹Walkability; ² Population density (Persons per hectare); ³ % of green space per hectare; ⁴ Fast food outlets; ⁵ Convenience stores; ⁶ Supermarkets; ⁷ Off-licence; ⁸ Social fragmentation; ⁹ Ethnic density; ¹⁰ Places of worship; ‡ services and retail outlets per 100,000 population

Geospatial analyses of the distributions of the standardised mortality ratios and the neighbourhood-level variables

Visual inspection of the distribution of the exposure variables and SMR was conducted by mapping the values to each MSOA in [Figure 5.2](#). Initial observations from Figure 5.2b indicated clusters of similar SMR values across the four boroughs. For example, in the eastern areas of Lambeth, there were several closely clustered MSOAs with SMR values ranging from 2.3 to 3. Similarly, in the southern areas of Croydon, four MSOAs exhibited SMR values between 1.3 and 2.2.

Figures 5.2c to 5.2m shows the distributions of the built environment variables. Figure 5.2c displays clusters of the most deprived areas, primarily concentrated in the northern parts of the study catchment area and a smaller area in the south-eastern part of Croydon. Notably, distinct geographical patterns were observed between area-level deprivation and the built and social environment variables. Generally, neighbourhoods with higher levels of walkability (Figure 5.2d), population density (Figure 5.2e), social fragmentation (Figure 5.2k), ethnic density (Figure 5.2l), and higher rates of convenience stores (Figure 5.2g) and fast-food outlets (Figure 5.2j) appeared to be situated in areas with higher deprivation. Figure 5.2h indicates a sparse distribution of supermarkets across the catchment area. Neighbourhoods exhibiting greater walkability (Figure 5.2d) seemed to display lower proportions of green spaces (Figure 5.2f). Additionally, neighbourhoods with moderate levels of places of worship (i.e., 21-48 religious sites per 100,000 population) appeared to cluster throughout the catchment area.

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Fig. 5.2 Mapped distributions of age- and sex-standardised mortality ratios, built and social environment variables per MSOA¹

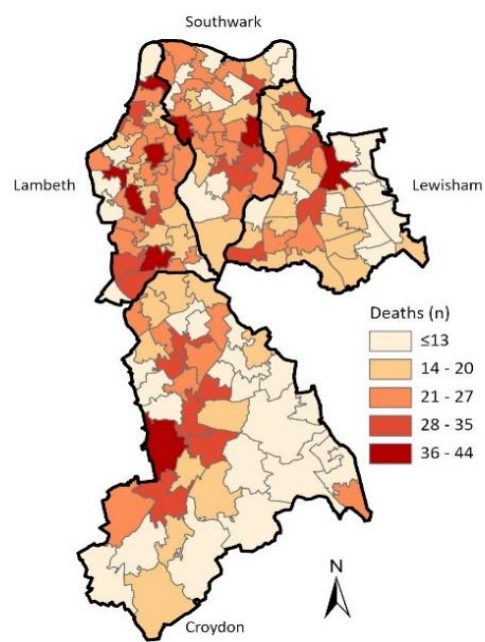


Fig. 5.2a Distribution of absolute number of deaths

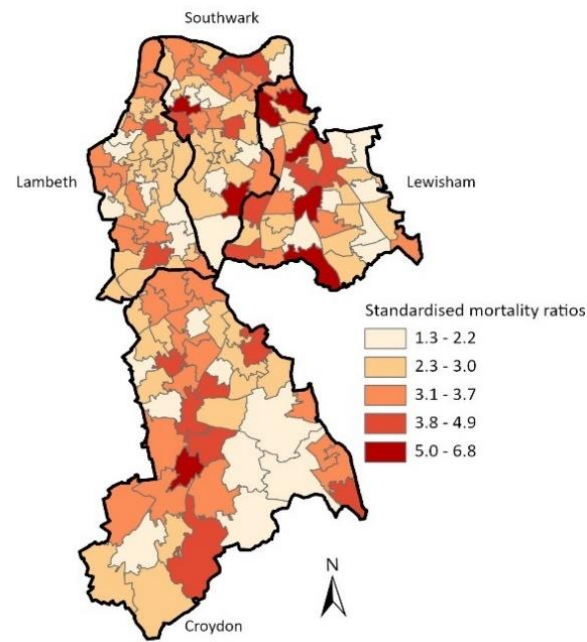


Fig. 5.2b Distribution of age and sex standardised mortality ratios

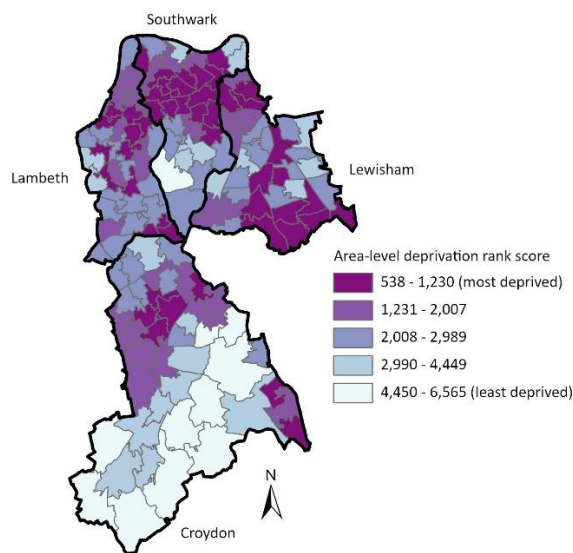


Fig. 5.2c Distribution of area-level deprivation rank score

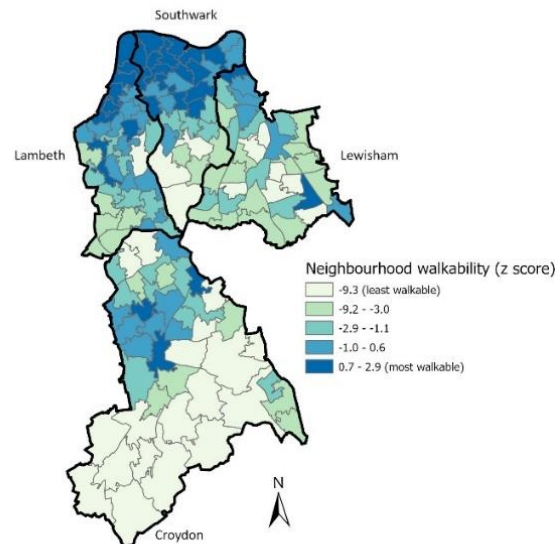


Fig. 5.2d Distribution of neighbourhood walkability score

¹ NB: Darker shaded areas in Figures 5.2a - 5.2b indicate higher number of deaths and SMRs respectively; Darker shaded areas in maps presented in Figures 5.2c - 5.2m indicate higher proportions of urban built and social environment indicator

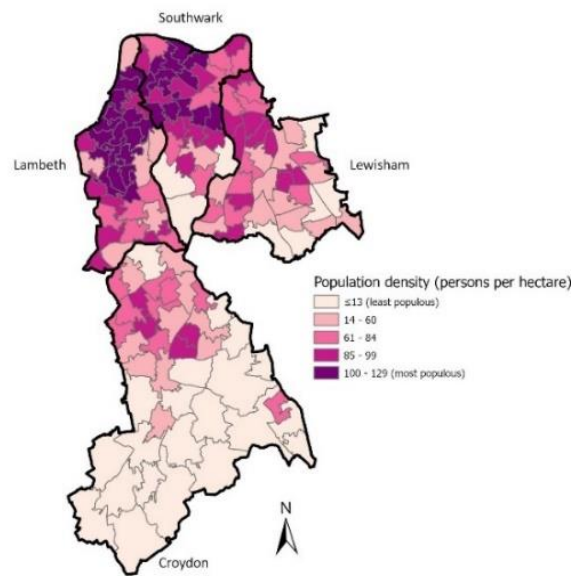


Fig. 5.2e Distribution of population density (persons per hectare)

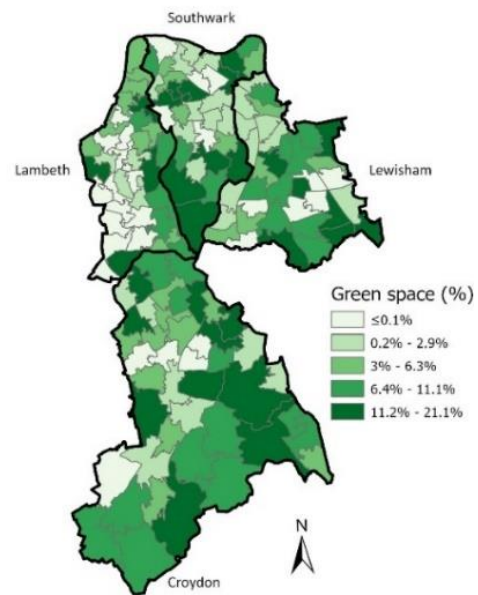


Fig. 5.2f Distribution of green spaces (%)

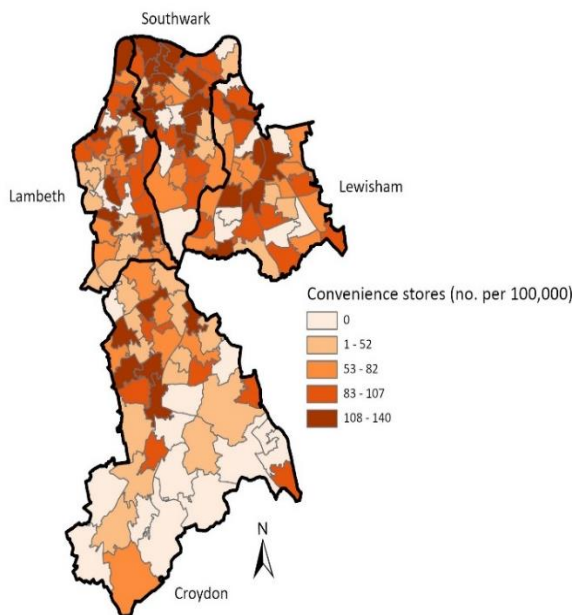


Fig. 5.2g Distribution of convenience stores (no. per 100,000 population)

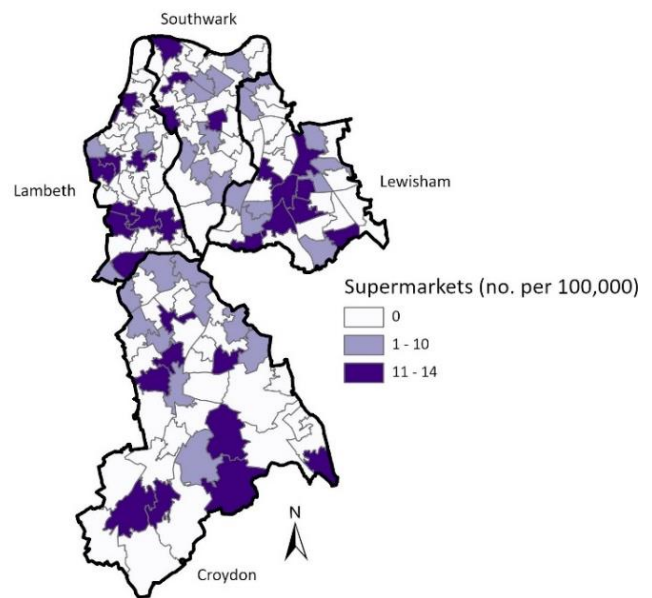


Fig. 5.2h Distribution of supermarkets (no. per 100,000 population)

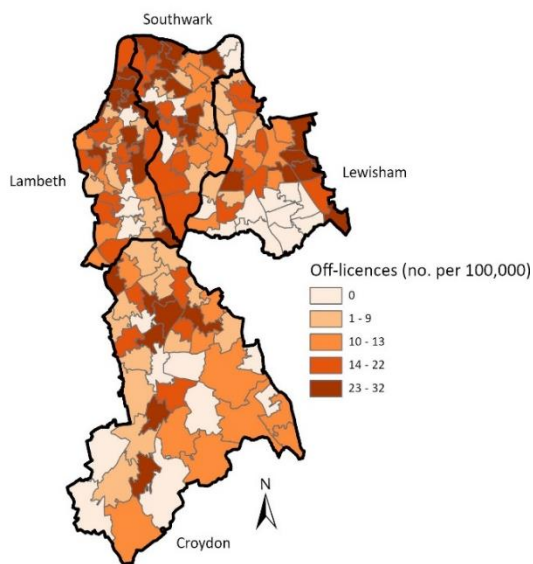


Fig. 5.2i Distribution of off-licences (no. per 100,000 population)

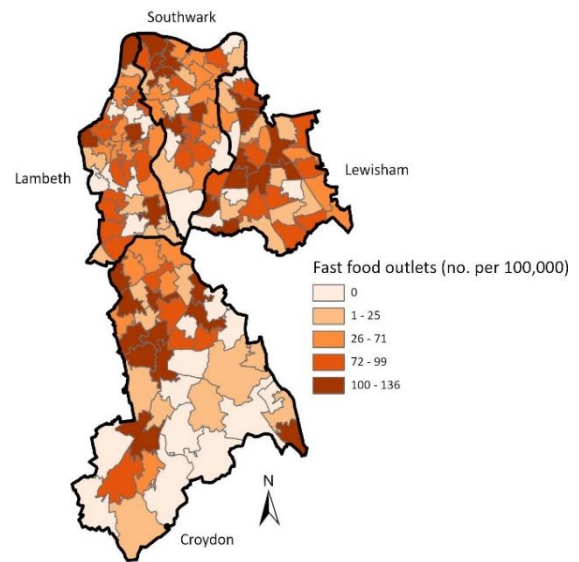


Fig. 5.2j Distribution of fast-food outlets (no. per 100,000 population)

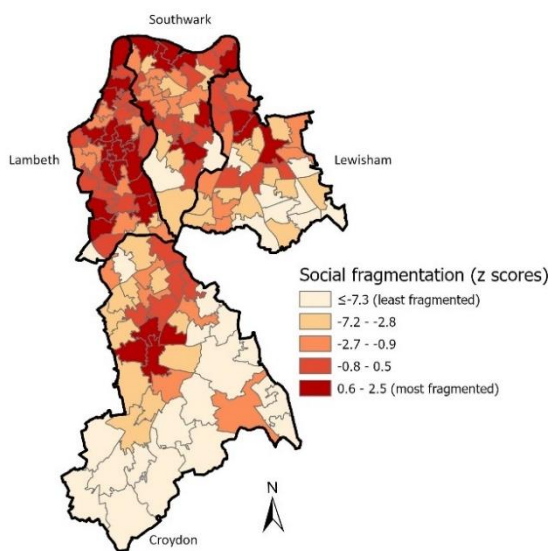


Fig. 5.2k Distribution of social fragmentation (z scores)

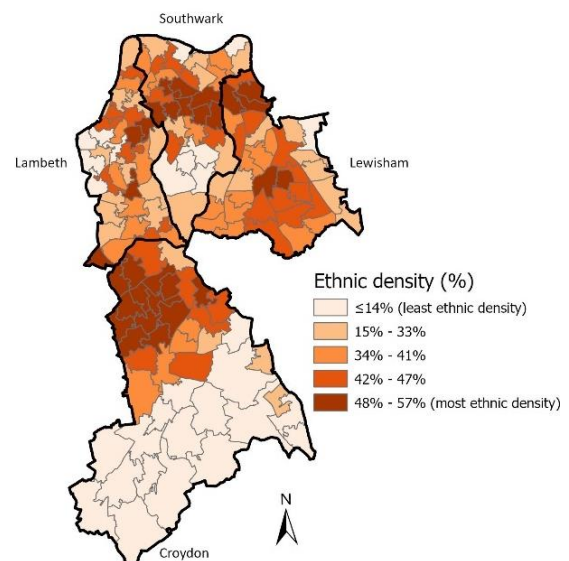


Fig. 5.2l Distribution of ethnic density (%)

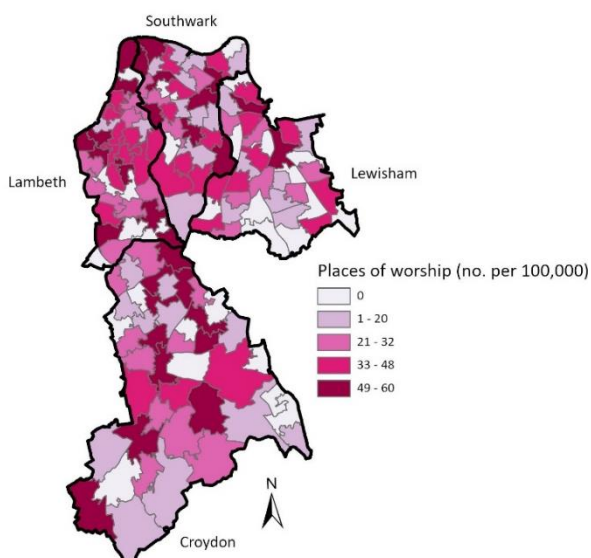


Fig. 5.2m Distribution of places of worship (no. per 100,000 population)

Additional mapping analysis was conducted by superimposing the SMR with each of the built and social environmental variables (see [Figure 5.3](#)). Higher SMRs were identified in areas with higher levels of deprivation, fast food outlets and convenience stores. However, this observation was not consistent across all parts of the study catchment area. For instance, in the southern parts of Lewisham, there were areas with higher deprivation and lower SMRs. Similarly, neighbourhoods with higher levels of ethnic density and green spaces, such as parts of northern Croydon, exhibited lower SMRs. However, there were also smaller pockets of areas where the spatial pattern contradicted this trend. Areas with lower population density, particularly in the southernmost areas of Croydon, were associated with lower SMRs. However, in the most northern parts of Southwark, the most densely populated areas had higher SMRs.

Fig. 5.3 Mapped distributions of age- and sex-standardised mortality ratio (SMR) superimposed on to each built and social environment variables¹

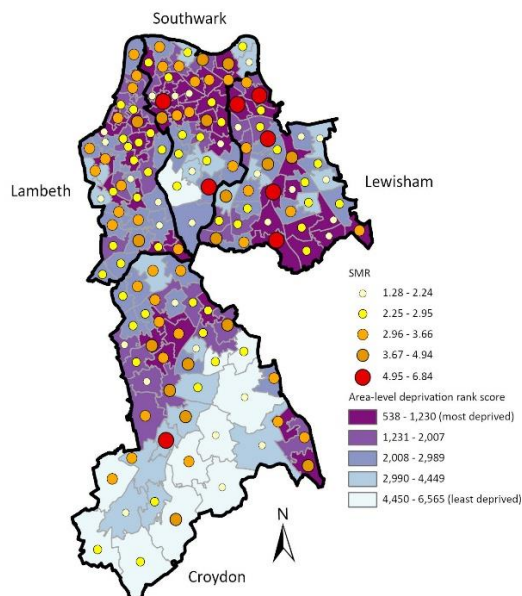


Fig 5.3a SMR and area-level deprivation rank score

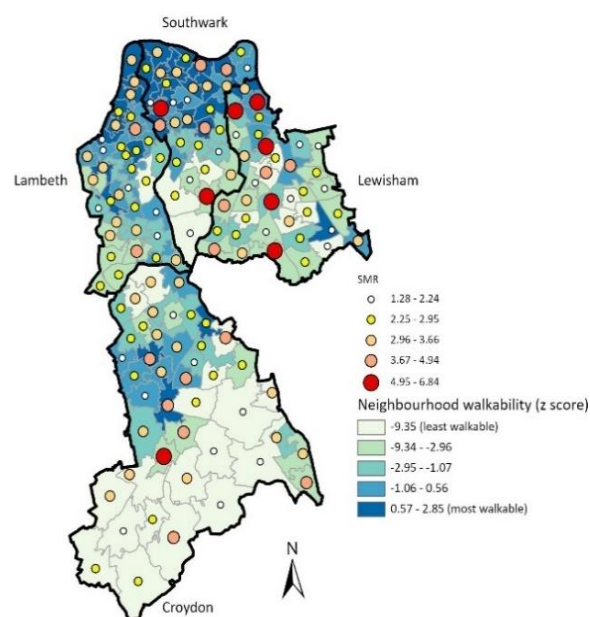


Fig 5.3b SMR and neighbourhood walkability score

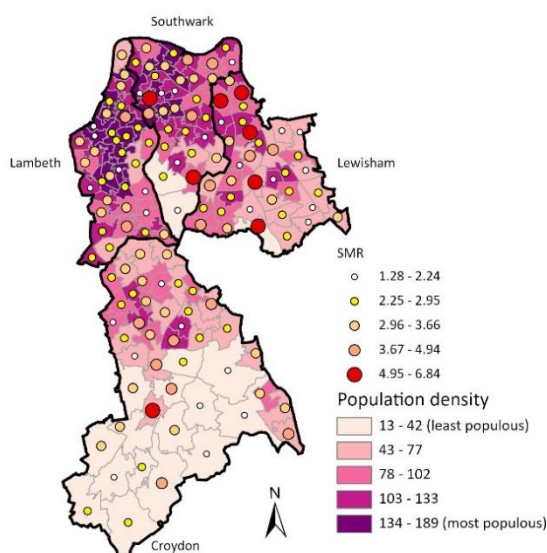


Fig 5.3c SMR and population density (persons per hectare)

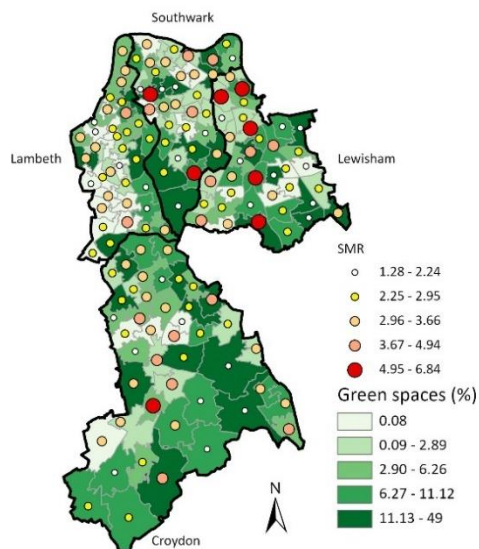


Fig 5.3d SMR and green spaces (%)

¹ NB: Darker shaded areas in maps presented in Figures 5.3a - 5.3k indicate higher proportions of urban built and social environment indicator; larger orange and red dots indicate higher SMRs

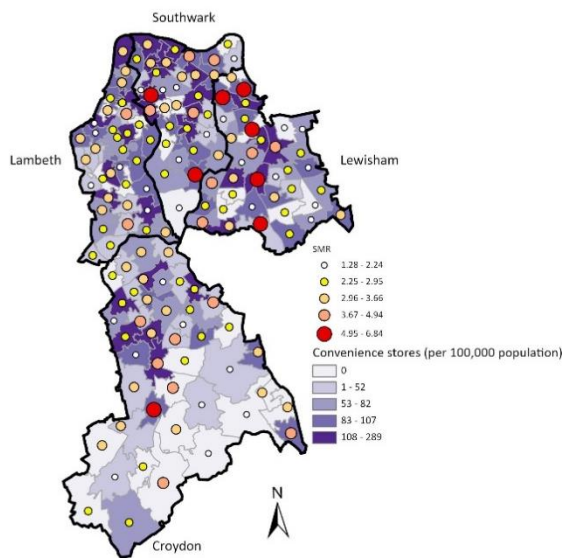


Fig 5.3e SMR and convenience stores (no. per 100,000 population)

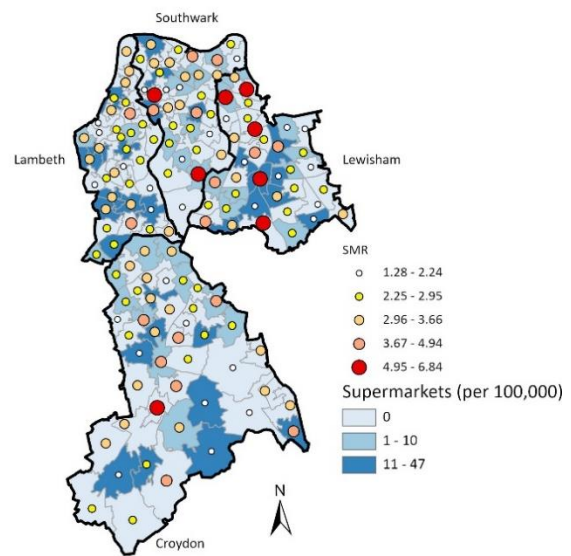


Fig 5.3f SMR and supermarkets (no. per 100,000 population)

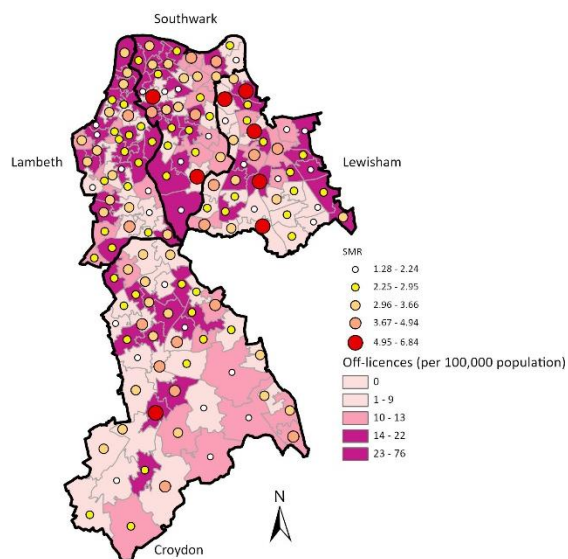


Fig 5.3g SMR and off-licences (no. per 100,000 population)

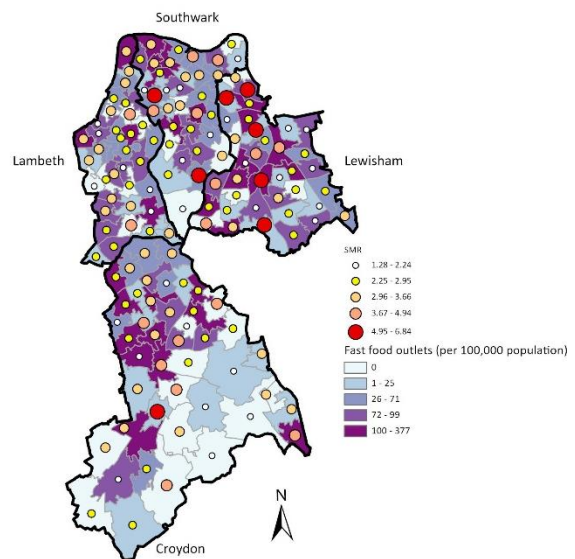


Fig 5.3h SMR and fast-food outlets (no. per 100,000 population)

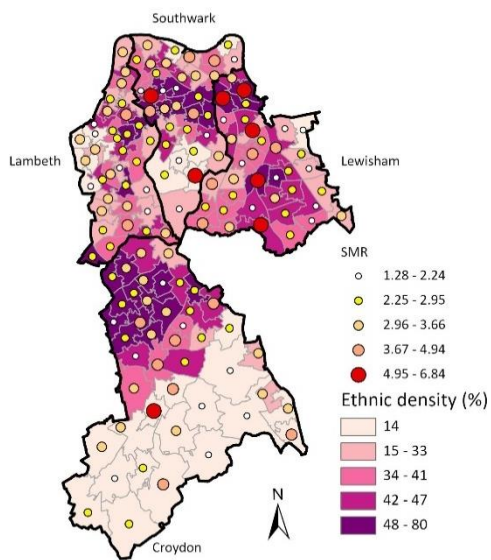


Fig. 5.3j. SMR and ethnic density (%)

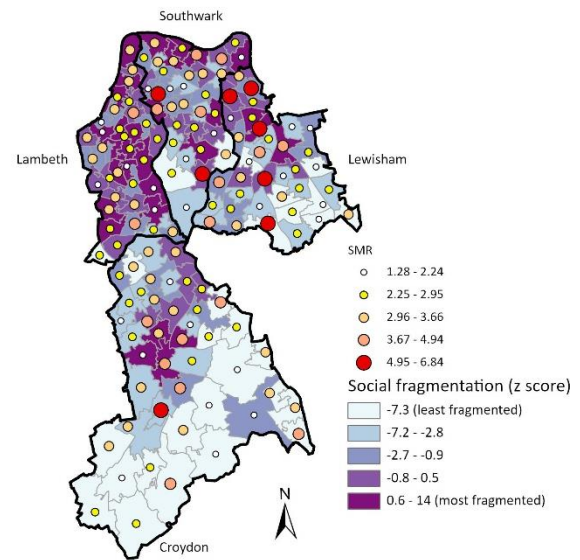


Fig 5.3i SMR and social fragmentation (z score)

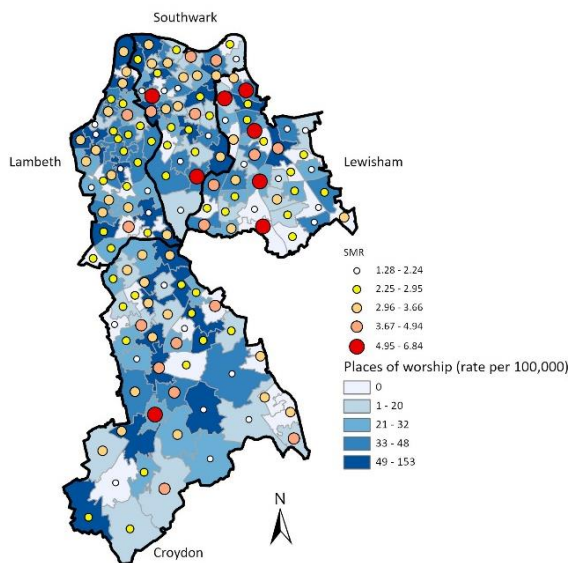


Fig 5.3k SMR and places of worship (no. per 100,000 population)

Spatial autocorrelation analyses of the standardized mortality ratios

Further analyses were performed to explore the presence of spatial autocorrelation in the standardized mortality ratio (SMR) within the study catchment area. The Getis-Ord GI^* and the Global Moran's I statistics were utilized for this purpose. The Global Moran's I statistic indicated a small value, suggesting weak clustering of SMR values among the 148 MSOAs. However, the spatial pattern observed across the entire study area was not statistically significant (Global Moran's $I = 0.02$, $p = 0.58$).

To further investigate localized spatial autocorrelation, the Getis-Ord GI^* statistic was employed (see Figures 5.4a – 5.4c, below). A distance threshold was chosen by assessing spatial clustering at different distances in increments of 500 metres (see [Appendix 5](#)). Figures 5.4b and 5.4c show the unadjusted spatial clustering using Getis-Ord GI^* statistic. Initially, a distance threshold of 1,000 metres (figure 3b) was selected to illustrate the spatial correlation among SMRs computed for MSOAs. This threshold was chosen as it represented the first point at which some clustering was identified (see [Appendix 5](#)). The 1,000 metre distance threshold indicated some clustering in the north-east of the study catchment area (i.e. within Southwark and Lewisham). However, this 1,000-metre threshold highlighted some isolated areas that lacked a clear clustering pattern, a phenomenon often referred to as the “salt and pepper” effect. This effect was particularly notable in Croydon and parts of Lewisham. Upon increasing the distance threshold to 2,500 meters (Figure 5.4c), this issue of isolated areas improved to some extent and similar to the 1,000 metre distance threshold, spatial clustering was identified in the north eastern parts of the study catchment area. To adjust for multiple comparisons, a false discovery rate correction was applied which meant that the spatial clustering observed in Figure 5.4b and Figure 5.4c were no longer significant at the MSOA level. This outcome aligns with the findings of earlier spatial autocorrelation analyses based on the Global Moran's I method.

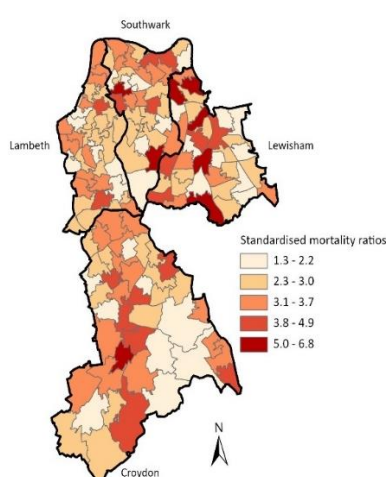


Fig. 5.4a Distribution of SMRs

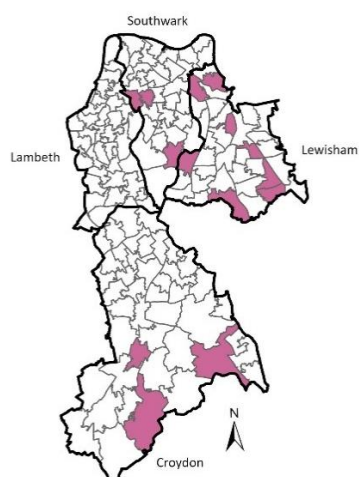


Fig. 5.4b 1,000 metre distance threshold

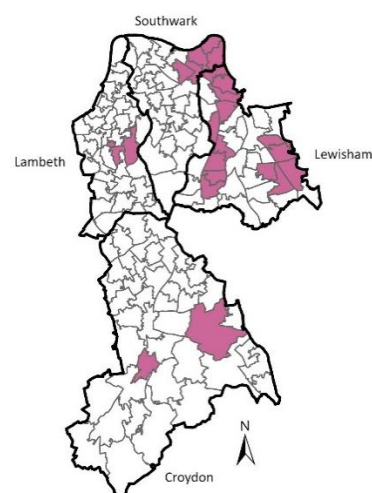


Fig. 5.4c 2,500 metre distance threshold

Correlational analysis of the standardized mortality ratios and the built and social environment variables

Following visual analysis of the mapped distributions of the exposure and outcome variables, correlational analyses were conducted to examine the relationships between these variables and SMR. The correlation coefficients for each built and social environment variable, as well as the SMR, are presented in [Table 5.4](#). Across the entire study catchment area, a weak inverse correlation was observed between area-level deprivation and SMR, indicating that neighbourhoods with higher levels of deprivation (as indicated by lower rank scores) were correlated with higher SMRs. Weak positive correlations were found between neighbourhoods with higher levels of walkability, social fragmentation and higher rates of convenience stores and SMR. Additionally, a weak negative correlation was observed between neighbourhoods with lower percentages of green space and higher SMR.

In the borough of Croydon, the highest coefficient was observed between the most deprived neighbourhoods and higher SMRs. Additionally, weak correlations were observed between areas with higher rates of convenience stores, higher social fragmentation, and higher walkability with high SMRs. Lower percentages of green space were weakly associated with higher SMRs.

In Lewisham, weak negative correlations were identified between neighbourhoods with higher levels of deprivation and lower rates of off-licences and higher SMRs. Weak positive correlations were noted between neighbourhoods with higher levels of walkability, social fragmentation, and convenience stores, and higher SMRs.

In Southwark, weak correlations were observed between areas with higher rates of convenience stores and supermarkets, indicating higher SMRs. Similarly, weak correlations were found between higher SMRs in areas with higher walkability, higher population density and high social fragmentation. Areas with higher levels of deprivation were also associated with higher SMRs.

Within Lambeth, weak correlations were observed between areas with higher levels of walkability and social fragmentation, and SMR. Weak negative correlations were also noted in areas with lower percentages of green space and lower rates of fast-food outlets and higher SMR.

Table 5.4 Spearman's correlation coefficients between standardised mortality ratios (SMR) and the built and social environment variables

	Croydon		Lambeth		Lewisham		Southwark		All boroughs	
Built environment variables	Rho	p	Rho	p	Rho	p	Rho	p	Rho	p
Area-level deprivation (rank score) ¹	-.31	.04	.06	.72	-.23	.17	-.19	.28	-.19	.02
Walkability (z score) ²	.16	.31	.14	.44	.14	.42	.30	.10	.15	.06
Population density ³	.09	.56	-.09	.62	-.04	.83	.18	.32	.02	.79
Green spaces (%) ⁴	-.16	.29	-.12	.51	-.01	.97	-.23	.19	-.10	.24
Convenience stores ‡	.11	.49	-.14	.42	.17	.31	.39	.02	.15	.06
Supermarkets ‡	<.01	.98	.10	.56	-.09	.61	.18	.33	.05	.55
Off-licences ‡	-.07	.66	<-.01	.99	-.11	.53	.00	.99	-.04	.63
Fast-food outlets ‡	.09	.56	-.19	.27	-.04	.80	.10	.59	<.01	.97
Social environment variables										
Social fragmentation (z score) ⁵	.16	.31	-.26	.13	.34	.04	.17	.36	.11	.18
Ethnic density (%) ⁶	.06	.70	.02	.92	.28	.10	.08	.64	.09	.27
Places of worship ‡	.14	.35	.05	.79	.03	.85	.09	.62	.09	.27

¹ Lower scores represent more deprived areas; ²higher scores indicate higher walkability; ³Persons per hectare; ⁴percentage of green spaces per hectare; ⁵higher scores indicates areas with higher social fragmentation; ⁶percentage of residential population that identify as a racialised minority; ‡retail outlets and services per 100,000 population.

Regression analyses assessing the relationship between the standardised mortality ratios and the built environment variables

Based on the correlation analyses in [Table 5.4](#), the relationship between built and social environment variables and SMR were further explored using OLS regression with robust standard errors in [Tables 5.5 – 5.8](#). To evaluate multicollinearity in the models, variance inflation factor (VIF) estimates were implemented. The VIFs indicated small correlations between area-level deprivation and the urban built and social environment variables. However, the VIF estimates did not exceed the threshold that would necessitate additional adjustments.

Unadjusted modelling of the built environment variables showed weak correlations between more deprived neighbourhoods and higher SMRs compared to less deprived areas. There were no correlations between all other built environment characteristics and SMRs.

[Table 5.5](#) displays the regression coefficients after adjusting for area-level deprivation only. The correlations between the built environment variables and SMRs were reduced after accounting for area-level deprivation when compared to the unadjusted coefficients (see [Appendix 5](#)). Within this model, there were no area-level correlations evident, between built environment variables and age/sex standardised mortality ratios, in people with SMI. [Table 5.6](#) presents the final multivariable model, which includes all the built environment variables from the unadjusted model (see [Appendix 6](#)). No correlations were noted with the built environment variables bar the exposure variable representing the number of convenience stores.

Table 5.5 Regression models for SMR and each built environment exposure variables adjusted for area-level deprivation

Built environment exposure	β Coef.	<i>T</i>	95% CI	<i>p</i>	<i>R</i> ²
Neighbourhood walkability (z score)					
Ref: Least walkable quintile	-	-	-		
2 nd quintile	-0.02	-0.07	-0.60 , 0.56	.87	.06
3 rd quintile	-0.24	-0.83	-0.80 , 0.33		
4 th quintile	-0.06	-0.17	-0.81 , 0.69		
Most walkable quintile	-0.10	-0.29	-0.76 , 0.57		
Population density (persons per hectare)					
Ref: Least populous quintile	-	-	-		
2 nd quintile	0.31	1.07	-0.27 , 0.89	.36	.09
3 rd quintile	-0.12	-0.47	-0.61 , 0.37		
4 th quintile	-0.16	-0.56	-0.72 , 0.40		
Most populous quintile	-0.27	-1.01	-0.79 , 0.25		
Green spaces (% per hectare)					
Ref: Least vegetation	-	-	-		
2 nd quintile	0.28	1.10	-0.22 , 0.77	.39	.08
3 rd quintile	-0.21	-0.99	-0.64 , 0.22		
4 th quintile	0.13	0.55	-0.32 , 0.58		
Most vegetation	-0.04	-0.15	-0.54 , 0.46		
Convenience stores[‡]					
Ref: lowest no. of outlets	-	-	-		
2 nd quintile	0.43	1.63	-0.09 , 0.95	.10	.10
3 rd quintile	0.01	0.04	-0.43 , 0.45		
4 th quintile	0.44	1.71	-0.07 , 0.95		
Highest no. of outlets	0.53	2.09	0.03 , 1.03		
Supermarkets[‡]					
Ref: Lowest no. of outlets	-	-	-		
2 nd tertile	0.22	1.04	-0.20 , 0.65	.47	.06
Highest no. of outlets	-0.05	-0.26	-0.48 , 0.37		
Off-licences[‡]					
Ref: lowest no. of outlets	-	-	-		
2 nd quintile	-0.25	-0.83	-0.83 , 0.34	.85	.06
3 rd quintile	-0.24	-0.90	-0.76 , 0.29		
4 th quintile	-0.31	-1.13	-0.87 , 0.24		
Highest no. of outlets	-0.20	-0.68	-0.78 , 0.38		
Fast food outlet[‡]					
Ref: lowest no. of outlets	-	-	-		
2 nd quintile	0.21	0.70	-0.38 , 0.80	.54	.07
3 rd quintile	-0.10	-0.41	-0.59 , 0.38		
4 th quintile	-0.23	-1.01	-0.68 , 0.22		
Highest no. of outlets	0.09	0.37	-0.37 , 0.55		

[‡] Services and retail outlets per 100,000 population; P values are for linear trend

Table 5.6 Final multivariable OLS regression models for SMR and all built environment exposure variables

Built environment exposure	β Coef.	<i>T</i>	95% CI	<i>p</i>	<i>R</i> ²
Index of multiple deprivation rank score					
Reference group: Least deprived quintile	-	-	-		
2 nd quintile	0.12	0.44	-0.42 , 0.66	.09	.25
3 rd quintile	0.13	0.44	-0.46 , 0.73		
4 th quintile	0.79	2.40	0.14 , 1.45		
Most deprived quintile	0.31	0.74	-0.53 , 1.16		
Neighbourhood walkability (z score)					
Ref: Least walkable quintile	-	-	-		
2 nd quintile	-0.04	-0.13	-0.64 , 0.56	.61	
3 rd quintile	-0.42	-1.22	-1.11 , 0.26		
4 th quintile	-0.07	-0.17	-0.92 , 0.78		
Most walkable quintile	-0.37	-0.83	-1.24 , 0.51		
Population density (persons per hectare)					
Ref: Least populous quintile	-	-	-		
2 nd quintile	0.36	1.25	-0.21 , 0.93	.50	
3 rd quintile	-0.19	-0.63	-0.78 , 0.41		
4 th quintile	-0.25	-0.71	-0.93 , 0.44		
Most populous quintile	-0.25	-0.72	-0.93 , 0.44		
Green spaces (% per hectare)					
Ref: Least vegetation	-	-	-		
2 nd quintile	0.37	1.27	-0.21 , 0.94	.43	
3 rd quintile	-0.13	-0.52	-0.64 , 0.38		
4 th quintile	-0.01	-0.02	-0.53 , 0.52		
Most vegetation	-0.20	-0.58	-0.86 , 0.47		
Convenience stores[‡]					
Ref: lowest no. of outlets	-	-	-		
2 nd quintile	0.58	2.00	0.01 , 1.14	.03	
3 rd quintile	0.44	1.53	-0.13 , 1.01		
4 th quintile	0.92	2.71	0.25 , 1.59		
Highest no. of outlets	1.27	2.70	0.34 , 2.20		
Supermarkets[‡]					
Ref: Lowest no. of outlets	-	-	-		
2 nd tertile	0.29	1.28	-0.16 , 0.74	.33	
Highest no. of outlets	-0.04	-0.19	-0.51 , 0.43		
Off-licences[‡]					
Ref: lowest no. of outlets	-	-	-		
2 nd quintile	-0.63	-0.80	-0.80 , 0.42	.86	
3 rd quintile	-0.69	-0.85	-0.85 , 0.41		
4 th quintile	-0.76	-0.90	-0.90 , 0.40		
Highest no. of outlets	-0.11	-0.78	-0.78 , 0.70		
Fast food outlet [‡]					
Ref: lowest no. of outlets	-	-	-		
2 nd quintile	0.06	0.18	-0.61 , 0.73	.15	
3 rd quintile	-0.42	-1.44	-1.00 , 0.16		
4 th quintile	-0.67	-2.00	-1.34 , -0.01		
Highest no. of outlets	-0.68	-1.94	-1.37 , 0.01		

[‡] services and retail outlets per 100,000 population; P value is for linear trend

Regression analyses assessing the relationship between the standardised mortality ratios and the social environment variables

[Tables 5.7 – 5.8](#) shows the regression models for the social environment variables and SMRs. Both the unadjusted models ([Appendix 6](#)) and the adjusted models in [Table 5.7](#) and [5.8](#) suggest no correlation between the social environment variables and SMRs. In [Table 5.7](#), following adjustment for area-level deprivation only, no correlations were found between the social environment variables and SMRs. In [Table 5.8](#), the coefficients from the final multivariable regression model are presented which included all three social environment factors and were adjusted for area-level deprivation. No correlations were noted in this model.

Table 5.7 OLS regression models for SMR and each social environment exposure variables adjusted for area-level deprivation

Social environment exposure	β Coef.	<i>T</i>	95% CI	<i>p</i>	<i>R</i> ²
Social fragmentation (z score)					
Reference group: Least fragmented quintile	-	-	-		
2 nd quintile	0.39	1.36	-0.18 , 0.97	.70	.07
3 rd quintile	0.20	0.74	-0.33 , 0.72		
4 th quintile	0.30	1.09	-0.24 , 0.84		
Most fragmented quintile	0.25	1.02	-0.23 , 0.73		
Ethnic density (%)					
Ref group: Least ethnically dense	-	-	-		
2 nd quintile	0.32	1.15	-0.23 , 0.87	.13	.09
3 rd quintile	-0.14	-0.52	-0.69 , 0.40		
4 th quintile	0.43	1.44	-0.16 , 1.01		
Most ethnically dense	0.01	0.02	-0.60 , 0.61		
Places of worship (PW) *					
Ref group: lowest no. of PWs	-	-	-		
2 nd quintile	0.07	0.26	-0.43 , 0.56	.79	.07
3 rd quintile	0.30	1.02	-0.28 , 0.89		
4 th quintile	0.28	0.97	-0.29 , 0.85		
Highest no. of PWs	0.18	0.80	-0.27 , 0.64		

*Places of worship per 100,000 population; P value is for linear trend

Table 5.8 Final multivariable OLS regression models for SMR and all social environment exposure variables and adjusted for area-level deprivation

Social environment exposure	β Coef.	<i>T</i>	95% CI	<i>p</i>	<i>R</i> ²
Social fragmentation (z score)					
Reference group: Least fragmented quintile	-	-	-		
2 nd quintile	1.53	-0.13	-0.13 , 1.02	.66	.13
3 rd quintile	0.64	-0.36	-0.36 , 0.71		
4 th quintile	0.73	-0.34	-0.34 , 0.73		
Most fragmented quintile	0.74	-0.32	-0.32 , 0.70		
Ethnic density (%)					
Ref group: Least ethnically dense	-	-	-		
2 nd quintile	0.97	-0.31	-0.31 , 0.89	.09	
3 rd quintile	-0.70	-0.89	-0.89 , 0.42		
4 th quintile	1.32	-0.22	-0.22 , 1.11		
Most ethnically dense	-0.11	-0.73	-0.73 , 0.66		
Places of worship (PW) *					
Ref group: lowest no. of PWs	-	-	-		
2 nd quintile	0.15	-0.46	-0.46 , 0.53	.79	
3 rd quintile	1.00	-0.27	-0.27 , 0.82		
4 th quintile	0.95	-0.31	-0.31 , 0.88		
Highest no. of PWs	0.74	-0.26	-0.26 , 0.58		

*Places of worship per 100,000 population; P value is for linear tr

6.5 5.5 Summary of findings and conclusion

This study found significantly higher standardized mortality ratios (SMRs) in persons with severe mental illnesses (SMI) compared to the general population. This finding is consistent with previous research (Hjorthøj, Stürup, McGrath, & Nordentoft, 2017; Saha, Chant, & McGrath, 2007) and highlights the pressing need to address premature mortality among individuals with SMI.

Further analyses using Global Moran's I and hot spot analyses indicated that there was no significant spatial clustering of the SMRs that were measured at the middle super output area level within the study catchment area. Across the entire study catchment area, spearman coefficients suggested a weak correlation between neighbourhoods with higher levels of deprivation and higher SMRs with observed nuances in these correlations at the borough level – for the borough of Croydon, the correlation between higher deprivation and higher SMR was more pronounced. However, in Lewisham and Southwark, higher levels of social fragmentation and higher numbers of convenience stores were correlated with higher SMRs. Additionally, regression analyses, indicated no correlation between most of these neighbourhood-level variables and the SMRs except for convenience stores. Fully adjusted models indicated that neighbourhoods with higher numbers of convenience stores were linked to higher SMRs despite no correlation being flagged in the crude model.

Some of the findings are consistent with studies identified in the systematic review that also found no association between area-level deprivation (Das-Munshi et al., 2019; 2017; Hayes et al., 2012), population density (Das-Munshi et al., 2019; 2017; Moreno-Küstner et al., 2020; Luo et al., 2020), and social fragmentation (Das-Munshi et al., 2019; 2017) and mortality. However, the findings contrast with previous research conducted within the general population that have found associations between area-level deprivation (Seaman et al., 2019), neighbourhood walkability (Kamath et al., 2020), population density (Tunstall et al., 2012), green space (Wang & Tassinari, 2019), food outlets (Kelli et al., 2017), alcohol outlets (Matheson et al., 2014), social fragmentation (Evans et al., 2004), ethnic density (Rodriguez et al., 2018) and mortality outcomes. The contrast in findings indicate that neighbourhood-level variables impact people with and without SMI differentially and that there may be other underlying mechanisms influencing these associations. For example, individuals with SMI may experience difficulties in accessing services and amenities in their neighbourhood because of the threat of victimisation (De Vries et al., 2019), inaccessibility of services and/or reduced insight into their mental health needs (Smith et al., 2013). Differences in the findings are also likely attributable to differences in study design and methodologies.

Strengths

To my knowledge this is the first ecological study to investigate the relationship, at the ecological level, between built and social environment variables and SMRs in SMI and within an urbanised inner-city location. Unlike previous investigations, this study included geospatial analyses to visualise distributions of both the SMR and the neighbourhood-level indicators. It also included spatial autocorrelation analyses to detect potential geographical clustering in the SMR.

Furthermore, by considering the SMR derived from mortality data in a cohort of people with SMI and comparing to mortality data from the general population of England and Wales, the study can take a broad, descriptive view of whether correlations exist between the SMR and the neighbourhood-level variables at the middle super output area level. This level of analysis provides a useful adjunct to other types of studies in this field, which includes more detailed longitudinal research (Hayes et al., 2012; Das-Munshi et al., 2019; 2017) and other qualitative investigations (Dinnie, Brown & Morris, 2013). It contributes to the diverse set of methodological and interdisciplinary approaches necessary for understanding the influence of environmental factors on population health (Franco et al, 2015).

Limitations

The primary limitation of this study arises from the inability to generalise the findings obtained from data aggregated at the middle super output area level to the individual level, a challenge in drawing inferences referred to as the ecologic fallacy. There is also the possibility of residual confounding within the analyses. Confounding arises in statistical analysis when an extraneous variable affects both the outcome variable and the exposure variable. To mitigate the risk of spurious correlations, it is common practice to account for potential confounding variables by including them as covariates in statistical analyses. Within the adjusted regression analyses, only the effect of area-level deprivation was adjusted for when investigating the relationship between both the built and social environment variables.

The lack of associations found between the urban built and social environment indicators may reflect the characteristics of the study catchment area. As shown in [table 5.2](#), the study catchment areas exhibited a notable degree of similarity with regard to area-level deprivation and several other indicators related to the built and social environment, however differed significantly from the national-level characteristics. The limited variation in these built and social environment indicators may have contributed to the lack of evidence of a relationship between the environment variables and the SMRs.

Findings relating to the unadjusted spatial autocorrelation analyses may reflect Type 1 error. The potential of this error occurring is two-fold. Firstly, the risk of identifying false-positive geographical clusters is increased through multiple testing of the data. Secondly, neighbourhood-level features (i.e. SMR) that are located near to each other tend to be similar; more often than not spatial data exhibits this type of dependency. This spatial dependency is particularly pronounced when using local pattern analysis tools like the Getis-Ord GI* statistic. These tools evaluate each feature in the context of its neighbouring features, and since nearby features often share many of the same neighbours, this shared proximity intensifies spatial dependency. Consequently, it elevates the risk of incorrectly rejecting the null hypothesis. To address this, I applied the false discovery rate correction.

However, after the false discovery rate correction was applied to the Getis-Ord GI* analyses to reduce the likelihood of false positives, the spatial clusters that had been identified in the unadjusted analyses were no longer significant. These findings may reflect a type 2 error. This could be linked to the geographical unit used for the spatial autocorrelation analyses. The relatively low numbers of mortality events in the SMI cohort meant that the data was aggregated to a larger geographical area. This decision was made to avoid potential issues relating to insufficient statistical power for detecting significant clustering among the SMR and subsequent regression analyses which might have occurred if a smaller geographical unit (e.g. lower super output area) had been used. However, the analyses back up the Global Moran's I test which also indicated that overall, there were no spatial clustering across the study catchment boroughs.

Conclusion

In summary, the findings of this study indicate that, within the study catchment area, individuals with SMI experience higher mortality than expected compared to the general population without these diagnoses, as demonstrated by the standardized mortality ratios (SMR). Correlations between SMR and the built and social environment variables were not evidenced at the middle super output area (MSOA). However, considering that these correlations were examined at the MSOA level, it would be advantageous to further take into account individual-level factors. This additional investigation could help determine whether similar relationships exist at the individual level while also accounting for the influence of individual-level factors not considered in the ecological analyses. In the following chapters this will be explored from within a multi-level modelling framework.

Chapter 5 Summary Points

- Prior research has indicated that individuals with severe mental illnesses (SMI) experience a significant reduction in life expectancy compared to the general population.
- There has been limited research investigating the relationship between urban built and social environment indicators and risk of mortality in SMI.
- Congruent with findings from previous investigations, this study found significantly higher standardized mortality ratios (SMR) in persons with SMI compared to the general population.
- Hot spot analyses indicated that there was no significant spatial autocorrelation of the SMRs that were measured at the middle super output area level.
- Fully adjusted ecological regression models indicated that measures of the urban built and social environment indicators were not correlated with the SMRs.
- Goodness of fit statistics indicated that the regression models accounted for a small proportion of the variance in the SMRs.

Chapter 6: Study 3 – Proportion of neighbourhood amenities and mortality analyses

6.1 Introduction

Ecological analyses documented in the previous chapter indicated significantly higher standardised mortality ratios (SMRs) in persons with severe mental illnesses (SMI) when compared to the general population. Preliminary visual inspections of the mapped distributions of the SMRs and area-level factors showed spatial clustering of the SMR values and the area-level factors. Notably, area-level deprivation and several other area-level factors such as population density, neighbourhood walkability, and ethnic density exhibited similar spatial patterns. For instance, areas with higher levels of deprivation tended to have higher population densities compared to less deprived areas. Subsequent regression analyses indicated no evidence of associations between neighbourhood-level variables and increased risk of all-cause mortality in individuals with SMI. However, associations observed at the middle super output area (MSOA) level may not be generalisable at the individual-level, known as ecological fallacy (in Das-Munshi, 2020). Therefore, this chapter will explore the association of these urban built and social environment factors with all-cause and cause-specific mortality outcomes using two statistical methods: (1) the association between all-cause mortality and the urban built and environment factors will be investigated using multilevel modelling analyses and (2) associations between cause-specific mortality outcomes and the urban built and social environment factors will be assessed using a modified cox regression analyses.

Studies conducted using cohorts from the general population have indicated that residence in neighbourhoods with higher levels of green spaces (Kua et al., 2021), improved walkability (Lang et al., 2022), and greater availability of healthy food outlets (e.g. supermarkets) confer protective benefits for mortality and other health outcomes (Kelli et al., 2019). In contrast, residence in neighbourhoods characterized by diminished social cohesion and weaker social networks has been linked to a higher risk of suicide within the general population (Evans, Middleton & Gunnell, 2004; Congdon, 2012). This heightened suicide risk has been attributed to the reduced capacity of community members to provide appropriate support (Ivory et al., 2012). The systematic review ([Chapter 3](#)) indicated that associations between deprivation and mortality in SMI was most consistently demonstrated when compared with other investigated associations and is also consistent with research conducted within the general population. Whilst one study demonstrated a protective effect of area-level ethnic density and the risk of mortality in the SMI cohort (Das-Munshi et al., 2017). However, the review indicated a dearth of studies investigating the impact of other urban built and social environment indicators in SMI.

Therefore, the aim of this chapter is to investigate the degree to which aspects of the built and social environment measured at the area-level contribute to mortality in SMI whilst accounting for the influence of other individual-level factors.

The research question is:

- To what extent do the built and social area-level factors influence the risk of all-cause and cause-specific mortality among people with SMI, taking into account individual-level sociodemographic indicators and clinical factors in the study catchment areas?

Hypotheses:

Based on previous research discussed in the introduction section and the ecological analyses, I hypothesized that:

- Neighbourhoods with higher levels of deprivation would be associated with higher risk of all-cause mortality and cause-specific mortality in individuals with SMI residing in these areas;
- Individuals with SMI residing in neighbourhoods with increased availability of convenience stores would be more likely to face an elevated risk of natural-cause mortality.
- Neighbourhoods with increased walkability, availability of green spaces and supermarkets would be associated with a lower risk of natural-cause mortality among individuals with SMI.
- Neighbourhoods with reduced levels of social cohesion and social networks (as measured by area-level social fragmentation, ethnic density and number of places of worship) would be associated with an increased risk of unnatural-cause mortality in individuals with SMI.

6.2 Summary of methods

I have described the cohort study design (see [Section 4.2](#) and [Table 4.1](#)), the exposure variables (see [Section 4.4](#)), mortality outcome ([Section 4.3](#)) and the multilevel modelling approach (see [Section 4.9](#)) used to investigate associations between the urban built and social environment indicators and mortality in the SMI cohort. In this chapter, I developed a cohort study comprising of individuals that were diagnosed with an SMI (defined here as schizophrenia spectrum disorder (ICD-10 codes: F20-F29) or bipolar disorder (ICD-10 codes: F30 and F31) within the study observation period (from January 1, 2007, to December 31, 2018). Participants were followed up until either death, migration from the cohort or the end of the study period (i.e., 31st December

2018). The cohort study only included individuals with an SMI diagnosis, which meant that all subsequent analyses explored how reduced exposure to several urban built and social environment indicators influenced the risk of mortality compared with those with greater exposure to these environmental factors within the cohort.

6.3 Statistical methods

Descriptive statistics (i.e. crude rates per 1,000 person years) were calculated for each urban built and social environment indicator, individual-level covariates and mortality outcomes using the *strate* command in Stata.

Age was modelled as a time-varying covariate by transforming the data from a single observation per subject into multiple observations per specified age band (i.e. 15-24, 25-34, 35-44, 45-54, 55-64, 65-74, 75-84 and ≥85 years) – using the process of lexis expansion. This procedure was implemented across both multilevel modelling and the competing risks regressions analyses. Robust standard errors were used to adjust for clustering at the MSOA level and Wald tests were used for hypothesis testing across both sets of analyses.

All-cause mortality (Poisson regression multi-level modelling approaches)

Data analysis was carried out using a multilevel modelling (MLM) approach. This statistical technique is advantageous for analysing data that exhibit a hierarchical or nested structure (Rasbash, 2023). Cohort members who reside in the same area (MSOA) may share similar levels of exposure to neighbourhood-level attributes (e.g. retail outlets, green spaces) and exposure to these attributes may differ between neighbourhoods (e.g. due to differences in availability of these attributes across neighbourhoods). These neighbourhood-level differences in exposure may, in turn, may contribute to potential differences in mortality outcomes among cohort members alongside other individual-level characteristics (e.g. substance misuse). Hence, the MLM approaches enables researchers to model the variability at both the individual and neighbourhood level and the impact this has on mortality outcomes. Hence the MLM approach enables researchers to understand how much of the variance in the outcome is attributed to unobserved variables at both the area- and individual-level.

The multilevel modelling analyses was based on the CSDH framework of the hierarchy of determinants of health (Solar & Irwin, 2010), according to the method proposed by Victora and colleagues (1997). After modelling the crude/ unadjusted association between the mortality outcomes and the urban built and social environment exposures in the cohort of people with severe mental illnesses, subsequent models adjusted for blocks of individual- and neighbourhood-level covariates as follows: area-level deprivation, sociodemographic indicators (i.e. age, sex,

ethnicity and marital status) and clinical factors at the individual-level (i.e. SMI diagnosis and substance misuse). Complete case analysis was used to handle missing data in the study.

Associations between the area-level factors and all-cause mortality were assessed using multilevel Poisson regression was conducted using the *mepoisson* command in Stata, with individuals nested within MSOAs specified as the level of analysis.

Cause-specific mortality outcomes using competing risks regression

Competing risks regression was used to model the associations between area-level factors and (1) natural- and (2) unnatural-cause mortality. The *stcrreg* command in Stata was used for this purpose. This statistical method estimates sub-hazard ratios for deaths attributed to a specific cause, whilst taking into consideration the concurrent risk of dying from another cause during the study observation window. Associations between individual-level covariates and mortality outcomes are included in [Appendices 7-9](#). The proportional hazards assumptions were assessed using Schoenfeld-like residual plots.

Procedure

Regression models were separated according to the classification of the area-level variables: (1) built environment models and (2) social environment models. The built environment models include the following area-level factors: neighbourhood walkability, population density, green spaces, supermarkets, convenience stores, fast-food outlets and alcohol outlets. The social environment models includes area-level social fragmentation, ethnic density and places of worship.

Firstly, to determine the suitability of using MLM analyses with the dataset, two “empty” models (i.e. models without predictor variables) were fitted: model 1 was an empty multilevel Poisson regression model and model 2 was an empty single-level Poisson model (Leckie et al., 2020). The fit of models 1 and 2 were compared using likelihood ratio tests which indicated that model 1 was a better fit for the dataset. From this point onwards, the extent of the clustering for each model was assessed by calculating the variance partition coefficients (VPCs; Goldstein, Browne, & Rasbash, 2002) which shows the proportion of the overall variation in the mortality outcome that can be attributed to (1) differences between the MSOAs and (2) between individual cohort members (Leckie et al., 2020; Merlo et al., 2006). The VPC was calculated using the formulae below. The total individual variance is made up of two parts: the variance in mortality outcomes between the MSOAs (V_m) and the variance between cohort members (V_i).

$$\text{VPC} = 100 \times \frac{V_m}{V_m + V_i}$$

Formula to calculate the between-MSOA variance

The VPC is expressed as a percentage. Higher VPCs for the variance between MSOAs indicate significant variation in the mortality outcome that can be attributed to MSOAs. On the other hand, smaller VPCs means that any differences between geographic areas are much smaller compared to the individual differences within each area. The VPCs were calculated for each subsequent model iteratively as predictors and covariates were added to the model (see [Appendices 10 -11](#)).

Deviance statistics were also reported as a measure of goodness of fit of the models – lower values of the deviance statistic indicates better model fit.

Sensitivity analyses

As described in the [Chapter 4](#), sensitivity analyses were performed to assess the potential impact of participant emigration before the study's end date on the association between the area-level variables and all-cause mortality. Using competing risks regression, emigration out of the cohort prior to the study end date was specified as a competing risk factor against all-cause mortality.

For more detailed information of methods used in this section please see: [Chapter 4](#) for the methodology. The protocol for this study has been registered on the Open Science Framework website (see: <https://osf.io/3jspv> for further information).

6.4 Results

25,874 patients with a diagnosis of SMI and a recorded MSOA residential code were identified from the initial CRIS data extraction. After excluding individuals with incomplete data, 22,689 were included in the cohort, contributing a median follow-up of 6.4 years (IQR 2.9 – 10.1). 12.8% of the cohort (n = 2,911) had died by the end date for the study observation period (31st December 2018) (see figure 6.1).

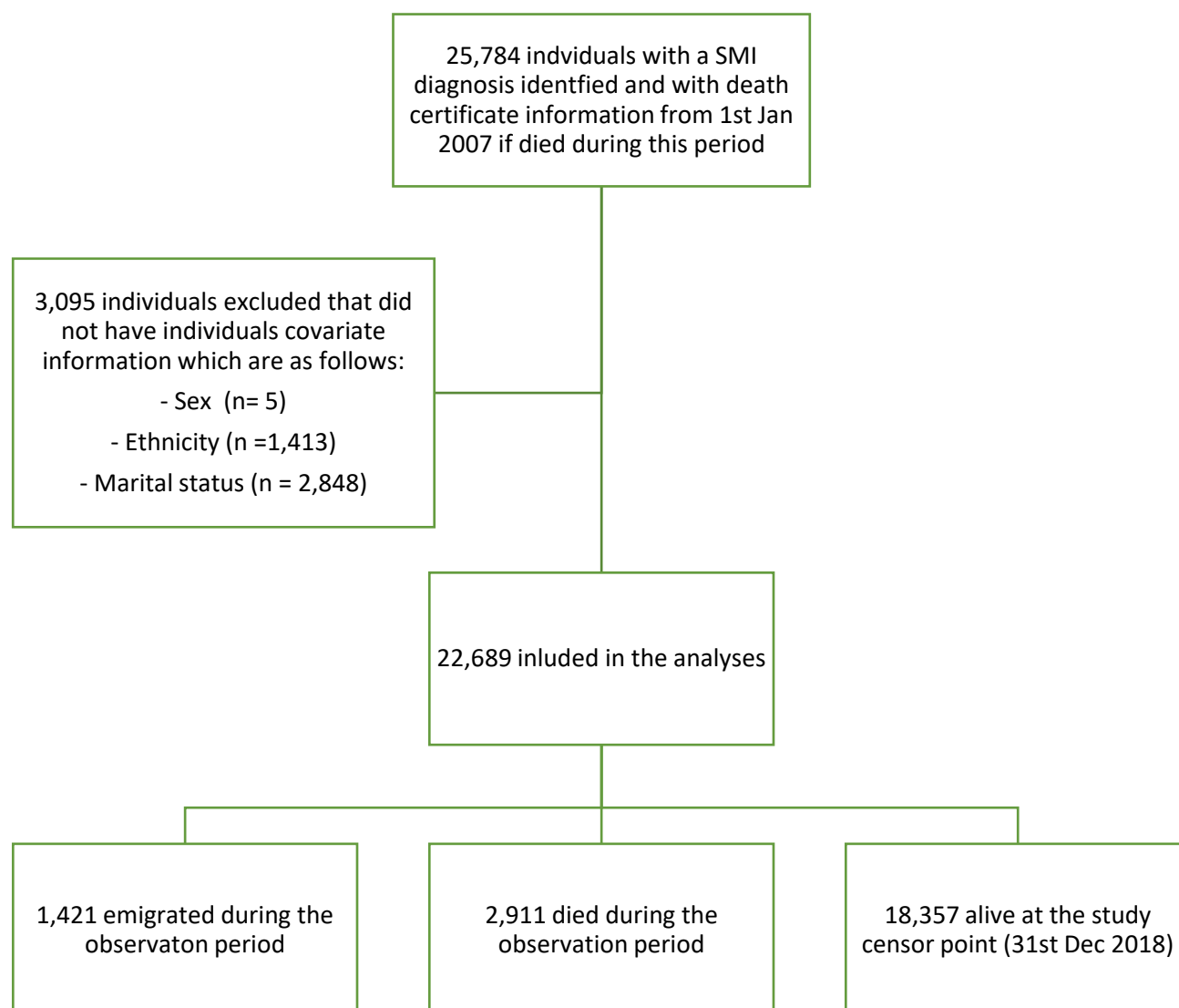


Figure 6.1 Cohort selection

[Table 6.1](#) shows descriptive characteristics of the study cohort. The median year of birth for the cohort was 1968 (IQR=1957 – 1980), 51% were male, and 72.5% had a diagnosis of a non-affective disorder. By the end of the follow-up period, 14.7% (n=2,911) of the cohort had died, of which 11.9% (n = 2,352) of the cohort had died due to natural causes and 1.7% (n= 336) had died of unnatural causes. 1% (n = 223) participants had died but their deaths were classified as ‘not otherwise specified’ (ICD-10 codes: R00-R99). 80% (n=2,352) of deaths recorded in the cohort were attributable to physical health conditions. There was considerable variability in terms of the area-level exposures, which included (but not limited to) the number of convenience stores ranged from 0 to ≥153 stores per 100,000 population and the percentage of residential areas comprised of open-access green spaces ranged from .08% to 49%.

Table 6.1 Descriptive characteristics of the cohort, included area-level exposures and crude mortality rates

	Total sample	All-cause mortality		Natural-cause mortality		Unnatural-cause mortality	
	N(%)	N (%)	Crude rate* (95% CI)	N (%)	Crude rate* (95% CI)	N (%)	Crude rate* (95% CI)
Total	22,689 (100)	2,911 (12.8)	17 (16.4 – 17.7)	2,352 (10.4)	14 (13.2 – 14.3)	336 (1.5)	2 (1.8 – 2.2)
Area-level exposure variables							
Area-level deprivation rank score							
≤538 (most deprived)	4,531 (20.0)	567 (2.5)	17 (15.3 - 18.1)	463 (2.0)	14 (12.5 - 15.0)	66 (0.3)	2 (1.5 - 2.5)
1,002	4,443 (19.6)	580 (2.6)	17 (16.1 - 19.0)	468 (2.1)	14 (13.0 - 15.6)	69 (0.3)	2 (1.7 - 2.7)
1,420	4,479 (19.7)	543 (2.4)	16 (14.7 - 17.4)	427 (1.9)	13 (11.5 - 14.0)	68 (0.3)	2 (1.6 - 2.6)
2,007	4,567 (20.1)	586 (2.6)	16 (15.4 - 18.2)	469 (2.1)	13 (12.3 - 14.8)	75 (0.3)	2 (1.7 - 2.7)
≥2,667 (least deprived)	4,669 (20.6)	635 (2.8)	18 (17.0 - 19.8)	525 (2.3)	15 (14.1 - 16.7)	58 (0.3)	2 (1.3 - 2.2)
N'hood walkability (z score)							
≤-9.3 (least walkable)	4,530 (20.0)	635 (2.8)	19 (17.6 - 20.6)	514 (2.9)	16 (14.3 - 16.9)	65 (2.9)	2 (1.5 - 2.5)
-2.4	4,473 (19.7)	611 (2.7)	18 (16.8 - 19.7)	495 (2.6)	15 (13.6 - 16.2)	64 (2.6)	2 (1.5 - 2.5)
-.6	4,597 (20.3)	538 (2.4)	15 (14.0 - 16.5)	424 (2.4)	12 (11.0 - 13.3)	73 (2.4)	2 (1.7 - 2.6)
1.3	4,376 (19.3)	533 (2.3)	16 (14.9 - 17.6)	430 (2.4)	13 (12.0 - 14.5)	68 (2.4)	2 (1.6 - 2.6)
≥3.2 (most walkable)	7,713 (20.8)	594 (2.6)	17 (15.5 - 18.2)	489 (2.6)	14 (12.7 - 15.2)	66 (2.6)	2 (1.5 - 2.4)
Population density (persons per hectare)							
≤13 (least populous)	4,492 (19.8)	647 (2.9)	20 (18.7 - 21.8)	520 (2.9)	16 (15.0 - 17.9)	68 (2.9)	2 (1.7 - 2.7)
68	4,518 (19.9)	582 (2.6)	17 (15.8 - 18.6)	472 (2.6)	14 (12.8 - 15.4)	60 (2.6)	2 (1.4 - 2.3)
89	4,564 (20.1)	546 (2.4)	16 (14.6 - 17.3)	442 (2.4)	13 (11.8 - 14.2)	74 (2.4)	2 (1.7 - 2.7)
107	4,440 (19.6)	549 (2.4)	16 (14.8 - 17.5)	447 (2.4)	13 (12.0 - 14.5)	61 (2.4)	2 (1.4 - 2.3)
≥133 (most populous)	4,675 (20.6)	587 (2.6)	16 (14.9 - 17.5)	471 (2.6)	13 (11.9 - 14.3)	73 (2.6)	2 (1.6 - 2.5)
Green spaces (%)							
≤.08 (least green spaces)	4,507 (19.9)	550 (2.4)	16 (14.6 - 17.2)	451 (2.9)	13 (11.9 - 14.3)	59 (2.9)	2 (1.3 - 2.2)
2.6	4,467 (19.7)	594 (2.6)	17 (16.0 - 18.8)	472 (2.6)	14 (12.7 - 15.2)	73 (2.6)	2 (1.7 - 2.7)
5.6	4,489 (19.8)	557 (2.5)	17 (15.2 - 18.0)	457 (2.4)	14 (12.5 - 15.0)	59 (2.4)	2 (1.4 - 2.3)
10.1	4,669 (20.6)	631 (2.8)	19 (17.1 - 20.0)	514 (2.4)	15 (13.9 - 16.6)	77 (2.4)	2 (1.8 - 2.8)
≥16.8 (most green spaces)	4,557 (20.1)	579 (2.6)	17 (15.7 - 18.5)	458 (2.6)	14 (12.4 - 14.9)	68 (2.6)	2 (1.6 - 2.6)
Supermarkets (n)†							
0 (lowest number)	13,545 (59.7)	1709 (7.5)	17 (15.9 - 17.5)	1,374 (6.1)	13 (12.7 - 14.1)	202 (0.9)	2 (1.7 - 2.3)
9	4,528 (20.0)	577 (2.5)	17 (15.7 - 18.4)	469 (2.1)	14 (12.6 - 15.1)	66 (0.3)	2 (1.5 - 2.5)
≥14 (highest number)	4,616 (20.3)	625 (2.8)	18 (16.8 - 19.7)	509 (2.2)	15 (13.6 - 16.2)	68 (0.3)	2 (1.6 - 2.5)
Off-licenses (n) †							

	Total sample	All-cause mortality		Natural-cause mortality		Unnatural-cause mortality	
	N(%)	N (%)	Crude rate* (95% CI)	N (%)	Crude rate* (95% CI)	N (%)	Crude rate* (95% CI)
0 (lowest number)	4,428 (19.5)	603 (2.7)	19 (17.1 - 20.1)	479 (2.1)	15 (13.5 - 16.1)	75 (0.3)	2 (1.8 - 2.9)
10	4,584 (20.2)	550 (2.4)	16 (14.6 - 17.2)	448 (2.0)	13 (11.8 - 14.2)	63 (0.3)	2 (1.4 - 2.3)
13	4,496 (19.8)	616 (2.7)	18 (17.0 - 19.9)	493 (2.2)	15 (13.5 - 16.1)	72 (0.3)	2 (1.7 - 2.7)
22	4,525 (19.9)	548 (2.4)	16 (14.6 - 17.2)	449 (2.0)	13 (11.8 - 14.2)	59 (0.3)	2 (1.3 - 2.2)
≥34 (highest number)	4,656 (20.5)	594 (2.6)	17 (15.5 - 18.2)	483 (2.1)	14 (12.5 - 14.9)	67 (0.3)	2 (1.5 - 2.4)
Convenience stores (n) †							
0 (lowest number)	4,522 (19.9)	601 (2.6)	18 (16.2 - 19.0)	487 (2.1)	14 (13.0 - 15.5)	66 (0.3)	2 (1.5 - 2.4)
59	4,525 (19.9)	621 (2.7)	18 (17.0 - 19.9)	489 (2.2)	14 (13.2 - 15.8)	75 (0.3)	2 (1.8 - 2.8)
84	4,462 (19.7)	528 (2.3)	15 (14.2 - 16.8)	429 (1.9)	13 (11.4 - 13.8)	62 (0.3)	2 (1.4 - 2.3)
110	4,576 (20.2)	624 (2.8)	18 (17.1 - 20.0)	511 (2.3)	15 (13.9 - 16.5)	72 (0.3)	2 (1.7 - 2.7)
≥153 (highest number)	4,604 (20.3)	537 (2.4)	15 (14.2 - 16.9)	436 (1.9)	13 (11.5 - 13.8)	61 (0.3)	2 (1.4 - 2.3)
Fast-food outlets (n) †							
0 (lowest number)	4,461 (19.7)	629 (2.8)	19 (17.3 - 20.2)	502 (2.2)	15 (13.7 - 16.3)	70 (0.3)	2 (1.6 - 2.6)
30	4,563 (20.1)	583 (2.6)	17 (15.8 - 18.5)	472 (2.1)	14 (12.6 - 15.1)	66 (0.3)	2 (1.5 - 2.5)
75	4,549 (20.1)	608 (2.7)	18 (16.4 - 19.2)	480 (2.1)	14 (12.8 - 15.3)	84 (0.4)	2 (2.0 - 3.0)
106	4,378 (19.3)	535 (2.4)	16 (14.8 - 17.6)	436 (1.9)	13 (12.0 - 14.4)	59 (0.3)	2 (1.4 - 2.3)
≥144 (highest number)	4,738 (20.9)	556 (2.5)	16 (14.4 - 17.0)	462 (2.0)	13 (11.9 - 14.2)	57 (0.3)	2 (1.2 - 2.1)
Social fragmentation (z score)							
-7.3 (least fragmented)	4,381 (19.3)	602 (2.7)	19 (17.7 - 20.8)	491 (2.2)	16 (14.3 - 17.1)	63 (0.3)	2 (1.6 - 2.6)
-1.9	4,684 (20.6)	606 (2.7)	17 (15.8 - 18.5)	492 (2.2)	14 (12.7 - 15.1)	72 (0.3)	2 (1.6 - 2.6)
-.39	4,458 (19.7)	572 (2.5)	17 (15.5 - 18.3)	475 (2.1)	14 (12.8 - 15.3)	51 (0.2)	2 (1.1 - 2.0)
1.5	4,608 (20.3)	580 (2.6)	17 (15.3 - 18)	453 (2)	13 (11.8 - 14.2)	78 (0.3)	2 (1.8 - 2.8)
≥3.4 (most fragmented)	4,558 (20.1)	551 (2.4)	16 (14.5 - 17.1)	441 (1.9)	13 (11.5 - 13.8)	72 (0.3)	2 (1.6 - 2.6)
Ethnic density (%)							
14 (least ethnically dense)	4,373 (19.3)	580 (2.6)	18 (16.3 - 19.2)	485 (2.1)	15 (13.5 - 16.2)	53 (0.2)	2 (1.2 - 2.1)
37	4,585 (20.2)	611 (2.7)	18 (16.3 - 19.2)	492 (2.2)	14 (13 - 15.6)	71 (0.3)	2 (1.6 - 2.6)
42	4,616 (20.3)	597 (2.6)	17 (15.7 - 18.4)	489 (2.2)	14 (12.7 - 15.2)	65 (0.3)	2 (1.4 - 2.4)
50	4,475 (19.7)	586 (2.6)	17 (16 - 18.8)	469 (2.1)	14 (12.7 - 15.2)	74 (0.3)	2 (1.7 - 2.7)
≥60 (most ethnically dense)	4,640 (20.5)	537 (2.4)	16 (14.3 - 17)	417 (1.8)	12 (11 - 13.3)	73 (0.3)	2 (1.7 - 2.7)
Places of worship (n) †							
0 (lowest number)	4,539 (20.0)	601 (2.6)	18 (16.5 - 19.4)	482 (2.1)	14 (13.1 - 15.7)	62 (0.3)	2 (1.4 - 2.4)
23	4,468 (19.7)	541 (2.4)	16 (15 - 17.8)	430 (1.9)	13 (11.8 - 14.3)	70 (0.3)	2 (1.7 - 2.7)
33	4,555 (20.1)	587 (2.6)	17 (15.6 - 18.3)	477 (2.1)	14 (12.6 - 15.0)	69 (0.3)	2 (1.6 - 2.5)
50	4,515 (19.9)	603 (2.7)	17 (16.1 - 18.9)	492 (2.2)	14 (13.0 - 15.5)	74 (0.3)	2 (1.7 - 2.7)

	Total sample	All-cause mortality			Natural-cause mortality		Unnatural-cause mortality	
	N(%)	N (%)	Crude rate* (95% CI)		N (%)	Crude rate* (95% CI)	N (%)	Crude rate* (95% CI)
≥65 (highest number)	4,612 (20.3)	579 (2.6)	17 (15.3 - 18.1)		471 (2.1)	14 (12.4 - 14.8)	61 (0.3)	2 (1.4 - 2.3)
Individual-level covariates								
Sociodemographic variables								
Age (at diagnosis)								
15-24	3,558 (15.7)	78 (0.3)	3 (2.5 - 3.9)		23 (0.1)	1 (0.6 - 1.4)	52 (0.2)	2 (1.6 - 2.8)
25-34	5,539 (24.4)	196 (0.9)	5 (4.0 - 5.4)		108 (0.5)	3 (2.1 - 3.1)	84 (0.4)	2 (1.6 - 2.5)
35-44	5,269 (23.2)	375 (1.7)	9 (7.7 - 9.4)		281 (1.2)	6 (5.7 - 7.2)	84 (0.4)	2 (1.5 - 2.4)
45-54	3,811 (16.8)	456 (2)	15 (13.5 - 16.2)		395 (1.7)	13 (11.6 - 14.1)	57 (0.3)	2 (1.4 - 2.4)
55-64	2,015 (8.9)	495 (2.2)	33 (30.2 - 36)		458 (2)	31 (27.8 - 33.4)	25 (0.1)	2 (1.1 - 2.5)
65-74	1,372 (6.1)	606 (2.7)	68 (63 - 73.9)		535 (2.4)	60 (55.3 - 65.5)	16 (0.1)	2 (1.1 - 2.9)
75-84	906 (4.0)	533 (2.3)	119 (109.3 - 129.5)		426 (1.9)	95 (86.4 - 100)	15 (0.1)	3 (2.0 - 5.6)
85 & over	219 (1.0)	172 (0.8)	231 (198.5 - 267.7)		126 (0.6)	170 (140 - 200)	3 (0)	4 (1.3 - 12.5)
Sex								
Male	11,655 (51.4)	1,477 (6.5)	16 (15.5 - 17.2)		1,175 (5.2)	13 (12.3 - 13.8)	226 (1)	3 (2.2 - 2.8)
Female	11,034 (48.6)	1,434 (6.3)	18 (16.9 - 18.8)		1,177 (5.2)	15 (13.8 - 15.5)	110 (0.5)	1 (1.1 - 1.6)
Marital status								
Single	15,800 (69.6)	1524 (6.7)	13 (12.1 - 13.4)		1,190 (5.2)	10 (9.4 - 10.5)	259 (1.1)	2 (1.9 - 2.4)
Married or cohabitating	3,547 (15.6)	457 (2)	18 (16.1 - 19.4)		380 (1.7)	15 (13.3 - 16.3)	35 (0.2)	1 (1.0 - 1.9)
Divorced , separated or widowed	3,342 (14.7)	930 (4.1)	37 (34.7 - 39.5)		782 (3.4)	31 (29 - 33.4)	42 (0.2)	2 (1.2 - 2.3)
Ethnicity								
White British	10,868 (47.9)	1,771 (7.8)	22 (21.2 - 23.3)		1,430 (6.3)	18 (17 - 18.9)	203 (0.9)	3 (2.2 - 2.9)
Racialized minority group	11,821 (52.1)	1,140 (5)	13 (11.8 - 13.3)		922 (4.1)	10 (9.5 - 10.8)	133 (0.6)	1 (1.2 - 1.7)
Clinical variables								
Lifetime substance misuse								
No substance misuse	18,989 (83.7)	2,555 (11.3)	18 (17.2 - 18.6)		2,118 (9.3)	15 (14.2 - 15.5)	221 (1.0)	2 (1.4 - 1.8)
Lifetime substance misuse	3,700 (16.3)	356 (1.6)	13 (11.5 - 14.2)		234 (1)	8 (7.4 - 9.5)	115 (0.5)	4 (3.4 - 5.0)
Diagnosis type								
Non-affective	16,444 (72.5)	2,255 (9.9)	18 (17.2 - 18.7)		1,824 (8)	15 (13.9 - 15.2)	248 (1.1)	2 (1.7 - 2.2)
Affective	6,245 (27.5)	656 (2.9)	15 (13.4 - 15.7)		528 (2.3)	12 (10.7 - 12.7)	88 (0.4)	2 (1.6 - 2.4)

*Crude rates are per 1,000 person years; deaths of 223 cohort members were classified as not otherwise specified (R00-R99) and therefore were only included in the analyses for all-cause mortality; † per 100,000 population, *330 cohort members were missing residential change information

All-cause mortality and the urban built environment

[Table 6.2](#) presents the associations between the built environment exposure variables and all-cause mortality in SMI. Unadjusted estimates from model 6.2a demonstrate a protective effect of neighbourhood walkability and population density with all-cause mortality and residence in the areas with the highest numbers of convenience stores (per 100,000 population) were also linked to lower risk of all-cause mortality in the SMI sample. Some of these associations were attenuated after adjusting for area-level deprivation (model 6.2b) except for population density which still showed a protective affect after this adjustment. However, in the latter models that accounted for sociodemographic and clinical indicators, and area-level deprivation (models 6.2c – 6.2f), all previous associations with the three aforementioned neighbourhood-level variables were attenuated. Fully adjusted models for the associations between all-cause mortality and the sociodemographic and individual-level covariates (see [Appendix 7](#) - Model A7.e) indicated higher risk of mortality among older cohort members with incidence risk ratios (IRR) ranging between 1.46 (95% CI: 1.10 – 1.93) and 10.63 (95% CI: 5.52 – 20.50). Those with a history of substance misuse were also indicated to have a higher risk of all-cause mortality (IRR: 1.23, 95% CI: 1.09 – 1.38). Individuals who were married or cohabiting (IRR = 0.80, 95% CI: 0.73 – 0.88), cohort members from racialized minority groups (IRR: 0.80, 95% CI: 0.74 – 0.85) and individuals with affective disorders (IRR: 0.87, 95% CI: 0.80 – 0.94) showed a lower risk of mortality in the fully adjusted models. The effect sizes for the individual-level covariates did not diminish much after accounting for the influence of the urban built and social environment factors.

Table 6.2 Associations between all-cause mortality and the area-level built environment factors in SMI cohort (n = 22,689)

	Model 6.2a			Model 6.2b		Model 6.2c		Model 6.2d		Model 6.2e		Model 6.2f	
	Died (n) / Alive (n)	Crude IRR (95% CI)	p	Adjusted (deprivation) IRR (95%CI)	p	Adjusted (deprivation & sociodemographi c) IRR (95%CI)	p	Adjusted (deprivation & clinical) IRR (95%CI)	p	Adjusted (deprivation, sociodemographi c & clinical) IRR (95%CI)	p	Fully adjusted IRR (95% CI)	p
Built environment variables													
Area-level deprivation (rank score)													
Ref. group: Least deprived quintile	635 / 4,035	-		-		-		-		-		-	
2 nd quintile	586 / 3,981	0.93 (0.80 - 1.08)	.70	-	-	1.01 (0.91 - 1.13)	.40	0.93 (0.80 - 1.08)	.69	1.01 (0.90 - 1.12)	.70	1.03 (0.91 - 1.17)	.76
3 rd quintile	543 / 3,936	0.88 (0.74 - 1.05)		-		1.02 (0.90 - 1.16)		0.88 (0.75 - 1.05)		1.01 (0.90 - 1.15)		1.04 (0.90 - 1.19)	
4 th quintile	580 / 3,863	0.95 (0.80 - 1.11)		-		1.10 (0.98 - 1.25)		0.95 (0.81 - 1.11)		1.09 (0.96 - 1.23)		1.10 (0.94 - 1.29)	
Most deprived quintile	567 / 3,964	0.91 (0.76 - 1.09)		-		1.09 (0.95 - 1.24)		0.91 (0.77 - 1.09)		1.07 (0.94 - 1.22)		1.06 (0.90 - 1.24)	
N'hood walkability (z score)													
Ref: Least walkable quintile	635 / 3,895	-		-		-		-		-		-	
2 nd quintile	611 / 3,862	0.95 (0.81 - 1.11)	.02	0.95 (0.80 - 1.12)	.06	1.04 (0.91 - 1.18)	.29	0.95 (0.81 - 1.12)	.09	1.03 (0.91 - 1.17)	.36	1.04 (0.93 - 1.17)	.52
3 rd quintile	538 / 4,059	0.81 (0.70 - 0.93)		0.78 (0.66 - 0.93)		0.95 (0.84 - 1.07)		0.79 (0.67 - 0.94)		0.94 (0.84 - 1.06)		0.94 (0.82 - 1.09)	
4 th quintile	533 / 3,843	0.84 (0.71 - 1.00)		0.81 (0.65 - 1.01)		1.03 (0.88 - 1.21)		0.82 (0.66 - 1.02)		1.02 (0.87 - 1.20)		1.03 (0.86 - 1.23)	
Most walkable quintile	594 / 4,119	0.87 (0.75 - 1.00)		0.83 (0.69 - 1.00)		1.04 (0.92 - 1.19)		0.85 (0.71 - 1.01)		1.03 (0.90 - 1.17)		1.00 (0.85 - 1.19)	
Population density													
Ref: Least populous quintile	647 / 3,845	-		-		-		-		-		-	
2 nd quintile	582 / 3,936	0.84 (0.72 - 0.99)	.01	0.85 (0.72 - 1.00)	.03	1.09 (0.97 - 1.24)	.39	0.85 (0.72 - 1.00)	.03	1.09 (0.96 - 1.23)	.36	1.13 (1.00 - 1.27)	.09
3 rd quintile	546 / 4,018	0.80 (0.69 - 0.93)		0.80 (0.68 - 0.93)		0.98 (0.88 - 1.09)		0.79 (0.68 - 0.93)		0.97 (0.87 - 1.08)		0.97 (0.85 - 1.10)	
4 th quintile	549 / 3,891	0.82 (0.70 - 0.96)		0.82 (0.70 - 0.97)		0.96 (0.86 - 1.08)		0.82 (0.70 - 0.97)		0.96 (0.85 - 1.07)		0.93 (0.81 - 1.07)	
Most populous quintile	587 / 4,088	0.82 (0.71 - 0.95)		0.83 (0.70 - 0.97)		1.03 (0.91 - 1.16)		0.83 (0.70 - 0.97)		1.02 (0.90 - 1.14)		1.01 (0.87 - 1.17)	
Green spaces (%)													
Ref: Least vegetation	550 / 3,957	-		-		-		-		-		-	
2 nd quintile	594 / 3,873	1.10 (0.93 - 1.29)	.36	1.12 (0.95 - 1.31)	.40	1.06 (0.93 - 1.20)	.33	1.12 (0.96 - 1.32)	.33	1.06 (0.93 - 1.21)	.28	1.10 (0.97 - 1.25)	.45
3 rd quintile	557 / 3,932	1.01 (0.85 - 1.20)		1.03 (0.85 - 1.23)		0.97 (0.86 - 1.09)		1.03 (0.86 - 1.24)		0.97 (0.86 - 1.09)		1.02 (0.91 - 1.15)	
4 th quintile	631 / 4,038	1.16 (0.99 - 1.36)		1.16 (0.99 - 1.37)		1.08 (0.95 - 1.22)		1.17 (1.00 - 1.38)		1.08 (0.96 - 1.22)		1.04 (0.92 - 1.17)	
Most vegetation	579 / 3,978	1.06 (0.89 - 1.26)		1.07 (0.91 - 1.27)		0.98 (0.86 - 1.12)		1.08 (0.91 - 1.28)		0.98 (0.86 - 1.12)		0.97 (0.83 - 1.13)	

	Model 6.2a			Model 6.2b		Model 6.2c		Model 6.2d		Model 6.2e		Model 6.2f	
	Died (n) / Alive (n)	Crude IRR (95% CI)	<i>p</i>	Adjusted (deprivation) IRR (95%CI)	<i>p</i>	Adjusted (deprivation & sociodemographi c) IRR (95%CI)	<i>p</i>	Adjusted (deprivation & clinical) IRR (95%CI)	<i>p</i>	Adjusted (deprivation, sociodemographi c & clinical) IRR (95%CI)	<i>p</i>	Fully adjusted IRR (95% CI)	<i>p</i>
Convenience stores†													
Ref: lowest no. of outlets	601 / 3,921	-		-		-		-		-		-	
2 nd quintile	621 / 3,904	1.01 (0.86 - 1.18)	.03	1.01 (0.86 - 1.19)	.03	1.06 (0.94 - 1.19)	.53	1.01 (0.86 - 1.19)	.03	1.06 (0.94 - 1.19)	.58	1.14 (1.01 - 1.28)	.08
3 rd quintile	528 / 3,934	0.86 (0.72 - 1.02)		0.85 (0.72 - 1.01)		0.96 (0.85 - 1.10)		0.85 (0.72 - 1.01)		0.96 (0.85 - 1.10)		1.04 (0.91 - 1.19)	
4 th quintile	624 / 3,952	1.03 (0.88 - 1.21)		1.05 (0.90 - 1.22)		1.07 (0.95 - 1.20)		1.05 (0.91 - 1.23)		1.06 (0.95 - 1.19)		1.16 (1.02 - 1.32)	
Highest no. of outlets	537 / 4,067	0.84 (0.72 - 0.98)		0.86 (0.74 - 1.00)		1.04 (0.92 - 1.17)		0.86 (0.74 - 1.00)		1.03 (0.91 - 1.17)		1.16 (0.97 - 1.39)	
Supermarkets†													
Ref: Lowest no. of outlets	1,709 / 11,836	-		-		-		-		-		-	
2 nd tertile	577 / 3,951	1.03 (0.91 - 1.17)	.48	1.04 (0.91 - 1.18)	.46	1.03 (0.95 - 1.12)	.60	1.04 (0.91 - 1.18)	.44	1.03 (0.95 - 1.13)	.56	1.06 (0.97 - 1.16)	.31
Highest no. of outlets	625 / 3,991	1.08 (0.95 - 1.23)		1.08 (0.96 - 1.22)		1.05 (0.95 - 1.16)		1.08 (0.96 - 1.22)		1.05 (0.95 - 1.16)		1.07 (0.97 - 1.18)	
Off-licences†													
Ref: lowest no. of outlets	603 / 3,825	-		-		-		-		-		-	
2 nd quintile	550 / 4,034	0.87 (0.75 - 1.02)	.17	0.87 (0.75 - 1.01)	.16	0.96 (0.85 - 1.09)	.71	0.87 (0.75 - 1.01)	.16	0.97 (0.86 - 1.09)	.74	0.98 (0.86 - 1.10)	.56
3 rd quintile	616 / 3,880	1.03 (0.87 - 1.22)		1.03 (0.87 - 1.22)		1.01 (0.89 - 1.14)		1.04 (0.88 - 1.22)		1.01 (0.89 - 1.14)		1.03 (0.91 - 1.16)	
4 th quintile	548 / 3,977	0.88 (0.74 - 1.04)		0.88 (0.74 - 1.04)		0.93 (0.82 - 1.05)		0.88 (0.75 - 1.04)		0.93 (0.82 - 1.06)		0.94 (0.83 - 1.08)	
Highest no. of outlets	594 / 4,062	0.91 (0.78 - 1.06)		0.91 (0.78 - 1.07)		0.97 (0.86 - 1.09)		0.92 (0.79 - 1.07)		0.96 (0.86 - 1.08)		1.02 (0.88 - 1.18)	
Fast-food outlets†													
Ref: lowest no. of outlets	629 / 3,832	-		-		-		-		-		-	
2 nd quintile	583 / 3,980	0.89 (0.76 - 1.05)	.13	0.91 (0.77 - 1.06)	.18	0.96 (0.85 - 1.08)	.36	0.91 (0.78 - 1.07)	.19	0.95 (0.84 - 1.07)	.32	0.93 (0.81 - 1.06)	.10
3 rd quintile	608 / 3,941	0.93 (0.79 - 1.10)		0.94 (0.80 - 1.10)		1.00 (0.88 - 1.13)		0.94 (0.80 - 1.10)		1.00 (0.88 - 1.13)		0.94 (0.83 - 1.06)	
4 th quintile	556 / 4,014	0.85 (0.73 - 1.00)		0.87 (0.74 - 1.02)		0.90 (0.80 - 1.01)		0.87 (0.74 - 1.02)		0.89 (0.79 - 1.00)		0.85 (0.74 - 0.97)	
Highest no. of outlets	535 / 4,011	0.81 (0.69 - 0.96)		0.83 (0.70 - 0.97)		0.94 (0.83 - 1.06)		0.83 (0.71 - 0.97)		0.94 (0.83 - 1.06)		0.82 (0.71 - 0.95)	

†Number of outlets per 100,000 population; Model 6.2a is crude estimates; Model 6.2b is adjusted for area-level deprivation; Model 6.2c is adjusted for area-level deprivation and sociodemographic factors (i.e. age, sex, ethnicity and marital status); ; Model 6.2c is adjusted for area-level deprivation and clinical factors (i.e. substance misuse and mental health diagnosis); Model 6.2e is adjusted for area-level deprivation, sociodemographic factors and clinical factors (i.e. SMI diagnosis and substance misuse); Model 6.2f is adjusted for area-level deprivation, sociodemographic and clinical factors and all other area-level variables predictor variables ; *P* values are for linear trend; Age modelled as a quadratic term across all models; Robust standard errors used to adjust for clustering at the Middle Super Output Area across all models; VPC = Variance Partition Coefficient.

Partitioning of variance

The partitioning of the variance between level 1 and 2 have been documented in the [Appendix 10](#) for the regression models documented in [Table 6.2](#) (models 6.2a – 6.2f). The VPC for the empty model (i.e. the model without the urban built and social environment variables and individual-level covariates) indicated that .4% of the variance in all-cause mortality was at the neighbourhood level (MSOAs). A likelihood ratio test indicated that the empty MLM Poisson regression model fitted the data better than a single-level Poisson regression model ($p < .0001$). Compared to the empty model, all subsequent two-level random intercept models (models 6.2a – 6.2f) exhibited a better model fit as indicated by the reduced deviance statistics. The VPCs for the unadjusted built environment models (Model 6.2a) and models adjusting for area-level deprivation (model 6.2b) were similar to the VPC calculated for the empty model, with VPCs ranging from .3% to .4% across the urban built environment indicators. However, VPCs calculated for models accounting for individual-level covariates and the fully adjusted model (models 6.2c – 6.2f) indicated that all of the variance in all-cause mortality was accounted for by differences among cohort members rather than differences between neighbourhoods (level 2 VPC = 0%).

All-cause mortality and the urban social environment

[Table 6.3](#) presents the associations between all-cause mortality and the social environment variables. Across both the adjusted and unadjusted models (models 6.3a-6.3f) null associations were indicated between the social environment variables and all-cause mortality. Models assessing associations between the individual-level covariates and all-cause mortality ([Appendix 7](#), Model A7.f) indicated that older cohort members and those with reported histories of substance misuse were at an increased risk of death after accounting for the influence of the social environment indicators. Conversely, lower risk of all-cause mortality was observed among female cohort members, racially minoritized groups and those with an affective disorder ([Appendix 7](#), Model A7.f).

The partitioning of the variance between level 1 and 2 have also been documented in [Appendix 11](#) for the regression models documented in [Table 6.3](#) (models 6.3a – 6.3f). VPCs for the fully adjusted social environment model (Model 3f) suggested that .003% of the

variance in all-cause mortality was found at the neighbourhood-level. Indicating that the observed clustering in all-cause mortality was largely accounted for by variation at the individual-level (see [Appendix 11](#)).

Table 6.3 Associations between all-cause mortality and the area-level social environment factors in SMI cohort (n = 22,689)

	Model 6.3a			Model 6.3b		Model 6.3c		Model 6.3d		Model 6.3e		Model 6.3f	
	Died (n) / Alive (n)	Crude IRR (95% CI)	<i>p</i>	Adjusted (deprivation) IRR (95%CI)	<i>p</i>	Adjusted (deprivation & sociodemographic) IRR (95%CI)	<i>p</i>	Adjusted (deprivation & clinical) IRR (95%CI)	<i>P</i>	Adjusted (deprivation, sociodemographi c & clinical) IRR (95%CI)	<i>p</i>	Fully adjusted IRR (95% CI)	<i>p</i>
Social environment variables													
Social fragmentation (z score)													
Ref: Least fragmented	610 / 3,927	-		-		-		-		-		-	
2 nd quintile	598 / 3,980	0.96 (0.81-1.14)	.43	0.97 (0.82 – 1.16)	.66	1.09 (0.97 – 1.23)	.60	0.97 (0.82 – 1.16)	.72	1.09 (0.96 – 1.22)	.55	1.08 (0.96 – 1.22)	.41
3 rd quintile	572 / 3,886	0.92 (0.78-1.09)		0.93 (0.78 – 1.10)		1.05 (0.92 – 1.20)		0.93 (0.79 – 1.10)		1.04 (0.91 – 1.19)		1.03 (0.90 – 1.18)	
4 th quintile	580 / 4,028	0.91 (0.78-1.06)		0.93 (0.79 – 1.09)		1.09 (0.97 – 1.22)		0.94 (0.80 – 1.10)		1.08 (0.97 – 1.22)		1.08 (0.95 – 1.23)	
Most fragmented	551 / 4,007	0.86 (0.73-1.01)		0.88 (0.73 – 1.05)		1.03 (0.90 – 1.18)		0.89 (0.74 – 1.06)		1.02 (0.89 – 1.17)		0.99 (0.85 – 1.15)	
Ethnic density (%)													
Ref: Least ethnically dense	580 / 3,793	-		-		-		-		-		-	
2 nd quintile	617 / 4,066	0.97 (0.82-1.14)	.39	1.02 (0.79 – 1.32)	.40	1.11 (0.92 – 1.33)	.73	1.02 (0.79 – 1.30)	.34	1.10 (0.92 – 1.32)	.68	1.08 (0.90 – 1.30)	.62
3 rd quintile	591 / 3,927	0.96 (0.80-1.16)		1.04 (0.81 – 1.34)		1.10 (0.93 – 1.31)		1.03 (0.81 – 1.32)		1.10 (0.92 – 1.31)		1.08 (0.90 – 1.28)	
4 th quintile	586 / 3,889	0.98 (0.84-1.13)		1.02 (0.81 – 1.29)		1.11 (0.94 – 1.31)		1.01 (0.80 – 1.27)		1.11 (0.94 – 1.31)		1.11 (0.93 – 1.33)	
Most ethnically dense	537 / 4,103	0.85 (0.72-1.01)		0.88 (0.67 – 1.16)		1.04 (0.86 – 1.26)		0.86 (0.66 – 1.13)		1.04 (0.86 – 1.26)		1.02 (0.84 – 1.24)	
Places of worship†													
Ref: lowest no. of outlets	580 / 3,806	-		-		-		-		-		-	
2 nd quintile	562 / 4,059	0.95 (0.81-1.11)	.93	0.94 (0.80 – 1.11)	.88	0.95 (0.85 – 1.07)	.34	0.95 (0.81 – 1.11)	.88	0.95 (0.85 – 1.06)	.30	0.95 (0.85 – 1.07)	.28
3 rd quintile	587 / 3,968	0.98 (0.82-1.16)		0.98 (0.83 – 1.16)		1.03 (0.91 – 1.17)		0.98 (0.83 – 1.16)		1.03 (0.91 – 1.16)		1.01 (0.89 – 1.15)	
4 th quintile	610 / 3,974	1.01 (0.86-1.18)		1.02 (0.87 – 1.21)		1.08 (0.95 – 1.22)		1.03 (0.87 – 1.21)		1.08 (0.95 – 1.22)		1.09 (0.95 – 1.26)	
Highest no. of outlets	572 / 3,971	0.96 (0.80-1.15)		0.97 (0.82 – 1.16)		1.01 (0.89 – 1.14)		0.98 (0.82 – 1.17)		1.00 (0.89 – 1.13)		1.02 (0.89 – 1.16)	

†Number of outlets per 100,000 population; Model 6.3a is crude estimates; Model 6.3b is adjusted for area-level deprivation; Model 6.3c is adjusted for area-level deprivation and sociodemographic factors (i.e. age, sex, ethnicity and marital status); ; Model 6.3c is adjusted for area-level deprivation and clinical factors (i.e. substance misuse and mental health diagnosis); Model 6.3e is adjusted for area-level deprivation, sociodemographic factors and clinical factors (i.e. SMI diagnosis and substance misuse); Model 6.3f is adjusted for area-level deprivation, sociodemographic and clinical factors and all other area-level variables predictor variables ; *P* values are for linear trend; Age modelled as a quadratic term across all models; Robust standard errors used to adjust for clustering at the Middle Super Output Area across all models; VPC = Variance Partition Coefficient.

Natural cause mortality and the urban built environment

[Table 6.4](#) shows the estimates from the competing risks regression for the built environment variables and natural-cause mortality. Crude estimates (model 6.4a) indicated a protective effect of residence in more populous and more walkable neighbourhoods compared to areas with lower levels of these attributes for natural-cause mortality in the cohort. However, these associations were attenuated in models adjusting for area-level deprivation (model 6.4b). The latter models adjusting for both area-level deprivation and individual-level covariates (models 6.4c - 6.4f) suggest that the association between neighbourhood walkability and population density may be explained by these same variables (see [Appendix 8](#)). Assessment of the coefficients for the individual-level covariates indicated a higher risk of natural-cause mortality among older cohort members. However, female cohort members, those with affective disorders, individuals in cohabiting or married relationships, along with racially minoritized individuals, showed a decreased risk of natural-cause mortality (see [Appendix 8](#) – Model A8.e). Examination of Schoenfeld-like residual plots revealed no major violations of the proportional hazards assumption.

Table 6.4 Sub-hazard ratios (SHR) for the association between natural-cause mortality and the built environment variables in SMI cohort (n = 22,466)¹

		Model 6.4a			Model 6.4b			Model 6.4c			Model 6.4d			Model 6.4e			Model 6.4f		
	Died (n) / Alive (n)	Crude SHR (95% CI)	p		Adjusted (deprivation) SHR (95%CI)	p		Adjusted (deprivation & socio-demographi c) SHR (95%CI)	p		Adjusted (deprivation & clinical) SHR (95%CI)	p		Adjusted (deprivation, socio-demographi c & clinical) SHR (95%CI)	p		Fully adjusted SHR (95% CI)	p	
Built environment variables																			
Area-level deprivation (rank score)																			
Ref. group: Least deprived quintile	525 / 4,034	-			-			-			-			-			-		
2 nd quintile	469 / 3,981	0.88 (0.75 – 1.03)	.27		-			0.92 (0.78 – 1.07)	.71		0.88 (0.75 – 1.03)	.28		0.92 (0.79 – 1.08)	.73		0.97 (0.79 – 1.20)	.83	
3 rd quintile	427 / 3,936	0.83 (0.69 – 0.98)			-			0.89 (0.75 – 1.07)			0.83 (0.70 – 0.99)			0.90 (0.75 – 1.08)			0.97 (0.78 – 1.21)		
4 th quintile	468 / 3,863	0.93 (0.78 – 1.10)			-			0.97 (0.81 – 1.16)			0.94 (0.79 – 1.11)			0.99 (0.83 – 1.18)			1.05 (0.83 – 1.34)		
Most deprived quintile	463 / 3,964	0.89 (0.74 – 1.07)			-			0.95 (0.79 – 1.14)			0.90 (0.75 – 1.08)			0.96 (0.81 – 1.15)			1.03 (0.84 – 1.27)		
N'hood walkability (z score)																			
Ref: Least walkable quintile	514 / 3,895	-			-			-			-			-			-		
2 nd quintile	495 / 3,862	0.95 (0.80 – 1.13)	.01		0.97 (0.82 – 1.16)	.03		0.98 (0.82 – 1.17)	.15		0.98 (0.82 – 1.16)	.05		0.99 (0.83 – 1.18)	.21		1.02 (0.84 – 1.23)	.39	
3 rd quintile	424 / 4,059	0.77 (0.67 – 0.90)			0.77 (0.65 – 0.91)			0.81 (0.68 – 0.97)			0.79 (0.66 – 0.93)			0.83 (0.70 – 0.99)			0.87 (0.70 – 1.08)		
4 th quintile	430 / 3,843	0.84 (0.70 – 1.01)			0.82 (0.66 – 1.02)			0.86 (0.69 – 1.07)			0.84 (0.67 – 1.04)			0.89 (0.72 – 1.10)			0.95 (0.74 – 1.21)		
Most walkable quintile	489 / 4,119	0.89 (0.77 – 1.04)			0.87 (0.73 – 1.04)			0.90 (0.75 – 1.08)			0.89 (0.75 – 1.07)			0.93 (0.78 – 1.12)			0.97 (0.75 – 1.24)		
Population density																			
Ref: Least populous quintile	520 / 3,845	-			-			-			-			-			-		
2 nd quintile	472 / 3,936	0.85 (0.72 – 1.01)	.03		0.86 (0.73 – 1.02)	.05		0.93 (0.78 – 1.11)	.50		0.86 (0.73 – 1.02)	.05		0.94 (0.78 – 1.11)	.52		1.02 (0.87 – 1.02)	.42	
3 rd quintile	442 / 4,018	0.79 (0.66 – 0.93)			0.80 (0.67 – 0.95)			0.86 (0.72 – 1.02)			0.79 (0.67 – 0.94)			0.86 (0.73 – 1.02)			0.87 (0.73 – 1.04)		
4 th quintile	447 / 3,891	0.80 (0.68 – 0.95)			0.81 (0.68 – 0.97)			0.90 (0.76 – 1.07)			0.82 (0.68 – 0.98)			0.92 (0.77 – 1.09)			0.90 (0.76 – 1.06)		
Most populous quintile	471 / 4,088	0.79 (0.67 – 0.94)			0.80 (0.67 – 0.95)			0.90 (0.75 – 1.08)			0.80 (0.67 – 0.96)			0.91 (0.75 – 1.09)			0.92 (0.74 – 1.13)		
Green spaces (%)																			
Ref: Least vegetation	451 / 3,957	-			-			-			-			-			-		
2 nd quintile	472 / 3,873	1.07 (0.90 – 1.26)	.49		1.08 (0.92 – 1.27)	.55		1.07 (0.91 – 1.26)	.63		1.09 (0.92 – 1.28)	.51		1.08 (0.91 – 1.27)	.58		1.09 (0.92 – 1.30)	.62	
3 rd quintile	457 / 3,932	1.05 (0.88 – 1.25)			1.07 (0.89 – 1.28)			1.02 (0.85 – 1.22)			1.07 (0.89 – 1.28)			1.03 (0.86 – 1.24)			1.09 (0.91 – 1.30)		
4 th quintile	514 / 4,038	1.17 (0.99 – 1.38)			1.16 (0.98 – 1.37)			1.11 (0.95 – 1.31)			1.17 (0.99 – 1.38)			1.12 (0.96 – 1.31)			1.05 (0.88 – 1.24)		
Most vegetation	458 / 3,978	1.04 (0.87 – 1.25)			1.05 (0.89 – 1.25)			0.98 (0.82 – 1.17)			1.05 (0.89 – 1.25)			0.99 (0.83 – 1.17)			0.94 (0.76 – 1.15)		
Convenience stores[†]																			
Ref: lowest no. of outlets	487 / 3,921	-			-			-			-			-			-		
2 nd quintile	489 / 3,904	1.02 (0.86 – 1.21)	.10		1.02 (0.86 – 1.21)	.08		1.06 (0.90 – 1.26)	.09		1.02 (0.86 – 1.21)	.07		1.07 (0.90 – 1.26)	.08		1.14 (0.95 – 1.36)	.11	
3 rd quintile	429 / 3,934	0.88 (0.73 – 1.07)			0.86 (0.71 – 1.05)			0.89 (0.73 – 1.09)			0.86 (0.71 – 1.04)			0.89 (0.73 – 1.08)			0.94 (0.75 – 1.18)		
4 th quintile	511 / 3,952	1.07 (0.89 – 1.27)			1.10 (0.93 – 1.29)			1.11 (0.94 – 1.30)			1.10 (0.94 – 1.30)			1.11 (0.95 – 1.30)			1.18 (0.95 – 1.46)		
Highest no. of outlets	436 / 4,067	0.89 (0.76 – 1.04)			0.90 (0.77 – 1.04)			0.93 (0.80 – 1.08)			0.91 (0.78 – 1.05)			0.94 (0.81 – 1.08)			1.02 (0.80 – 1.29)		
Supermarkets[†]																			
Ref: Lowest no. of outlets	1,374 / 11,836	-			-			-			-			-			-		
2 nd tertile	469 / 3,951	1.03 (0.90 – 1.18)	.31		1.04 (0.91 – 1.19)	.32		1.02 (0.89 – 1.17)	.48		1.04 (0.91 – 1.19)	.32		1.02 (0.89 – 1.16)	.46		1.04 (0.91 – 1.19)	.24	
Highest no. of outlets	509 / 3,991	1.11 (0.97 – 1.26)			1.10 (0.97 – 1.25)			1.08 (0.95 – 1.22)			1.10 (0.97 – 1.25)			1.08 (0.96 – 1.22)			1.11 (0.98 – 1.25)		

	Model 6.4a			Model 6.4b		Model 6.4c		Model 6.4d		Model 6.4e		Model 6.4f	
	Died (n) / Alive (n)	Crude SHR (95% CI)	<i>p</i>	Adjusted (deprivation) SHR (95%CI)	<i>p</i>	Adjusted (deprivation & sociodemographi c) SHR (95%CI)	<i>p</i>	Adjusted (deprivation & clinical) SHR (95%CI)	<i>p</i>	Adjusted (deprivation, sociodemographi c & clinical) SHR (95%CI)	<i>p</i>	Fully adjusted SHR (95% CI)	<i>p</i>
Off-licences[†]													
Ref: lowest no. of outlets	479 / 3,825	-		-		-		-		-		-	
2 nd quintile	448 / 4,034	0.88 (0.75 – 1.03)	.37	0.88 (0.75 – 1.03)	.36	0.93 (0.79 – 1.09)	.69	0.88 (0.75 – 1.03)	.35	0.94 (0.80 – 1.10)	.76	0.99 (0.84 – 1.17)	.75
3 rd quintile	493 / 3,880	1.00 (0.83 – 1.20)		1.01 (0.84 – 1.21)		1.02 (0.86 – 1.22)		1.01 (0.84 – 1.21)		1.02 (0.86 – 1.22)		1.06 (0.89 – 1.26)	
4 th quintile	449 / 3,977	0.88 (0.75 – 1.04)		0.89 (0.76 – 1.04)		0.92 (0.78 – 1.08)		0.89 (0.76 – 1.04)		0.93 (0.80 – 1.08)		0.96 (0.81 – 1.13)	
Highest no. of outlets	483 / 4,062	0.93 (0.79 – 1.09)		0.93 (0.79 – 1.09)		0.94 (0.80 – 1.11)		0.93 (0.79 – 1.09)		0.95 (0.81 – 1.12)		1.03 (0.85 – 1.24)	
Fast-food outlets[†]													
Ref: lowest no. of outlets	502 / 3,832	-		-		-		-		-		-	
2 nd quintile	472 / 3,980	0.93 (0.78 – 1.11)	.55	0.95 (0.80 – 1.13)	.72	0.93 (0.78 – 1.11)	.65	0.96 (0.81 – 1.14)	.72	0.93 (0.78 – 1.11)	.59	0.91 (0.75 – 1.09)	.66
3 rd quintile	480 / 3,941	0.93 (0.78 – 1.13)		0.95 (0.80 – 1.14)		0.98 (0.82 – 1.18)		0.95 (0.80 – 1.14)		0.98 (0.82 – 1.18)		0.94 (0.77 – 1.14)	
4 th quintile	454 / 4,014	0.88 (0.74 – 1.05)		0.91 (0.76 – 1.08)		0.90 (0.76 – 1.07)		0.91 (0.76 – 1.08)		0.89 (0.75 – 1.06)		0.90 (0.73 – 1.11)	
Highest no. of outlets	444 / 4,011	0.87 (0.73 – 1.04)		0.89 (0.76 – 1.06)		0.90 (0.76 – 1.06)		0.90 (0.76 – 1.06)		0.90 (0.76 – 1.06)		0.85 (0.67 – 1.07)	

[†] 223 cohort members were classified as not otherwise specified (R00-R99) and therefore were **not** included in the analyses for cause-specific mortality; [†]Number of outlets per 100,000 population; Model 6.4a is crude estimates; Model 6.4b is adjusted for area-level deprivation; Model 6.4c is adjusted for area-level deprivation and sociodemographic factors (i.e. age, sex, ethnicity and marital status); Model 6.4d is adjusted for area-level deprivation and clinical factors (i.e. substance misuse and mental health diagnosis); Model 6.4e is adjusted for area-level deprivation, sociodemographic factors and clinical factors (i.e. SMI diagnosis and substance misuse); Model 6.4f is adjusted for area-level deprivation, sociodemographic and clinical factors and all other area-level variables predictor variables ; *P* values are for linear trend; Age modelled as a quadratic term across all models; Robust standard errors used to adjust for clustering at the Middle Super Output Area across all models.

Natural-cause mortality and the urban social environment

[Table 6.5](#) presents the sub-hazard ratios for the association between natural-cause mortality and variables related to the social environment. Across both the adjusted and unadjusted models (models 6.5a – 6.5f) no associations were evident between the social environment variables and natural-cause mortality. Associations between the individual-level factors and natural-cause mortality revealed an increased risk of death among older cohort members. In contrast, female cohort members, individuals with affective disorders, married or cohabitating individuals as well as racially minoritized groups, exhibited a reduced risk of natural-cause mortality (see [Appendix 8](#), Model A8.f). Examination of Schoenfeld-like residual plots revealed no major violations of the proportional hazards assumption.

Table 6.5 Sub-hazard ratios (SHR) for the association between natural-cause mortality and the social environment variables in SMI cohort (n = 22,466)¹

	Model 6.5a			Model 6.5b		Model 6.5c		Model 6.5d		Model 6.5e		Model 6.5f	
	Died (n) / Alive (n)	Crude SHR (95% CI)	<i>p</i>	Adjusted (deprivation) SHR (95%CI)	<i>p</i>	Adjusted (deprivation & sociodemograph ic) SHR (95%CI)	<i>p</i>	Adjusted (deprivation & clinical) SHR (95%CI)	<i>P</i>	Adjusted (deprivation, sociodemograph ic & clinical) SHR (95%CI)	<i>p</i>	Fully adjusted SHR (95% CI)	<i>p</i>
Social environment variables													
Social fragmentation (z score)													
Ref: Least fragmented	499 / 3,927	-		-		-		-		-		-	
2 nd quintile	484 / 3,980	0.92 (0.76 – 1.11)	.15	0.93 (0.77 – 1.13)	.39	1.05 (0.91 – 1.21)	.90	0.94 (0.78 – 1.14)	.51	1.05 (0.91 – 1.21)	.91	1.04 (0.91 – 1.20)	.70
3 rd quintile	475 / 3,886	0.91 (0.75 – 1.10)		0.92 (0.76 – 1.11)		1.06 (0.90 – 1.26)		0.92 (0.76 – 1.12)		1.06 (0.89 – 1.26)		1.03 (0.88 – 1.22)	
4 th quintile	453 / 4,028	0.84 (0.71 – 1.00)		0.87 (0.73 – 1.04)		1.01 (0.88 – 1.16)		0.88 (0.74 – 1.05)		1.01 (0.88 – 1.16)		0.99 (0.85 – 1.15)	
Most fragmented	441 / 4,007	0.81 (0.68 – 0.97)		0.84 (0.70 – 1.01)		1.00 (0.86 – 1.18)		0.86 (0.71 – 1.03)		1.00 (0.85 – 1.17)		0.94 (0.79 – 1.11)	
Ethnic density (%)													
Ref: Least ethnically dense	485 / 3,793	-		-		-		-		-		-	
2 nd quintile	496 / 4,066	0.95 (0.79 – 1.14)	.24	1.03 (0.79 – 1.35)	.27	1.11 (0.89 – 1.39)	.51	1.02 (0.78 – 1.34)	.21	1.11 (0.89 – 1.39)	.54	1.09 (0.88 – 1.36)	.50
3 rd quintile	485 / 3,927	0.95 (0.79 – 1.15)		1.06 (0.82 – 1.39)		1.09 (0.89 – 1.33)		1.05 (0.81 – 1.37)		1.08 (0.89 – 1.31)		1.05 (0.86 – 1.28)	
4 th quintile	469 / 3,889	0.93 (0.79 – 1.10)		0.97 (0.75 – 1.27)		1.03 (0.85 – 1.25)		0.96 (0.74 – 1.24)		1.03 (0.85 – 1.25)		1.04 (0.85 – 1.28)	
Most ethnically dense	417 / 4,103	0.82 (0.68 – 0.98)		0.84 (0.62 – 1.14)		0.97 (0.77 – 1.21)		0.82 (0.61 – 1.11)		0.96 (0.77 – 1.20)		0.95 (0.76 – 1.19)	
Places of worship[†]													
Ref: lowest no. of outlets	464 / 3,806	-		-		-		-		-		-	
2 nd quintile	448 / 4,059	0.90 (0.76 – 1.07)	.77	0.91 (0.76 – 1.07)	.71	0.92 (0.80 – 1.07)	.28	0.91 (0.77 – 1.08)	.72	0.93 (0.80 – 1.07)	.31	0.94 (0.82 – 1.08)	.32
3 rd quintile	477 / 3,968	0.95 (0.80 – 1.13)		0.97 (0.81 – 1.15)		1.02 (0.87 – 1.18)		0.96 (0.81 – 1.15)		1.02 (0.88 – 1.18)		1.02 (0.88 – 1.19)	
4 th quintile	497 / 3,974	0.98 (0.83 – 1.16)		1.01 (0.85 – 1.19)		1.07 (0.93 – 1.23)		1.01 (0.86 – 1.20)		1.07 (0.93 – 1.23)		1.09 (0.94 – 1.27)	
Highest no. of outlets	466 / 3,971	0.94 (0.77 – 1.15)		0.97 (0.80 – 1.17)		1.06 (0.92 – 1.23)		0.98 (0.81 – 1.18)		1.06 (0.92 – 1.22)		1.08 (0.93 – 1.26)	

¹ 223 cohort members were classified as not otherwise specified (R00-R99) and therefore were **not** included in the analyses for cause-specific mortality;

[†]Number of places of worship per 100,000 population; Model 6.5a is crude estimates; Model 6.5b is adjusted for area-level deprivation; Model 6.5c is adjusted for area-level deprivation and sociodemographic factors (i.e. age, sex, ethnicity and marital status); Model 6.5d is adjusted for area-level deprivation and clinical factors (i.e. substance misuse and mental health diagnosis); Model 6.5e is adjusted for area-level deprivation, sociodemographic factors and clinical factors (i.e. SMI diagnosis and substance misuse); Model 6.5f is adjusted for area-level deprivation, sociodemographic and clinical factors and all other area-level variables predictor variables ; *P* values are for linear trend; Age modelled as a quadratic term across all models; Robust standard errors used to adjust for clustering at the Middle Super Output Area across all models.

Unnatural cause mortality (deaths from suicides and accidents) and the urban built environment

[Table 6.6](#) presents the sub-hazard ratios for the association the built environment factors and unnatural-cause mortality. No associations were observed between the built environment variables and unnatural cause mortality across both the unadjusted and adjusted models (models 6.6a – 6.6f). Assessment of associations between the individual-level covariates and unnatural-cause mortality revealed a lower risk of unnatural-cause mortality among female cohort members and those from racially minoritized backgrounds. A higher risk of unnatural-cause mortality was observed among those with histories of substance misuse (see [Appendix 9](#), Model A9.e). Schoenfeld-like residual plots revealed violations of the proportional hazards.

Table 6.6 Sub-hazard ratios (SHR) for the association between unnatural-cause mortality and the built environment variables in SMI cohort (n = 22,466)¹

	Model 6.6a			Model 6.6b		Model 6.6c		Model 6.6d		Model 6.6e		Model 6.6f	
	Died (n) / Alive (n)	Crude SHR (95% CI)	p	Adjusted (deprivation) SHR (95%CI)	p	Adjusted (deprivation & sociodemographi c) SHR (95%CI)	p	Adjusted (deprivation & clinical) SHR (95%CI)	P	Adjusted (deprivation, sociodemographi c & clinical) SHR (95%CI)	p	Fully adjusted SHR (95% CI)	p
Built environment variables													
Area-level deprivation (rank score)													
Ref. group: Least deprived quintile	58 / 4,034	-		-		-		-		-		-	
2 nd quintile	75 / 3,981	1.17 (0.81 – 1.67)	.73	-		1.33 (0.92 – 1.94)	.64	1.25 (0.86 – 1.81)	.79	1.30 (0.90 – 1.90)	.73	1.32 (0.88 – 2.00)	.61
3 rd quintile	68 / 3,936	1.24 (0.83 – 1.87)		-		1.25 (0.86 – 1.81)		1.16 (0.80 – 1.68)		1.21 (0.83 – 1.76)		1.38 (0.88 – 2.15)	
4 th quintile	69 / 3,863	1.21 (0.84 – 1.75)		-		1.30 (0.85 – 1.99)		1.16 (0.77 – 1.74)		1.23 (0.81 – 1.87)		1.25 (0.74 – 2.10)	
Most deprived quintile	66 / 3,964	1.29 (0.89 – 1.86)		-		1.24 (0.85 – 1.81)		1.08 (0.75 – 1.55)		1.16 (0.79 – 1.70)		1.17 (0.70 – 1.95)	
N'hood walkability (z score)													
Ref: Least walkable quintile	65 / 3,895	-		-		-		-		-		-	
2 nd quintile	64 / 3,862	0.99 (0.71 – 1.38)	.96	0.91 (0.65 – 1.29)	.95	0.92 (0.66 – 1.29)	.95	0.90 (0.63 – 1.26)	.88	0.91 (0.64 – 1.28)	.90	0.96 (0.66 – 1.39)	.75
3 rd quintile	73 / 4,059	1.08 (0.79 – 1.47)		0.94 (0.66 – 1.35)		0.97 (0.68 – 1.39)		0.89 (0.62 – 1.29)		0.92 (0.64 – 1.32)		1.01 (0.65 – 1.59)	
4 th quintile	68 / 3,843	1.07 (0.76 – 1.52)		0.97 (0.64 – 1.46)		0.98 (0.65 – 1.48)		0.91 (0.60 – 1.38)		0.93 (0.62 – 1.41)		0.86 (0.52 – 1.44)	
Most walkable quintile	66 / 4,119	0.97 (0.68 – 1.37)		0.86 (0.56 – 1.32)		0.87 (0.57 – 1.32)		0.80 (0.52 – 1.23)		0.81 (0.53 – 1.25)		0.77 (0.46 – 1.29)	
Population density													
Ref: Least populous quintile	68 / 3,845	-		-		-		-		-		-	
2 nd quintile	60 / 3,936	0.85 (0.59 – 1.22)	.76	0.82 (0.58 – 1.16)	.67	0.85 (0.60 – 1.20)	.75	0.80 (0.56 – 1.13)	.54	1.00 – 1.00 – 1.00)	.68	0.92 (0.62 – 1.34)	.63
3 rd quintile	74 / 4,018	1.03 (0.74 – 1.44)		0.96 (0.68 – 1.35)		0.99 (0.69 – 1.40)		0.95 (0.67 – 1.33)		0.83 (0.59 – 1.18)		1.10 (0.71 – 1.68)	
4 th quintile	61 / 3,891	0.86 (0.62 – 1.20)		0.81 (0.58 – 1.13)		0.83 (0.60 – 1.17)		0.78 (0.56 – 1.09)		0.98 (0.69 – 1.40)		0.88 (0.55 – 1.41)	
Most populous quintile	73 / 4,088	0.97 (0.69 – 1.37)		0.90 (0.62 – 1.31)		0.94 (0.64 – 1.37)		0.87 (0.60 – 1.27)		0.82 (0.58 – 1.14)		1.15 (0.67 – 1.96)	
Green spaces (%)													
Ref: Least vegetation	59 / 3,957	-		-		-		-		-		-	
2 nd quintile	73 / 3,873	1.26 (0.85 – 1.86)	.57	1.28 (0.86 – 1.90)	.44	1.27 (0.85 – 1.88)	.55	1.28 (0.86 – 1.89)	.46	1.27 (0.85 – 1.88)	.55	1.33 (0.86 – 2.06)	.54
3 rd quintile	59 / 3,932	1.02 (0.65 – 1.61)		1.02 (0.65 – 1.60)		1.05 (0.66 – 1.65)		1.03 (0.65 – 1.62)		1.05 (0.66 – 1.65)		1.17 (0.77 – 1.77)	
4 th quintile	77 / 4,038	1.31 (0.88 – 1.95)		1.36 (0.92 – 2.01)		1.35 (0.90 – 2.01)		1.36 (0.92 – 2.02)		1.35 (0.90 – 2.01)		1.41 (0.93 – 2.13)	
Most vegetation	68 / 3,978	1.18 (0.80 – 1.72)		1.19 (0.82 – 1.74)		1.20 (0.82 – 1.76)		1.20 (0.82 – 1.76)		1.20 (0.82 – 1.77)		1.26 (0.76 – 2.10)	
Convenience stores†													
Ref: lowest no. of outlets	66 / 3,921	-		-		-		-		-		-	
2 nd quintile	75 / 3,904	1.15 (0.83 – 1.60)	.70	1.16 (0.84 – 1.60)	.72	1.16 (0.84 – 1.60)	.74	1.16 (0.84 – 1.60)	.65	1.16 (0.84 – 1.60)	.67	1.23 (0.85 – 1.77)	.77
3 rd quintile	62 / 3,934	0.95 (0.68 – 1.35)		0.99 (0.70 – 1.39)		1.00 (0.71 – 1.41)		0.99 (0.70 – 1.39)		1.00 (0.71 – 1.41)		1.20 (0.84 – 1.73)	
4 th quintile	72 / 3,952	1.10 (0.77 – 1.57)		1.07 (0.75 – 1.53)		1.06 (0.74 – 1.53)		1.04 (0.73 – 1.49)		1.04 (0.73 – 1.49)		1.13 (0.71 – 1.78)	

	Model 6.6a			Model 6.6b		Model 6.6c		Model 6.6d		Model 6.6e		Model 6.6f	
	Died (n) / Alive (n)	Crude SHR (95% CI)	<i>p</i>	Adjusted (deprivation) SHR (95%CI)	<i>p</i>	Adjusted (deprivation & sociodemographi c) SHR (95%CI)	<i>p</i>	Adjusted (deprivation & clinical) SHR (95%CI)	<i>P</i>	Adjusted (deprivation, sociodemographi c & clinical) SHR (95%CI)	<i>p</i>	Fully adjusted SHR (95% CI)	<i>p</i>
Highest no. of outlets	61 / 4,067	0.92 (0.63 – 1.35)		0.91 (0.61 – 1.34)		0.91 (0.61 – 1.35)		0.88 (0.59 – 1.29)		0.88 (0.60 – 1.31)		1.20 (0.72 – 1.99)	
Supermarkets†													
Ref: Lowest no. of outlets	202 / 11,836	-		-		-		-		-		-	
2 nd tertile	66 / 3,951	0.98 (0.75 – 1.29)	.99	0.97 (0.73 – 1.28)	.97	0.97 (0.73 – 1.27)	.96	0.98 (0.74 – 1.30)	.99	0.97 (0.74 – 1.29)	.98	1.08 (0.80 – 1.46)	.81
Highest no. of outlets	68 / 3,991	1.00 (0.73 – 1.35)		0.99 (0.72 – 1.37)		0.97 (0.71 – 1.34)		1.00 (0.72 – 1.37)		0.97 (0.71 – 1.34)		1.09 (0.78 – 1.52)	
Off-licences†													
Ref: lowest no. of outlets	75 / 3,825	-		-		-		-		-		-	
2 nd quintile	63 / 4,034	0.80 (0.56 – 1.14)	.48	0.80 (0.56 – 1.14)	.50	0.81 (0.56 – 1.16)	.57	0.80 (0.56 – 1.14)	.50	0.81 (0.57 – 1.16)	.58	0.75 (0.52 – 1.07)	.47
3 rd quintile	72 / 3,880	0.93 (0.69 – 1.27)		0.93 (0.68 – 1.26)		0.92 (0.67 – 1.25)		0.92 (0.68 – 1.25)		0.91 (0.67 – 1.24)		0.83 (0.58 – 1.18)	
4 th quintile	59 / 3,977	0.75 (0.52 – 1.07)		0.75 (0.52 – 1.08)		0.75 (0.52 – 1.09)		0.74 (0.51 – 1.08)		0.75 (0.52 – 1.09)		0.75 (0.50 – 1.12)	
Highest no. of outlets	67 / 4,062	0.83 (0.57 – 1.20)		0.83 (0.58 – 1.19)		0.83 (0.58 – 1.20)		0.82 (0.57 – 1.18)		0.83 (0.57 – 1.20)		0.90 (0.58 – 1.40)	
Fast-food outlets†													
Ref: lowest no. of outlets	70 / 3,832	-		-		-		-		-		-	
2 nd quintile	66 / 3,980	0.93 (0.67 – 1.29)	.19	0.90 (0.65 – 1.26)	.16	0.89 (0.64 – 1.24)	.16	0.89 (0.64 – 1.24)	.15	0.88 (0.63 – 1.22)	.15	0.83 (0.58 – 1.20)	.18
3 rd quintile	84 / 3,941	1.18 (0.85 – 1.64)		1.14 (0.83 – 1.58)		1.12 (0.81 – 1.56)		1.12 (0.81 – 1.55)		1.11 (0.80 – 1.54)		1.15 (0.80 – 1.64)	
4 th quintile	60 / 4,014	0.84 (0.58 – 1.22)		0.81 (0.55 – 1.18)		0.80 (0.55 – 1.18)		0.79 (0.54 – 1.16)		0.79 (0.54 – 1.16)		0.76 (0.47 – 1.21)	
Highest no. of outlets	56 / 4,011	0.79 (0.56 – 1.13)		0.76 (0.54 – 1.07)		0.74 (0.52 – 1.05)		0.75 (0.53 – 1.05)		0.73 (0.51 – 1.04)		0.72 (0.45 – 1.18)	

¹ 223 cohort members were classified as not otherwise specified (R00-R99) and therefore were **not** included in the analyses for cause-specific mortality;

†Number of outlets per 100,000 population; Model 6.6a is crude estimates; Model 6.6b is adjusted for area-level deprivation; Model 6.6c is adjusted for area-level deprivation and sociodemographic factors (i.e. age, sex, ethnicity and marital status); Model 6.6d is adjusted for area-level deprivation and clinical factors (i.e. substance misuse and mental health diagnosis); Model 6.6e is adjusted for area-level deprivation, sociodemographic factors and clinical factors (i.e. SMI diagnosis and substance misuse); Model 6.6f is adjusted for area-level deprivation, sociodemographic and clinical factors and all other area-level variables predictor variables ; *P* values are for linear trend; Age modelled as a quadratic term across all models; Robust standard errors used to adjust for clustering at the Middle Super Output Area across all models.

Unnatural cause mortality and the urban social environment

[Table 6.7](#) presents the associations between the social environment variables and unnatural-cause mortality. Overall, there did not appear to be any association between the social environment variables and unnatural-cause mortality in both the unadjusted and adjusted models (models 6.7a – 6.7f). The coefficients associated with individual-level covariates exhibited a similar pattern of risk for unnatural-cause mortality, after adjusting for the social environment variables, mirroring the observations made in models that adjusted for the built environment variables (see [Appendix 9](#) – Model A9.f). Schoenfeld-like residual plots revealed violations of the proportional hazards.

Table 6.7 Sub-hazard ratios (SHR) for the association between unnatural-cause mortality and the social environment variables in SMI cohort (n = 22,466)¹

	Model 6.7a			Model 6.7b			Model 6.7c			Model 6.7d			Model 6.7e			Model 6.7f		
	Died (n) / Alive (n)	Crude SHR (95% CI)	p	Adjusted (deprivation) SHR (95%CI)	p	Adjusted (deprivation & sociodemographi c) SHR (95%CI)	p	Adjusted (deprivation & clinical) SHR (95%CI)	p	Adjusted (deprivation, sociodemographi c & clinical) SHR (95%CI)	p	Fully adjusted SHR (95% CI)	p					
Social environment variables																		
Social fragmentation (z score)																		
Ref: Least fragmented	63 / 3,927	-		-		-		-		-		-						
2 nd quintile	72 / 3,980	1.10 (0.81 – 1.50)	.35	1.08 (0.79 – 1.48)	.40	1.09 (0.79 – 1.50)	.38	1.04 (0.76 – 1.43)	.52	1.06 (0.77 – 1.47)	.49	1.09 (0.79 – 1.50)	.51					
3 rd quintile	51 / 3,886	0.79 (0.54 – 1.16)		0.78 (0.52 – 1.15)		0.76 (0.52 – 1.13)		0.76 (0.51 – 1.13)		0.76 (0.51 – 1.13)		0.79 (0.54 – 1.17)						
4 th quintile	78 / 4,028	1.18 (0.83 – 1.67)		1.11 (0.79 – 1.56)		1.11 (0.79 – 1.57)		1.06 (0.75 – 1.49)		1.07 (0.70 – 1.44)		1.08 (0.75 – 1.57)						
Most fragmented	72 / 4,007	1.08 (0.78 – 1.51)		1.09 (0.76 – 1.55)		1.05 (0.74 – 1.50)		1.02 (0.71 – 1.46)		1.01 (0.70 – 1.44)		1.09 (0.74 – 1.60)						
Ethnic density (%)																		
Ref: Least ethnically dense	53 / 3,793	-		-		-		-		-		-						
2 nd quintile	73 / 4,066	1.29 (0.88 – 1.89)	.43	1.23 (0.77 – 1.97)	.57	1.27 (0.79 – 2.04)	.30	1.25 (0.77 – 2.03)	.45	1.30 (0.80 – 2.11)	.25	1.30 (0.81 – 1.56)	.36					
3 rd quintile	63 / 3,927	1.14 (0.79 – 1.64)		1.10 (0.68 – 1.79)		1.15 (0.71 – 1.86)		1.10 (0.67 – 1.83)		1.15 (0.70 – 1.89)		1.19 (0.72 – 1.96)						
4 th quintile	74 / 3,889	1.36 (0.96 – 1.94)		1.38 (0.84 – 2.28)		1.50 (0.91 – 2.47)		1.42 (0.85 – 2.38)		1.53 (0.91 – 2.55)		1.56 (0.91 – 2.65)						
Most ethnically dense	73 / 4,103	1.33 (0.91 – 1.94)		1.37 (0.82 – 2.29)		1.53 (0.92 – 2.56)		1.43 (0.85 – 2.40)		1.57 (0.94 – 2.65)		1.59 (0.92 – 2.74)						
Places of worship [†]																		
Ref: lowest no. of outlets	59 / 3,806	-		-		-		-		-		-						
2 nd quintile	73 / 4,059	1.15 (0.84 – 1.57)	.74	1.17 (0.86 – 1.61)	.53	1.18 (0.86 – 1.62)	.45	1.16 (0.85 – 1.58)	.52	1.17 (0.85 – 1.60)	.45	1.13 (0.81 – 1.56)	.46					
3 rd quintile	69 / 3,968	1.08 (0.73 – 1.60)		1.06 (0.71 – 1.58)		1.05 (0.70 – 1.58)		1.06 (0.71 – 1.59)		1.06 (0.71 – 1.59)		1.06 (0.69 – 1.63)						
4 th quintile	75 / 3,974	1.16 (0.84 – 1.62)		1.21 (0.85 – 1.70)		1.20 (0.85 – 1.70)		1.18 (0.83 – 1.67)		1.19 (0.84 – 1.69)		1.21 (0.83 – 1.76)						
Highest no. of outlets	60 / 3,971	0.95 (0.65 – 1.37)		0.93 (0.64 – 1.35)		0.91 (0.62 – 1.32)		0.90 (0.62 – 1.30)		0.89 (0.61 – 1.29)		0.90 (0.61 – 1.31)						

¹ 223 cohort members were classified as not otherwise specified (R00-R99) and therefore were **not** included in the analyses for cause-specific mortality;

[†]Number of places of worship per 100,000 population; Model 6.7a is crude estimates; Model 6.7b is adjusted for area-level deprivation; Model 6.7c is adjusted for area-level deprivation and sociodemographic factors (i.e. age, sex, ethnicity and marital status); Model 6.7d is adjusted for area-level deprivation and clinical factors (i.e. substance misuse and mental health diagnosis); Model 6.7e is adjusted for area-level deprivation, sociodemographic factors and clinical factors (i.e. SMI diagnosis and substance misuse); Model 6.7f is adjusted for area-level deprivation, sociodemographic and clinical factors and all other area-level variables predictor variables ; P values are for linear trend; Age modelled as a quadratic term across all models; Robust standard errors used to adjust for clustering at the Middle Super Output Area across all models.

Sensitivity analysis

Across all models, sensitivity analyses were performed to assess the possible influence of emigration of participants out of the study catchment area for the association between the urban built and social environment variables and all-cause mortality prior to the censor date of the study observation period ([Appendices 12 – 13](#)). Associations in [tables 6.2 – 6.7](#) were robust to these additional sensitivity analyses.

6.5 Summary of findings

This study did not find associations between the built and social environment variables and all-cause or cause-specific mortality outcomes in a cohort of people diagnosed with severe mental illnesses (SMI). Although unadjusted estimates indicated weak associations between residence in neighbourhoods with higher levels of walkability, higher numbers of convenience stores and higher population density with a lower risk of all-cause and natural-cause mortality, associations were attenuated after adjusting for area-level deprivation, sociodemographic indicators and clinical factors. The variance partition coefficients (VPC) (see [Appendices 10](#) and [11](#)) for the multilevel regression models suggested that a larger proportion of the variance in all-cause mortality was attributable to clustering at the individual level rather than at the neighbourhood level (level 2 VPC = 0%). Additionally, 80% (n = 2,352) of deaths reported for the study cohort were attributable to physical causes.

The findings are consistent with studies conducted with Individuals with SMI that found no association between population density (Das-Munshi et al., 2019; 2017; Moreno-Küstner et al., 2020; Luo et al., 2020), area-level deprivation (Das-Munshi et al., 2019; 2017; Hayes et al., 2012) and social fragmentation (Das-Munshi et al., 2019; 2017) and mortality. However, the findings contrast with previous research conducted within the general population that have found associations between area-level deprivation (Seaman et al., 2019), neighbourhood walkability (Kamath et al., 2020), population density (Tunstall et al., 2012), green space (Wang & Tassinary, 2019), food outlets (Kelli et al., 2017), alcohol outlets (Matheson et al., 2014), social fragmentation (Evans et al., 2004), ethnic density (Rodriguez et al., 2018) and mortality outcomes. The contrast in findings may indicate that neighbourhood-level variables impact people with and without SMI differentially and that there may be other underlying mechanisms influencing these associations. For example, individuals with SMI may experience difficulties in accessing services and amenities in their neighbourhood because of the threat of victimisation (De Vries et al., 2019), inaccessibility of services, reduced insight into their mental health needs (Smith et al., 2013) and ongoing active symptoms of their mental health condition (e.g. positive symptoms) make it difficult to access these services (Leclerc, Noto, Bressan, & Brietzke, 2015; Solmi et al., 2018). However, it is important to note that differences in the findings from general population samples compared to the present study may also be due to differences in study design and methodologies. The absence of a control group without SMI in this study prevented me

from comparing the effect of exposure to the urban and built social environments indicators between individuals with and without SMI.

When comparing the results with those obtained from the ecological and geospatial analyses (see [Chapter 5](#)), some differences were evident. In previously presented ecological and geospatial analyses, only area-level deprivation was correlated with mortality, in unadjusted models. However, in this chapter, there was an association between residence in densely populated areas, areas with higher walkability, and higher numbers of convenience stores with a lowered risk of mortality in SMI, across unadjusted models. Whereas in the ecological regression analyses, the risk of mortality between people with SMI was compared to those without SMI (i.e., through the age and sex standardized mortality ratio measure), the analyses in this chapter was not able to include a population control group without SMI. Additionally, the analyses in this chapter modelled the risk of mortality among individual cohort members rather than the risk of mortality at the ecological level, further contributing to some of the differences in findings.

Strengths

This is the first study to systematically investigate the association of built and social environment variables with mortality in a cohort with SMI. Unlike previous studies, this study included a range of built and social environment indicators that were not limited to area-level deprivation and urbanicity measures as typically used in previous investigations identified in the systematic review (see [Chapter 3](#)). Data for the neighbourhood-level variables were collated from various publicly accessible sources, including the Ordnance Survey (2022c) Points of Interest 2012 dataset and the London Datastore. In cases where multiple data sources were available, datasets for neighbourhood-level variables were cross-checked to validate the accuracy of the data before aggregation at the geographic level (i.e. middle super output area) for subsequent statistical analyses.

This study used a multilevel modelling approach to investigate associations between the built and social environment variables and mortality. Using this approach meant that the influence of both neighbourhood-level variables and individual-level indicators could be estimated together, in relation to their association with mortality in SMI. The resulting models contribute to our current understanding of the extent to which neighbourhood-level factors influence the risk of mortality in people with SMI residing in urbanised inner-city areas in the UK.

The longitudinal design of this study has enabled examination of the association of neighbourhood-level factors on mortality in individuals with SMI over a period of just over a decade. Previous investigations have typically relied on ecological analyses to explore links between mortality outcomes and area-level variables, predominantly using samples from the general population (Middleton et al., 2004; Bray et al., 2020; Evans et al., 2004; Congdon, 2012). Extrapolating associations observed between neighbourhood-level variables and health outcomes at the group level, and assuming this applies at the individual level, can lead to ecological fallacy. The design of this study overcomes the limitations encountered in previous ecological analyses by considering the influence of variables that have been measured at both the neighbourhood- and individual-levels respectively.

The study included a large sample that encompassed all individuals with SMI who had engaged with mental health services within an urbanised geographic area over an 11-year timespan. The South London and Maudsley (SLaM) NHS trust provides secondary mental healthcare services to a large geographic catchment area containing around 1.3 million residents and holds a near-monopoly provision of these mental health services. The large dataset enabled assessment of differences in the risk of mortality across different levels of each of the neighbourhood-level measures of people with SMI living in urbanised inner-city settings in the UK. It is worth noting, however, that there is a possibility that not all individuals with SMI were in contact with SLaM and might have been missed (e.g. those who access privately funded care).

The electronic health records of the cohort also included data about patients who had been documented as having left the NHS service, which are referred to as embarkation codes. These codes allowed an assessment of the potential influence of loss to follow up which may introduce bias into the study findings. This effect arises from the possibility that associations between the risk of mortality and the urban built and social environment indicators vary between the study participants and those who have dropped out of the cohort. I conducted sensitivity analyses, which indicated that the risk estimates remained unchanged when adjusting for migration out of the cohort.

Furthermore, in the UK, healthcare providers are legally obligated to maintain accurate mortality records. These records are subject to monthly updates using national certification, minimizing the likelihood of missing any deaths among the cohort except those occurring outside the UK.

Limitations

It is important to note the limitations in this study. Firstly, there were far fewer deaths from unnatural causes (<1%) compared to natural causes in the cohort. The lower numbers of deaths from unnatural causes could have meant that subsequent analyses lacked statistical power to detect an association between these aforementioned causes of death and the neighbourhood-level variables, known as a type II error. Therefore, the findings pertaining to unnatural cause mortality should be interpreted with caution.

Secondly, while efforts were made to account for a broad spectrum of potential confounding factors, the potential for residual confounding remains. Specifically, our analysis did not include physical health comorbidities and health-related behaviours, including physical inactivity and unhealthy dietary habits which could play a role in health outcomes among individuals with SMI alongside neighbourhood-level factors (Poelman et al., 2018; Saluja, Davies, Oldmeadow, & Boyle, 2021). Unfortunately, data regarding these individual-level variables were not available, and their presence could potentially mediate the association between neighbourhood-level factors and the risk of mortality. For instance, increased levels of walkability within neighbourhoods may indirectly affect the risk of mortality by encouraging residents to walk for exercise and walking to other destinations which may indirectly lower the risk of cardiovascular diseases and other physical health complications (Lang et al., 2022).

Thirdly, assessment of exposure to neighbourhood-level variables was based on the neighbourhood where cohort members resided at the time of their SMI diagnosis. Unfortunately, there was no information regarding the length of time individuals had lived in these geographical areas. For instance, individuals who had been long-term residents of neighbourhoods with a higher prevalence of fast-food takeaway outlets would have experienced greater exposure to this risk factor compared to those who had resided there for only a short time or had recently moved. Consequently, it was not possible to make comparisons between short- and long-term residents in these areas regarding their risk of mortality. Also, the measures included in this study assessed the overall proportions of amenities in the local area, rather than the actual distance to the amenity, potentially affecting the ability to identify associations between urban, built, and social environment indicators and the risk of mortality in the cohort.

Conclusion

Overall, this study identified associations between living in neighbourhoods characterized by increased walkability, higher population density, and increased numbers of convenience stores with all-cause mortality in the unadjusted models. Nevertheless, in the fully adjusted models, which accounted for the influence of individual-level covariates, these associations were attenuated. However, other potential indirect influences on the risk of mortality (i.e. the impact of neighbourhood-level variables on physical health comorbidities and physical activity) were not included in these analyses. Therefore, further investigation including these contextual variables would be beneficial to understand other potential mechanisms that the environment could influence mortality in SMI.

Chapter 6 Summary Points

- Findings from the ecological and geospatial analyses documented in the previous chapter (see [Chapter 5 Summary Points](#)) indicated significantly higher standardised mortality ratios (SMRs) in persons with SMI when compared to the general population.
- 80% (n=2,352) of deaths recorded in the cohort were attributed to physical health conditions.
- Multilevel modelling revealed weak associations between residence in areas with higher proportions of more walkable areas, convenience stores and higher population density with lowered risk of all-cause and natural-cause mortality at the MSOA level. Associations were attenuated after adjusting for area deprivation and individual-level confounders.
- No evidence of associations between the urban built and social environment indicators and unnatural-cause mortality.
- Variance partition coefficients suggested that a larger proportion of the variance in the mortality outcome were attributed to differences at the individual level rather than at the neighbourhood level.

Chapter 7: Study 4 – Proximity to neighbourhood amenities and mortality analyses

7.1 Introduction

The multilevel modelling analyses documented in the previous chapter indicated that a larger proportion of the variance in mortality was attributable to differences between cohort members than between neighbourhoods in which cohort members resided. No associations were observed across adjusted models between a range of urban built environment and social indicators with mortality in SMI across multi-level models in the previous chapter, although some associations between increased neighbourhood walkability, population density and convenience stores with all-cause mortality in SMI were initially evident in unadjusted/ crude models. Additionally, ecological analyses (see [Chapter 5](#)) showed significantly higher standardised mortality ratios (SMRs) in persons with severe mental illnesses (SMI) when compared to the general population. Although there were potential “hot spot” or areas of higher mortality in people with SMI evident in certain areas (e.g. the northeast of the catchment area for this study), the geospatial analyses revealed no significant spatial autocorrelation among the SMRs at the middle super output area level. Subsequent regression analyses indicated no evidence of associations between neighbourhood-level variables and increased risk of mortality in individuals with SMI.

However, it is important to note the limitations of the previous analyses. the multilevel modelling analyses conducted in the preceding chapter assessed the number of neighbourhood-level amenities available to cohort members - these neighbourhood-level amenities were aggregated to the middle super output area level and for the addresses that the cohort members lived in. These measures do not consider the potential influence of accessibility (for example, as a measure of actual distance to the amenity) with the risk of mortality in SMI.

Furthermore, studies conducted using cohorts from the general population have indicated better health outcomes and health-related behaviours when living in closer proximity to neighbourhood level amenities such as supermarkets (Laraia, Siega-Riz, Kaufman, & Jones, 2004) and green spaces (Sturm & Cohen, 2014). A longitudinal study reported that living further away from the nearest fast-food outlet was associated with lower body mass index (Block, Christakis, O’Malley, & Subramanian, 2011). Therefore, the aim of this chapter was to investigate the extent to which proximity to neighbourhood-level amenities contributes

to mortality in SMI, whilst accounting for the influence of other individual-level factors.

The research question is:

- To what extent does actual distance to the nearest neighbourhood-level amenity influence the risk of all-cause and cause-specific mortality among people with SMI, taking into account individual-level sociodemographic indicators and clinical factors in the study catchment areas?

Hypotheses:

Based on previous research and analyses, I hypothesized that:

- Residence in neighbourhoods with shorter distances to the nearest publicly accessible green space, supermarket and place of worship would be associated with a lower risk of mortality among individuals with SMI.
- Residence in neighbourhoods with shorter distances to the nearest fast-food outlet, convenience store would be associated with an elevated risk of mortality among individuals with SMI.

7.2 Summary of methods

This study was an extension of analyses conducted for Study 3 and therefore uses the same cohort dataset, mortality data linkages and geographical measures (i.e. middle super output area). For further details on the cohort dataset please refer to the methods section in Study 3 ([Section 6.2](#)). This section will outline the environmental exposure measures used in Study 4, because they measure distance to the nearest environment feature, as opposed to the proportion of environment features as utilized in the analyses of Study 3.

Measures

Distance measures

I have described the cohort study design (see [Section 4.2](#) and summary study design table), the mortality outcome ([Section 4.3](#)), the exposure variables (see [Section 4.4](#)) and the multilevel modelling approach (see [Section 4.9](#)) used to investigate associations between the distance to the urban built and social environment indicators and mortality in the SMI cohort. In this chapter, I developed a cohort study comprising of individuals that were diagnosed with an SMI (defined here as schizophrenia spectrum disorder (ICD-10 codes:

F20-F29) or bipolar disorder (ICD-10 codes: F30 and F31) within the study observation period (from January 1, 2007, to December 31, 2018). Participants were followed up until either death, migration from the cohort or the end of the study period (i.e., 31st December 2018). The cohort study only included individuals with an SMI diagnosis, which meant that all subsequent analyses compared cohort members who resided in closer proximity to the nearest urban, built, and social environment indicators with other cohort members who lived at a greater distance from similar neighbourhood amenities.

7.3 Statistical methods

As previously mentioned, study 4 was an extension of analyses conducted for Study 3 and therefore uses the same statistical methods that was used in Study 3, namely multilevel modelling, variance partition coefficients and competing risks regression. The key distinction between this study and Study 3 ([Chapter 6](#)) lies in the measurement of exposure variables. In this study, the exposure variables measured the distance to the nearest urban environment indicator which are as follows: supermarkets, fast food outlets, off-licences, convenience stores, green spaces, and places of worship. In Study 3, however, the exposure variables assessed the proportion of the urban environment indicators within the study catchment area. For further details on the statistical methodology please refer to the methods section for Study 3 (see [Section 6.3](#)).

7.4 Results

25,874 patients with a diagnosis of SMI and a recorded MSOA residential code were identified from the initial CRIS data extraction. After excluding individuals with incomplete data, 22,564 were included in the cohort, contributing a median follow-up of 6.1 years (IQR 2.9 - 10.1) and a total of 2,898 deaths by the end date for the study observation period (31st December 2018) (see [Figure 7.1](#)). The cohort size for this study differed from Study 3 due to the exclusion of 125 individuals with SMI who lacked a recorded residential address which meant that I was unable to derive distance variables for these participants.

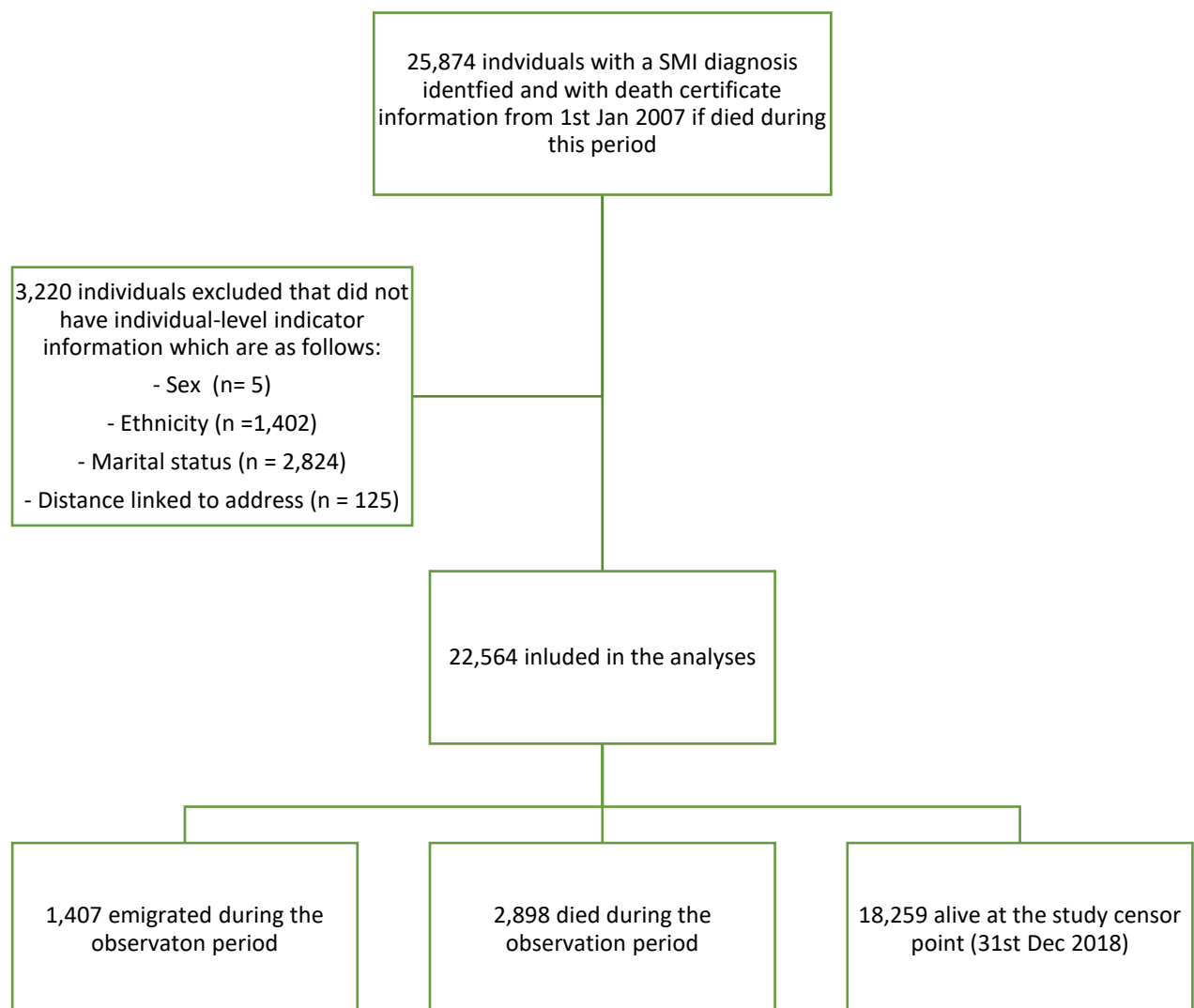


Figure 7.1. Cohort selection

[Table 7.1](#) shows descriptive characteristics of the study cohort. The median year of birth for the cohort was 1970 (IQR 1957 - 1982), 51% were male, and 72.4% had a diagnosis of a non-affective disorder. By the end of the follow-up period, 12.8% (n=2,898) of the cohort had died, of which 10.5% (n = 2,343) of the cohort had died due to natural causes and 1.5% (n= 332) had died of unnatural causes. 223 participants had died but their deaths were classified as 'not otherwise specified' (ICD-10 codes: R00-R99).

Table 7.1 Descriptive characteristics of the cohort

	Total sample	All-cause mortality		Natural-cause mortality		Unnatural-cause mortality	
	N(%)	N (%)	Crude rate* (95% CI)	N (%)	Crude rate* (95% CI)	N (%)	Crude rate* (95% CI)
Total	22,564	2,898 (12.8)	15 (14.3 – 15.3)	2,343 (10.5)	12 (11.6 – 12.5)	332 (1.5)	2 (1.5 – 1.9)
Nearest distance variables[†]							
Supermarket							
Ref. group: <0.32 km	4,491 (19.9)	551 (2.4)	14 (13.0 – 15.4)	447 (2.0)	12 (10.5 – 12.7)	67 (0.3)	2 (1.4 – 2.2)
0.32 – 0.47 km	4,547 (20.2)	571 (2.5)	14 (13.1 – 15.5)	455 (2.0)	11 (10.4 – 12.5)	69 (0.3)	2 (1.4 – 2.2)
0.48 – 0.65 km	4,496 (19.9)	562 (2.5)	14 (13.3 – 15.7)	461 (2.1)	12 (10.9 – 13.1)	52 (0.2)	1 (1.0 – 1.8)
0.66 – 0.88 km	4,516 (20.0)	583 (2.6)	15 (13.7 – 16.1)	483 (2.2)	12 (11.3 – 13.5)	61 (0.3)	2 (1.2 – 2.0)
≥0.89 km	4,514 (20.0)	631 (2.8)	16 (15.1 – 17.6)	497 (2.2)	13 (11.9 – 14.2)	83 (0.4)	2 (1.7 – 2.7)
Convenience store							
Ref. group: <0.09 km	4,514 (20.0)	587 (2.6)	15 (14.1 – 16.6)	480 (2.2)	13 (11.6 – 13.8)	60 (0.3)	2 (1.2 – 2.0)
0.09 – 0.14 km	4,528 (20.1)	574 (2.5)	14 (13.2 – 15.5)	461 (2.1)	12 (10.5 – 12.6)	78 (0.4)	2 (1.6 – 2.4)
0.15 – 0.19 km	4,557 (20.2)	579 (2.6)	14 (13.1 – 15.5)	474 (2.1)	12 (10.8 – 12.9)	61 (0.3)	2 (1.2 – 1.9)
0.20 – 0.28 km	4,494 (19.9)	543 (2.4)	14 (12.5 – 14.8)	442 (2.0)	11 (10.1 – 12.2)	62 (0.3)	2 (1.2 – 2.0)
≥0.29 km	4,471 (19.8)	615 (2.7)	17 (15.4 – 18.0)	486 (2.2)	13 (12.2 – 14.5)	71 (0.3)	2 (1.5 – 2.5)
Off-licence							
Ref. group: <0.18 km	4,519 (20.0)	552 (2.5)	14 (12.7 – 15.0)	440 (2.0)	11 (10.1 – 12.2)	78 (0.4)	2 (1.6 – 2.5)
0.18 – 0.27 km	4,488 (19.9)	549 (2.4)	14 (12.8 – 15.2)	458 (2.1)	12 (10.7 – 12.8)	55 (0.3)	1 (1.1 – 1.8)
0.28 – 0.38 km	4,557 (20.2)	572 (2.5)	14 (13.3 – 15.6)	463 (2.1)	12 (10.7 – 12.9)	69 (0.3)	2 (1.4 – 2.2)
0.39 – 0.56 km	4,510 (20.0)	585 (2.6)	15 (13.5 – 15.9)	464 (2.1)	12 (10.7 – 12.8)	64 (0.3)	2 (1.3 – 2.1)
≥0.57 km	4,490 (19.9)	640 (2.8)	17 (16.0 – 18.7)	518 (2.3)	14 (13.0 – 15.4)	66 (0.3)	2 (1.4 – 2.3)
Fast-food outlet							
Ref. group: <0.10 km	4,486 (19.9)	516 (2.3)	13 (12.2 – 14.5)	414 (1.9)	11 (9.7 – 11.8)	67 (0.3)	2 (1.4 – 2.2)
0.11 – 0.17 km	4,497 (19.9)	619 (2.7)	16 (14.5 – 17.0)	504 (2.3)	13 (11.8 – 14.1)	70 (0.3)	2 (1.4 – 2.3)
0.18 – 0.25 km	4,562 (20.2)	541 (2.4)	13 (12.3 – 14.6)	443 (2.0)	11 (10.0 – 12.1)	65 (0.8)	2 (1.3 – 2.1)

	Total sample	All-cause mortality		Natural-cause mortality		Unnatural-cause mortality	
	N(%)	N (%)	Crude rate* (95% CI)	N (%)	Crude rate* (95% CI)	N (%)	Crude rate* (95% CI)
0.26 – 0.36 km	4,557 (20.2)	572 (2.5)	14 (16.0 – 18.7)	470 (2.1)	12 (10.9 – 13.0)	60 (0.3)	2 (1.2 – 2.0)
≥0.37 km	4,462 (19.8)	650 (2.9)	17 (16.0 – 18.7)	512 (2.3)	14 (12.7 – 15.0)	70 (0.3)	2 (1.5 – 2.4)
Green spaces[‡]							
Ref. group: <0.07 km	4,561 (20.2)	531 (2.4)	13 (12.0 – 14.3)	434 (1.9)	11 (9.8 – 11.8)	64 (0.3)	2 (1.2 – 2.0)
0.07 – 0.11 km	4,527 (20.1)	560 (2.5)	14 (12.9 – 15.3)	457 (2.1)	12 (10.5 – 12.7)	61 (0.3)	2 (1.2 – 2.0)
0.12 – 0.16 km	4,545 (20.1)	672 (3.0)	17 (15.6 – 18.3)	530 (2.4)	14 (12.5 – 14.8)	73 (0.3)	2 (1.5 – 2.4)
0.17 – 0.23 km	4,461 (19.8)	554 (2.5)	15 (13.5 – 15.9)	445 (2.0)	12 (10.8 – 13.0)	62 (0.3)	2 (1.3 – 2.1)
≥0.24 km	4,470 (19.8)	581 (2.6)	15 (14.0 – 16.4)	477 (2.1)	13 (11.4 – 13.7)	72 (0.3)	2 (1.5 – 2.4)
Place of worship							
Ref. group: <0.12 km	4,503 (20.0)	582 (2.6)	15 (13.8 – 16.2)	476 (2.1)	12 (11.2 – 13.5)	62 (0.3)	2 (1.2 – 2.1)
0.12 – 0.18 km	4,532 (20.1)	574 (2.5)	14 (13.1 – 15.4)	469 (2.1)	12 (10.7 – 12.8)	61 (0.3)	2 (1.2 – 2.0)
0.19 – 0.25 km	4,537 (20.1)	558 (2.5)	14 (12.8 – 15.1)	450 (2.0)	11 (10.3 – 12.4)	69 (0.3)	2 (1.4 – 2.2)
0.26 – 0.34 km	4,521 (20.4)	591 (2.6)	15 (13.9 – 16.4)	473 (2.1)	12 (11.1 – 13.3)	74 (0.3)	2 (1.5 – 2.4)
≥0.35 km	4,471 (19.8)	590 (2.6)	16 (14.6 – 17.1)	475 (2.1)	13 (11.7 – 14.0)	66 (0.3)	2 (1.4 – 2.3)
Individual-level covariates¹							

[†]Distance (km) to the nearest neighbourhood amenity; [‡]publicly accessible green spaces; *Crude rates are per 1,000 person years; deaths of 223 cohort members were classified as not otherwise specified (R00-R99) and therefore were only included in the analyses for all-cause mortality; ¹please refer to the descriptive characteristics table in Study 3 (see [Table 6.1](#)) for information on proportions related to the individual-level covariates

Distributions of the average distance to neighbourhood amenities

[Figure 7.1](#) show the aggregated distributions of the average distance to the nearest neighbourhood amenities at the level of the middle super output area. Average distance to the nearest supermarket showed the greatest variability, with mean distances ranging from .26 km to 2.45 km across the four boroughs (Figure 7.1a). Figures 7.1b - 7.1f show that cohort members living in the northern parts of Southwark and Lambeth on average lived closer to convenience stores, off-licences, fast-food outlets, publicly accessible green spaces and places of worship. The distributions of the average distance to the neighbourhood amenities differ to the mapped proportions of these same neighbourhood amenities that were aggregated to the middle super output area level in Study 2 (see [Figure 5.2](#)). Namely, the spatial clustering is clearer when using the distance to the nearest neighbourhood amenity measures compared with the measures of the proportions of these neighbourhood features (see Study 2, [Figure 5.2](#)) most maps (Figures 7.1b - 7.1e) showed that cohort members residing in the most northerly parts of the study catchment area appeared to live in closer proximity to a neighbourhood-level amenity. These clusters also happen to be in areas which are more densely populated as indicated by the population density map in Study 2 (see [Figure 5.3e](#)).

Fig. 7.1 Mapped distributions of the average distance to urban environment indicators per MSOA¹

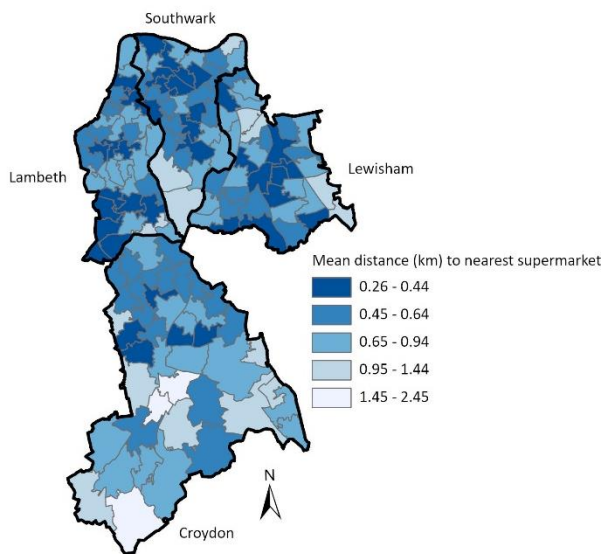


Fig. 7.1a. Distribution of the average distance (km) to the nearest supermarket

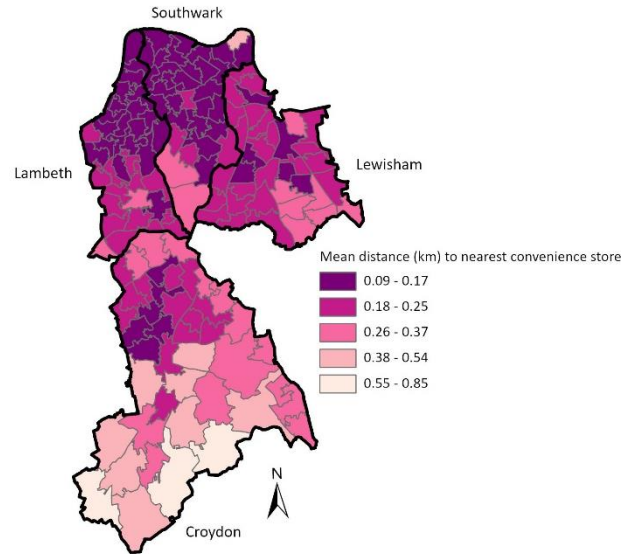


Fig. 7.1b. Distribution of the average distance (km) to the nearest convenience store

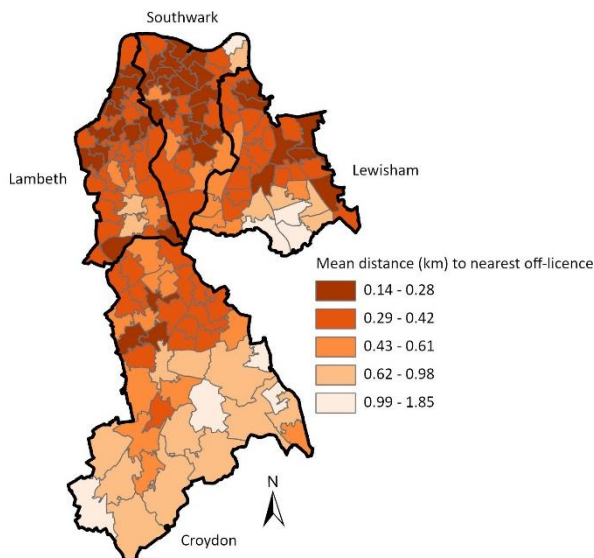


Fig. 7.1c. Distribution of the average distance (km) to the nearest off-licence

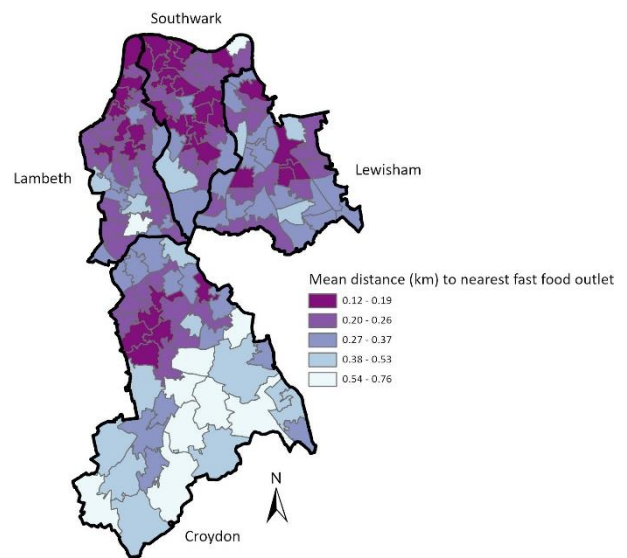


Fig. 7.1d. Distribution of the average distance (km) to the nearest fast-food outlet

¹ NB: Darker shaded areas of the maps in figures 7.1 - 7.1f indicate shorter mean distance to urban environment indicator

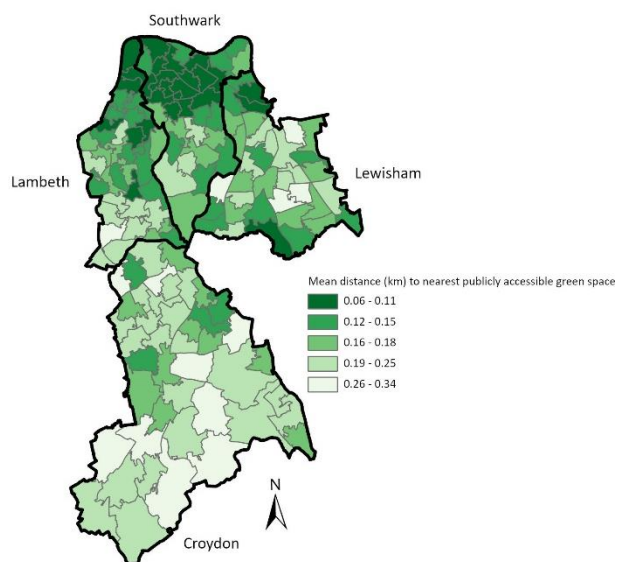


Fig. 7.1e. Distribution of the average distance (km) to the nearest publicly accessible green space

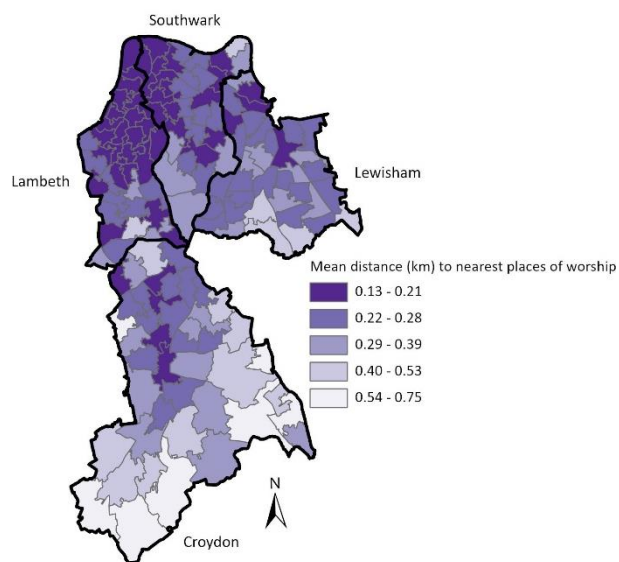


Fig. 7.1f. Distribution of the average distance (km) to the nearest place of worship

All-cause mortality and distance to nearest environment exposure

[Table 7.2](#) presents the associations between the distance to the nearest built environment exposure variables and all-cause mortality in SMI. Unadjusted estimates from model 7.2a showed that cohort members that lived further away from the nearest publicly accessible green space and fast-food outlet had a higher risk of mortality compared to those that lived close to these neighbourhood amenities. These associations were not attenuated by models accounting for the influence of area-level deprivation (model 7.2b). In the fully adjusted models (model 7.2f), the association between higher risk of all-cause mortality and residence further away from a publicly accessible green space remained after accounting for the influence of individual-level covariates. However, the impact of distance to the nearest fast-food outlet and all-cause mortality was attenuated in the fully adjusted models. Fully adjusted models for the associations between all-cause mortality and the sociodemographic and individual-level covariates rendered the same associations as observed in Study 3 (see [Appendix 14](#), Model A14.e).

The variance partition coefficients (VPC) and associated goodness-of-fit statistics have been documented in [Appendix 17](#). The VPCs and goodness-of-fit (deviance) statistics were similar to those derived for Study 3 (see [Section 6.3](#)), in that the empty model VPC indicated low levels of clustering of mortality outcomes by neighbourhood (empty model VPC = 0.4%) which also reduced in the fully adjusted models (VPC = .005%). Additionally, goodness-of-fit coefficients showed the most improvement in models that accounted for the individual-level covariates ([Appendix 17](#)) as observed in Study 3.

Table 7.2 Distance to the nearest built environment variable and all-cause mortality (n = 22,564)

	Model 7.2a			Model 7.2b		Model 7.2c		Model 7.2d		Model 7.2e		Model 7.2f	
	Died (n) / Alive (n)	Crude IRR (95% CI)	p	Adjusted (deprivation) IRR (95%CI)	p	Adjusted (deprivation & sociodemographic) IRR (95%CI)	p	Adjusted (deprivation & clinical) IRR (95%CI)	p	Adjusted (deprivation, sociodemograph ic & clinical) IRR (95%CI)	p	Fully adjusted IRR (95% CI)	p
Nearest distance variables[†]													
Supermarket													
Ref. group: <0.32 km	551 / 3,940	-		-		-		-		-		-	
0.32 – 0.47 km	571 / 3,976	1.01 (0.88 – 1.17)	.28	1.01 (0.88 – 1.18)	.29	1.04 (0.93 – 1.16)	.27	1.01 (0.87 – 1.17)	.29	1.04 (0.93 – 1.16)	.25	1.05 (0.94 – 1.18)	.20
0.48 – 0.65 km	562 / 3,934	1.04 (0.90 – 1.20)		1.04 (0.90 – 1.20)		0.98 (0.89 – 1.09)		1.03 (0.89 – 1.20)		0.99 (0.89 – 1.10)		0.98 (0.88 – 1.09)	
0.66 – 0.88 km	583 / 3,933	1.06 (0.93 – 1.21)		1.06 (0.93 – 1.21)		1.04 (0.94 – 1.14)		1.06 (0.93 – 1.20)		1.04 (0.94 – 1.14)		1.03 (0.93 – 1.15)	
≥0.89 km	631 / 3,883	1.15 (0.99 – 1.32)		1.14 (0.99 – 1.31)		1.10 (0.98 – 1.22)		1.14 (0.99 – 1.31)		1.10 (0.99 – 1.23)		1.10 (0.97 – 1.25)	
Convenience store													
Ref. group: <0.09 km	587 / 3,927	-		-		-		-		-		-	
0.09 – 0.14 km	574 / 3,954	0.97 (0.86 – 1.09)	.49	0.97 (0.86 – 1.09)	.53	0.97 (0.88 – 1.08)	.05	0.97 (0.86 – 1.09)	.52	0.97 (0.88 – 1.08)	.09	0.95 (0.85 – 1.06)	.04
0.15 – 0.19 km	579 / 3,978	0.97 (0.85 – 1.11)		0.97 (0.85 – 1.11)		0.94 (0.86 – 1.03)		0.97 (0.85 – 1.10)		0.95 (0.86 – 1.04)		0.91 (0.83 – 1.01)	
0.20 – 0.28 km	543 / 3,951	0.93 (0.82 – 1.05)		0.92 (0.81 – 1.05)		0.88 (0.80 – 0.96)		0.92 (0.81 – 1.04)		0.88 (0.81 – 0.97)		0.85 (0.76 – 0.96)	
≥0.29 km	615 / 3,856	1.04 (0.90 – 1.20)		1.03 (0.89 – 1.19)		0.93 (0.85 – 1.02)		1.03 (0.89 – 1.19)		0.94 (0.85 – 1.03)		0.85 (0.75 – 0.96)	
Off-licence													
Ref. group: <0.18 km	552 / 3,967	-		-		-		-		-		-	
0.18 – 0.27 km	549 / 3,939	1.01 (0.89 – 1.14)	.22	1.01 (0.89 – 1.14)	.24	0.93 (0.83 – 1.03)	.57	1.00 (0.88 – 1.13)	.25	0.93 (0.83 – 1.03)	.56	0.96 (0.86 – 1.07)	.81
0.28 – 0.38 km	572 / 3,985	1.04 (0.91 – 1.19)		1.04 (0.91 – 1.19)		0.96 (0.87 – 1.06)		1.03 (0.90 – 1.18)		0.96 (0.87 – 1.06)		0.99 (0.89 – 1.10)	
0.39 – 0.56 km	585 / 3,925	1.06 (0.94 – 1.20)		1.06 (0.94 – 1.21)		0.95 (0.86 – 1.05)		1.05 (0.93 – 1.19)		0.95 (0.86 – 1.05)		0.97 (0.87 – 1.07)	
≥0.57 km	640 / 3,850	1.17 (1.02 – 1.35)		1.17 (1.01 – 1.34)		1.00 (0.90 – 1.11)		1.16 (1.01 – 1.33)		1.00 (0.90 – 1.11)		1.02 (0.91 – 1.14)	
Fast food outlet													
Ref. group: <0.10 km	516 / 3,970	-		-		-		-		-		-	
0.11 – 0.17 km	619 / 3,878	1.19 (1.04 – 1.36)	.003	1.19 (1.04 – 1.36)	.004	1.06 (0.96 – 1.17)	.29	1.18 (1.04 – 1.34)	.004	1.07 (0.96 – 1.18)	.26	1.11 (1.00 – 1.24)	.33
0.18 – 0.25 km	541 / 4,021	1.02 (0.89 – 1.17)		1.02 (0.89 – 1.17)		0.94 (0.85 – 1.04)		1.02 (0.89 – 1.16)		0.94 (0.85 – 1.04)		1.02 (0.90 – 1.15)	
0.26 – 0.36 km	572 / 3,985	1.08 (0.96 – 1.22)		1.08 (0.95 – 1.22)		0.99 (0.90 – 1.10)		1.07 (0.95 – 1.21)		1.00 (0.90 – 1.10)		1.09 (0.95 – 1.24)	
≥0.37 km	650 / 3,812	1.25 (1.08 – 1.43)		1.24 (1.07 – 1.43)		1.02 (0.92 – 1.14)		1.23 (1.07 – 1.42)		1.04 (0.93 – 1.15)		1.11 (0.96 – 1.29)	
Green spaces[‡]													

	Model 7.2a			Model 7.2b		Model 7.2c		Model 7.2d		Model 7.2e		Model 7.2f	
	Died (n) / Alive (n)	Crude IRR (95% CI)	p	Adjusted (deprivation) IRR (95%CI)	p	Adjusted (deprivation & sociodemographic) IRR (95%CI)	p	Adjusted (deprivation & clinical) IRR (95%CI)	p	Adjusted (deprivation, sociodemograph ic & clinical) IRR (95%CI)	p	Fully adjusted IRR (95% CI)	p
Ref. group: <0.07 km	531 / 4,030	-		-		-		-		-		-	
0.07 – 0.11 km	560 / 3,967	1.08 (0.94 – 1.24)	.004	1.08 (0.94 – 1.24)	.005	1.01 (0.91 – 1.13)	.03	1.08 (0.94 – 1.24)	.004	1.02 (0.92 – 1.13)	.03	1.02 (0.91 – 1.13)	.04
0.12 – 0.16 km	672 / 3,873	1.30 (1.13 – 1.50)		1.30 (1.13 – 1.50)		1.16 (1.04 – 1.30)		1.30 (1.13 – 1.49)		1.17 (1.05 – 1.30)		1.15 (1.03 – 1.29)	
0.17 – 0.23 km	554 / 3,907	1.09 (0.94 – 1.27)		1.09 (0.93 – 1.27)		1.02 (0.91 – 1.16)		1.10 (0.94 – 1.28)		1.03 (0.91 – 1.16)		1.02 (0.90 – 1.15)	
≥0.24 km	581 / 3,889	1.13 (0.98 – 1.32)		1.13 (0.96 – 1.32)		1.07 (0.94 – 1.21)		1.12 (0.96 – 1.31)		1.08 (0.95 – 1.22)		1.07 (0.94 – 1.21)	
Place of worship													
Ref. group: <0.12 km	585 / 3,918	-		-		-		-		-		-	
0.12 – 0.18 km	574 / 3,985	0.96 (0.84 – 1.10)	.93	0.96 (0.84 – 1.10)	.94	0.98 (0.88 – 1.08)	.38	0.96 (0.84 – 1.10)	.95	0.98 (0.88 – 1.09)	.37	0.97 (0.88 – 1.08)	.29
0.19 – 0.25 km	558 / 3,979	0.95 (0.83 – 1.09)		0.95 (0.83 – 1.08)		0.95 (0.87 – 1.05)		0.95 (0.84 – 1.09)		0.96 (0.87 – 1.06)		0.96 (0.87 – 1.05)	
0.26 – 0.34 km	591 / 3,930	0.99 (0.88 – 1.13)		0.99 (0.88 – 1.12)		1.05 (0.95 – 1.17)		1.00 (0.88 – 1.13)		1.06 (0.95 – 1.18)		1.06 (0.95 – 1.18)	
≥0.35 km	590 / 3,881	1.00 (0.87 – 1.15)		0.99 (0.86 – 1.13)		1.00 (0.90 – 1.10)		0.99 (0.87 – 1.13)		1.00 (0.91 – 1.11)		0.99 (0.89 – 1.10)	

[†]Distance (km) to the nearest neighbourhood amenity; [‡]publicly accessible green spaces; Model 7.2a is crude estimates; Model 7.2b is adjusted for area-level deprivation; Model 7.2c is adjusted for area-level deprivation and sociodemographic factors (i.e. age, sex, ethnicity and marital status); ; Model 7.2c is adjusted for area-level deprivation and clinical factors (i.e. substance misuse and mental health diagnosis); Model 7.2e is adjusted for area-level deprivation, sociodemographic factors and clinical factors (i.e. SMI diagnosis and substance misuse); Model 7.2f is adjusted for area-level deprivation, sociodemographic and clinical factors and all other area-level variables predictor variables ; P values are for linear trend; Age modelled as a quadratic term across all models; Robust standard errors used to adjust for clustering at the Middle Super Output Area across all models; VPC = Variance Partition Coefficient.

Natural-cause mortality and distance to the nearest built environment feature

[Table 7.3](#) shows the sub-hazard ratios from the competing risks regression for the distance to the nearest built environment variables and natural-cause mortality. Crude estimates (model 7.3a) indicated that cohort members that lived further away from the nearest off-licence and fast-food outlet were at increased risk of natural-cause mortality. However, these associations were attenuated in models that accounted for the influence of sociodemographic and clinical variables (models 7.3d - 7.3f).

Assessment of the coefficients for the individual-level covariates indicated a lower risk of natural-cause mortality among cohort members, those with affective disorders, individuals in cohabiting or married relationships and among racially minoritized individuals. However, a higher risk of natural-cause mortality was observed among older cohort members ([Appendix 15](#), Model A15.e).

Schoenfeld-like residual plots revealed no major violations of the proportional hazards.

Table 7.3 Distance to the nearest built environment variable and natural-cause mortality (n = 22,341)

	Model 7.3a			Model 7.3b			Model 7.3c			Model 7.3d			Model 7.3e			Model 7.3f		
	Died (n) / Alive (n)	Crude IRR (95% CI)	p	Adjusted (deprivation) IRR (95%CI)	p	Adjusted (deprivation & sociodemographi c) IRR (95%CI)	p	Adjusted (deprivation & clinical) IRR (95%CI)	p	Adjusted (deprivation, sociodemographi c & clinical) IRR (95%CI)	p	Fully adjusted IRR (95% CI)	p					
Nearest distance variables [†]																		
Supermarket																		
Ref. group: <0.32 km	447 / 3,940	-	-	-	-	-	-	-	-	-	-	-	-					
0.32 – 0.47 km	455 / 3,976	0.99 (0.84 – 1.17)	.61	0.99 (0.84 – 1.17)	.63	1.02 (0.88 – 1.17)	.60	0.99 (0.84 – 1.16)	.64	1.01 (0.88 – 1.17)	.62	1.05 (0.90 – 1.21)	.54					
0.48 – 0.65 km	461 / 3,934	1.04 (0.88 – 1.22)		1.04 (0.89 – 1.22)		0.97 (0.86 – 1.10)		1.03 (0.88 – 1.21)		0.97 (0.86 – 1.10)		0.98 (0.86 – 1.12)						
0.66 – 0.88 km	483 / 3,933	1.07 (0.91 – 1.25)		1.07 (0.91 – 1.24)		1.07 (0.94 – 1.20)		1.07 (0.91 – 1.24)		1.06 (0.94 – 1.20)		1.08 (0.95 – 1.22)						
≥0.89 km	497 / 3,883	1.11 (0.94 – 1.30)		1.10 (0.94 – 1.28)		1.03 (0.91 – 1.17)		1.09 (0.93 – 1.27)		1.04 (0.92 – 1.17)		1.06 (0.93 – 1.21)						
Convenience store																		
Ref. group: <0.09 km	480 / 3,927	-	-	-	-	-	-	-	-	-	-	-	-					
0.09 – 0.14 km	461 / 3,954	0.92 (0.79 – 1.06)	.17	0.91 (0.79 – 1.06)	.21	0.91 (0.80 – 1.05)	.04	0.91 (0.79 – 1.05)	.18	0.91 (0.80 – 1.05)	.05	0.89 (0.77 – 1.03)	.13					
0.15 – 0.19 km	474 / 3,978	0.93 (0.81 – 1.08)		0.94 (0.81 – 1.09)		0.91 (0.81 – 1.02)		0.93 (0.80 – 1.08)		0.91 (0.81 – 1.03)		0.89 (0.77 – 1.03)						
0.20 – 0.28 km	442 / 3,951	0.88 (0.77 – 1.01)		0.88 (0.77 – 1.00)		0.82 (0.73 – 0.93)		0.87 (0.76 – 0.99)		0.83 (0.73 – 0.94)		0.82 (0.69 – 0.96)						
≥0.29 km	486 / 3,856	1.03 (0.88 – 1.21)		1.01 (0.86 – 1.19)		0.87 (0.77 – 0.98)		1.00 (0.85 – 1.18)		0.87 (0.77 – 0.99)		0.81 (0.68 – 0.97)						
Off-licence																		
Ref. group: <0.18 km	440 / 3,967	-	-	-	-	-	-	-	-	-	-	-	-					
0.18 – 0.27 km	458 / 3,938	1.05 (0.91 – 1.21)	.04	1.06 (0.92 – 1.22)	.04	0.94 (0.82 – 1.07)	.56	1.05 (0.91 – 1.20)	.05	0.94 (0.82 – 1.08)	.52	1.00 (0.87 – 1.16)	.56					
0.28 – 0.38 km	463 / 3,985	1.06 (0.90 – 1.23)		1.06 (0.90 – 1.24)		0.96 (0.84 – 1.10)		1.05 (0.90 – 1.23)		0.96 (0.84 – 1.10)		1.02 (0.88 – 1.18)						
0.39 – 0.56 km	464 / 3,925	1.06 (0.92 – 1.22)		1.06 (0.92 – 1.22)		0.92 (0.81 – 1.04)		1.05 (0.91 – 1.20)		0.92 (0.81 – 1.04)		0.97 (0.85 – 1.11)						
≥0.57 km	518 / 3,850	1.26 (1.08 – 1.47)		1.25 (1.08 – 1.44)		1.00 (0.89 – 1.14)		1.23 (1.07 – 1.42)		1.01 (0.89 – 1.14)		1.08 (0.93 – 1.24)						
Fast food outlet																		
Ref. group: <0.10 km	414 / 3,970	-	-	-	-	-	-	-	-	-	-	-	-					
0.11 – 0.17 km	504 / 3,878	1.21 (1.03 – 1.42)	.01	1.20 (1.03 – 1.40)	.03	1.04 (0.90 – 1.18)	.23	1.19 (1.02 – 1.38)	.04	1.04 (0.91 – 1.19)	.25	1.09 (0.94 – 1.26)	.54					
0.18 – 0.25 km	443 / 4,021	1.03 (0.88 – 1.20)		1.03 (0.88 – 1.20)		0.88 (0.77 – 1.00)		1.02 (0.87 – 1.19)		0.88 (0.77 – 1.00)		0.96 (0.81 – 1.13)						
0.26 – 0.36 km	470 / 3,985	1.11 (0.97 – 1.28)		1.10 (0.96 – 1.27)		0.97 (0.85 – 1.11)		1.09 (0.95 – 1.26)		0.97 (0.86 – 1.11)		1.07 (0.89 – 1.27)						
≥0.37 km	512 / 3,812	1.27 (1.07 – 1.50)		1.24 (1.05 – 1.46)		0.94 (0.82 – 1.09)		1.22 (1.03 – 1.45)		0.95 (0.82 – 1.10)		1.02 (0.84 – 1.24)						
Green spaces [†]																		
Ref. group: <0.07 km	434 / 4,030	-	-	-	-	-	-	-	-	-	-	-	-					
0.07 – 0.11 km	457 / 3,967	1.08 (0.91 – 1.27)	.06	1.08 (0.91 – 1.27)	.07	0.98 (0.86 – 1.12)	.35	1.07 (0.91 – 1.26)	.08	0.98 (0.86 – 1.12)	.37	0.98 (0.86 – 1.12)	.44					
0.12 – 0.16 km	530 / 3,873	1.26 (1.07 – 1.48)		1.25 (1.07 – 1.46)		1.11 (0.97 – 1.28)		1.25 (1.06 – 1.46)		1.11 (0.97 – 1.28)		1.10 (0.96 – 1.27)						
0.17 – 0.23 km	445 / 3,907	1.10 (0.93 – 1.30)		1.09 (0.92 – 1.29)		1.01 (0.87 – 1.18)		1.09 (0.92 – 1.29)		1.02 (0.88 – 1.18)		1.01 (0.87 – 1.17)						
≥0.24 km	577 / 3,889	1.15 (0.99 – 1.34)		1.15 (0.98 – 1.34)		1.06 (0.92 – 1.23)		1.13 (0.96 – 1.32)		1.07 (0.93 – 1.23)		1.07 (0.92 – 1.23)						
Place of worship																		
Ref. group: <0.12 km	476 / 3,918	-	-	-	-	-	-	-	-	-	-	-	-					
0.12 – 0.18 km	469 / 3,958	0.95 (0.81 – 1.11)	.70	0.95 (0.81 – 1.10)	.77	0.99 (0.87 – 1.13)	.33	0.95 (0.82 – 1.10)	.80	0.99 (0.87 – 1.13)	.32	0.99 (0.87 – 1.12)	.24					

	Model 7.3a			Model 7.3b		Model 7.3c		Model 7.3d		Model 7.3e		Model 7.3f	
	Died (n) / Alive (n)	Crude IRR (95% CI)	<i>p</i>	Adjusted (deprivation) IRR (95%CI)	<i>p</i>	Adjusted (deprivation & sociodemographi c) IRR (95%CI)	<i>p</i>	Adjusted (deprivation & clinical) IRR (95%CI)	<i>p</i>	Adjusted (deprivation, sociodemographi c & clinical) IRR (95%CI)	<i>p</i>	Fully adjusted IRR (95% CI)	<i>p</i>
0.19 – 0.25 km	450 / 3,979	0.91 (0.78 – 1.07)		0.91 (0.78 – 1.07)		0.93 (0.81 – 1.06)		0.92 (0.79 – 1.07)		0.93 (0.82 – 1.06)		0.94 (0.83 – 1.07)	
0.26 – 0.34 km	473 / 3,930	0.99 (0.85 – 1.14)		0.98 (0.85 – 1.13)		1.06 (0.93 – 1.20)		0.98 (0.85 – 1.13)		1.06 (0.93 – 1.20)		1.08 (0.95 – 1.22)	
≥0.35 km	475 / 3,881	1.02 (0.87 – 1.21)		0.99 (0.85 – 1.16)		0.99 (0.87 – 1.14)		0.99 (0.85 – 1.15)		1.00 (0.87 – 1.15)		1.02 (0.88 – 1.18)	

[†]Distance (km) to the nearest neighbourhood amenity; [‡]publicly accessible green spaces; Model 7.3a is crude estimates; Model 7.3b is adjusted for area-level deprivation; Model 7.3c is adjusted for area-level deprivation and sociodemographic factors (i.e. age, sex, ethnicity and marital status); ; Model 7.3c is adjusted for area-level deprivation and clinical factors (i.e. substance misuse and mental health diagnosis); Model 7.3e is adjusted for area-level deprivation, sociodemographic factors and clinical factors (i.e. SMI diagnosis and substance misuse); Model 7.3f is adjusted for area-level deprivation, sociodemographic and clinical factors and all other area-level variables predictor variables ; P values are for linear trend; Age modelled as a quadratic term across all models; Robust standard errors used to adjust for clustering at the Middle Super Output Area across all models; VPC = Variance Partition Coefficient.

Unnatural cause mortality (deaths from suicides and accidents) and distance to nearest environment exposure

[Table 7.4](#) presents the sub-hazard ratios for the association of the nearest distance to features of the built environment and unnatural-cause mortality. No associations were observed between the distance variables and unnatural cause mortality across both the unadjusted and adjusted models (models 7.4a - 7.4f). Assessment of associations between the individual-level covariates and unnatural-cause mortality revealed a lower risk of unnatural-cause mortality among female cohort members, those who were married or cohabitating and those from racially minoritized backgrounds. A higher risk of unnatural-cause mortality was observed among those with histories of substance misuse (see [Appendix 16](#), Model A16.e). Schoenfeld-like residual plots revealed violations of the proportional hazards.

Table 7.4 Distance to the nearest built environment variable and unnatural-cause mortality (n = 22,341)

	Model 7.4a			Model 7.4b		Model 7.4c		Model 7.4d		Model 7.4e		Model 7.4f	
	Died (n) / Alive (n)	Crude IRR (95% CI)	p	Adjusted (deprivation) IRR (95%CI)	p	Adjusted (deprivation & socio-demographi c) IRR (95%CI)	p	Adjusted (deprivation & clinical) IRR (95%CI)	p	Adjusted (deprivation, socio-demographi c & clinical) IRR (95%CI)	p	Fully adjusted IRR (95% CI)	p
Nearest distance variables†													
Supermarket													
Ref. group: <0.32 km	67 / 3,940	-	-	-	-	-	-	-	-	-	-	-	-
0.32 – 0.47 km	69 / 3,976	1.01 (0.71 – 1.43)	.09	1.00 (0.70 – 1.42)	.06	0.99 (0.70 – 1.41)	.09	1.01 (0.71 – 1.44)	.06	1.00 (0.71 – 1.42)	.09	1.01 (0.69 – 1.47)	.13
0.48 – 0.65 km	52 / 3,934	0.78 (0.57 – 1.06)		0.77 (0.57 – 1.05)		0.78 (0.57 – 1.05)		0.79 (0.58 – 1.08)		0.79 (0.58 – 1.07)		0.80 (0.59 – 1.09)	
0.66 – 0.88 km	61 / 3,933	0.90 (0.64 – 1.26)		0.90 (0.64 – 1.26)		0.91 (0.65 – 1.28)		0.91 (0.65 – 1.27)		0.93 (0.66 – 1.30)		0.93 (0.65 – 1.33)	
≥0.89 km	83 / 3,883	1.23 (0.90 – 1.69)		1.27 (0.92 – 1.75)		1.26 (0.91 – 1.74)		1.31 (0.95 – 1.81)		1.29 (0.94 – 1.78)		1.27 (0.88 – 1.82)	
Convenience store													
Ref. group: <0.09 km	60 / 3,927	-	-	-	-	-	-	-	-	-	-	-	-
0.09 – 0.14 km	78 / 3,954	1.26 (0.85 – 1.86)	.60	1.27 (0.86 – 1.88)	.51	1.29 (0.87 – 1.91)	.52	1.28 (0.86 – 1.90)	.44	1.30 (0.87 – 1.93)	.48	1.31 (0.86 – 1.98)	.59
0.15 – 0.19 km	61 / 3,978	0.98 (0.70 – 1.35)		0.98 (0.71 – 1.36)		0.99 (0.71 – 1.37)		0.99 (0.72 – 1.38)		1.00 (0.73 – 1.39)		1.03 (0.71 – 1.49)	
0.20 – 0.28 km	62 / 3,951	1.01 (0.70 – 1.44)		1.02 (0.71 – 1.45)		1.03 (0.72 – 1.47)		1.04 (0.73 – 1.48)		1.05 (0.74 – 1.49)		1.13 (0.74 – 1.74)	
≥0.29 km	71 / 3,856	1.20 (0.85 – 1.70)		1.25 (0.89 – 1.76)		1.25 (0.89 – 1.76)		1.30 (0.92 – 1.83)		1.29 (0.91 – 1.81)		1.30 (0.82 – 2.07)	
Off-licence													
Ref. group: <0.18 km	78 / 3,967	-	-	-	-	-	-	-	-	-	-	-	-
0.18 – 0.27 km	55 / 3,939	0.71 (0.51 – 0.99)	.37	0.71 (0.51 – 1.00)	.36	0.71 (0.51 – 1.00)	.38	0.73 (0.52 – 1.02)	.41	0.72 (0.52 – 1.02)	.42	0.72 (0.51 – 1.02)	.45
0.28 – 0.38 km	69 / 3,985	0.88 (0.65 – 1.19)		0.88 (0.65 – 1.19)		0.88 (0.65 – 1.20)		0.90 (0.66 – 1.23)		0.89 (0.65 – 1.22)		0.88 (0.64 – 1.21)	
0.39 – 0.56 km	64 / 3,925	0.82 (0.59 – 1.14)		0.82 (0.59 – 1.14)		0.83 (0.60 – 1.15)		0.83 (0.60 – 1.16)		0.84 (0.60 – 1.16)		0.79 (0.55 – 1.14)	
≥0.57 km	66 / 3,850	0.88 (0.63 – 1.24)		0.91 (0.65 – 1.26)		0.91 (0.66 – 1.26)		0.94 (0.68 – 1.31)		0.92 (0.66 – 1.29)		0.81 (0.56 – 1.19)	
Fast food outlet													
Ref. group: <0.10 km	67 / 3,970	-	-	-	-	-	-	-	-	-	-	-	-
0.11 – 0.17 km	70 / 3,878	1.03 (0.76 – 1.40)	.79	1.03 (0.75 – 1.40)	.71	1.04 (0.77 – 1.42)	.70	1.06 (0.78 – 1.43)	.67	1.06 (0.78 – 1.43)	.67	1.05 (0.74 – 1.48)	.78
0.18 – 0.25 km	65 / 4,021	0.94 (0.69 – 1.28)		0.94 (0.69 – 1.29)		0.97 (0.71 – 1.33)		0.96 (0.70 – 1.32)		0.98 (0.72 – 1.33)		1.04 (0.72 – 1.50)	
0.26 – 0.36 km	60 / 3,985	0.87 (0.63 – 1.20)		0.88 (0.64 – 1.20)		0.89 (0.64 – 1.22)		0.91 (0.66 – 1.24)		0.90 (0.66 – 1.24)		0.86 (0.58 – 1.29)	
≥0.37 km	70 / 3,812	1.05 (0.77 – 1.44)		1.09 (0.81 – 1.48)		1.11 (0.82 – 1.50)		1.14 (0.85 – 1.55)		1.14 (0.85 – 1.53)		1.01 (0.66 – 1.56)	
Green spaces‡													
Ref. group: <0.07 km	64 / 4,030	-	-	-	-	-	-	-	-	-	-	-	-
0.07 – 0.11 km	61 / 3,967	0.97 (0.68 – 1.38)	.67	0.97 (0.68 – 1.38)	.58	0.97 (0.68 – 1.39)	.66	0.98 (0.69 – 1.40)	.48	0.99 (0.69 – 1.42)	.55	0.97 (0.68 – 1.40)	.61
0.12 – 0.16 km	73 / 3,873	1.16 (0.82 – 1.63)		1.16 (0.82 – 1.66)		1.14 (0.80 – 1.63)		1.18 (0.83 – 1.68)		1.17 (0.82 – 1.66)		1.13 (0.80 – 1.61)	
0.17 – 0.23 km	62 / 3,907	1.02 (0.71 – 1.46)		1.03 (0.71 – 1.49)		1.03 (0.72 – 1.49)		1.04 (0.72 – 1.49)		1.05 (0.73 – 1.51)		0.98 (0.68 – 1.41)	
≥0.24 km	72 / 3,889	1.16 (0.82 – 1.66)		1.21 (0.83 – 1.74)		1.20 (0.83 – 1.74)		1.25 (0.87 – 1.80)		1.24 (0.86 – 1.80)		1.20 (0.83 – 1.74)	
Place of worship													
Ref. group: <0.12 km	62 / 3,918	-	-	-	-	-	-	-	-	-	-	-	-
0.12 – 0.18 km	61 / 3,958	0.96 (0.68 – 1.34)	.72	0.96 (0.69 – 1.35)	.66	0.97 (0.69 – 1.37)	.67	0.97 (0.69 – 1.35)	.59	0.97 (0.69 – 1.36)	.60	0.96 (0.68 – 1.35)	.74
0.19 – 0.25 km	69 / 3,979	1.09 (0.79 – 1.50)		1.10 (0.79 – 1.52)		1.10 (0.79 – 1.54)		1.10 (0.79 – 1.53)		1.10 (0.79 – 1.54)		1.11 (0.79 – 1.55)	

	Model 7.4a			Model 7.4b		Model 7.4c		Model 7.4d		Model 7.4e		Model 7.4f	
	Died (n) / Alive (n)	Crude IRR (95% CI)	p	Adjusted (deprivation) IRR (95%CI)	p	Adjusted (deprivation & sociodemographi c) IRR (95%CI)	p	Adjusted (deprivation & clinical) IRR (95%CI)	p	Adjusted (deprivation, sociodemographi c & clinical) IRR (95%CI)	p	Fully adjusted IRR (95% CI)	p
0.26 – 0.34 km	74 / 3,930	1.19 (0.85 – 1.66)		1.20 (0.86 – 1.68)		1.19 (0.85 – 1.68)		1.20 (0.86 – 1.68)		1.19 (0.85 – 1.68)		1.19 (0.84 – 1.69)	
≥0.35 km	66 / 3,881	1.09 (0.78 – 1.51)		1.14 (0.82 – 1.59)		1.17 (0.84 – 1.62)		1.19 (0.86 – 1.66)		1.20 (0.87 – 1.67)		1.12 (0.78 – 1.60)	

[†]Distance (km) to the nearest neighbourhood amenity; [‡]publicly accessible green spaces; Model 7.4a is crude estimates; Model 7.4b is adjusted for area-level deprivation; Model 7.4c is adjusted for area-level deprivation and sociodemographic factors (i.e. age, sex, ethnicity and marital status); ; Model 7.4c is adjusted for area-level deprivation and clinical factors (i.e. substance misuse and mental health diagnosis); Model 7.4e is adjusted for area-level deprivation, sociodemographic factors and clinical factors (i.e. SMI diagnosis and substance misuse); Model 7.4f is adjusted for area-level deprivation, sociodemographic and clinical factors and all other area-level variables predictor variables ; P values are for linear trend; Age modelled as a quadratic term across all models; Robust standard errors used to adjust for clustering at the Middle Super Output Area across all models; VPC = Variance Partition Coefficient.

Sensitivity analysis

Sensitivity tests were performed to assess the possible influence of emigration of participants out of the study catchment area for the association between the distance to the nearest built environment feature and all-cause mortality prior to the censor date of the study observation period ([Appendix 18](#)). Associations in [tables 7.2 - 7.4](#) were robust to these additional sensitivity analyses.

7.5 Summary of findings

This study found higher risk of all-cause mortality among individuals with SMI who lived further away from the nearest publicly accessible green spaces, compared to people with SMI who lived closer. However, no associations were found between nearest distance to other neighbourhood amenities and all-cause and cause-specific outcomes respectively. In the fully adjusted models, analyses using variance partition coefficients (VPC) revealed that a small proportion of the variance in all-cause mortality were attributed to clustering at the neighbourhood level (level 2 VPC = .005%).

The geospatial mapping of the average distance to the nearest neighbourhood-level amenity contrasted with the maps in [Chapter 5](#) (see [Figure 5.2](#)) which showed the proportion of these same amenities within each middle super output area (MSOA). The contrast shows that both these measures were capturing different aspects of the urban environment, with Study 3 maps proxying for 'availability' of amenities versus the Study 4 maps which proxied for the accessibility of the same amenities.

One possible mechanism that could explain the association between proximity to green spaces and all-cause mortality is that living closer to these green spaces can create more favourable conditions for physical activity, recreational pursuits, and active modes of transportation like cycling and walking. It is noteworthy to highlight the contrast in green space findings between Study 3 and Study 4. While Study 3 found no evidence of an association between residing in areas with reduced proportions of publicly available green spaces and the risk of mortality, Study 4 indicated a relationship between living farther away from green spaces and an elevated risk of all-cause mortality in the cohort. One possible explanation is that individuals with SMI are more prone to physical health comorbidities (Rodrigues et al., 2021; De Hert et al., 2011), which could impact their mobility in their neighbourhoods. Hence, for their health, accessibility to green spaces might be more crucial than their mere availability.

Strengths

To my knowledge this is first study to investigate the relationship between distance to the nearest neighbourhood amenities with mortality, in a cohort with SMI. The preceding chapter focussed on the influence of the availability of these neighbourhood facilities on the risk of mortality, however this study has investigated an aspect of accessibility of these amenities among individuals with SMI.

The differences in the measurement of the urban built and social environment exposure variables between the studies presented in this chapter and the previous chapter (see [Chapter 6](#)) likely contributed to the differences in findings related to the relationship of green spaces with the risk of mortality in the cohort. Distance variables were derived by calculating the distance from individual-level geographical coordinates, linked to the residential postcode recorded for each cohort member, to the nearest neighbourhood amenity using geographical coordinates linked to that amenity. Utilizing geographical coordinates (i.e. Northings and Eastings) enhanced the accuracy in assessing the impact of neighbourhood amenities on mortality risk in the cohort, making it more likely to detect an association between publicly accessible green spaces and the risk of mortality.

Additionally, this study used Ordnance Survey shapefiles for publicly accessible green spaces. This confers an advantage to studying the impact of green spaces on mortality outcomes in SMI over the use of other green spaces measures such as the Normalized difference vegetation index (NDVI) that have been used in previous studies (Mendoza et al., 2023; Chen et al., 2020). The NDVI uses satellite images to measure vegetation density, however this measure does not differentiate between private and publicly accessible green spaces (Kua & Lee, 2021). Given that the accessibility of different types of green spaces can potentially impact health outcomes within the population, the inclusion of Ordnance Survey data is particularly pertinent.

This study used a multilevel modelling approach to investigate associations between the proximity of built and social environment variables and mortality in SMI. Using this approach has meant that the influence of both proximity to neighbourhood-level variables and individual-level indicators could be estimated simultaneously in relation to their impact on mortality in SMI. The resulting models contribute to current understanding of the extent to which distance to neighbourhood-level factors influence the risk of mortality in people with SMI residing in urbanised inner-city areas in the UK, whilst taking into account individual-level confounders.

Limitations

It is important to note the limitations in this study. The distance between the cohort members' residences and the nearest neighbourhood amenity was calculated using a straight-line distance. However, there are other factors that can alter the distance to neighbourhood amenities, which include physical obstacles such as cul-de-sacs and lack of publicly accessible pathways. These obstacles may influence the potential distance cohort members would have to

travel access the neighbourhood amenity. Consequently, it is possible that associations between distance and the neighbourhood-level feature could have been underestimated.

Secondly, although an association was found between all-cause mortality and distance to the nearest publicly accessible green space, similar associations were not indicated for natural- and unnatural cause mortality. It is important to note that there were far fewer deaths from unnatural causes (<1%) compared to natural causes in the cohort. The lower numbers of deaths from unnatural causes could have meant that subsequent analyses lacked statistical power to detect an association between these causes of death and the neighbourhood-level variables, known as a type 2 error. Therefore, the findings pertaining to unnatural cause mortality should be interpreted with caution.

Additionally, the association found between all-cause mortality and distance to the nearest publicly accessible green space could be attributed to multiple testing. Conducting multiple statistical tests on different categories may increase the likelihood of finding significant results by chance (type 1 error) which might explain why only one of the distance quintiles was found to be significant. However, this association persisted despite accounting for the influence of individual-level covariates. This may indicate that there may be underlying factors that may account for this specific association.

While efforts were made to account for a broad spectrum of potential confounding factors, the potential for residual confounding remains. Specifically, our analysis did not include physical health comorbidities and health-related behaviours, including physical inactivity and unhealthy dietary habits which could play a role in health outcomes among individuals with SMI alongside neighbourhood-level factors (Poelman et al., 2018; Saluja, Davies, Oldmeadow, & Boyle, 2021). Unfortunately, data regarding these individual-level variables were not available. For instance, increased levels of walkability within neighbourhoods may indirectly affect the risk of mortality by encouraging residents to walk for exercise and walking to other destinations which may indirectly lower the risk of cardiovascular diseases and other physical health complications (Lang et al., 2022).

Conclusion

Overall, the study suggests a link between living further away from the nearest publicly available green space and higher risk of all-cause mortality in individuals with SMI. The variance partition coefficients suggests that a larger part of the variance observed in the mortality were

accounted for by difference between individuals rather than differences between neighbourhoods. However, these associations may be mediated by other health-related behaviours and comorbidities. Therefore, future studies would benefit from including these potential mediators when investigating links between the environment and health outcomes in SMI.

Chapter 7 Summary points

- Multilevel modelling analyses documented in the previous chapter (Study 3) revealed weak associations between residence in areas with higher proportions of more walkable areas, convenience stores and higher population density with lowered risk of all-cause and natural-cause mortality at the MSOA level, in unadjusted models. All Associations were attenuated after accounting for the influence individual-level confounders.
- Extending the multilevel modelling analyses conducted in the previous chapter, this study used 'distance to the nearest neighbourhood feature' (proxying as a measure of accessibility of these features) to assess accessibility of these features and the risk of mortality in the SMI cohort.
- In this analysis I found a higher risk of all-cause mortality among individuals with SMI who lived further away from the nearest publicly accessible green spaces, compared to those who lived closer. However, no associations were indicated between nearest distance to other neighbourhood amenities and all-cause and cause-specific mortality outcomes respectively.
- Similar to the study findings reported in Chapter 6 (see [Chapter 6 Summary Points](#)), variance partition coefficients suggested that a larger proportion of the variance in the mortality outcome were attributed to differences at the individual level rather than between neighbourhood level.

Chapter 8: Discussion

8.1 Summary of findings

This thesis had four aims:

1. To systematically review the existing literature on the association between mortality and urban built and social environment variables in SMI;
2. To explore whether there are areas of higher mortality in SMI (relative to the general population), and identify the urban, built and environmental factors potentially associated with this.
3. To assess associations between the urban built and social environment indicators and the mortality outcomes in the SMI cohort.
4. To assess how much of the variation in the mortality outcomes are attributable to differences at both the neighbourhood and individual levels.

The study cohort consisted of individuals aged 15 years old or above at the time of their diagnosis, following contact with any of the services (outpatient, inpatient, and accident and emergency) provided by South London and Maudsley NHS Trust. The study observation period was from 1st January 2007 to 31st December 2018, with individuals entering the cohort at the date of their SMI diagnosis.

The systematic review of the existing literature on the association between mortality and neighbourhood-level variables in SMI ([Chapter 3](#)) identified 5,820 abstracts, but only 7 studies from 4 countries that met the inclusion criteria were included in the synthesis. The overall quality of the studies was between moderate and high and area-level indicators assessed included deprivation, ethnic density, social fragmentation, and population density. The review indicated more consistent associations between residence in more deprived areas and increased risk of mortality outcomes in SMI, and evidence of an association between areas with higher proportions of racialised minority groups and a reduced risk of mortality in SMI. There were no studies that investigated the effect of the area-level indicators of the built environment on these mortality outcomes.

To investigate mortality in the local sample, the risk of mortality in the study cohort was compared to the general population without these diagnoses, standardised mortality ratios (SMR) were derived using both the cohort mortality data and the publicly accessible mortality data for the general population of England and Wales. To understand the geographical

patterning of the SMRs across the study catchment area, geospatial analyses were used to assess spatial clustering of the SMRs in the cohort. To assess ecological associations between the neighbourhood-level indicators and the SMR, OLS regression was used.

The ecological and geospatial analysis study ([Chapter 5](#)) indicated that the SMRs were consistently higher among cohort members compared to the general population. SMRs ranged from 1.28 to 6.84 across the study catchment areas. Geospatial analyses using the Global Moran's I and the Getis-Ord GI* statistic indicated that there was no evidence of spatial clustering of the SMRs across the study catchment area. Ecological analyses unadjusted estimates suggested that residence in areas with higher levels of deprivation and convenience stores were associated with higher SMRs. However, this association was attenuated in the fully adjusted models. No evidence of associations were found between SMR and the urban social environment indicators.

To explore associations between mortality and the availability of neighbourhood-level variables both a multilevel modelling (MLM) approach and a modified cox regression (i.e. competing risks regression) approach was used. The multilevel modelling analyses ([Chapter 6](#)) included 22,689 individuals with SMI with a median follow-up time of 7.9 years and was used to assess neighbourhood-level associations with all-cause mortality in people with SMI. There were 2,911 (12.8%) deaths in the cohort, 2,352 (10.4%) from natural causes and 336 (1.5%) from unnatural causes. Analyses indicated weak associations between residence in neighbourhoods with higher levels of walkability, higher numbers of convenience stores and higher population density with a lower risk of all-cause mortality; similar associations were noted for deaths from natural causes, using competing risks regression. However, these associations were attenuated after adjusting for individual-level sociodemographic and clinical covariates. No associations were observed between other urban built or social area-level indicators and unnatural-cause mortality. Variance partition coefficients (VPC) showed that most of the variance in all-cause mortality were largely attributed to clustering at the individual level rather than at the neighbourhood level (neighbourhood VPCs = 0%).

MLM approach and competing risks regression were also used to explore associations between the risk of mortality and the accessibility of neighbourhood-level amenities, such as access points for green space. These analyses ([Chapter 7](#)) included 22,564 individuals with SMI with a median follow-up time of 6.1 years. There were 2,898 (12.8%) deaths in the cohort, 2,343

(10.4%) from natural causes and 332 (1.5%) from unnatural causes. Analyses indicated a higher risk of all-cause mortality among individuals with SMI who lived further away from the nearest publicly accessible green space across all adjusted models. However, no associations were indicated between nearest distance to other neighbourhood amenities and all-cause and cause-specific outcomes respectively. Similar to the multilevel analyses in [Chapter 6](#), the VPCs also revealed that most of the variance in mortality were attributed to clustering at the individual level rather than at the neighbourhood level (level 2 VPC = .005%).

8.2 Strengths

To my knowledge, this is the first UK study to investigate the influence of several urban built and social environmental factors on the risk of mortality in SMI whilst simultaneously adjusting for individual-level covariates using multilevel modelling (MLM) analyses. Most studies in the systematic review (see [Chapter 3](#)), did not account for the clustered nature of the data using appropriate approaches such as MLM methods, or robust standard errors. MLM has an advantage over traditional regression models in that the total variance can be partitioned between variances observed both between neighbourhoods and within neighbourhoods which enables an understanding of the contextual/ compositional contexts which affect health outcomes (Merlo, Chaix, Yang, Lynch, & Råstam, 2005). This also meant that I was able to quantify the variation in mortality that was attributed to the neighbourhood-level indicators using variance partition coefficients – a coefficient that has not been routinely reported in studies assessing mortality in severe mental health conditions.

Additionally, unlike prior investigations, this study assessed the spatial relationships among the geographical areas included in the analyses in relation to the standardized mortality ratios (SMR) calculated for each middle super output area, using geospatial mapping approaches. Previous studies have indicated that deprived neighbourhoods located near to clusters of similarly deprived areas have a distinct impact on individuals compared to deprived neighbourhoods surrounded by more affluent neighbourhoods, known as spatial autocorrelation (Arcaya et al., 2016; Diez Roux & Mair, 2010). Hot spot analyses with correction for multiple testing was used to assess the presence of spatial autocorrelation within the dataset.

Data for the neighbourhood-level variables were collected from publicly accessible sources, including the Office for National Statistics (2012), Ordnance Survey (2022c) Points of Interest 2012 dataset and the London Datastore (2022). In cases where multiple data sources were available, datasets for neighbourhood-level variables were cross-checked to validate the accuracy of the data before aggregation at the geographic level (i.e., middle super output area) for subsequent statistical analyses.

Area-level deprivation was measured using the Index of Multiple Deprivation (IMD). By amalgamating across domains of deprivation¹⁰, the IMD encapsulates the multifaceted nature of deprivation in the UK and show the collective effect of experiencing deprivation across various dimensions. Moreover, from a statistical standpoint, using a composite measure of area-level deprivation, in quantitative studies reduces the potential for multicollinearity stemming from the use of different deprivation measures, which can complicate the statistical modelling process (Congdon, 2011).

Having access to a sizable and ethnically diverse cohort in an urban South London setting enabled longitudinal analysis of the association of neighbourhood-level factors with mortality outcomes. The study included a large sample that encompassed all individuals with SMI in contact with mental health services within a specific geographic region over an 11-year span. It is worth noting that the South London and Maudsley NHS Trust, a major provider of secondary mental healthcare, is the sole provider over this geographic catchment area, which means that the data should be representative of people with SMI who have had contact with secondary mental health services residing in both urban and suburban locales.

In the UK, both primary and secondary healthcare providers are obligated by law to maintain accurate and current death records. The process of tracking mortality in the source records system is conducted monthly and follows national certification standards, which means that it is highly unlikely for deaths within the UK to have been missed. Sensitivity tests were also performed to assess potential biases from related to emigration of cohort members out of the study catchment area for the association between the urban built and social environment indicators and all-cause mortality prior to the censor date of the study observation period. Associations in both Chapters 6 and 7 were robust to these additional sensitivity analyses.

¹⁰ The IMD (2015) is based on 37 separate indicators that are organised across seven domains which are: employment, income, education, employment, health, crime barriers to housing and services and the living environment

Additionally, measures of both natural and unnatural cause mortality were included in the analyses. Two thirds of the studies in the systematic review also investigated all-cause mortality as the only mortality outcome. Inclusion of cause-specific outcomes in the investigation enabled potential associations between the neighbourhood-level indicators and specific causes of death within the sample to be identified.

8.3 Limitations

A potential limitation is that neighbourhood-level factors were identified at a single timepoint, specifically at the midpoint or near the midpoint of the study observation period. It is reasonable to assume that neighbourhood characteristics evolve over time, including factors like the opening and closing of retail outlets, which could affect the risk of mortality in SMI. This approach might have introduced random measurement error. If this were indeed the case, it is possible that the associations between exposures and outcomes were underestimated.

One of the domains within the Index of Multiple Deprivation (IMD) is the "Health Deprivation and Disability" domain, which encompasses data that overlaps with the mortality outcome investigated in this thesis (Smith et al., 2015). Despite this limitation, I made the choice to use the composite IMD measure. The IMD is widely used as an indicator of deprivation in Public Health England datasets and in public health policy – the measure also reflects the robust methodology tailored specifically for Lower-layer Super Output Area level geographies (Smith et al., 2015). It would be technically difficult to replicate the IMD measure while excluding the health domain and subsequently aggregating it to the Middle-layer Super Output Area (MSOA) geography. The health domain contributes 13.5% to the overall measure. Consequently, I do not anticipate that its inclusion had a substantial impact on the results; any potential influence, if present, would likely have amplified the association between area-level deprivation and the risk of mortality in the cohort.

The assessment of exposure to neighbourhood-level variables was based on the geographic area where cohort members resided at the time of their SMI diagnosis. Unfortunately, there was no information regarding the length of time individuals had lived in these geographical areas. For instance, individuals who had been long-term residents of neighbourhoods with a higher prevalence of fast-food takeaway outlets would have experienced greater exposure to this risk factor compared to those who had resided there for only a short time or had recently

moved. Consequently, it was not possible to make comparisons between short- and long-term residents in these areas regarding their risk of mortality.

Additionally, analyses were limited to quantitative methods, which precluded us from assessing cohort members' subjective experiences of their neighbourhoods and their health, including factors like their perceptions of social cohesion within their residential areas. This is an area that needs further investigation.

The analyses incorporated a diverse set of covariates; nevertheless, the possibility of residual confounding remains. Specifically, factors such as physical health comorbidities and health-related behaviours, including physical inactivity and diet, could also play a role in health outcomes among individuals with SMI alongside neighbourhood-level factors (Poelman et al., 2018; Saluja, Davies, Oldmeadow, & Boyle, 2021). Unfortunately, data regarding these variables were not available, and their presence could potentially affect the connection between neighbourhood-level factors and the risk of mortality. For instance, pre-existing physical health issues might influence how cohort members engage with community services and resources.

Populations with SMI are more likely to have comorbid physical health problems and other health-related behaviours that likely contributes to the elevated risk of premature mortality. A UK longitudinal study revealed that among people with SMI, the most common conditions at the time of diagnosis were asthma (15.4%), hypertension (12.6%), diabetes (7.1%), neurological disease (5.1%), and hypothyroidism (4.6%) (Launders et al., 2022). Over an 18-year follow up period, those with SMI had significantly increased odds of developing chronic physical health conditions compared to controls (Launders et al., 2022). Smoking and substance misuse have also been linked to a higher risk of mortality in SMI populations (Chang et al., 2011; de Mooij et al., 2019; Hayes et al., 2011). Inadequate treatment of these comorbidities further compounds the risk of mortality in SMI. A recent review found that people with schizophrenia are more likely to receive poorer care, which included lower rates of screening and prescriptions for hypertension and less chance of receiving guideline care for breast cancer (Laursen, 2019). The presence of comorbid physical health conditions may hinder access to neighbourhood services and facilities (Corazon et al., 2019). Unfortunately, information on physical health comorbidities and health-related behaviours were not available for the study cohort which precluded analyses of these factors in assessing the risk of mortality.

Lastly, the low numbers of unnatural-cause mortality among the study sample may have influenced the ability to detect associations between this mortality outcome and the area-level variables due to insufficient statistical power potentially increasing the likelihood of a Type 2 error.

8.4 Findings in context

People with SMI experience a significant reduction in life expectancy compared to the general population (Hayes, Marston, Walters, King, & Osborn, 2017; Hjorthøj, Stürup, McGrath, & Nordentoft, 2017; Saha, Chant, & McGrath, 2007), mostly from preventable physical causes (Ilyas, Chesney, & Patel, 2017). Despite advances in healthcare, there is limited evidence of improvements in the life expectancy of people with SMI (Chwastiak & Tek, 2009) emphasizing the urgent need for further research (O'Connor et al., 2023). Despite the heightened risk of mortality across low-, middle- and high-income contexts, interventions have primarily concentrated on individual-level risk factors, which have been ineffective in reducing excess mortality in this population. There is a growing recognition within public health research place-based approaches to address this health disparity (O'Connor et al., 2023), nevertheless, research remains limited. This thesis aimed to address this gap in the literature by examining how neighbourhood-level factors influence the risk of mortality within a cohort of individuals with SMI residing in urbanized and ethnically diverse neighbourhoods in south London.

8.4.1 Premature mortality in SMI

The standardised mortality ratios calculated for the study catchment areas in the ecological and geospatial analyses chapter showed an elevated risk of mortality among individuals with SMI when compared with the general population of England and Wales. These findings align with international systematic reviews that have found higher risk of mortality across low-, middle-, and high-income countries in populations with SMI compared with those without these diagnoses in the general population (Hayes et al., 2017; Hjorthøj et al., 2017; Saha, Chant, & McGrath, 2007).

8.4.2 Built environment and mortality

In this section I will summarise how findings relating to each of the built environment indicators relate to the broader literature on mortality.

8.4.2.a Area-level deprivation

As discussed in the Literature Review chapter (see [Section 2.2.1](#)), residence in deprived neighbourhoods is associated with significantly worse health outcomes, including higher morbidity and mortality rates (Knies & Kumari, 2022; Mackenbach et al., 2008; Schiøtz, Stockmarr, Høst, Glümer, & Frølich, 2017) when compared with health outcomes in more affluent areas. This health disparity is evident in the UK's "North-South divide", where the North experiences poorer health outcomes linked to higher deprivation levels (Kontopantelis et al., 2018). Among individuals with SMI, the systematic review indicated more consistent associations between residence in deprived neighbourhoods and elevated risk of mortality (see [Section 3.2.1b](#)). However, this finding was not replicated in the ecological and geospatial analyses ([Chapter 5](#)) and subsequent analyses using multilevel modelling ([Chapter 6](#) and [7](#) respectively).

The contrast in findings may stem from limited variation in the study catchment area, making it challenging for the current analyses to detect an association between area-level deprivation and mortality risk in the SMI cohort. Furthermore, previous studies compared mortality risk between individuals with and without SMI in deprived areas (Martin et al., 2014; Osborn et al., 2018) whereas the regression models in [Chapters 6](#) and [7](#) did not include a comparative general population sample. The absence of general population comparison group may have hindered the detection of associations between mortality and the urban built and social environment indicators.

8.4.2.b Neighbourhood walkability

Living in walkable neighbourhoods has been associated with increased physical activity and lower risks of obesity, diabetes, and cardiometabolic diseases (Rundle et al., 2016; Sallis et al., 2016; Creatore et al., 2016; Hirsch et al., 2014; Koh et al., 2022; Booth et al., 2019; Chandrabose et al., 2019; Sarkar et al., 2018). However, there have been few studies exploring the link between neighbourhood walkability and mortality, leading to inconsistent findings. One cohort

study revealed a 9% and 1% reduction in cardiovascular- and non-accidental mortality risk in high-walkability neighbourhoods in the general population (Lang et al., 2022). Similar protective associations were observed among women in highly walkable U.S. neighbourhoods, with lower hazard ratios for obesity-related cancer mortality, obesity-related disease, and all-cause mortality (India-Aldana et al., 2021). Ecological investigations suggested an inverse association between walkability and cardiovascular-related mortality, especially in women, but associations were attenuated after adjustment for socioeconomic status and demographic variables in the general population (Gaglioti et al., 2018; Sánchez-Villegas, Cabrera-León, & Gil García, 2021).

Other researchers have reported associations between residence in highly walkable neighbourhoods and increased physical activity and reduced obesity in the general population (Paquet et al., 2014; Van Dyck et al., 2011). Hence, in the general population, neighbourhood walkability may indirectly affect risk of mortality by fostering an environment conducive to physical activity and diminishing health factors linked to mortality (Gaglioti et al., 2018). Contrary to general population studies, the findings in this thesis did not indicate a relationship between neighbourhood walkability and mortality in the study cohort in the fully adjusted models. The absence of a relationship with the risk of mortality in the SMI cohort may be linked to clinical (e.g. physical health comorbidities) and social (e.g. fewer meaningful social relationships) challenges of living with SMI (Liu et al., 2017; O'Connor et al., 2023) which may affect how people with these mental health conditions are able to engage with or use facilities in their neighbourhoods.

8.4.2.c Population density

As discussed in the Literature Review chapter (see [Section 2.2.3](#)), living in densely populated neighbourhoods has both positive and negative effects on population health. Researchers propose a non-linear relationship between population density and health outcomes, with benefits increasing due to improved access to services but declining after reaching higher population density thresholds, which may be due to overcrowding and constraints on neighbourhood services (Sarkar & Webster, 2017). A recent systematic review of 54 studies in the general population, showed an elevated risk of mortality in densely populated neighbourhoods even after adjusting for socioeconomic status (Carnegie et al., 2022).

The systematic review ([Chapter 3](#)) demonstrated less consistent links between population density and the risk of mortality in SMI. The results from the ecological and multilevel

modelling analyses indicated that associations between population density and risk of mortality in the cohort were attenuated by sociodemographic and clinical indicators. This observation suggests that while densely populated neighbourhoods may serve as proxies for improved access to neighbourhood facilities (Sarkar & Webster, 2017), individuals with SMI may encounter additional barriers hindering their access to these resources. Factors such as stigmatisation, symptom severity, poor service provision and discriminatory policies (Liu et al., 2017).

8.4.2.d Food environment

Research in the general population on the link between the food environment and mortality outcomes is inconsistent and limited as indicated in Literature Review chapter (see [Section 2.2.4](#)). Ecological studies conducted using general population samples have suggested negative associations between areas with high exposure to fast-food outlets and all-cause mortality (Alter & Eny, 2005) and between areas with a high supply of ultra-processed foods and cardiovascular-related mortality (Victor et al., 2023). Conversely, other general population cohort studies have found no associations between food desert residence and myocardial infarction mortality (sub-hazard ratio: 1.05; 95% CI: 0.80- 1.38), all-cause mortality (HR: 0.99; 95% CI = 0.87-1.14) (Kelli et al., 2019), and between healthy food outlets and cardiovascular mortality (SHR: 1.03; 95% CI 1.00 - 1.07) (Lovasi et al., 2021). Other general population studies have also indicated lower risk of cause-specific mortality outcomes and residence in neighbourhoods with lower numbers of alcohol outlets (Spoerri et al., 2013; Richardson et al., 2015).

The findings from the ecological and geospatial analyses ([Chapter 5](#)) and multilevel modelling indicated no evidence of an association between both the availability ([Chapter 6](#)) and accessibility ([Chapter 7](#)) of all four food environment indicators (i.e., supermarkets, convenience stores, off-licences and fast-food outlets) and the risk of mortality in the study cohort which supports the findings of some studies conducted with general population samples (Kelli et al., 2019; Lovasi et al., 2021). Other researchers have proposed that associations between retail food and alcohol outlets and the risk of mortality may be explained by area-level deprivation (Kelli et al., 2019). However, accounting for the influence of area-level deprivation did not substantially change the risk estimates from the regression models indicating that individual-level covariates played a larger role in the risk of mortality in the SMI cohort.

8.4.2.e Green spaces

Studies investigating the relationship between green spaces and mortality have consistently shown a decrease in the risk of mortality in the general population as discussed in the literature review chapter (see [Section 2.2.5](#)). Several systematic reviews have highlighted associations between residence in neighbourhoods with higher proportions of green spaces and lowered risk of all-cause mortality (Kua & Lee, 2021) as well as mortality related to various health conditions, including cancer (Kua & Lee, 2021), cardiometabolic diseases (Kua & Lee, 2021; Meo, Al-Khlaiwi, & Aqil, 2022; Twohig-Bennett & Jones, 2018), and stroke (Yuan, Huang, Lin, Zhu, & Zhu, 2021). In contrast to the previous studies, the findings of both the ecological and the multilevel modelling analyses investigating the link between the availability of publicly accessible green spaces and the risk of mortality rendered no evidence of an association.

However, when expanding the multilevel modelling to investigate the relationship between the distance to the nearest publicly accessible green space and the risk of mortality, the analysis indicated that cohort members with SMI residing at a greater distance from the nearest publicly accessible green space had an increased risk of all-cause mortality compared with those living closer to the green space. Although this association was only observed for cohort members living between 0.12km and 0.16km to the nearest green space. The measurement of publicly accessible green space likely played a role in these associations, as the distance to this neighbourhood-level amenity is likely to provide a more accurate measure of exposure among the cohort compared to the previous measure, which indicated the proportion of a neighbourhood that was comprised of publicly accessible green space.

As shown in figures 1a and 1b, the proportion of publicly accessible green spaces for each neighbourhood in the study catchment area indicates higher levels of green spaces clustered in the most southerly neighbourhoods of the study catchment area ([Figure 8.1a](#)). However, [Figure 8.1b](#) shows a shift in terms of the accessibility of those green spaces, with better accessibility of those green spaces being highlighted in darker shaded areas in the northerly parts of the study catchment area. It is possible that the reduced access to the publicly accessible green space may confer additional risk factors for adverse physical outcomes. The mechanism underlying this link could be that the reduced availability of green areas reduces levels of physical activity among residents which in turn may elevate the risk of health conditions like diabetes and obesity (De la Fuente et al., 2021).

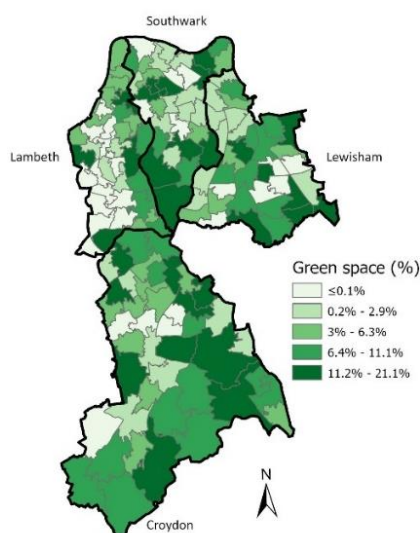


Fig. 8.1a Distribution of green spaces (%)

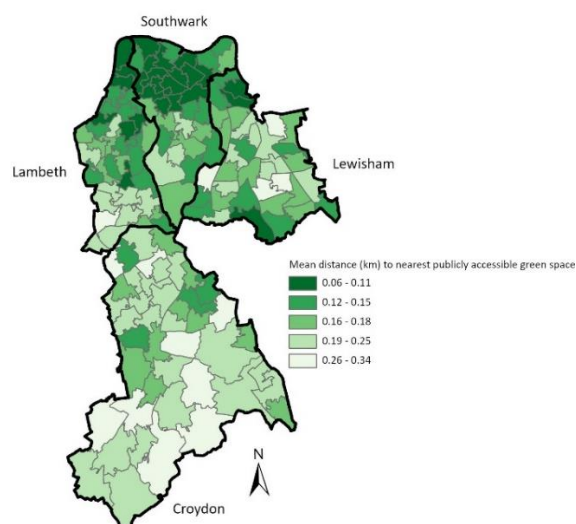


Fig. 8.1b Distribution of the average distance (km) to the nearest publicly accessible green space

8.4.3 Social environment and mortality

8.4.3.a Social fragmentation

Studies exploring the relationship between social fragmentation and mortality outcomes have shown inconsistent findings. Several ecological investigations in the general population found higher risk of suicide-related mortality in more socially fragmented neighbourhoods (Mok et al., 2013; Middleton et al., 2004; Evans et al., 2004; Yoshioka et al., 2022). A Dutch cohort study conducted in the general population found that individuals moving to less socially fragmented neighbourhoods had significantly lower risks of suicide, while another study, identified a higher risk of suicide in individuals residing in more socially fragmented neighbourhoods after adjusting for individual factors (Hagedoorn & Helbich, 2022; Jakobsen et al., 2022). Some investigators have found stronger associations between area-level deprivation and both natural-cause mortality and suicide compared to social fragmentation (O'Farrell, Corcoran, & Perry, 2016; Smith et al., 2001; Whitley, Gunnell, Dorling, & Smith, 1999; Yeung et al., 2022). The systematic review identified only one study investigating the association of neighbourhood social fragmentation and mortality among a cohort with SMI and found no association (Das-Munshi et al., 2019).

The results of the ecological and multilevel modelling analyses are consistent with the findings of the 2019 cohort study by Das-Munshi and colleagues. In both studies, there was no evidence supporting the hypothesized association between the neighbourhood-level indicator and the

risk of unnatural-cause mortality. The contrast in the study findings compared with other general population studies may be related to sampling differences and a smaller cohort size.

8.4.3.b Ethnic density

Most research investigating the association between area-level ethnic density and mortality have been conducted in the United States using general population samples. The findings of a systematic review indicated that areas with higher proportions of Black residents were associated with increased risk of all-cause and cause-specific mortality in the general population (Bécares et al., 2012). Another systematic review indicated that neighbourhoods with a greater proportion of Black residents exhibited an elevated risk of cancer-related mortality in the general population (Fang & Tseng, 2018). The systematic review ([Chapter 3](#)) identified only one study had investigated this association and found a protective effect of area-level ethnic density and mortality among racialised minority individuals with SMI (Das-Munshi et al., 2019).

The evidence from this study indicated no association between area-level ethnic density and the risk of mortality in the cohort which is in contrast with the findings from Das-Munshi and colleagues (2019) cohort study. The evidence from my analysis indicated no association between area-level ethnic density and the risk of mortality in the cohort which is in contrast with the findings from Das-Munshi and colleagues' (2019) cohort study. One possible explanation is that Das-Munshi and colleagues assessed this association using different models, incorporating cross-level interactions, while my study did not use the same approach.

8.4.3.c Places of worship

As discussed in the literature review (see [Section 2.3.3](#)) several longitudinal studies have shown a link between religion and mortality outcomes. One systematic review found that most cohort studies reported a positive association between religiosity and longer lifespans, with only a few suggesting shorter lifespans with increased religiosity (Koenig, 2012). Other studies found that regular attendance at religious services was associated with a reduced risk of mortality, with reductions ranging from 10% to 33% for various causes (Doolittle, McGinnis, Ransome, Fiellin, & Justice, 2021; Shanshan, Stampfer, Williams, and Vanderweele, 2016). However, most of these studies were conducted in the US, so it is unclear if similar associations exist in the UK or among people with severe mental illness. These studies typically focussed on religious beliefs, they did not explore the availability and proximity of places of worship at the neighbourhood level and

how this might affect the risk of mortality in individuals with SMI. The results of the ecological and multilevel analyses showed no evidence of a link between availability ([Chapters 5 and 6](#)) or accessibility ([Chapter 7](#)) of places of worship with the risk of mortality in SMI. An explanation for these findings is that the measurements of exposure to neighbourhood faith-based organisations (as an indicator of community social cohesion) in this study may not accurately reflect the extent of social support available to individuals with SMI and their risk of mortality in the UK context.

8.4.4 The influence of neighbourhood-level factors in the risk of mortality in SMI

One contribution of this thesis to the current evidence was the inclusion of a measure (i.e. variance partition coefficient [VPC]) that quantified the influence of both individual- and neighbourhood-level indicators to the risk of mortality in SMI. Across the multilevel modelling analyses investigating the link between availability ([Chapter 6](#)) and accessibility ([Chapter 7](#)) of neighbourhood-level indicators, the VPC consistently indicated that most of the variation in the risk of mortality was attributed to clustering at the individual-level rather than at the neighbourhood level. The smaller VPCs reflects existing literature conducted in the general population that also found small VPCs for area-level variation in mortality (Merlo, Vicianá-Fernández, Ramiro-Fariñas, & Population, 2012; Rodríguez-Lopez, Merlo, Perez-Vicente, Austin, & Leckie, 2020; Wang et al., 2021) and other health outcomes (Christiani, Byles, Tavener, & Dugdale, 2015).

8.5 Key themes

8.5.1 Indirect mechanisms, neighbourhood-level indicators and mortality in SMI

The absence of associations between most of the neighbourhood-level factors and mortality outcomes contrasts with the mechanisms hypothesised from the integrated model (Krieger, 2001; Krieger, 2012) (Solar & Irwin, 2010) described in [section 2.6](#). The integrated model suggested that the neighbourhood-level indicators function as intermediary factors in influencing the risk of mortality in the cohort. For example, residence in neighbourhoods with a greater concentration of fast-food establishments may affect dietary choices that elevate the risk of adverse health outcomes (Daniel, Paquet, Auger, Zang, & Kestens, 2010). However, it is important to note that the studies in [Chapters 6 and 7](#) did not include a comparative sample without SMI diagnoses. The absence of a comparative sample may have reduced the ability to

detect associations between the urban built and social environment indicators and mortality outcomes in the study.

Other studies conducted in the general population have investigated the influence of the neighbourhood-level factors on health behaviours. For example, studies investigating the influence of green spaces on health outcomes have cited the benefits of green spaces in increasing physical activity (Lee & Maheswaran, 2011), which in turn reduces the risk of cardiovascular diseases (Liu et al., 2022) and obesity (De la Fuente et al., 2021). In this sense, neighbourhood-level indicators such as green spaces may play an indirect role in lowering the risk of mortality by having green spaces which are conducive for residents to participate in physical activity. However, it was not possible to assess this association in the cohort because data on individual-level physical activity is not routinely recorded in the electronic health records presently.

The severity of symptoms associated with SMI may increase the difficulty of people with SMI in accessing amenities and services in their neighbourhoods. Although there have been no studies specifically investigating symptom severity and access to neighbourhood services and amenities, other studies have looked at this in relation to access to healthcare services and found that an increase in the positive symptoms and relapses were among some of the more common reasons for disengagement with healthcare services among people with first episode psychoses (Leclerc, Noto, Bressan, & Brietzke, 2015; Solmi et al., 2018). This may partly explain the lack of association between neighbourhood-level factors and mortality in the study cohort.

8.5.2 Contributions of the thesis findings to the current evidence base

The findings of this thesis have contributed to the current evidence base on the excess mortality in SMI in the following ways:

- Both the literature review and the systematic review have highlighted the dearth of studies investigating the link between neighbourhood-level factors and excess mortality in people with SMI. This thesis has contributed to bridging this gap in the literature by investigating these associations.
- To my knowledge this is the first investigation to assess:
 - The association of several neighbourhood-level indicators with the risk of mortality in SMI in an urbanised and ethnically diverse geographical area in south London.

- Not only the availability of neighbourhood-level indicators in the study catchment area but also to assess the accessibility of these neighbourhood-level indicators using “as the crow flies” distance measures and linking that to the cohort members’ residential post codes.
- The geographical variation of standardised mortality ratios among the sample with SMI using geospatial analyses.
- The findings of the investigation suggest that cohort members with SMI who lived further away from a publicly available green space were at increased risk of all-cause mortality. This association persisted even after accounting for the influence of individual-level covariates such as age and sex.
- No other associations between other neighbourhood level indicators and risk of mortality were observed in the SMI cohort. This contrasts with findings of studies conducted with the general population which could indicate that the use of services and amenities in the neighbourhood differ between individuals with and without SMI.

8.6 Implications for research

The finding that individuals with SMI have a higher likelihood of premature mortality compared to those without such diagnoses aligns with well-established and known significant difference in life expectancy between these two populations. However, these findings have implications for both research and clinical practice. Firstly, indicators of health-related behaviours and physical comorbidities were not available for the study cohort. Future studies could assess the role of these mediators of excess mortality in SMI, which could include (but not limited to) smoking status, cardiovascular diseases, obesity and diabetes and how these physical health factors may influence the use of services and amenities in the neighbourhood among this population.

Secondly, the methodology used by this study was solely quantitative. As highlighted in the ‘key themes’ section, many of neighbourhood-level indicators included the analyses of this thesis were not associated with the risk of mortality among the SMI cohort. This contrasts with studies conducted on samples from the general population, where similar neighbourhood-level indicators were found to be associated with health outcomes. Qualitative methods can be helpful in understanding possible mechanisms that drive the difference in these findings between those reported in this thesis and those observed for the general population. Also, qualitative investigations can be helpful in understanding the experience of accessing facilities in

the local area. For example, qualitative investigations have found that green spaces have different social meanings for different user groups in the general population which affect the way in which they are used and how they facilitate social interactions (Dinnie, Brown, & Morris, 2013; Lee, Jordan, & Horsley, 2015). However, it remains unclear as to whether people with SMI hold similar beliefs and / or attitudes about green spaces and how it might affect their use of these green spaces. Therefore, the inclusion of qualitative methods may therefore enhance our understanding of the mechanisms underlying the interaction between individual factors, environmental factors and mortality risk and help to inform related policies that can have an impact on health outcomes. Therefore, researchers should consider incorporating qualitative methods into future investigations.

Thirdly, this study exclusively focused on cohort members residing in urbanized neighbourhoods within the study catchment area. Consequently, comparisons regarding the relationship between neighbourhood-level variables and mortality for individuals with SMI living in more rural settings was not possible. Therefore, future investigations should include cohorts with individuals with SMI residing in both rural and urban areas. This would enable further examination of whether the geographical context exerts an influence on these associations.

Fourthly, in reflection of the integrated theory presented in [section 2.6](#), this study did not include measures for more upstream socio-political factors that are likely to influence health outcomes in SMI populations. For example, mental health services have historically been neglected within the healthcare system and are often referred to as the ‘Cinderella’ of healthcare provision (Ougrin, 2009). They typically receive minimal funding, hold a low position on priority lists, and, until recently, were not deemed important enough to have to meet NHS performance standards (Manthorpe, Bourne, Bernal, & Iliffe, 2022). Therefore, future research could benefit from integration of these factors into a developing a more nuanced understanding of the socio-political mechanisms that may influence access to neighbourhood-level services underpinning excess mortality in SMI and update policies and the evidence base as appropriate.

8.7 Implications for public health and clinical practice

Population health

The findings of this thesis have potential implications for public health policies. NHS England has outlined a strategy aimed at improving health and disease prevention by establishing place-based health and care systems, referred to as integrated care systems (ICSs), across England

(Briggs et al., 2020). The ICSs are collaborative and localised endeavours between local government, NHS organisations and other relevant organisations with the shared task of assuming collective responsibility for the health and well-being of populations numbering approximately one to three million individuals (Briggs et al., 2020). The creation of ICSs mirrors a widespread agreement on the need for more integrated services that address the distinct needs of local communities (Alderwick et al., 2015; Ham & Alderwick, 2015; NHS England, 2014; Curry & Ham, 2010). In tandem with the implementation of integrated care, another essential objective is to tackle elements outside the realm of the healthcare system that have an influence on population health (Charles et al., 2018). Prior research suggests that social determinants, including education, housing, employment, and social connections, have a more profound impact on health and overall well-being than the healthcare services provided by the NHS (Marmot et al., 2010).

In this respect, the geospatial analyses showed some clustering of standardised mortality ratios in study catchment area and could be useful in informing the work of ICSs in identifying neighbourhoods with specific unmet health needs and directing appropriate resources to those neighbourhoods. For example, the findings of this thesis have highlighted that individuals within the cohort who live farther from the nearest publicly accessible green space have an elevated risk of all-cause mortality. Therefore, schemes akin to the Walking for Health program (Walking for Health, 2016) could be implemented in neighbourhoods where individuals with SMI have limited access to these green spaces. This could involve establishing social support groups that facilitate outings and physical activities for individuals with SMI in these publicly accessible green spaces and integrating these schemes with other health and social care services provided by other relevant organisations.

Clinical practice

The finding across the multilevel modelling analyses in [Chapters 6](#) and [7](#) that associations between the risk of mortality and the neighbourhood-level indicators were largely accounted for by differences between cohort members rather than between neighbourhoods supports the ongoing need for clinical practices that address individual-level risk factors in populations with SMI. The connection between physical and mental health is often complex, and bidirectional (Manthorpe et al., 2022). Physical health conditions and other disabilities can have a significant impact on an individual's mental health, potentially leading to experiences of depression and

stress. Equally, mental health issues can affect a person's general well-being, which can lead to neglect of their physical health (Barber, 2020).

Given that around 80% (n=2,352) of deaths in the study cohort were attributable to preventable physical causes, it would be beneficial for clinical policymakers to explore integrated approaches to healthcare tailored to the needs of individuals with mental health difficulties (Mulvale, Embrett, & Razavi, 2016). This could involve screening measures at the point of access when accessing secondary care settings and interdisciplinary working involving the integration of both mental health and physical health professionals to ensure a more comprehensive and holistic approach to caring for individuals with SMI (O'Connor et al., 2023).

Lastly, access to the de-identified clinical records dataset highlighted limitations of record keeping and associated disadvantages for both clinical practice and research. The datasets utilized for the analyses in this thesis lacked information concerning physical health comorbidities or other pertinent physical health information, as these variables are not consistently recorded in electronic health records. The drawbacks of this omission underscore the persistent lack of parity between mental and physical health (Millard & Wessely, 2014) and creates a barrier to implementing a more joined up approach to healthcare for individuals with SMI (NHS England, 2016). This limitation meant that the effect of physical health comorbidities could not be accounted for in the multilevel modelling analyses. Given these constraints, it would be beneficial for public health policymakers to implement policies facilitating the integration of both physical and mental health records. This not only supports more comprehensive research analyses but also contributes to the facilitation of streamlined integrated care for individuals with SMI who are likely to have comorbid physical health conditions.

8.8 Conclusion

In conclusion, the findings of this investigation indicated a higher risk of mortality among individuals with SMI compared to the general population. Assessment of associations between neighbourhood-level variables and mortality outcomes suggested that the variation in mortality was largely accounted for by differences between cohort members rather than differences between neighbourhoods. However, the geospatial mapping approaches showed utility in identifying areas of 'high' mortality in SMI over the catchment area, which could be developed in future work to inform local clinical/ service provision. Future research would benefit from the inclusion of comparative analyses of the risk of mortality in SMI within both

rural and urban areas and between different countries and contexts. Future research could benefit from qualitative analyses that may aid the understanding of the mechanisms underlying the interaction between individual factors, environmental factors and mortality risk and help to inform related policies that can have an impact on health outcomes. Premature mortality continues to be a tractable and stark health inequality in people living with SMI. It is imperative to prioritize efforts aimed at addressing this inequality to enhance the overall well-being of this population.

References

- AbdAleati, N. S., Mohd Zaharim, N., & Mydin, Y. O. (2016). Religiousness and mental health: Systematic review study. *Journal of religion and health*, 55, 1929-1937.
- Adams, J., & White, M. (2015). Prevalence and socio-demographic correlates of time spent cooking by adults in the 2005 UK Time Use Survey. Cross-sectional analysis. *Appetite*, 92, 185-191.
- Adams, M. A., Frank, L. D., Schipperijn, J., Smith, G., Chapman, J., Christiansen, L. B., Coffee, N., Salvo, D., du Toit, L., Dygrýn, J., Hino, A. A., Lai, P. C., Mavoa, S., Pinzón, J. D., Van de Weghe, N., Cerin, E., Davey, R., Macfarlane, D., Owen, N., & Sallis, J. F. (2014). International variation in neighborhood walkability, transit, and recreation environments using geographic information systems: the IPEN adult study. *Int J Health Geogr*, 13, 43. doi:10.1186/1476-072x-13-43
- Afshin, A., Sur, P. J., Fay, K. A., Cornaby, L., Ferrara, G., Salama, J. S., Mullany, E. C., Abate, K. H., Abbafati, C., & Abebe, Z. (2019). Health effects of dietary risks in 195 countries, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017. *The Lancet*, 393(10184), 1958-1972.
- Agovino, M., Aprile, M. C., Garofalo, A., & Mariani, A. (2018). Cancer mortality rates and spillover effects among different areas: A case study in Campania (southern Italy). *Social Science & Medicine*, 204, 67-83.
- Alcock, I., White, M. P., Wheeler, B. W., Fleming, L. E., & Depledge, M. H. (2014). Longitudinal effects on mental health of moving to greener and less green urban areas. *Environmental science & technology*, 48(2), 1247-1255.
- Alderwick, H., Ham, C., & Buck, D. (2015). Population health systems: going beyond integrated care. Retrieved from <https://www.kingsfund.org.uk/publications/population-health-systems>
- Alter, D. A., & Eny, K. (2005). The relationship between the supply of fast-food chains and cardiovascular outcomes. *Can J Public Health*, 96(3), 173-177. doi:10.1007/bf03403684
- Arcaya, M. C., Tucker-Seeley, R. D., Kim, R., Schnake-Mahl, A., So, M., & Subramanian, S. (2016). Research on neighborhood effects on health in the United States: a systematic review of study characteristics. *Social Science & Medicine*, 168, 16-29.
- ArcGIS. (2009). What is a z-score? What is a p-value?. Retrieved from <https://desktop.arcgis.com/en/arcmap/latest/tools/spatial-statistics-toolbox/what-is-a-z-score-what-is-a-p-value.htm>
- Astell-Burt, T., & Feng, X. (2019). Association of urban green space with mental health and general health among adults in Australia. *JAMA network open*, 2(7), e198209-e198209.
- Austin, P. C., Stryhn, H., Leckie, G., & Merlo, J. (2018). Measures of clustering and heterogeneity in multilevel P oisson regression analyses of rates/count data. *Statistics in medicine*, 37(4), 572-589.
- Bahadoran, Z., Mirmiran, P., & Azizi, F. (2015). Fast Food Pattern and Cardiometabolic Disorders: A Review of Current Studies. *Health Promot Perspect*, 5(4), 231-240. doi:10.15171/hpp.2015.028
- Baker, E. A., Schootman, M., Barnidge, E., & Kelly, C. (2006). The role of race and poverty in access to foods that enable individuals to adhere to dietary guidelines. *Preventing chronic disease*, 3(3), A76.
- Ball, K., Lamb, K., Travaglini, N., & Ellaway, A. (2012). Street connectivity and obesity in Glasgow, Scotland: impact of age, sex and socioeconomic position. *Health Place*, 18(6), 1307-1313. doi:10.1016/j.healthplace.2012.09.007

- Bambra, C., Gibson, M., Sowden, A., Wright, K., Whitehead, M., & Petticrew, M. (2010). Tackling the wider social determinants of health and health inequalities: evidence from systematic reviews. *Journal of Epidemiology & Community Health*, 64(4), 284-291.
- Barber, C. F. (2020). No health without mental health? *British Journal of Mental Health Nursing*, 9(2), 1-7.
- Baum, A., Davis, G. E., Aiello, J. R., & Davis, G. E. (1978). Crowding and neighborhood mediation of urban density. *Journal of Population*, 266-279.
- Bauwelinck, M., Casas, L., Nawrot, T. S., Nemery, B., Trabelsi, S., Thomas, I., Aerts, R., Lefebvre, W., Vanpoucke, C., Van Nieuwenhuyse, A., Deboosere, P., & Vandenheede, H. (2021). Residing in urban areas with higher green space is associated with lower mortality risk: A census-based cohort study with ten years of follow-up. *Environ Int*, 148, 106365. doi:10.1016/j.envint.2020.106365
- Bécares, L., Dewey, M. E., & Das-Munshi, J. (2018). Ethnic density effects for adult mental health: systematic review and meta-analysis of international studies. *Psychological medicine*, 48(12), 2054-2072.
- Bécares, L., Nazroo, J., & Stafford, M. (2011). The ethnic density effect on alcohol use among ethnic minority people in the UK. *J Epidemiol Community Health*, 65(1), 20-25. doi:10.1136/jech.2009.087114e33-e66.
- Bécares, L., Shaw, R., Nazroo, J., Stafford, M., Albor, C., Atkin, K., Kiernan, K., Wilkinson, R., & Pickett, K. (2012). Ethnic density effects on physical morbidity, mortality, and health behaviors: a systematic review of the literature. *American journal of public health*, 102(12), e33-e66.
- Beck, H. (2009). Linking the quality of public spaces to quality of life. *Journal of Place Management and Development*.
- Bentley, R., Blakely, T., Kavanagh, A., Aitken, Z., King, T., McElwee, P., Giles-Corti, B., & Turrell, G. (2018). A Longitudinal Study Examining Changes in Street Connectivity, Land Use, and Density of Dwellings and Walking for Transport in Brisbane, Australia. *Environ Health Perspect*, 126(5), 057003. doi:10.1289/ehp2080
- Berrigan, D., Pickle, L. W., & Dill, J. (2010). Associations between street connectivity and active transportation. *International journal of health geographics*, 9, 1-18.
- Block, J. P., Christakis, N. A., O'Malley, A. J., & Subramanian, S. V. (2011). Proximity to Food Establishments and Body Mass Index in the Framingham Heart Study Offspring Cohort Over 30 Years. *American Journal of Epidemiology*, 174(10), 1108-1114. doi:10.1093/aje/kwr244
- Bloomfield, D. (2014). Sometimes patients could use a dose of nature, but how could it be prescribed? BMJ opinion. Retrieved from <https://blogs.bmj.com/bmj/2014/09/22/dan-bloomfield-sometimes-patients-could-use-a-dose-of-nature-but-how-could-it-be-prescribed/>
- Bodor, J. N., Ulmer, V. M., Futrell Dunaway, L., Farley, T. A., & Rose, D. (2010). The rationale behind small food store interventions in low-income urban neighborhoods: insights from New Orleans. *The Journal of nutrition*, 140(6), 1185-1188.
- Booth, G. L., Creatore, M. I., Luo, J., Fazli, G. S., Johns, A., Rosella, L. C., Glazier, R. H., Moineddin, R., Gozdyra, P., & Austin, P. C. (2019). Neighbourhood walkability and the incidence of diabetes: an inverse probability of treatment weighting analysis. *J Epidemiol Community Health*, 73(4), 287-294.
- Bordoloi, R., Mote, A., Sarkar, P. P., & Mallikarjuna, C. (2013). Quantification of land use diversity in the context of mixed land use. *Procedia-Social and Behavioral Sciences*, 104, 563-572.

- Bourdieu, P. (1986). The forms of social capital. In J. Richardson (Ed.), *Handbook of Theory and Research for the Sociology of Education*. (pp. 241-258). Westport: Greenwood.
- Bray, I., Gibson, A., & White, J. (2020). Coronavirus disease 2019 mortality: a multivariate ecological analysis in relation to ethnicity, population density, obesity, deprivation and pollution. *Public Health*, 185, 261-263. doi:10.1016/j.puhe.2020.06.056
- Briggs, A. D. M., Göpfert, A., Thorlby, R., Allwood, D., & Alderwick, H. (2020). Integrated health and care systems in England: can they help prevent disease? *Integr Healthc J*, 2(1), e000013. doi:10.1136/ihj-2019-000013
- Brotman, D. J., Golden, S. H., & Wittstein, I. S. (2007). The cardiovascular toll of stress. *The Lancet*, 370(9592), 1089-1100.
- Brownson, R. C., Hoehner, C. M., Day, K., Forsyth, A., & Sallis, J. F. (2009). Measuring the built environment for physical activity: state of the science. *Am J Prev Med*, 36(4 Suppl), S99-123.e112. doi:10.1016/j.amepre.2009.01.005
- Burgoine, T., & Harrison, F. (2013). Comparing the accuracy of two secondary food environment data sources in the UK across socio-economic and urban/rural divides. *International journal of health geographics*, 12(1), 2. doi:10.1186/1476-072X-12-2
- Burgoine, T., Forouhi, N. G., Griffin, S. J., Brage, S., Wareham, N. J., & Monsivais, P. (2016). Does neighborhood fast-food outlet exposure amplify inequalities in diet and obesity? A cross-sectional study. *Am J Clin Nutr*, 103(6), 1540-1547. doi:10.3945/ajcn.115.128132
- Burgoine, T., Forouhi, N. G., Griffin, S. J., Wareham, N. J., & Monsivais, P. (2014). Associations between exposure to takeaway food outlets, takeaway food consumption, and body weight in Cambridgeshire, UK: population based, cross sectional study. *Bmj*, 348, g1464. doi:10.1136/bmj.g1464
- Burgoine, T., Gallis, J. A., Penney, T. L., Monsivais, P., & Benjamin-Neelon, S. E. (2017). Association between distance to nearest supermarket and provision of fruits and vegetables in English nurseries. *Health Place*, 46, 229-233. doi:10.1016/j.healthplace.2017.05.018
- Burgoine, T., Sarkar, C., Webster, C. J., & Monsivais, P. (2018). Examining the interaction of fast-food outlet exposure and income on diet and obesity: evidence from 51,361 UK Biobank participants. *Int J Behav Nutr Phys Act*, 15(1), 71. doi:10.1186/s12966-018-0699-8
- Cabinet Office & Geospatial Commission. (2022). UK Geospatial Data Standards - Coordinate Reference Systems: Guidance on the choice of recommended coordinate reference system (CRS) in the UK Geospatial Data Standards Register for exchanging geospatial information. Retrieved from <https://www.gov.uk/guidance/uk-geospatial-data-standards-coordinate-reference-systems#:~:text=Data%20Standards%20Register-,%20CRS%20for%20Great%20Britain%20and%20Ireland,data%20quoted%20in%20this%20system.>
- Cannuscio, C. C., Weiss, E. E., & Asch, D. A. (2010). The contribution of urban foodways to health disparities. *Journal of Urban Health*, 87, 381-393.
- Carnegie, E. R., Inglis, G., Taylor, A., Bak-Klimek, A., & Okoye, O. (2022). Is Population Density Associated with Non-Communicable Disease in Western Developed Countries? A Systematic Review. *International Journal of Environmental Research and Public Health*, 19(5), 2638.
- Castillejos, M. C., Martín-Pérez, C., & Moreno-Küstner, B. (2018). A systematic review and meta-analysis of the incidence of psychotic disorders: the distribution of rates and the influence of gender, urbanicity, immigration and socio-economic level. *Psychological medicine*, 48(13), 2101-2115.

- Centers for Disease Control and Prevention. (2013). Healthy Places Terminology. Retrieved from <https://www.cdc.gov/healthyplaces/terminology.htm>
- Centre for Multilevel Modelling. (2014). Types of model. Retrieved from <https://www.bristol.ac.uk/cmm/learning/multilevel-models/types.html>
- Cerin, E., Sallis, J. F., Salvo, D., Hinckson, E., Conway, T. L., Owen, N., Van Dyck, D., Lowe, M., Higgs, C., & Moudon, A. V. (2022). Determining thresholds for spatial urban design and transport features that support walking to create healthy and sustainable cities: findings from the IPEN Adult study. *The Lancet Global Health*, 10(6), e895-e906.
- Chandrabose, M., Rachele, J. N., Gunn, L., Kavanagh, A., Owen, N., Turrell, G., Giles-Corti, B., & Sugiyama, T. (2019). Built environment and cardio-metabolic health: systematic review and meta-analysis of longitudinal studies. *Obes Rev*, 20(1), 41-54. doi:10.1111/obr.12759
- Chang, C. K., Hayes, R. D., Perera, G., Broadbent, M. T., Fernandes, A. C., Lee, W. E., Hotopf, M., & Stewart, R. (2011). Life expectancy at birth for people with serious mental illness and other major disorders from a secondary mental health care case register in London. *pLoS One*, 6(5), e19590. doi:10.1371/journal.pone.0019590
- Chang, Q., Conwell, Y., Wu, D., Guo, Y., & Yip, P. S. (2019). A study on household headship, living arrangement, and recipient of pension among the older adults in association with suicidal risks. *Journal of affective disorders*, 256, 618-626.
- Chen, H., Burnett, R. T., Bai, L., Kwong, J. C., Crouse, D. L., Lavigne, E., Goldberg, M. S., Copes, R., Benmarhnia, T., Ilango, S. D., van Donkelaar, A., Martin, R. V., & Hystad, P. (2020). Residential Greenness and Cardiovascular Disease Incidence, Readmission, and Mortality. *Environ Health Perspect*, 128(8), 87005. doi:10.1289/ehp6161
- Chen, W., Qian, L., Shi, J., & Franklin, M. (2018). Comparing performance between log-binomial and robust Poisson regression models for estimating risk ratios under model misspecification. *BMC medical research methodology*, 18(1), 1-12.
- Chesney, E., Goodwin, G. M., & Fazel, S. (2014). Risks of all-cause and suicide mortality in mental disorders: a meta-review. *World Psychiatry*, 13(2), 153-160. doi:10.1002/wps.20128
- Christian, H. E., Bull, F. C., Middleton, N. J., Knuiman, M. W., Divitini, M. L., Hooper, P., Amarasinghe, A., & Giles-Corti, B. (2011). How important is the land use mix measure in understanding walking behaviour? Results from the RESIDE study. *Int J Behav Nutr Phys Act*, 8, 55. doi:10.1186/1479-5868-8-55
- Christiani, Y., Byles, J., Tavener, M., & Dugdale, P. (2015). Assessing socioeconomic inequalities of hypertension among women in Indonesia's major cities. *Journal of human hypertension*, 29(11), 683-688.
- Chwastiak, L. A., & Tek, C. (2009). The unchanging mortality gap for people with schizophrenia. *The Lancet*, 374(9690), 590-592.
- Clegg, S., Cunha, M. P. E., & Rego, A. (2016). Explaining suicide in organizations: Durkheim revisited. *Business and Society Review*, 121(3), 391-414.
- Cobb, L. K., Appel, L. J., Franco, M., Jones-Smith, J. C., Nur, A., & Anderson, C. A. (2015). The relationship of the local food environment with obesity: A systematic review of methods, study quality, and results. *Obesity (Silver Spring)*, 23(7), 1331-1344. doi:10.1002/oby.21118
- Collings, S., Ivory, V., Blakely, T., & Atkinson, J. (2009). Are neighbourhood social fragmentation and suicide associated in New Zealand? A national multilevel cohort study. *J Epidemiol Community Health*, 63(12), 1035-1042. doi:10.1136/jech.2009.090985

- Companies House. (2022). Nature of business: Standard Industrial Classification (SIC) codes. Retrieved from <https://resources.companieshouse.gov.uk/sic/>
- Congdon, P. (1996). Suicide and parasuicide in London: a small-area study. *Urban studies*, 33(1), 137-158.
- Congdon, P. (2011). Explaining the spatial pattern of suicide and self-harm rates: A case study of east and south east England. *Applied Spatial Analysis and Policy*, 4, 23-43.
- Congdon, P. (2012). Assessing the impact of socioeconomic variables on small area variations in suicide outcomes in England. *Int J Environ Res Public Health*, 10(1), 158-177. doi:10.3390/ijerph10010158
- Cooksey Stowers, K., Jiang, Q., Atoloye, A., Lucan, S., & Gans, K. (2020). Racial Differences in Perceived Food Swamp and Food Desert Exposure and Disparities in Self-Reported Dietary Habits. *Int J Environ Res Public Health*, 17(19). doi:10.3390/ijerph17197143
- Cooper, R. S. (2001). Social inequality, ethnicity and cardiovascular disease. *International journal of epidemiology*, 30(suppl_1), S48.
- Corazon, S. S., Gramkov, M. C., Poulsen, D. V., Lygum, V. L., Zhang, G., & Stigsdotter, U. K. (2019). I Would Really like to Visit the Forest, but it is Just Too Difficult: A Qualitative Study on Mobility Disability and Green Spaces. *Scandinavian Journal of Disability Research*. doi:10.16993/sjdr.50
- Cormie, P., Zopf, E. M., Zhang, X., & Schmitz, K. H. (2017). The Impact of Exercise on Cancer Mortality, Recurrence, and Treatment-Related Adverse Effects. *Epidemiol Rev*, 39(1), 71-92. doi:10.1093/epirev/mxx007
- Creatore, M. I., Glazier, R. H., Moineddin, R., Fazli, G. S., Johns, A., Gozdyra, P., Matheson, F. I., Kaufman-Shriqui, V., Rosella, L. C., & Manuel, D. G. (2016). Association of neighborhood walkability with change in overweight, obesity, and diabetes. *Jama*, 315(20), 2211-2220.
- Croydon Council. (2021). Director of Public Health Annual Report 2021. Retrieved from <https://www.croydon.gov.uk/sites/default/files/2021-12/DPH%20ANNUAL%20REPORT.pdf>
- Croydon Observatory. (2012). Croydon borough profile. Retrieved from: https://www.croydonobservatory.org/wp-content/uploads/2016/11/Overall_Borough_Profile_2012_Final1.pdf
- Cumpston M., & Chandler J. (2022). Chapter IV: Updating a review. In: Higgins JPT, Thomas J, Chandler J, Cumpston M, Li T, Page MJ, Welch VA (editors). *Cochrane Handbook for Systematic Reviews of Interventions* version 6.3 (updated February 2022). Cochrane, 2022. Available from: www.training.cochrane.org/handbook.
- Curry, N., & Ham, C. (2010). Clinical and service integration: the route to improved outcomes. Retrieved from <https://www.kingsfund.org.uk/publications/clinical-and-service-integration>
- Dadvand, P., & Nieuwenhuijsen, M. (2019). Green Space and Health. In M. Nieuwenhuijsen & H. Khries (Eds.), *Integrating Human Health into Urban and Transport Planning: A Framework* (pp. 409 - 424). Barcelona, Spain: Springer.
- Dai, D., & Wang, F. (2011). Geographic disparities in accessibility to food stores in southwest Mississippi. *Environment and Planning B: Planning and Design*, 38(4), 659-677.
- Daniel, M., Paquet, C., Auger, N., Zang, G., & Kestens, Y. (2010). Association of fast-food restaurant and fruit and vegetable store densities with cardiovascular mortality in a metropolitan population. *Eur J Epidemiol*, 25(10), 711-719. doi:10.1007/s10654-010-9499-4
- Das-Munshi, J. (2020). Ecological studies. In J. Das-Munshi, T. Ford, M. Hotopf, & R. Stewart (Eds.), *Practical Psychiatric Epidemiology* (pp. 113-126). UK: Oxford University Press.

- Das-Munshi, J., Bécaries, L., Boydell, J. E., Dewey, M. E., Morgan, C., Stansfeld, S. A., & Prince, M. J. (2012). Ethnic density as a buffer for psychotic experiences: findings from a national survey (EMPIRIC). *The British Journal of Psychiatry*, 201(4), 282-290.
- Das-Munshi, J., Becares, L., Dewey, M. E., Stansfeld, S. A., & Prince, M. J. (2010). Understanding the effect of ethnic density on mental health: multi-level investigation of survey data from England. *Bmj*, 341.
- Das-Munshi, J., Chang, C. K., Bakolis, I., Broadbent, M., Dregan, A., Hotopf, M., Morgan, C., & Stewart, R. (2021). All-cause and cause-specific mortality in people with mental disorders and intellectual disabilities, before and during the COVID-19 pandemic: cohort study. *The Lancet Regional Health–Europe*, 11.
- Das-Munshi, J., Chang, C.K., Dutta, R., Morgan, C., Nazroo, J., Stewart, R., & Prince, M. (2017). Ethnicity and excess mortality in severe mental illness: A cohort study. *The Lancet Psychiatry*, 4. doi:10.1016/S2215-0366(17)30097-4
- Das-Munshi, J., Schofield, P., Bhavsar, V., Chang, C.-K., Dewey, M. E., Morgan, C., Stewart, R., Thornicroft, G., & Prince, M. J. (2019). Ethnic density and other neighbourhood associations for mortality in severe mental illness: a retrospective cohort study with multi-level analysis from an urbanised and ethnically diverse location in the UK. *The Lancet Psychiatry*, 6(6), 506-517.
- De Hert, M., Correll, C. U., Bobes, J., Cetkovich-Bakmas, M., Cohen, D., Asai, I., Detraux, J., Gautam, S., Möller, H.-J., & Ndeti, D. M. (2011). Physical illness in patients with severe mental disorders. I. Prevalence, impact of medications and disparities in health care. *World Psychiatry*, 10(1), 52.
- De la Fuente, F., Saldías, M. A., Cubillos, C., Mery, G., Carvajal, D., Bowen, M., & Bertoglia, M. P. (2021). Green space exposure association with type 2 diabetes mellitus, physical activity, and obesity: a systematic review. *International Journal of Environmental Research and Public Health*, 18(1), 97.
- de Mooij, L. D., Kikkert, M., Theunissen, J., Beekman, A. T. F., de Haan, L., Duurkoop, P., Van, H. L., & Dekker, J. J. M. (2019). Dying Too Soon: Excess Mortality in Severe Mental Illness. *Front Psychiatry*, 10, 855. doi:10.3389/fpsyt.2019.00855
- de Vries, B., van Busschbach, J. T., van der Stouwe, E. C. D., Aleman, A., van Dijk, J. J. M., Lysaker, P. H., Arends, J., Nijman, S. A., & Pijnenborg, G. H. M. (2018). Prevalence Rate and Risk Factors of Victimization in Adult Patients With a Psychotic Disorder: A Systematic Review and Meta-analysis. *Schizophrenia Bulletin*, 45(1), 114-126. doi:10.1093/schbul/sby020
- Department for Communities and Local Government. (2015a). The English Indices of Deprivation 2015 - Statistical Release. Retrieved from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/465791/English_Indices_of_Deprivation_2015_-_Statistical_Release.pdf
- Department for Communities and Local Government. (2015b). The English Indices of Deprivation: Research Report. England Retrieved from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/464597/English_Indices_of_Deprivation_2015_-_Research_Report.pdf
- Diez Roux, A. V. (2016). Neighborhoods and Health: What Do We Know? What Should We Do? *Am J Public Health*, 106(3), 430-431. doi:10.2105/ajph.2016.303064
- Diez Roux, A. V., & Mair, C. (2010). Neighborhoods and health. *Annals of the New York academy of sciences*, 1186(1), 125-145.

- Dinnie, E., Brown, K. M., & Morris, S. (2013). Reprint of "Community, cooperation and conflict: Negotiating the social well-being benefits of urban greenspace experiences". *Landscape and urban planning*, 118, 103-111.
- Doolittle, B. R., McGinnis, K., Ransome, Y., Fiellin, D., & Justice, A. (2021). Mortality, Health, and Substance Abuse by Religious Attendance Among HIV Infected Patients from the Veterans Aging Cohort Study. *AIDS Behav*, 25(3), 653-660. doi:10.1007/s10461-020-03028-4
- Doran, T., Drever, F., & Whitehead, M. (2004). Is there a north-south divide in social class inequalities in health in Great Britain? Cross sectional study using data from the 2001 census. *Journal of Epidemiology & Community Health*, 58(10), 869-869.
- Drewnowski, A. (2009). Obesity, diets, and social inequalities. *Nutrition reviews*, 67(suppl_1), S36-S39.
- Duffy, S. (2013). A fair society? How the cuts target disabled people. The Centre for Welfare Reform.
- Durkheim, E. (1915). *The Elementary Forms of the Religious Life* (Trans by Carol Cosman Ed.). Oxford: Oxford University Press.
- Durkheim, E. (1952). *Suicide: A study in sociology*. London: Routledge
- Eaton, W., & Harrison, G. (2001). Life chances, life planning, and schizophrenia: a review and interpretation of research on social deprivation. *International Journal of Mental Health*, 30(1), 58-81.
- ESRI. (2012). Using spatial analysis to measure city accessibility by intersection density. Retrieved from <https://www.esri.com/arcgis-blog/products/arcgis-desktop/analytics/using-spatial-analysis-to-measure-city-accessibility-by-intersection-density/>
- ESRI. (2015a). Hot Spot Analysis (Getis-Ord Gi*) (Spatial Statistics). Retrieved from <https://pro.arcgis.com/en/pro-app/latest/tool-reference/spatial-statistics/hot-spot-analysis.htm>
- ESRI. (2015b). How Spatial Autocorrelation (Global Moran's I) works. Retrieved from <https://pro.arcgis.com/en/pro-app/latest/tool-reference/spatial-statistics/h-how-spatial-autocorrelation-moran-s-i-spatial-st.htm>
- Evans, J., Middleton, N., & Gunnell, D. (2004). Social fragmentation, severe mental illness and suicide. *Soc Psychiatry Psychiatr Epidemiol*, 39(3), 165-170. doi:10.1007/s00127-004-0733-9
- Ewing, R., & Cervero, R. (2010). Travel and the built environment: A meta-analysis. *Journal of the American planning association*, 76(3), 265-294.
- Fan, Y., Das, K. V., & Chen, Q. (2011). Neighborhood green, social support, physical activity, and stress: Assessing the cumulative impact. *Health & place*, 17(6), 1202-1211.
- Fang, C. Y., & Tseng, M. (2018). Ethnic density and cancer: a review of the evidence. *Cancer*, 124(9), 1877-1903.
- Faris, R., & Dunham, W. (1939). *Mental Disorders in Urban Areas: An Ecological Study of Schizophrenia and Other Psychoses*. Chicago: University of Chicago Press.
- Faustini, A., Rapp, R., & Forastiere, F. (2014b). Nitrogen dioxide and mortality: review and meta-analysis of long-term studies. *European Respiratory Journal*, 44(3), 744-753. doi:10.1183/09031936.00114713
- Fekadu, A., Medhin, G., Kebede, D., Alem, A., Cleare, A. J., Prince, M., Hanlon, C., & Shibre, T. (2015). Excess mortality in severe mental illness: 10-year population-based cohort study in rural Ethiopia. *The British Journal of Psychiatry*, 206(4), 289-296.

- Ferdinand, A. O., Sen, B., Rahurkar, S., Engler, S., & Menachemi, N. (2012). The relationship between built environments and physical activity: a systematic review. *Am J Public Health*, 102(10), e7-e13. doi:10.2105/ajph.2012.300740
- Fine, J. P., & Gray, R. J. (1999). A proportional hazards model for the subdistribution of a competing risk. *Journal of the American statistical association*, 94(446), 496-509.
- Fone, D. L., Farewell, D. M., White, J., Lyons, R. A., & Dunstan, F. D. (2013). Socioeconomic patterning of excess alcohol consumption and binge drinking: a cross-sectional study of multilevel associations with neighbourhood deprivation. *BMJ Open*, 3(4). doi:10.1136/bmjopen-2012-002337
- Fong, A. J., Lafaro, K., Ituarte, P. H. G., & Fong, Y. (2021). Association of Living in Urban Food Deserts with Mortality from Breast and Colorectal Cancer. *Ann Surg Oncol*, 28(3), 1311-1319. doi:10.1245/s10434-020-09049-6
- Forsyth, A., Oakes, J. M., Schmitz, K. H., & Hearst, M. (2007). Does residential density increase walking and other physical activity? *Urban studies*, 44(4), 679-697.
- Foss, M., Royston, S., Atkinson, M., & Hawkes, C. (2019). FRC Food Policy Evidence Review: Engaging with convenience stores for healthier food provision: what works? Retrieved from <https://foodresearch.org.uk/publications/engaging-convenience-stores/>
- Franco, M., Bilal, U., & Diez-Roux, A. V. (2015). Preventing non-communicable diseases through structural changes in urban environments. *J Epidemiol Community Health*, 69(6), 509-511. doi:10.1136/jech-2014-203865
- Frank, L. D., & Engelke, P. (2005a). Multiple impacts of the built environment on public health: walkable places and the exposure to air pollution. *International regional science review*, 28(2), 193-216.
- Frank, L. D., Andresen, M. A., & Schmid, T. L. (2004). Obesity relationships with community design, physical activity, and time spent in cars. *American Journal of Preventive Medicine*, 27(2), 87-96.
- Frank, L. D., Sallis, J. F., Saelens, B. E., Leary, L., Cain, K., Conway, T. L., & Hess, P. M. (2010). The development of a walkability index: application to the Neighborhood Quality of Life Study. *Br J Sports Med*, 44(13), 924-933. doi:10.1136/bjsm.2009.058701
- Frank, L. D., Schmid, T. L., Sallis, J. F., Chapman, J., & Saelens, B. E. (2005b). Linking objectively measured physical activity with objectively measured urban form: findings from SMARTRAQ. *American journal of preventive medicine*, 28(2), 117-125.
- Freeman, L., Neckerman, K., Schwartz-Soicher, O., Quinn, J., Richards, C., Bader, M. D., Lovasi, G., Jack, D., Weiss, C., Konty, K., Arno, P., Viola, D., Kerker, B., & Rundle, A. G. (2013). Neighborhood walkability and active travel (walking and cycling) in New York City. *J Urban Health*, 90(4), 575-585. doi:10.1007/s11524-012-9758-7
- Gaglioti, A. H., Xu, J., Rollins, L., Baltrus, P., O'Connell, L. K., Cooper, D. L., Hopkins, J., Botchwey, N. D., & Akintobi, T. H. (2018). Neighborhood Environmental Health and Premature Death From Cardiovascular Disease. *Preventing chronic disease*, 15, E17. <https://doi.org/10.5888/pcd15.170220>
- Gascon, M., Triguero-Mas, M., Martínez, D., Dadvand, P., Forns, J., Plasència, A., & Nieuwenhuijsen, M. J. (2015). Mental Health Benefits of Long-Term Exposure to Residential Green and Blue Spaces: A Systematic Review. *International Journal of Environmental Research and Public Health*, 12(4), 4354-4379. Retrieved from <https://www.mdpi.com/1660-4601/12/4/4354>
- Gascon, M., Triguero-Mas, M., Martínez, D., Dadvand, P., Rojas-Rueda, D., Plasència, A., & Nieuwenhuijsen, M. J. (2016). Residential green spaces and mortality: A systematic review. *Environ Int*, 86, 60-67. doi:10.1016/j.envint.2015.10.013

- Glass, T., & Balfour, J. (2003). Neighborhoods, aging, and functional limitations. In I. Kawachi & L. Berkman (Eds.), *Neighborhoods and Health* (pp. 303-334). New York: Oxford University Press.
- Goldstein, H., Browne, W., & Rasbash, J. (2002). Partitioning variation in multilevel models. *Understanding statistics: statistical issues in psychology, education, and the social sciences*, 1(4), 223-231.
- Goossensen, M., Garcia, X., Garcia-Sierra, M., Calvet-Mir, L., & Domene, E. (2023). The role of convenience stores in healthy food environments: The case of Barcelona (Spain). *Cities*, 133, 104118.
- Grasser, G., Van Dyck, D., Titze, S., & Stronegger, W. (2013). Objectively measured walkability and active transport and weight-related outcomes in adults: a systematic review. *International journal of public health*, 58, 615-625.
- Hagedoorn, P., & Helbich, M. (2022). Longitudinal effects of physical and social neighbourhood change on suicide mortality: A full population cohort study among movers and non-movers in the Netherlands. *Soc Sci Med*, 294, 114690. doi:10.1016/j.socscimed.2021.114690
- Hajna, S., Dasgupta, K., Joseph, L., & Ross, N. A. (2014). A call for caution and transparency in the calculation of land use mix: measurement bias in the estimation of associations between land use mix and physical activity. *Health & place*, 29, 79-83.
- Hajna, S., Ross, N. A., Brazeau, A.-S., Bélisle, P., Joseph, L., & Dasgupta, K. (2015). Associations between neighbourhood walkability and daily steps in adults: a systematic review and meta-analysis. *BMC public health*, 15, 1-8.
- Hakim, A. A., Petrovitch, H., Burchfiel, C. M., Ross, G. W., Rodriguez, B. L., White, L. R., Yano, K., Curb, J. D., & Abbott, R. D. (1998). Effects of walking on mortality among nonsmoking retired men. *N Engl J Med*, 338(2), 94-99. doi:10.1056/nejm199801083380204
- Halpern, D. (1993). Minorities and mental health. *Social science & medicine*, 36(5), 597-607.
- Halpern, D. (1995). *Mental Health and the Built Environment: More Than Bricks and Mortar?* London: Taylor & Francis.
- Ham, C., & Alderwick, H. (2015). Place-based systems of care: a way forward for the NHS in England. Retrieved from <https://www.kingsfund.org.uk/publications/place-based-systems-care>
- Hawe, P., & Shiell, A. (2000). Social capital and health promotion: a review. *Soc Sci Med*, 51(6), 871-885. doi:10.1016/s0277-9536(00)00067-8
- Hayes, J. F., Marston, L., Walters, K., King, M. B., & Osborn, D. P. J. (2017). Mortality gap for people with bipolar disorder and schizophrenia: UK-based cohort study 2000-2014. *Br J Psychiatry*, 211(3), 175-181. doi:10.1192/bjp.bp.117.202606
- Hayes, J., Miles, J., Walters, K., King, M., & Osborn, D. (2015). A systematic review and meta-analysis of premature mortality in bipolar affective disorder. *Acta Psychiatrica Scandinavica*, 131(6), 417-425.
- Hayes, R. D., Chang, C. K., Fernandes, A. C., Begum, A., To, D., Broadbent, M., Hotopf, M., & Stewart, R. (2012). Functional status and all-cause mortality in serious mental illness. *pLoS One*, 7(9), e44613. doi:10.1371/journal.pone.0044613
- Hayes, R. D., Chang, C. K., Fernandes, A., Broadbent, M., Lee, W., Hotopf, M., & Stewart, R. (2011). Associations between substance use disorder sub-groups, life expectancy and all-cause mortality in a large British specialist mental healthcare service. *Drug Alcohol Depend*, 118(1), 56-61. doi:10.1016/j.drugalcdep.2011.02.021
- Heinz, A., Deserno, L., & Reininghaus, U. (2013). Urbanicity, social adversity and psychosis. *World Psychiatry*, 12(3), 187-197.

- Hernandez, L. M., & Blazer, D. G. (2006). Genes, Behavior, and the Social Environment: Moving Beyond the Nature/Nurture Debate.
- Hickman, C. (2013). 'To brighten the aspect of our streets and increase the health and enjoyment of our city': The National Health Society and urban green space in late-nineteenth century London. *Landscape and urban planning*, 118, 112-119.
- Hilmers, A., Hilmers, D. C., & Dave, J. (2012). Neighborhood disparities in access to healthy foods and their effects on environmental justice. *American journal of public health*, 102(9), 1644-1654.
- Hirsch, J. A., Moore, K. A., Barrientos-Gutierrez, T., Brines, S. J., Zagorski, M. A., Rodriguez, D. A., & Diez Roux, A. V. (2014). Built environment change and change in BMI and waist circumference: Multi-ethnic Study of Atherosclerosis. *Obesity*, 22(11), 2450-2457.
- Hjorthøj, C., Stürup, A. E., McGrath, J. J., & Nordentoft, M. (2017). Years of potential life lost and life expectancy in schizophrenia: a systematic review and meta-analysis. *Lancet Psychiatry*, 4(4), 295-301. doi:10.1016/s2215-0366(17)30078-0
- Hoang, U., Goldacre, M. J., & Stewart, R. (2013). Avoidable mortality in people with schizophrenia or bipolar disorder in England. *Acta Psychiatr Scand*, 127(3), 195-201. doi:10.1111/acps.12045
- Hoang, U., Stewart, R., & Goldacre, M. J. (2011). Mortality after hospital discharge for people with schizophrenia or bipolar disorder: retrospective study of linked English hospital episode statistics, 1999-2006. *Bmj*, 343, d5422. doi:10.1136/bmj.d5422
- Hoek, G., Krishnan, R. M., Beelen, R., Peters, A., Ostro, B., Brunekreef, B., & Kaufman, J. D. (2013). Long-term air pollution exposure and cardio-respiratory mortality: a review. *Environmental health*, 12(1), 1-16.
- Hopper, K., & Wanderling, J. (2000). Revisiting the Developed Versus Developing Country Distinction in Course and Outcome in Schizophrenia: Results From iSoS, the WHO Collaborative Followup Project. *Schizophrenia Bulletin*, 26(4), 835-846. doi:10.1093/oxfordjournals.schbul.a033498
- Hossen, A. (2022). The Social Suicide Rates: A Review on Durkheim's Theory of Suicide. *Asian Research Journal of Arts & Social Sciences*, 18(4), 129-134.
- Hsu, C. Y., Chang, S. S., Lee, E. S., & Yip, P. S. (2015). "Geography of suicide in Hong Kong: spatial patterning, and socioeconomic correlates and inequalities". *Soc Sci Med*, 130, 190-203. doi:10.1016/j.socscimed.2015.02.019
- Iacobucci, G. (2019). People with mental illness are most at risk of losing benefits, study shows. *Bmj*, 364, l345. doi:10.1136/bmj.l345
- Idler, E. L., & Kasl, S. V. (1997). Religion among disabled and nondisabled persons I: cross-sectional patterns in health practices, social activities, and well-being. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, 52(6), S294-S305.
- Ikeda, T., Inoue, S., Konta, T., Murakami, M., Fujimoto, S., Iseki, K., Moriyama, T., Yamagata, K., Tsuruya, K., Narita, I., Kondo, M., Shibagaki, Y., Kasahara, M., Asahi, K., & Watanabe, T. (2020). Can Daily Walking Alone Reduce Pneumonia-Related Mortality among Older People? *Sci Rep*, 10(1), 8556. doi:10.1038/s41598-020-65440-z
- Ilyas, A., Chesney, E., & Patel, R. (2017). Improving life expectancy in people with serious mental illness: should we place more emphasis on primary prevention? *Br J Psychiatry*, 211(4), 194-197. doi:10.1192/bjp.bp.117.203240
- India-Aldana, S., Rundle, A. G., Zeleniuch-Jacquotte, A., Quinn, J. W., Kim, B., Afanasyeva, Y., Clendenen, T. V., Koenig, K. L., Liu, M., Neckerman, K. M., Thorpe, L. E., & Chen, Y. (2021). Neighborhood Walkability and Mortality in a Prospective Cohort of Women. *Epidemiology*, 32(6), 763-772. Retrieved from

<https://access.ovid.com/custom/redirector/wayfless.html?idp=https://kclidpdev.kcl.ac.uk/idp/shibboleth&url=http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=emed22&AN=2014994360>

- Inoue, S., Ohya, Y., Odagiri, Y., Takamiya, T., Ishii, K., Kitabayashi, M., Suijo, K., Sallis, J. F., & Shimomitsu, T. (2010). Association between perceived neighborhood environment and walking among adults in 4 cities in Japan. *J Epidemiol*, 20(4), 277-286. doi:10.2188/jea.je20090120
- Institute of Medicine (US). (2002). *The Future of the Public's Health in the 21st Century*. Retrieved from <https://www.ncbi.nlm.nih.gov/books/NBK221239/>
- Ivory, V. C., Collings, S. C., Blakely, T., & Dew, K. (2011). When does neighbourhood matter? Multilevel relationships between neighbourhood social fragmentation and mental health.
- Ivory, V., Witten, K., Salmond, C., Lin, E.-Y., You, R. Q., & Blakely, T. (2012). The New Zealand index of neighbourhood social fragmentation: Integrating theory and data. *Environment and Planning A*, 44(4), 972-988.
- Jablensky, A., & Sartorius, N. (2008). What did the WHO studies really find? *Schizophrenia Bulletin*, 34(2), 253-255. doi:10.1093/schbul/sbm151
- Jakobsen, A. L., & Lund, R. L. (2022). Neighborhood social context and suicide mortality: A multilevel register-based 5-year follow-up study of 2.7 million individuals. *Soc Sci Med*, 311, 115320. doi:10.1016/j.socscimed.2022.115320
- Jayatileke, N., Hayes, R. D., Dutta, R., Shetty, H., Hotopf, M., Chang, C. K., & Stewart, R. (2017). Contributions of specific causes of death to lost life expectancy in severe mental illness. *Eur Psychiatry*, 43, 109-115. doi:10.1016/j.eurpsy.2017.02.487
- John, A., McGregor, J., Jones, I., Lee, S. C., Walters, J. T. R., Owen, M. J., O'Donovan, M., DelPozo-Banos, M., Berridge, D., & Lloyd, K. (2018). Premature mortality among people with severe mental illness - New evidence from linked primary care data. *Schizophr Res*, 199, 154-162. doi:10.1016/j.schres.2018.04.009
- Johnson, B., & Blackwell, L. (2007). Review of methods for estimating life expectancy by social class using the ONS Longitudinal Study. *Health Statistics Quarterly*, 35, 28-36.
- Johnson, S. D., & Bowers, K. J. (2010). Permeability and burglary risk: Are cul-de-sacs safer? *Journal of Quantitative Criminology*, 26, 89-111.
- Jones, A., Hillsdon, M., & Coombes, E. (2009). Greenspace access, use, and physical activity: understanding the effects of area deprivation. *Prev Med*, 49(6), 500-505. doi:10.1016/j.ypmed.2009.10.012
- Kamath, G. R., Renteria, A. S., Jagannath, S., Gallagher, E. J., Parekh, S., & Bickell, N. A. (2020). Where you live can impact your cancer risk: a look at multiple myeloma in New York City. *Ann Epidemiol*, 48, 43-50.e44. doi:10.1016/j.annepidem.2020.05.005
- Kantar Worldpanel. (2012). Grocery market share. Retrieved from <https://www.kantarworldpanel.com/en/grocery-market-share/great-britain/snapshot/11.11.12/>
- Kawachi, I., & Berkman, L. (2000). Social cohesion, social capital and health. In L. Berkman & I. Kawachi (Eds.), *Social epidemiology*. Oxford: Oxford University Press.
- Kawachi, I., Kennedy, B. P., & Glass, R. (1999). Social capital and self-rated health: a contextual analysis. *Am J Public Health*, 89(8), 1187-1193. doi:10.2105/ajph.89.8.1187
- Kawachi, I., Subramanian, S. V., & Kim, D. (2008). *Social capital and health: a decade of progress and beyond*. Springer.
- Kelli, H. M., Hammadah, M., Ahmed, H., Ko, Y. A., Topel, M., Samman-Tahhan, A., Awad, M., Patel, K., Mohammed, K., Sperling, L. S., Pemu, P., Vaccarino, V., Lewis, T., Taylor, H.,

- Martin, G., Gibbons, G. H., & Quyyumi, A. A. (2017). Association Between Living in Food Deserts and Cardiovascular Risk. *Circ Cardiovasc Qual Outcomes*, 10(9). doi:10.1161/circoutcomes.116.003532
- Kelli, H. M., Kim, J. H., Samman Tahhan, A., Liu, C., Ko, Y. A., Hammadah, M., Sullivan, S., Sandesara, P., Alkhoder, A. A., Choudhary, F. K., Gafeer, M. M., Patel, K., Qadir, S., Lewis, T. T., Vaccarino, V., Sperling, L. S., & Quyyumi, A. A. (2019). Living in Food Deserts and Adverse Cardiovascular Outcomes in Patients With Cardiovascular Disease. *J Am Heart Assoc*, 8(4), e010694. doi:10.1161/jaha.118.010694
- Kent Nature Partnership. (2021). Retrieved from <https://kentnature.org.uk/>
- Kersten, E., Laraia, B., Kelly, M., Adler, N., & Yen, I. H. (2012). Small food stores and availability of nutritious foods: a comparison of database and in-store measures, Northern California, 2009. *Prev Chronic Dis*, 9, E127. doi:10.5888/pcd9.120023
- Kim, J., & Kaplan, R. (2004). Physical and psychological factors in sense of community: New urbanist Kentlands and nearby Orchard Village. *Environment and behavior*, 36(3), 313-340.
- Kinney, N. T., & Winter, W. E. (2006). Places of worship and neighborhood stability. *Journal of urban affairs*, 28(4), 335-352.
- Kirkwood, B., & Sterne, J. (2003). Analysis of clustered data. In B. K. J. Sterne (Ed.), *Essential medical statistics* (Second Edition ed., pp. 355 - 370). Oxford: Blackwell Publishing.
- Knies, G., & Kumari, M. (2022). Multimorbidity is associated with the income, education, employment and health domains of area-level deprivation in adult residents in the UK. *Sci Rep*, 12(1), 7280. doi:10.1038/s41598-022-11310-9
- Koenig, H. G. (2012). Religion, spirituality, and health: The research and clinical implications. *International Scholarly Research Notices*, 2012.
- Koh, G., Sekine, M., Yamada, M., Fujimura, Y., & Tatsuse, T. (2022). Neighbourhood walkability and obesity among adults in rural Japan: results from a Japanese health database. *Journal of Public Health*, 44(4), e467-e474.
- Kontopantelis, E., Buchan, I., Webb, R. T., Ashcroft, D. M., Mamas, M. A., & Doran, T. (2018). Disparities in mortality among 25-44-year-olds in England: a longitudinal, population-based study. *Lancet Public Health*, 3(12), e567-e575. doi:10.1016/s2468-2667(18)30177-4
- Koohsari, M. J., Sugiyama, T., Lamb, K. E., Villanueva, K., & Owen, N. (2014). Street connectivity and walking for transport: role of neighborhood destinations. *Prev Med*, 66, 118-122. doi:10.1016/j.ypmed.2014.06.019
- Krieger, N. (2001). Theories for social epidemiology in the 21st century: an ecosocial perspective. *International journal of epidemiology*, 30(4), 668-677. doi:10.1093/ije/30.4.668
- Krieger, N. (2012). Methods for the scientific study of discrimination and health: an ecosocial approach. *Am J Public Health*, 102(5), 936-944. doi:10.2105/ajph.2011.300544
- Krieger, N., Chen, J. T., Coull, B. A., Beckfield, J., Kiang, M. V., & Waterman, P. D. (2014). Jim Crow and premature mortality among the US Black and White population, 1960-2009: an age-period-cohort analysis. *Epidemiology*, 25(4), 494-504. doi:10.1097/ede.0000000000000104
- Kruger, D. J., Greenberg, E., Murphy, J. B., DiFazio, L. A., & Youra, K. R. (2014). Local concentration of fast-food outlets is associated with poor nutrition and obesity. *American journal of health promotion*, 28(5), 340-343.
- Ku, B. S., Compton, M. T., Walker, E. F., & Druss, B. G. (2021). Social fragmentation and schizophrenia: A systematic review. *The Journal of Clinical Psychiatry*, 83(1), 38587.

- Kua, K. P., & Lee, S. (2021). The influence of residential greenness on mortality in the Asia-Pacific region: a systematic review and meta-analysis. *Perspect Public Health*, 141(6), 342-353. doi:10.1177/17579139211011496
- Kubzansky, L. D., & Kawachi, I. (2000). Going to the heart of the matter: do negative emotions cause coronary heart disease? *J Psychosom Res*, 48(4-5), 323-337. doi:10.1016/s0022-3999(99)00091-4
- Kushner, H. I., & Sterk, C. E. (2005). The limits of social capital: Durkheim, suicide, and social cohesion. *American journal of public health*, 95(7), 1139-1143.
- Lachowycz, K., & Jones, A. P. (2014). Does walking explain associations between access to greenspace and lower mortality? *Social science & medicine*, 107, 9-17.
- Lambeth Clinical Commissioning Group. (2013). Public Health Report for Lambeth. Retrieved from <https://www.lambeth.gov.uk/sites/default/files/ssh-annual-report-data-section.pdf>
- Lambeth Council. (2012). State of the Borough. Retrieved from <https://www.lambeth.gov.uk/sites/default/files/State-of-the-borough-2012.pdf>
- Lamichhane, A. P., Warren, J., Puett, R., Porter, D. E., Bottai, M., Mayer-Davis, E. J., & Liese, A. D. (2013). Spatial patterning of supermarkets and fast food outlets with respect to neighborhood characteristics. *Health Place*, 23, 157-164. doi:10.1016/j.healthplace.2013.07.002
- Lamnisos, D., Lambrianidou, G., & Middleton, N. (2019). Small-area socioeconomic deprivation indices in Cyprus: development and association with premature mortality. *BMC Public Health*, 19(1), 627. doi:10.1186/s12889-019-6973-0
- Lang, J. J., Pinault, L., Colley, R. C., Prince, S. A., Christidis, T., Tjepkema, M., Crouse, D. L., de Groh, M., Ross, N., & Villeneuve, P. J. (2022). Neighbourhood walkability and mortality: Findings from a 15-year follow-up of a nationally representative cohort of Canadian adults in urban areas. *Environ Int*, 161, 107141. doi:10.1016/j.envint.2022.107141
- Lang, T., Caraher, M., Dixon, P., & Carr-Hill, R. (1999). *Cooking skills and health*. London: Health Education Authority.
- Laraia, B. A., Siega-Riz, A. M., Kaufman, J. S., & Jones, S. J. (2004). Proximity of supermarkets is positively associated with diet quality index for pregnancy. *Preventive medicine*, 39(5), 869-875.
- Launders, N., Kirsh, L., Osborn, D. P., & Hayes, J. F. (2022). The temporal relationship between severe mental illness diagnosis and chronic physical comorbidity: a UK primary care cohort study of disease burden over 10 years. *The Lancet Psychiatry*, 9(9), 725-735.
- Laursen, T. M. (2011). Life expectancy among persons with schizophrenia or bipolar affective disorder. *Schizophrenia research*, 131(1-3), 101-104.
- Laursen, T. M. (2019). Causes of premature mortality in schizophrenia: a review of literature published in 2018. *Current Opinion in Psychiatry*, 32(5), 388-393. doi:10.1097/ycp.0000000000000530
- Lawrence, R. E., Oquendo, M. A., & Stanley, B. (2016). Religion and suicide risk: a systematic review. *Archives of suicide research*, 20(1), 1-21.
- Leckie, G., Browne, W. J., Goldstein, H., Merlo, J., & Austin, P. C. (2020). Partitioning variation in multilevel models for count data. *Psychological Methods*, 25(6), 787.
- Leclerc, E., Noto, C., Bressan, R. A., & Brietzke, E. (2015). Determinants of adherence to treatment in first-episode psychosis: a comprehensive review. *Brazilian Journal of Psychiatry*, 37, 168-176.

- Lee, A. C. K., Jordan, H. C., & Horsley, J. (2015). Value of urban green spaces in promoting healthy living and wellbeing: prospects for planning. *Risk management and healthcare policy*, 131-137.
- Lee, A. C., & Maheswaran, R. (2011). The health benefits of urban green spaces: a review of the evidence. *Journal of public health*, 33(2), 212-222.
- Lee, E. E., Liu, J., Tu, X., Palmer, B. W., Eyler, L. T., & Jeste, D. V. (2018). A widening longevity gap between people with schizophrenia and general population: a literature review and call for action. *Schizophrenia research*, 196, 9-13.
- Lengen, C., & Kistemann, T. (2012). Sense of place and place identity: Review of neuroscientific evidence. *Health & place*, 18(5), 1162-1171.
- Leslie, E., Cerin, E., & Kremer, P. (2010). Perceived neighborhood environment and park use as mediators of the effect of area socio-economic status on walking behaviors. *Journal of physical activity and health*, 7(6), 802-810.
- Leslie, E., Coffee, N., Frank, L., Owen, N., Bauman, A., & Hugo, G. (2007). Walkability of local communities: using geographic information systems to objectively assess relevant environmental attributes. *Health & place*, 13(1), 111-122.
- Lewisham Council. (2017). Overview and scrutiny: Demographic change Retrieved from <https://councilmeetings.lewisham.gov.uk/documents/s52135/Demographic%20Change%20in%20Lewisham.pdf>
- Leyden, K. M. (2003). Social capital and the built environment: the importance of walkable neighborhoods. *Am J Public Health*, 93(9), 1546-1551. doi:10.2105/ajph.93.9.1546
- Leyland, A., & Groenewegen, P. (2020). Multilevel Modelling for Public Health and Health Services Research: Health in Context. Retrieved from https://link.springer.com/chapter/10.1007/978-3-030-34801-4_3
- Li, L. W., Xu, H., Zhang, Z., & Liu, J. (2016). An Ecological Study of Social Fragmentation, Socioeconomic Deprivation, and Suicide in Rural China: 2008-2010. *SSM Popul Health*, 2, 365-372. doi:10.1016/j.ssmph.2016.05.007
- Lin, C. Y., Hsu, C. Y., Gunnell, D., Chen, Y. Y., & Chang, S. S. (2019). Spatial patterning, correlates, and inequality in suicide across 432 neighborhoods in Taipei City, Taiwan. *Soc Sci Med*, 222, 20-34. doi:10.1016/j.socscimed.2018.12.011
- Lindström, M. (2008). Social Capital and Health-Related Behaviors. In I. Kawachi, S. V. Subramanian, & D. Kim (Eds.), *Social Capital and Health* (pp. 215-238). USA: Springer.
- Liu, N. H., Daumit, G. L., Dua, T., Aquila, R., Charlson, F., Cuijpers, P., Druss, B., Dudek, K., Freeman, M., Fujii, C., Gaebel, W., Hegerl, U., Levav, I., Munk Laursen, T., Ma, H., Maj, M., Elena Medina-Mora, M., Nordentoft, M., Prabhakaran, D., Pratt, K., Prince, M., Rangaswamy, T., Shiers, D., Susser, E., Thornicroft, G., Wahlbeck, K., Fekadu Wassie, A., Whiteford, H., & Saxena, S. (2017). Excess mortality in persons with severe mental disorders: a multilevel intervention framework and priorities for clinical practice, policy and research agendas. *World Psychiatry*, 16(1), 30-40. doi:10.1002/wps.20384
- Liu, X.-X., Ma, X.-L., Huang, W.-Z., Luo, Y.-N., He, C.-J., Zhong, X.-M., Dadvand, P., Browning, M. H., Li, L., & Zou, X.-G. (2022). Green space and cardiovascular disease: A systematic review with meta-analysis. *Environmental Pollution*, 118990.
- Livingston, M., Chikritzhs, T., & Room, R. (2007). Changing the density of alcohol outlets to reduce alcohol-related problems. *Drug and alcohol review*, 26(5), 557-566.
- Lomholt, L. H., Andersen, D. V., Sejrsgaard-Jacobsen, C., Øzdemir, C. M., Graff, C., Schjerning, O., Jensen, S. E., Straszek, S. P. V., Licht, R. W., Grøntved, S., & Nielsen, R. E. (2019). Mortality rate trends in patients diagnosed with schizophrenia or bipolar disorder: a

- nationwide study with 20 years of follow-up. *Int J Bipolar Disord*, 7(1), 6.
doi:10.1186/s40345-018-0140-x
- London Datastore (2022). Retrieved from <https://data.london.gov.uk/>
- Loopstra, R., & Lalor, D. (2017). Financial insecurity, food insecurity, and disability: The profile of people receiving emergency food assistance from The Trussell Trust Foodbank Network in Britain. London: the Trussell trust.
- Lovasi, G. S., Johnson, N. J., Altekruze, S. F., Hirsch, J. A., Moore, K. A., Brown, J. R., Rundle, A. G., Quinn, J. W., Neckerman, K., & Siscovick, D. S. (2021). Healthy food retail availability and cardiovascular mortality in the United States: a cohort study. *BMJ open*, 11(7), e048390. doi:10.1136/bmjopen-2020-048390
- Lund, C., Brooke-Sumner, C., Baingana, F., Baron, E. C., Breuer, E., Chandra, P., Haushofer, J., Herrman, H., Jordans, M., & Kieling, C. (2018). Social determinants of mental disorders and the Sustainable Development Goals: a systematic review of reviews. *The Lancet Psychiatry*, 5(4), 357-369.
- Luo, Y., Pang, L., Guo, C., Zhang, L., & Zheng, X. (2021). Association of Urbanicity with Schizophrenia and Related Mortality in China: Association de l'urbanité avec la schizophrénie et la mortalité qui y est reliée en Chine. *Can J Psychiatry*, 66(4), 385-394. doi:10.1177/0706743720954059
- Maas, J., Verheij, R. A., de Vries, S., Spreeuwenberg, P., Schellevis, F. G., & Groenewegen, P. P. (2009). Morbidity is related to a green living environment. *Journal of Epidemiology & Community Health*, 63(12), 967-973.
- Macintyre, S. (2007). Deprivation amplification revisited; or, is it always true that poorer places have poorer access to resources for healthy diets and physical activity? *Int J Behav Nutr Phys Act*, 4, 32. doi:10.1186/1479-5868-4-32
- Mackenbach, J. P., Stirbu, I., Roskam, A. J., Schaap, M. M., Menvielle, G., Leinsalu, M., & Kunst, A. E. (2008). Socioeconomic inequalities in health in 22 European countries. *N Engl J Med*, 358(23), 2468-2481. doi:10.1056/NEJMsa0707519
- Malambo, P., Kengne, A. P., De Villiers, A., Lambert, E. V., & Puoane, T. (2016). Built Environment, Selected Risk Factors and Major Cardiovascular Disease Outcomes: A Systematic Review. *pLoS One*, 11(11), e0166846. doi:10.1371/journal.pone.0166846
- Manthorpe, J., Bourne, R., Bernal, J., & Iliffe, S. (2022). THE NHS: Mental health and parity of esteem: A policy quandary for Labour? *Renewal: a Journal of Social Democracy*, 30(4), 51-67.
- Marmot, M. (2010). Fair society, healthy lives. Retrieved from <https://www.instituteofhealthequity.org/resources-reports/fair-society-healthy-lives-the-marmot-review>
- Martin, J. L., McLean, G., Park, J., Martin, D. J., Connolly, M., Mercer, S. W., & Smith, D. J. (2014). Impact of socioeconomic deprivation on rate and cause of death in severe mental illness. *BMC psychiatry*, 14, 261. doi:10.1186/s12888-014-0261-4
- Martin, K. S., Ghosh, D., Page, M., Wolff, M., McMinimee, K., & Zhang, M. (2014). What role do local grocery stores play in urban food environments? A case study of Hartford-Connecticut. *pLoS One*, 9(4), e94033.
- Maselko, J., Hughes, C., & Cheney, R. (2011). Religious social capital: its measurement and utility in the study of the social determinants of health. *Soc Sci Med*, 73(5), 759-767. doi:10.1016/j.socscimed.2011.06.019
- Matheson, F. I., Creatore, M. I., Gozdyra, P., Park, A. L., & Ray, J. G. (2014). A population-based study of premature mortality in relation to neighbourhood density of alcohol sales and cheque cashing outlets in Toronto, Canada. *BMJ Open*, 4(12), e006032.

- Mathur, R., Schofield, P., Smith, D., Gilkes, A., White, P., & Hull, S. (2017). Is individual smoking behaviour influenced by area-level ethnic density? A cross-sectional electronic health database study of inner south-east London. *ERJ Open Res*, 3(1). doi:10.1183/23120541.00130-2016
- Mattheys, K. (2015). The Coalition, austerity and mental health. *Disability & Society*, 30(3), 475-478. doi:10.1080/09687599.2014.1000513
- McCormack, G. R., & Shiell, A. (2011). In search of causality: a systematic review of the relationship between the built environment and physical activity among adults. *International Journal of Behavioral Nutrition and Physical Activity*, 8(1), 125. doi:10.1186/1479-5868-8-125
- McCullough, M. E., & Smith, T. B. (2003). Religion and health: Depressive symptoms and mortality as case studies. In M. Dillon (Ed.), *Handbook of the sociology of religion* (pp. 190-206). Cambridge: Cambridge University Press.
- McLaren, L. (2007). Socioeconomic status and obesity. *Epidemiologic reviews*, 29(1), 29-48.
- Mecredy, G., Pickett, W., & Janssen, I. (2011). Street connectivity is negatively associated with physical activity in Canadian youth. *Int J Environ Res Public Health*, 8(8), 3333-3350. doi:10.3390/ijerph8083333
- Meijer, M., Kejs, A. M., Stock, C., Bloomfield, K., Ejstrup, B., & Schlattmann, P. (2012). Population density, socioeconomic environment and all-cause mortality: a multilevel survival analysis of 2.7 million individuals in Denmark. *Health Place*, 18(2), 391-399. doi:10.1016/j.healthplace.2011.12.001
- Mendoza, H., Rodriguez-Loureiro, L., Gadeyne, S., Lefebvre, W., Vanpoucke, C., & Casas, L. (2023). Urban green spaces and suicide mortality in Belgium (2001-2011): A census-based longitudinal study. *Environ Res*, 216(Pt 1), 114517. doi:10.1016/j.envres.2022.114517
- Meo, S., Al-Khlaiwi, T., & Aqil, M. (2022). Impact of the residential green space environment on the prevalence and mortality of Type 2 diabetes mellitus. *Eur Rev Med Pharmacol Sci*, 26(10), 3599-3606.
- Merlo, J., Chaix, B., Ohlsson, H., Beckman, A., Johnell, K., Hjerpe, P., Råstam, L., & Larsen, K. (2006). A brief conceptual tutorial of multilevel analysis in social epidemiology: using measures of clustering in multilevel logistic regression to investigate contextual phenomena. *Journal of Epidemiology & Community Health*, 60(4), 290-297.
- Merlo, J., Chaix, B., Yang, M., Lynch, J., & Råstam, L. (2005). A brief conceptual tutorial of multilevel analysis in social epidemiology: linking the statistical concept of clustering to the idea of contextual phenomenon. *Journal of Epidemiology & Community Health*, 59(6), 443-449.
- Merlo, J., Viciano-Fernández, F. J., Ramiro-Fariñas, D., & Research Group of Longitudinal Database of Andalusian Population (LDAP). (2012). Bringing the individual back to small-area variation studies: a multilevel analysis of all-cause mortality in Andalusia, Spain. *Social science & medicine*, 75(8), 1477-1487.
- Messiah, S. E., D'Agostino, E. M., Hansen, E., Mathew, M. S., Okeke, D., Nardi, M., Kardys, J., & Arheart, K. L. (2018). Longitudinal impact of a park-based afterschool healthy weight program on modifiable cardiovascular disease risk factors in youth. *Journal of community health*, 43, 103-116.
- Middleton, N., Whitley, E., Frankel, S., Dorling, D., Sterne, J., & Gunnell, D. (2004). Suicide risk in small areas in England and Wales, 1991-1993. *Soc Psychiatry Psychiatr Epidemiol*, 39(1), 45-52. doi:10.1007/s00127-004-0707-y

- Millard, C., & Wessely, S. (2014). Parity of esteem between mental and physical health. In (Vol. 349): British Medical Journal Publishing Group.
- Miller, H. J. (2004). Tobler's first law and spatial analysis. *Annals of the association of American geographers*, 94(2), 284-289.
- Mills, S., Adams, J., Wrieden, W., White, M., & Brown, H. (2018). Sociodemographic characteristics and frequency of consuming home-cooked meals and meals from out-of-home sources: cross-sectional analysis of a population-based cohort study. *Public health nutrition*, 21(12), 2255-2266.
- Ministry of Housing Communities & Local Government. (2015). National Statistics: English indices of deprivation 2015. Retrieved from <https://www.gov.uk/government/statistics219englishh-indices-of-deprivation-2015>
- Mitchell, R., & Popham, F. (2008). Effect of exposure to natural environment on health inequalities: an observational population study. *Lancet*, 372(9650), 1655-1660. doi:10.1016/s0140-6736(08)61689-x
- Mitchell, R., Astell-Burt, T., & Richardson, E. A. (2011). A comparison of green space indicators for epidemiological research. *J Epidemiol Community Health*, 65(10), 853-858.
- Mok, P. L., Leyland, A. H., Kapur, N., Windfuhr, K., Appleby, L., Platt, S., & Webb, R. T. (2013). Why does Scotland have a higher suicide rate than England? An area-level investigation of health and social factors. *J Epidemiol Community Health*, 67(1), 63-70. doi:10.1136/jech-2011-200855
- Montgomery, M. R., Stren, R., Cohen, B., & Reed, H. E. (2003). *Cities transformed: Demographic change and its implications in the developing world*. UK: Earthscan.
- Molaei, P., Tang, L., & Hardie, M. (2021). Measuring Walkability with Street Connectivity and Physical Activity: A Case Study in Iran. *World*, 2(1), 49-61.
- Mollica, K. A., Gray, B., & Trevino, L. K. (2003). Racial homophily and its persistence in newcomers' social networks. *Organization Science*, 14(2), 123-136.
- Moody, A., Cowley, G., Fat, L. N., & Mindell, J. S. (2016). Social inequalities in prevalence of diagnosed and undiagnosed diabetes and impaired glucose regulation in participants in the Health Surveys for England series. *BMJ open*, 6(2), e010155.
- Moreno-Küstner, B., Guzman-Parra, J., Pardo, Y., Sanchidrián, Y., Díaz-Ruiz, S., & Mayoral-Cleries, F. (2021). Excess mortality in patients with schizophrenia spectrum disorders in Malaga (Spain): A cohort study. *Epidemiology and psychiatric sciences*, 30, e11.
- Morleo, M., Lightowlers, C., Anderson, Z., Cook, P. A., Harkins, C., & Bellis, M. A. (2009). A review of the impact of the Licensing Act 2003 on levels of violence in England and Wales: A public health perspective. *Crime Prevention and Community Safety*, 11(3), 204-218. doi:10.1057/cpcs.2009.14
- Morris, A. A., McAllister, P., Grant, A., Geng, S., Kelli, H. M., Kalogeropoulos, A., Quyyumi, A., & Butler, J. (2019). Relation of Living in a "Food Desert" to Recurrent Hospitalizations in Patients With Heart Failure. *Am J Cardiol*, 123(2), 291-296. doi:10.1016/j.amjcard.2018.10.004
- Mueller, A. S., & Abrutyn, S. (2016). Adolescents under pressure: A new Durkheimian framework for understanding adolescent suicide in a cohesive community. *American sociological review*, 81(5), 877-899.
- Mueller, A. S., Abrutyn, S., Pescosolido, B., & Diefendorf, S. (2021). The Social Roots of Suicide: Theorizing How the External Social World Matters to Suicide and Suicide Prevention. *Front Psychol*, 12, 621569. doi:10.3389/fpsyg.2021.621569

- Mulvale, G., Embrett, M., & Razavi, S. D. (2016). 'Gearing Up to improve interprofessional collaboration in primary care: a systematic review and conceptual framework. *BMC family practice*, 17(1), 1-13.
- Murali, V., & Oyeboode, F. (2004). Poverty, social inequality and mental health. *Advances in psychiatric treatment*, 10(3), 216-224.
- Musick, M. A., House, J. S., & Williams, D. R. (2004). Attendance at religious services and mortality in a national sample. *J Health Soc Behav*, 45(2), 198-213. doi:10.1177/002214650404500206
- National Research Council (US). (2013). The National Academies Collection: Reports funded by National Institutes of Health. In S. H. Woolf & L. Aron (Eds.), *U.S. Health in International Perspective: Shorter Lives, Poorer Health*. Washington (DC): National Academies Press (US)
- National Research Council (US); Institute of Medicine (US) (2018). Woolf SH, Aron L, editors. *U.S. Health in International Perspective: Shorter Lives, Poorer Health*. Washington (DC): National Academies Press (US); 2013. 7, Physical and Social Environmental Factors. Available from: <https://www.ncbi.nlm.nih.gov/books/NBK154491/>
- Natural Cambridgeshire. (2021). Our vision: healthy communities. Retrieved from <https://naturalcambridgeshire.org.uk/vision/healthy-communities/>
- NHS England. (2016). Improving the physical health of people with mental health problems: Actions for mental health nurses. Retrieved from https://assets.publishing.service.gov.uk/media/5a74cb3640f0b619c865a7c4/JRA_Physical_Health_revised.pdf
- Niggebrugge, A., Haynes, R., Jones, A., Lovett, A., & Harvey, I. (2005). The index of multiple deprivation 2000 access domain: a useful indicator for public health? *Soc Sci Med*, 60(12), 2743-2753. doi:10.1016/j.socscimed.2004.11.026
- National Institute for Health and Care Research (NIHR). (2018). Supported employment helps people with severe mental illness to obtain work. Retrieved from <https://evidence.nihr.ac.uk/alert/supported-employment-helps-people-with-severe-mental-illness-to-obtain-work/>
- O'Connor, R. C., Worthman, C. M., Abanga, M., Athanassopoulou, N., Boyce, N., Chan, L. F., Christensen, H., Das-Munshi, J., Downs, J., & Koenen, K. C. (2023). Gone Too Soon: priorities for action to prevent premature mortality associated with mental illness and mental distress. *The Lancet Psychiatry*, 10(6), 452-464.
- O'Farrell, I. B., Corcoran, P., & Perry, I. J. (2016). The area level association between suicide, deprivation, social fragmentation and population density in the Republic of Ireland: a national study. *Soc Psychiatry Psychiatr Epidemiol*, 51(6), 839-847. doi:10.1007/s00127-016-1205-8.
- Office for Health Improvements & Disparities. (2022). Public health profiles. Retrieved from <https://fingertips.phe.org.uk/search/healthy%20life%20expectancy#page/3/gid/1/pat/15/par/E92000001/ati/6/are/E12000004/iid/90362/age/1/sex/2/cat/-1/ctp/-1/yr/3/cid/4/tbm/1/page-options/tre-do-1>
- Office for Health Improvement & Disparities. (2012). Local Authority Health Profiles. Retrieved from <https://fingertips.phe.org.uk/profile/health-profiles/data#page/13/gid/1938132696/pat/6/ati/202/are/E09000028/iid/90366/age/1/sex/1/cat/-1/ctp/-1/yr/3/cid/4/tbm/1>
- Office for National Statistics. (2023). Deprivation and the impact on smoking prevalence, England and Wales: 2017 to 2021. Retrieved from <https://www.ons.gov.uk/peoplepopulationandcommunity/healthandsocialcare/druguse>

- [alcoholandsmoking/bulletins/deprivationandtheimpactonsmokingprevalenceenglandandwales/2017to2021#:~:text=Smoking%20prevalence%20and%20deprivation%20in,and%20this%20was%20statistically%20significant.](#)
- Office for National Statistics. (2020). Religion and health in England and Wales: February 2020. Retrieved from <https://www.ons.gov.uk/peoplepopulationandcommunity/culturalidentity/religion/articles/religionandhealthinenglandandwales/february2020#self-reported-physical-health-state>.
- Office for National Statistics. (2020). ONS Postcode Directory (May 2020). Retrieved from <https://geoportal.statistics.gov.uk/datasets/fb894c51e72748ec8004cc582bf27e83/about>
- Office for National Statistics. (2019). Socioeconomic inequalities in avoidable mortality, England and Wales: 2001 to 2017. Retrieved from <https://www.ons.gov.uk/peoplepopulationandcommunity/healthandsocialcare/causesofdeath/articles/measuring socioeconomic inequalities in avoidable mortality in england and wales/2001to2017>
- Office for National Statistics. (2012a). 2011 Census: Population and Household Estimates for Small Areas in England and Wales, March 2011. Retrieved from <https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates/bulletins/2011censuspopulationandhouseholdestimatesforsmallareasinenglandandwales/2012-11-23#:~:text=Population,-The%20average%20population&text=The%20average%20population%20of%20lower,of%20between%201%2C157%20and%202%2C354>
- Office for National Statistics. (2012b). Changes to Output Areas and Super Output Areas in England and Wales, 2001 to 2011. Retrieved from <https://www.ons.gov.uk/file?uri=/methodology/geography/ukgeographies/censusgeography/changetooutputareasandsuperoutputareas2001to2011tcm77288393.pdf>
- Olfson, M., Gerhard, T., Huang, C., Crystal, S., & Stroup, T. S. (2015). Premature mortality among adults with schizophrenia in the United States. *JAMA psychiatry*, 72(12), 1172-1181.
- Ordnance Survey. (2022a). OS Open Roads. Retrieved from <https://osdatahub.os.uk/downloads/open/OpenRoads>
- Ordnance Survey. (2022b). OS Open Greenspace. Retrieved from <https://www.ordnancesurvey.co.uk/business-government/products/open-map-greenspace>
- Ordnance Survey (2022c). Points of interest 2012. Retrieved from <https://www.ordnancesurvey.co.uk/products/points-of-interest>
- Ordnance Survey. (2021). OS Greenspace - technical specification (version 1.2). Online Retrieved from <https://www.ordnancesurvey.co.uk/business-government/products/open-map-greenspace>
- Ordnance Survey. (2020). A Guide to Coordinate Systems in Great Britain: An introduction to mapping coordinate systems and the use of GNSS datasets with Ordnance Survey mapping. Retrieved from <https://www.ordnancesurvey.co.uk/documents/resources/guide-coordinate-systems-great-britain.pdf>
- Ordnance Survey. (2016). OS Fact Sheet: Using the National Grid. Retrieved from <https://www.ordnancesurvey.co.uk/documents/resources/guide-to-nationalgrid.pdf>

- Osborn, D., Levy, G., Nazareth, I., & King, M. (2008). Suicide and severe mental illnesses. Cohort study within the UK general practice research database. *Schizophr Res*, 99(1-3), 134-138. doi:10.1016/j.schres.2007.11.025
- Ougrin, D. (2009). The extraordinary potential of primary care to improve mental health. In (Vol. 2, pp. 3-4): Taylor & Francis.
- Oyesanya, M., Lopez-Morinigo, J., & Dutta, R. (2015). Systematic review of suicide in economic recession. *World journal of psychiatry*, 5(2), 243.
- Palm, K., Schmitz, S., & Mangelsdorf, M. (2013). Embodiment and ecosocial theory-interview with Nancy Krieger. *FZG—Freiburger Zeitschrift für GeschlechterStudien*, 19(2), 15-16.
- Paquet, C., Coffee, N. T., Haren, M. T., Howard, N. J., Adams, R. J., Taylor, A. W., & Daniel, M. (2014). Food environment, walkability, and public open spaces are associated with incident development of cardio-metabolic risk factors in a biomedical cohort. *Health & Place*, 28, 173-176.
- Parmenter, K., Waller, J., & Wardle, J. (2000). Demographic variation in nutrition knowledge in England. *Health education research*, 15(2), 163-174.
- Pasch, K. E., Hearst, M. O., Nelson, M. C., Forsyth, A., & Lytle, L. A. (2009). Alcohol outlets and youth alcohol use: Exposure in suburban areas. *Health & Place*, 15(2), 642-646.
- Patel, A. V., Hildebrand, J. S., Leach, C. R., Campbell, P. T., Doyle, C., Shuval, K., Wang, Y., & Gapstur, S. M. (2018). Walking in Relation to Mortality in a Large Prospective Cohort of Older U.S. Adults. *Am J Prev Med*, 54(1), 10-19. doi:10.1016/j.amepre.2017.08.019
- Patel, V., Cohen, A., Thara, R., & Gureje, O. (2006). Is the outcome of schizophrenia really better in developing countries? *Brazilian Journal of Psychiatry*, 28(2), 149-152.
- Peach, C., & Byron, M. (1994). Council house sales, residualisation and Afro Caribbean tenants. *Journal of Social Policy*, 23(3), 363-383.
- Pearce, J., Mitchell, R., & Shortt, N. (2015). Place, space, and health inequalities. *Health inequalities: Critical perspectives*, 192, 205.
- Perera, G., Broadbent, M., Callard, F., Chang, C.-K., Downs, J., Dutta, R., Fernandes, A., Hayes, R. D., Henderson, M., & Jackson, R. (2016). Cohort profile of the South London and Maudsley NHS Foundation trust biomedical research centre (SLAM BRC) case register: current status and recent enhancement of an electronic mental health Record-derived data resource. *BMJ open*, 6(3), e008721.
- Perese, E. F. (2007). Stigma, poverty, and victimization: Roadblocks to recovery for individuals with severe mental illness. *Journal of the American Psychiatric Nurses Association*, 13(5), 285-295.
- Pickett, K. E., & Wilkinson, R. G. (2008). People like us: ethnic group density effects on health. *Ethn Health*, 13(4), 321-334. doi:10.1080/13557850701882928
- Poelman, M., Strak, M., Schmitz, O., Hoek, G., Karssenberg, D., Helbich, M., Ntarladima, A. M., Bots, M., Brunekreef, B., Grobbee, R., Dijst, M., & Vaartjes, I. (2018). Relations between the residential fast-food environment and the individual risk of cardiovascular diseases in The Netherlands: A nationwide follow-up study. *Eur J Prev Cardiol*, 25(13), 1397-1405. doi:10.1177/2047487318769458
- Pollard, G., Roetman, P., Ward, J., Chiera, B., & Mantzioris, E. (2018). Beyond productivity: Considering the health, social value and happiness of home and community food gardens. *Urban Science*, 2(4), 97.
- Popkin, B. M. (2015). Nutrition transition and the global diabetes epidemic. *Current diabetes reports*, 15, 1-8.
- Popkin, B. M., Adair, L. S., & Ng, S. W. (2012). Global nutrition transition and the pandemic of obesity in developing countries. *Nutrition reviews*, 70(1), 3-21.

- Popova, S., Giesbrecht, N., Bekmuradov, D., & Patra, J. (2009). Hours and days of sale and density of alcohol outlets: impacts on alcohol consumption and damage: a systematic review. *Alcohol & Alcoholism*, 44(5), 500-516.
- Portes, A. (1997). Immigration theory for a new century: some problems and opportunities. *Int Migr Rev*, 31(4), 799-825.
- Portes, A. (1998). Social capital: Its origins and applications in modern sociology. *Annual review of sociology*, 24(1), 1-24.
- Powell, L. M., Han, E., Zenk, S. N., Khan, T., Quinn, C. M., Gibbs, K. P., Pugach, O., Barker, D. C., Resnick, E. A., Myllyluoma, J., & Chaloupka, F. J. (2011). Field validation of secondary commercial data sources on the retail food outlet environment in the U.S. *Health Place*, 17(5), 1122-1131. doi:10.1016/j.healthplace.2011.05.010
- Power, M., Pybus, K. J., Pickett, K. E., & Doherty, B. (2021). "The reality is that on Universal Credit I cannot provide the recommended amount of fresh fruit and vegetables per day for my children": Moving from a behavioural to a systemic understanding of food practices [version 1; peer review: 2 approved]. *Emerald open research*, 3.
- Public Health England. (2020b). Lewisham Local Authority Health Profile 2019. Retrieved from <https://fingertips.phe.org.uk/static-reports/health-profiles/2019/E09000023.html?area-name=lewisham>
- Putnam, R. (1993). *Making Democracy Work: Civic Traditions in Modern Italy* Text.
- Pybus, K. (2018). *Mental illness and stigma from a socioeconomic perspective* (Doctoral dissertation, University of York). Retrieved from https://etheses.whiterose.ac.uk/23426/1/Thesis_final_corrections.pdf
- Rasbash, J. (2023). What are multilevel models and why should I use them? Retrieved from <https://www.bristol.ac.uk/cmm/learning/multilevel-models/what-why.html>
- Rezende, L. F., Azeredo, C. M., Canella, D. S., Luiz Odo, C., Levy, R. B., & Eluf-Neto, J. (2016). Coronary heart disease mortality, cardiovascular disease mortality and all-cause mortality attributable to dietary intake over 20years in Brazil. *Int J Cardiol*, 217, 64-68. doi:10.1016/j.ijcard.2016.04.176
- Ribeiro, A. I., & Hoffmann, E. (2018). Development of a neighbourhood walkability index for Porto metropolitan area. How strongly is walkability associated with walking for transport? *International Journal of Environmental Research and Public Health*, 15(12), 2767.
- Richardson, E., Hill, S., Mitchell, R., Pearce, J., & Shortt, N. (2015). Is local alcohol outlet density related to alcohol-related morbidity and mortality in Scottish cities? *Health & Place*, 33, 172-180.
- Rifaat, S. M., Tay, R., & De Barros, A. (2010). Effect of street pattern on road safety: Are policy recommendations sensitive to aggregations of crashes by severity? *Transportation Research Record*, 2147(1), 58-65.
- Robinson, K. L., McBeth, J., & Macfarlane, G. J. (2004). Psychological distress and premature mortality in the general population: a prospective study. *Ann Epidemiol*, 14(7), 467-472. doi:10.1016/j.annepidem.2003.11.007
- Rodrigues, M., Wiener, J. C., Stranges, S., Ryan, B. L., & Anderson, K. K. (2021). The risk of physical multimorbidity in people with psychotic disorders: A systematic review and meta-analysis. *Journal of Psychosomatic Research*, 140, 110315.
- Rodriguez, F., Hu, J., Kershaw, K., Hastings, K. G., López, L., Cullen, M. R., Harrington, R. A., & Palaniappan, L. P. (2018). County-level Hispanic ethnic density and cardiovascular disease mortality. *Journal of the American Heart Association*, 7(19), e009107.

- Rodriguez-Lopez, M., Merlo, J., Perez-Vicente, R., Austin, P., & Leckie, G. (2020). Cross-classified Multilevel Analysis of Individual Heterogeneity and Discriminatory Accuracy (MAIHDA) to evaluate hospital performance: the case of hospital differences in patient survival after acute myocardial infarction. *BMJ open*, 10(10), e036130.
- Rodriguez-Loureiro, L., Verdoodt, F., Lefebvre, W., Vanpoucke, C., Casas, L., & Gadeyne, S. (2022). Long-term exposure to residential green spaces and site-specific cancer mortality in urban Belgium: A 13-year follow-up cohort study. *Environ Int*, 170, 107571. doi:10.1016/j.envint.2022.107571
- Rojas-Rueda, D., Nieuwenhuijsen, M. J., Gascon, M., Perez-Leon, D., & Mudu, P. (2019). Green spaces and mortality: a systematic review and meta-analysis of cohort studies. *Lancet Planet Health*, 3(11), e469-e477. doi:10.1016/s2542-5196(19)30215-3
- Roof, K., & Oleru, N. (2008). Public health: Seattle and King County's push for the built environment. *Journal of environmental health*, 71(1), 24-27.
- Ruff, R. R., Akhund, A., Adjoian, T., & Kansagra, S. M. (2014). Calorie intake, sugar-sweetened beverage consumption, and obesity among New York City adults: findings from a 2013 population study using dietary recalls. *Journal of community health*, 39, 1117-1123.
- Rundle, A. G., Sheehan, D. M., Quinn, J. W., Bartley, K., Eisenhower, D., Bader, M. M., Lovasi, G. S., & Neckerman, K. M. (2016). Using GPS data to study neighborhood walkability and physical activity. *American journal of preventive medicine*, 50(3), e65-e72.
- Russ, T. C., Stamatakis, E., Hamer, M., Starr, J. M., Kivimäki, M., & Batty, G. D. (2012). Association between psychological distress and mortality: individual participant pooled analysis of 10 prospective cohort studies. *Bmj*, 345.
- Saarloos, D., Alfonso, H., Giles-Corti, B., Middleton, N., & Almeida, O. P. (2011). The built environment and depression in later life: the health in men study. *Am J Geriatr Psychiatry*, 19(5), 461-470. doi:10.1097/JGP.0b013e3181e9b9bf
- Saelens, B. E., & Handy, S. L. (2008). Built environment correlates of walking: a review. *Med Sci Sports Exerc*, 40(7 Suppl), S550-S566. doi:10.1249/MSS.0b013e31817c67a4
- Saelens, B. E., Sallis, J. F., Black, J. B., & Chen, D. (2003). Neighborhood-based differences in physical activity: an environment scale evaluation. *American journal of public health*, 93(9), 1552-1558.
- Saha, S., Chant, D., & McGrath, J. (2007). A systematic review of mortality in schizophrenia: is the differential mortality gap worsening over time? *Arch Gen Psychiatry*, 64(10), 1123-1131. doi:10.1001/archpsyc.64.10.1123
- Sallis, J. F., Bauman, A., & Pratt, M. (1998). Environmental and policy interventions to promote physical activity. *Am J Prev Med*, 15(4), 379-397. doi:10.1016/s0749-3797(98)00076-2
- Sallis, J. F., Cerin, E., Conway, T. L., Adams, M. A., Frank, L. D., Pratt, M., Salvo, D., Schipperijn, J., Smith, G., & Cain, K. L. (2016). Physical activity in relation to urban environments in 14 cities worldwide: a cross-sectional study. *The Lancet*, 387(10034), 2207-2217.
- Saluja, T., Davies, A., Oldmeadow, C., & Boyle, A. J. (2021). Impact of fast-food outlet density on incidence of myocardial infarction in the Hunter region. *Intern Med J*, 51(2), 243-248. doi:10.1111/imj.14745
- Sampson, R. J., Raudenbush, S. W., & Earls, F. (1997). Neighborhoods and violent crime: a multilevel study of collective efficacy. *Science*, 277(5328), 918-924. doi:10.1126/science.277.5328.918
- Sánchez-Villegas, P., Cabrera-León, A., & Gil García, E. (2021). [Association between neighborhood walkability and mortality due to different causes in Andalusia (Spain)]. *Gac Sanit*, 35(3), 260-263. doi:10.1016/j.gaceta.2019.06.004

- Sarkar, C., & Webster, C. (2017). Healthy cities of tomorrow: The case for large scale built environment–health studies. *Journal of Urban Health*, 94, 4-19.
- Sarkar, C., Webster, C., & Gallacher, J. (2018). Neighbourhood walkability and incidence of hypertension: Findings from the study of 429,334 UK Biobank participants. *Int J Hyg Environ Health*, 221(3), 458-468. doi:10.1016/j.ijheh.2018.01.009
- Schiøtz, M. L., Stockmarr, A., Høst, D., Glümer, C., & Frølich, A. (2017). Social disparities in the prevalence of multimorbidity - A register-based population study. *BMC Public Health*, 17(1), 422. doi:10.1186/s12889-017-4314-8
- Seaman, R., Riffe, T., & Caswell, H. (2019). Changing contribution of area-level deprivation to total variance in age at death: a population-based decomposition analysis. *BMJ open*, 9(3), e024952. doi:10.1136/bmjopen-2018-024952
- Shanshan, L., Stampfer, M. J., Williams, D. R., & Vanderweele, T. J. (2016). Religious service attendance and mortality among women. *JAMA internal medicine*, 176(6), 777-785. Retrieved from <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5503841/>
- Sherk, A., Stockwell, T., Chikritzhs, T., Andréasson, S., Angus, C., Gripenberg, J., Holder, H., Holmes, J., Mäkelä, P., & Mills, M. (2018). Alcohol consumption and the physical availability of take-away alcohol: systematic reviews and meta-analyses of the days and hours of sale and outlet density. *Journal of studies on alcohol and drugs*, 79(1), 58-67.
- Sierra, H., Cordova, M., Chen, C.-S. J., & Rajadhyaksha, M. (2015). Confocal imaging-guided laser ablation of basal cell carcinomas: an ex vivo study. *The Journal of investigative dermatology*, 135(2), 612.
- Smith, G. D., Whitley, E., Dorling, D., & Gunnell, D. (2001). Area based measures of social and economic circumstances: cause specific mortality patterns depend on the choice of index. *Journal of Epidemiology & Community Health*, 55(2), 149-150.
- Smith, T. C., Wingard, D. L., Smith, B., Kritz-Silverstein, D., & Barrett-Connor, E. (2007). Walking decreased risk of cardiovascular disease mortality in older adults with diabetes. *J Clin Epidemiol*, 60(3), 309-317. doi:10.1016/j.jclinepi.2006.06.013
- Smith, T. E., Easter, A., Pollock, M., Pope, L. G., & Wisdom, J. P. (2013). Disengagement from care: perspectives of individuals with serious mental illness and of service providers. *Psychiatric Services*, 64(8), 770-775.
- Social Exclusion Unit. (2004). Mental Health and Social Exclusion: Social Exclusion Unit Report. Retrieved from https://www.centreformentalhealth.org.uk/sites/default/files/mental_health_and_social_exclusion.pdf
- Social Mobility Commission. (2017). State of the nation 2017: social mobility in Great Britain. Retrieved from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/662744/State_of_the_Nation_2017_-_Social_Mobility_in_Great_Britain.pdf
- Solar, S., & Irwin, A. (2010). A Conceptual Framework for Action on the Social Determinants of Health: Paper 2 (Policy and Practice). Retrieved from <https://apps.who.int/iris/handle/10665/44489>
- Solmi, F., Mohammadi, A., Perez, J. A., Hameed, Y., Jones, P. B., & Kirkbride, J. B. (2018). Predictors of disengagement from Early Intervention in Psychosis services. *The British Journal of Psychiatry*, 213(2), 477-483.
- Southwark Council. (2014). Community council profiles overview. Retrieved from [file:///C:/Users/Dionne/OneDrive/Documents/KCL%20PhD/Methods/Borough%20wide%20profile%20data%20\(1\).pdf](file:///C:/Users/Dionne/OneDrive/Documents/KCL%20PhD/Methods/Borough%20wide%20profile%20data%20(1).pdf)

- Southwark Council. (2021). Census 2011 Briefing. Retrieved from <https://www.southwark.gov.uk/council-and-democracy/statistics-and-census/census-2011-briefing?chapter=6>
- Spoerri, A., Zwahlen, M., Panczak, R., Egger, M., Huss, A., & Cohort, S. N. (2013). Alcohol-selling outlets and mortality in Switzerland—the Swiss National Cohort. *Addiction*, 108(9), 1603-1611.
- Stack S. (2000). Suicide: a 15-year review of the sociological literature. Part II: modernization and social integration perspectives. *Suicide & life-threatening behavior*, 30(2), 163–176.
- Stark, R., Doyle, D. P., & Rushing, J. L. (1983). Beyond Durkheim: religion and suicide. *Journal for the Scientific Study of Religion*, 120-131
- Statista. (2022). Number of McDonald's restaurants worldwide from 2005 to 2022. Retrieved from <https://www.statista.com/statistics/219454/mcdonalds-restaurants-worldwide/>
- Stevenson, M., Thompson, J., de Sá, T. H., Ewing, R., Mohan, D., McClure, R., Roberts, I., Tiwari, G., Giles-Corti, B., & Sun, X. (2016). Land use, transport, and population health: estimating the health benefits of compact cities. *The Lancet*, 388(10062), 2925-2935.
- Stewart, R., Soremekun, M., Perera, G., Broadbent, M., Callard, F., Denis, M., Hotopf, M., Thornicroft, G., & Lovestone, S. (2009). The South London and Maudsley NHS Foundation Trust Biomedical Research Centre (SLAM BRC) case register: development and descriptive data. *BMC Psychiatry*, 9(1), 51. doi:10.1186/1471-244X-9-51
- Stjärne, M. K., Ponce de Leon, A., & Hallqvist, J. (2004). Contextual effects of social fragmentation and material deprivation on risk of myocardial infarction-results from the Stockholm Heart Epidemiology Program (SHEEP). *Int J Epidemiol*, 33(4), 732-741. doi:10.1093/ije/dyh087
- Stuckler, D., Reeves, A., Loopstra, R., Karanikolos, M., & McKee, M. (2017). Austerity and health: the impact in the UK and Europe. *European journal of public health*, 27(suppl_4), 18-21. doi:10.1093/eurpub/ckx167
- Sturm, R., & Cohen, D. (2014). Proximity to urban parks and mental health. *J Ment Health Policy Econ*, 17(1), 19-24.
- Sugiyama, T., Neuhaus, M., Cole, R., Giles-Corti, B., & Owen, N. (2012). Destination and route attributes associated with adults' walking: a review. *Medicine and science in sports and exercise*, 44(7), 1275-1286.
- Susser, E., & Kirkbride, J. B. (2019). Neighbourhood and mortality in severe mental illness. *The Lancet Psychiatry*, 6(6), 456-458.
- Swinburn, B., Sacks, G., Vandevijvere, S., Kumanyika, S., Lobstein, T., Neal, B., Barquera, S., Friel, S., Hawkes, C., & Kelly, B. (2013). INFORMAS (International Network for Food and Obesity/non-communicable diseases Research, Monitoring and Action Support): overview and key principles. *Obesity reviews*, 14, 1-12.
- Taylor, S., & Ashworth. (1987). Durkheim and social realism: an approach to health and illness. In G. Scambler (Ed.), *Sociological theory and medical sociology* (pp. 37 - 58). London: Routledge.
- Teferra, S., Shibre, T., Fekadu, A., Medhin, G., Wakwoya, A., Alem, A., Kullgren, G., & Jacobsson, L. (2011). Five-year mortality in a cohort of people with schizophrenia in Ethiopia. *BMC psychiatry*, 11(1), 165. doi:10.1186/1471-244X-11-165
- Testa, A., Jackson, D. B., Semenza, D. C., & Vaughn, M. G. (2021). Food deserts and cardiovascular health among young adults. *Public Health Nutr*, 24(1), 117-124. doi:10.1017/s1368980020001536

- Thornicroft, G., Sunkel, C., Aliev, A. A., Baker, S., Brohan, E., El Chammay, R., Davies, K., Demissie, M., Duncan, J., & Fekadu, W. (2022). The Lancet Commission on ending stigma and discrimination in mental health. *The Lancet*, 400(10361), 1438-1480.
- Tiihonen, J., Lönnqvist, J., Wahlbeck, K., Klaukka, T., Niskanen, L., Tanskanen, A., & Haukka, J. (2009). 11-year follow-up of mortality in patients with schizophrenia: a population-based cohort study (FIN11 study). *Lancet*, 374(9690), 620-627. doi:10.1016/s0140-6736(09)60742-x
- Todd, A., Copeland, A., Husband, A., Kasim, A., & Bamba, C. (2015). Access all areas? An area-level analysis of accessibility to general practice and community pharmacy services in England by urbanity and social deprivation. *BMJ Open*, 5(5), e007328. doi:10.1136/bmjopen-2014-007328
- Travert, A.-S., Sidney Annerstedt, K., & Daivadanam, M. (2019). Built environment and health behaviors: deconstructing the black box of interactions—a review of reviews. *International Journal of Environmental Research and Public Health*, 16(8), 1454.
- Tressider, M. (2005). Using GIS to measure connectivity: An exploration of issues. Retrieved from https://web.pdx.edu/~jdill/Tresidder_Using_GIS_to_Measure_Connectivity.pdf
- Tunstall, H., Mitchell, R., Gibbs, J., Platt, S., & Dorling, D. (2012). Socio-demographic diversity and unexplained variation in death rates among the most deprived parliamentary constituencies in Britain. *Journal of public health*, 34(2), 296-304.
- Turner, C., Aggarwal, A., Walls, H., Herforth, A., Drewnowski, A., Coates, J., Kalamatianou, S., & Kadiyala, S. (2018). Concepts and critical perspectives for food environment research: a global framework with implications for action in low-and middle-income countries. *Global food security*, 18, 93-101.
- Twohig-Bennett, C., & Jones, A. (2018). The health benefits of the great outdoors: A systematic review and meta-analysis of greenspace exposure and health outcomes. *Environ Res*, 166, 628-637. doi:10.1016/j.envres.2018.06.030
- Ulrich, R. S. (1984). View through a window may influence recovery from surgery. *Science*, 224(4647), 420-421. doi:10.1126/science.6143402
- United States Environmental Protection Agency. (2023). Reduce Urban Heat Island Effect. Retrieved from <https://www.epa.gov/green-infrastructure/reduce-urban-heat-island-effect>
- Uphoff, E. P., Pickett, K. E., Cabieses, B., Small, N., & Wright, J. (2013). A systematic review of the relationships between social capital and socioeconomic inequalities in health: a contribution to understanding the psychosocial pathway of health inequalities. *International journal for equity in health*, 12, 1-12.
- Van den Berg, M., Wendel-Vos, W., van Poppel, M., Kemper, H., van Mechelen, W., & Maas, J. (2015). Health benefits of green spaces in the living environment: A systematic review of epidemiological studies. *Urban forestry & urban greening*, 14(4), 806-816.
- Van Dyck, D., Cardon, G., Deforche, B., Owen, N., & De Bourdeaudhuij, I. (2011). Relationships between neighborhood walkability and adults' physical activity: How important is residential self-selection? *Health & Place*, 17(4), 1011-1014.
- Victor, A., Silva, R. C. R., Silva, N. J., Ferreira, A., Barreto, M. L., & Campello, T. (2023). Influence of Unhealthy Food Environment on Premature Cardiovascular Disease Mortality in Brazil: An Ecologic Approach. *Am J Prev Med*, 64(2), 285-292. doi:10.1016/j.amepre.2022.09.018
- Victora, C. G., Huttly, S. R., Fuchs, S. C., & Olinto, M. T. (1997). The role of conceptual frameworks in epidemiological analysis: a hierarchical approach. *International journal of epidemiology*, 26(1), 224-227.

- Villeneuve, P. J., Jerrett, M., Su, J. G., Burnett, R. T., Chen, H., Wheeler, A. J., & Goldberg, M. S. (2012). A cohort study relating urban green space with mortality in Ontario, Canada. *Environmental research*, 115, 51-58.
- Walking for Health. (2016). Retrieved from <https://blessedcbd.co.uk/walking-for-health/>
- Wang, B., Li, P., He, F., Sha, Y., Wan, X., & Wang, L. (2021). Spatiotemporal variations in ischemic heart disease mortality and related risk factors in China between 2010 and 2015: a multilevel analysis. *BMC Public Health*, 21, 1-10.
- Wang, F., Wen, M., & Xu, Y. (2013). Population-adjusted street connectivity, urbanicity and risk of obesity in the US. *Applied geography*, 41, 1-14.
- Wang, H., & Tassinari, L. G. (2019). Effects of greenspace morphology on mortality at the neighbourhood level: a cross-sectional ecological study. *The Lancet Planetary Health*, 3(11), e460-e468.
- Wannamethee, S. G., Shaper, A. G., & Walker, M. (2000). Physical activity and mortality in older men with diagnosed coronary heart disease. *Circulation*, 102(12), 1358-1363. doi:10.1161/01.cir.102.12.1358
- Wells, G., Shea, B., O'Connell, D., Peterson, J., Welch, V., Losos, M., & Tugwell, P. (2012). The Newcastle-Ottawa Scale (NOS) for assessing the quality of nonrandomised studies in meta-analyses. Ottawa: Ottawa Hospital Research Institute.
- Werner, S., Malaspina, D., & Rabinowitz, J. (2007). Socioeconomic status at birth is associated with risk of schizophrenia: population-based multilevel study. *Schizophr Bull*, 33(6), 1373-1378. doi:10.1093/schbul/sbm032
- Whitley, E., Gunnell, D., Dorling, D., & Smith, G. D. (1999). Ecological study of social fragmentation, poverty, and suicide. *Bmj*, 319(7216), 1034-1037. doi:10.1136/bmj.319.7216.1034
- Whitley, R., Prince, M., McKenzie, K., & Stewart, R. (2006). Exploring the ethnic density effect: a qualitative study of a London electoral ward. *Int J Soc Psychiatry*, 52(4), 376-391. doi:10.1177/0020764006067239
- Wilkins, E. L., Radley, D., Morris, M. A., & Griffiths, C. (2017). Examining the validity and utility of two secondary sources of food environment data against street audits in England. *Nutrition journal*, 16, 1-13.
- Wilkins, E., Morris, M., Radley, D., & Griffiths, C. (2019). Methods of measuring associations between the Retail Food Environment and weight status: Importance of classifications and metrics. *SSM Popul Health*, 8, 100404. doi:10.1016/j.ssmph.2019.100404
- Wilkinson, C., Livingston, M., & Room, R. (2016). Impacts of changes to trading hours of liquor licences on alcohol-related harm: a systematic review 2005–2015. *Public health research & practice*.
- Williams, E., Buck, D., Babalola, G., & Maguire, D. (2022). What are health inequalities? . Retrieved from <https://www.kingsfund.org.uk/publications/what-are-health-inequalities>
- Witten, K., Blakely, T., Bagheri, N., Badland, H., Ivory, V., Pearce, J., Mavoa, S., Hinckson, E., & Schofield, G. (2012). Neighborhood built environment and transport and leisure physical activity: findings using objective exposure and outcome measures in New Zealand. *Environmental Health Perspectives*, 120(7), 971-977.
- World Health Organization. (2019). Environmental health inequalities in Europe: Second assessment report. Retrieved from <https://www.who.int/europe/publications/i/item/9789289054157>
- World Health Organization. (2020). Global Health Estimates: Life expectancy and healthy life expectancy. Retrieved from <https://www.who.int/data/gho/data/themes/mortality->

- and-global-health-estimates/ghe-life-expectancy-and-healthy-life-expectancy#:~:text=Situation%20and%20trends,to%2073.4%20years%20in%202019.
- Wu, Y. T., Prina, A. M., Jones, A., Barnes, L. E., Matthews, F. E., & Brayne, C. (2016). Land use mix and five-year mortality in later life: Results from the Cognitive Function and Ageing Study. *Health Place*, 38, 54-60. doi:10.1016/j.healthplace.2015.12.002
- Yang, M., Wang, H., & Qiu, F. (2019). The built environment of schools: Access to unhealthy food outlets and outdoor recreational facilities. *Cities*, 87, 229-237.
- Yang, T. C., Lei, L., & Kurtulus, A. (2018). Neighborhood ethnic density and self-rated health: Investigating the mechanisms through social capital and health behaviors. *Health Place*, 53, 193-202. doi:10.1016/j.healthplace.2018.08.011
- Yell.com. (2021). About Yell.com. Retrieved from <https://support.yell.com/support/solutions/articles/77000496908-about-yell-com>
- Yeung, C. Y., Men, Y. V., Caine, E. D., & Yip, P. S. F. (2022). The differential impacts of social deprivation and social fragmentation on suicides: A lesson from Hong Kong. *Soc Sci Med*, 315, 115524. doi:10.1016/j.socscimed.2022.115524
- Yoshioka, E., Hanley, S., Sato, Y., & Saijo, Y. (2022). Associations between social fragmentation, socioeconomic deprivation and suicide risk across 1887 municipalities in Japan, 2009–2017: A spatial analysis using the Bayesian hierarchical model. *BMJ open*, 12(8), e063255.
- Yu, J., Gustafson, P., Tran, M., & Brauer, M. (2022). Assessing Trade-Offs and Optimal Ranges of Density for Life Expectancy and 12 Causes of Mortality in Metro Vancouver, Canada, 1990-2016. *Int J Environ Res Public Health*, 19(5). doi:10.3390/ijerph19052900
- Yuan, Y., Huang, F., Lin, F., Zhu, P., & Zhu, P. (2021). Green space exposure on mortality and cardiovascular outcomes in older adults: a systematic review and meta-analysis of observational studies. *Aging Clin Exp Res*, 33(7), 1783-1797. doi:10.1007/s40520-020-01710-0
- Zenk, S. N., Schulz, A. J., Israel, B. A., James, S. A., Bao, S., & Wilson, M. L. (2006). Fruit and vegetable access differs by community racial composition and socioeconomic position in Detroit, Michigan. *Ethnicity & disease*, 16(1), 275-280.
- Zhang, J. (2016). The Social Integration Theory of Suicide. *Crisis*, 37(3), 169-175.

Appendix 1. Study 1 - Draft manuscript

Schizophrenia Research

The association between area-level factors and mortality in severe mental illnesses: A systematic review --Manuscript Draft--

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Article Type:	Review Article
Keywords:	severe mental illness; schizophrenia; bipolar disorder; mortality; area-level factors; systematic review
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Order of Authors:	Dionne Laporte Natasha Chilman Craig Morgan Peter Schofield Til Wykes Jayati Das-Munshi
Abstract:	Background: Premature mortality is a well-documented adverse outcome for people living with severe mental illnesses (SMI). Emerging evidence suggests that area-level factors play a role that are experienced disproportionately by this population. This review assesses the potential association between area-level factors and mortality in people with SMI. Method: We searched Medline, EMBASE, PsychINFO, Social Policy and Practice, Web of Science and OpenGrey databases. Literature searches were conducted in May 2020 and updated in June 2023. Reference lists were hand-searched and authors of included studies contacted to identify additional studies and minimise publication biases. Narrative synthesis was used to appraise the included studies. The review protocol was registered on PROSPERO (CRD42019155447). Results: Our searches identified 7 studies (8 papers), which were included in the review, and indicated evidence of an association between deprivation and mortality. One study suggested an association between mortality in SMI and urbanicity in low to middle income settings which was not observed in studies from high income settings. One study suggested a protective association of area-level ethnic density with mortality within urbanised settings. Conclusion: Consistent associations were reported between residence in areas of higher deprivation and increased risk of mortality in SMI. Two studies suggested an association between area-level ethnic density and urbanicity and mortality in SMI. Most studies were conducted across high income countries and therefore future research could benefit from similar investigations being conducted in low- and middle-income countries. These methods would inform health and social policies, including interventions to reduce premature mortality in SMI.
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Title: The association between area-level factors and mortality in severe mental illnesses: A systematic review

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Abstract

Background: Premature mortality is a well-documented adverse outcome for people living with severe mental illnesses (SMI). Emerging evidence suggests that area-level factors play a role that are experienced disproportionately by this population. This review assesses the potential association between area-level factors and mortality in people with SMI.

Method: We searched Medline, EMBASE, PsychINFO, Social Policy and Practice, Web of Science and OpenGrey databases. Literature searches were conducted in May 2020 and updated in June 2023. Reference lists were hand-searched and authors of included studies contacted to identify additional studies and minimise publication biases. Narrative synthesis was used to appraise the included studies. The review protocol was registered on PROSPERO (CRD42019155447).

Results: Our searches identified 7 studies (8 papers), which were included in the review, and indicated evidence of an association between deprivation and mortality. One study suggested an association between mortality in SMI and urbanicity in low to middle income settings which was not observed in studies from high income settings. One study suggested a protective association of area-level ethnic density with mortality within urbanised settings.

Conclusion: Consistent associations were reported between residence in areas of higher deprivation and increased risk of mortality in SMI. Two studies suggested an association between area-level ethnic density and urbanicity and mortality in SMI. Most studies were conducted across high income countries and therefore future research could benefit from similar investigations being conducted in low- and middle-income countries. These methods would inform health and social policies, including interventions to reduce premature mortality in SMI.

Keywords: severe mental illness, schizophrenia, bipolar disorder, mortality, area-level factors, systematic review

Introduction

People diagnosed with severe mental illnesses (SMI) (defined as non-affective and affective psychoses, and bipolar disorder) experience a 10-20 year reduction in life expectancy compared with the general population (Hjorthøj, Stürup, McGrath, & Nordentoft, 2017; Saha, Chant, & McGrath, 2007). This mortality gap continues to widen (Hayes, Marston, Walters, King & Osborn, 2017; Hjorthøj et al., 2017; Lomholt et al., 2019; Saha et al., 2007).

Mortality risks vary geographically (Hjorthøj et al., 2017) and until the mid-2000s, it was assumed that people with schizophrenia had better prognoses and outcomes in developing countries (Hopper & Wanderling, 2000), reported in the World Health Organisation (WHO) studies (Jablensky & Sartorius, 2008). These studies concluded that although the risk of mortality was higher in people living with SMI compared to general population samples across the international research sites, the mortality rates were higher in industrialised research sites. The WHO studies, however, have methodological shortcomings which include the use of outcome measures (e.g. hospital stay duration) that largely reflect socio-environmental factors rather than the course of schizophrenia, limited analyses of the socio-cultural variations in schizophrenia diagnoses and its impact on outcomes (Patel, Cohen, Thara, & Gureje, 2006), other unmeasured potential confounders (e.g. social support) (Jablensky & Sartorius, 2008) and no inclusion of area-level factors within analyses. Additionally, other investigations provide contradictory findings that suggest worse prognoses for people with schizophrenia in low and middle income countries (Patel et al., 2006).

Research investigating the correlates of health outcomes in the general population tended to focus on individual-level factors despite evidence of geographical disparities, but within the last two decades has there been a renewed focus on the inclusion of area-level factors that can influence the course and distribution of health outcomes (Diez Roux, 2016). These area-level factors typically include aspects of the built and social environments. The built environment refers to the human-made aspects of the physical surroundings, including rural or urban buildings, facilities, infrastructures and open spaces (Roof & Oleru, 2008). It encompasses all structures and spaces that are created or modified by humans and serve as places for people to live, work, and engage in recreational activities (Travert et al., 2019). The social environment typically refers to aspects of the environment that influence societal norms, enforce patterns of social control, impact stress levels, offer or limit opportunities for specific behaviours, and impose restrictions on individual choices (Institute of Medicine, 2002). At the area-level this typically includes (but not limited to) social cohesion and social networks (Hernandez & Blazer, 2006). These social environment factors have been measured through area-level indicators like social fragmentation (Collings et al., 2009) and the proportions of different racial / ethnic minority communities coexisting in specific geographic locations (Faris & Dunham, 1939; Halpern, 1993).

Area-level factors, by their nature, impact sizeable populations coexisting in shared residential or work environments, making them potential explanatory factors for observed geographic disparities in health outcomes (Woolf & Aron, 2013). Several area-level features that have been found to be associated with an increased risk of mortality in the general population have been identified, which includes: reduced exposure to green spaces (Gascon et al., 2016), higher air pollution (Faustini et al., 2014), reduced ethnic density (Bécares et al., 2012), higher population density (Carnegie et al., 2022), access to fast food outlets (Alter & Eny, 2005) area-level deprivation (Office for National Statistics, 2019) and social fragmentation (Mok et al., 2013). These studies demonstrated that after adjusting for

individual-level factors (e.g. sex, ethnicity, socio-economic status), there remained a proportion of variance in mortality risk accounted for by environmental factors. Although the existence of these associations between area-level factors and mortality within SMI are yet to be clarified.

This review aims to evaluate the existing evidence on the relationship between social and built area-level factors and mortality risk in the population with SMI. Specifically, we aim to identify area-level factors that may affect the risk of premature mortality in people diagnosed with SMI aged 15 and older. To our knowledge, this is the first review to focus on the association between environmental factors at the area-level, and mortality in SMI.

Method

Search strategy and inclusion criteria

We searched the titles and abstracts in the following databases from their earliest date, including Embase (1947), MEDLINE (1946), PsycINFO (1806), Social Policy and Practice (1890), and Web of Science Core Collection (1900). Searches were conducted in May 2020 and repeated in December 2021. To align with the current guidelines on updating reviews (Cumpston & Chandler, 2022) and to account for any potentially overlooked studies in previous searches, additional search terms were incorporated when the searches were updated in June 2023 (see Figure 1 and supplement 1 for more details). Grey literature was searched using the OpenGrey database (<http://www.opengrey.eu/>). No time or language restrictions were imposed. The search terms were developed through prior literature searches and in consultation with the King's College London library service. The search strategy was developed to achieve a balance between sensitivity and specificity. The objective was to encompass a wide scope of relevant studies while minimizing the inclusion of irrelevant studies.

Studies were included if they:

- a) reported results on the relationship between area-level factors (e.g. area deprivation, urbanicity, ethnic density, social fragmentation and other features of the urban built and social environment) and mortality outcomes .
- b) included participants aged 15 and older
- c) included participants with a diagnosis of SMI (defined here as schizophreniform disorders, non-organic psychotic disorders and bipolar disorder)
- d) used case-control, cross-sectional, prospective or retrospective cohort designs and (e) were available in full-text.

We excluded studies that were reviews, editorials, research protocols and letters and ecological studies.

Authors of included studies were contacted to identify additional studies. The reference lists of all included studies were hand-searched by DL for further articles that could be eligible for inclusion. After removing duplicates, the papers were screened and a random sample (17%) were reviewed by NC. Agreement was 100% between the two raters.

The search terms used for SMI were: 'schizophrenia,' OR 'psychoses,' OR 'psychosis,' OR 'bipolar disorder', OR 'severe mental illne*', OR 'serious mental disorde*', ' OR 'schiz*.' These SMI terms were paired with search terms for mortality, (e.g. 'mortality,' OR 'all cause mortality,' OR 'mortality risk,' OR 'premature mortality,' OR 'death') and area-level factors measuring aspects of the built environment (e.g., 'area-level deprivation,' OR 'urbanicity,' OR 'green spaces,' 'pollution,' OR 'population density') and the social environment (e.g., 'ethnic density,' OR 'social fragmentation,' OR 'social cohesion,' OR 'social networks,' OR 'social capital'). 'Built environment', 'natural environment', 'social environment', 'food environment' and 'environment' were included as search terms to identify all potential environmental factors that have been measured at the area-level, across both the social and built environment spectrum. These terms were utilized as a broader search term to capture studies that might have

employed area-level indicators not covered by the more specific search terms. (see Supplement 1 for the full electronic search strategy).

Data extraction and quality assessment

We extracted data from eligible studies according to the following fields: study design, country, sample size and characteristics (age, ethnicity, mental health diagnoses), follow-up period, mortality outcomes, area-level exposures, study measures, statistical analyses, covariates/ confounders, and findings. Authors were contacted for information that could not be found in the articles. Results from a single dataset presented in more than one published paper were considered to be from the same study.

The heterogeneity of measures used to assess area-level exposures, omission of effect sizes for some area-level variables and the differences in confounders adjusted across different studies, meant that a meta-analysis was not feasible, hence a narrative synthesis and tabulated presentations of the results was conducted. DL and NC independently conducted a risk of bias assessment using the Newcastle Ottawa Scale (NOS) (Wells et al., 2012). Agreement between the reviewers was 80%. The remaining proportion of disagreements were discussed and agreed upon with a third reviewer (JD).

The protocol for this narrative review and was registered to the PROSPERO website (registration number: CRD42019155447) and follows the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (see Supplement 2).

Results

Figure 1 displays the PRISMA flow diagram with reasons for exclusion. A total of eight studies were initially identified, however two of them utilized the same dataset. Therefore, the results from these two studies were combined, resulting in a total of seven studies included in the review. Table 1 provides an overview of characteristics of included studies. All included studies were cohort studies. Just over a quarter of studies reported geographical measures relating to the areas under investigation; however, these largely related to population density, as a measure for urbanicity, only. The follow-up period for the cohort studies ranged between 3 years and 15 years. SMI sample sizes ranged from 307 to 46,136 participants. Two studies recruited cohorts from clinical populations only. Four studies were conducted in the UK while three studies were conducted in China Ethiopia and Spain respectively. Lastly, none of the studies included a measure of the built environment (e.g. green spaces, food take-away outlets).

Effect of area-level exposures on mortality outcomes

An overview of the findings from the included studies is presented in tables 2 and 3.

(i) Urban-rural factors and all-cause mortality

Four studies investigated the influence of urbanicity on the risk of all-cause mortality; one study¹ used a measure of population density, with higher population density taken to indicate more urbanised areas. Two studies^{5,7} mentioned the use of rural-urban classification variables and one study³ used the ratio of non-agricultural population to total population (%). However, no further information relating to area-level characteristics were reported on how the rural-urban variables were created and defined. Two studies^{1,5} were conducted in high income countries and these investigations found no association between urban areas and mortality in SMI. One Chinese study³ also found no statistically significant association between urbanicity and mortality. Whereas an Ethiopian study⁷ reported that residency in urban areas was associated with a higher mortality risk in people with SMI, investigators of three other studies, all from high income settings, did not find an association between urbanicity and excess mortality in SMI.

(ii) Deprivation and all-cause mortality

Five studies^{1,2,4,6} investigated the association between area-level deprivation and mortality in SMI - all investigations were conducted in high income countries. Most studies^{1,2,4,6} included measures of relative deprivation that have been generated from individual-level variables, these include the English Index of Multiple Deprivation (IMD)^{1,2}, the Carstairs Index⁶ and the Scottish IMD⁴. These measures of deprivation relate to how people live and are typically derived from census variables (e.g. housing facilities, health, employment, income) which are combined to generate a score that indicates the overall level of deprivation individuals experience living in an area.

Three studies^{4,6,5} reported an association between increasing levels of deprivation and increases in mortality outcomes. One UK study⁴ found higher proportions of deaths in the SMI cohort compared to the general Scottish population who lived in the most deprived areas. One Spanish study⁵ reported a higher risk for all-cause mortality risk in participants with SMI living in deprived urban areas compared to those with similar diagnoses who resided in non-deprived urban areas. However, two studies^{1,2} conducted primarily in deprived geographical areas in south-east London found no association between mortality outcomes and area-level deprivation.

(iii) Deprivation and cause-specific mortality

Two UK-based studies^{4,6} reported associations between cause-specific mortality in areas with both lower and higher levels of deprivation. One study⁴ reported lowered proportions of cancer- and alcohol-related deaths among people with SMI living in the most deprived areas compared to both the local Glaswegian and wider Scottish populations without SMI living in similarly deprived areas. The second study⁶ found lowered suicide-related mortality among people with SMI living in the most deprived areas compared to people with SMI living in the least deprived areas. They also reported higher risk of suicide mortality in the most deprived areas among people with SMI compared to the control group living in similarly deprived areas⁶.

(iv) Other area-level factors and all-cause mortality

One UK study¹ investigated the association between mortality and two area-level factors: (1) social fragmentation (a measure of social cohesion within communities) and (2) ethnic density (proportion of the population within a geographic area in racially minoritized groups). The social fragmentation measure was derived from four UK Census variables: (1) numbers of privately rented households, (2) single-person households, (3) unmarried individuals or individuals not in cohabiting relationships and (4) mobility in the previous year.

The study¹ reported elevated levels of mortality outcomes among people with SMI compared to the general population although they found no association between area-level social fragmentation and mortality outcomes among people with SMI living in south-east London. However, the same study¹ found that residency in areas with higher ethnic density was associated with a lowered risk of all-cause and natural-cause mortality among racially minoritized groups with SMI compared to their White counterparts living in the same areas.

Risk of bias

The NOS ratings ranged for the cohort studies ranged between 6 and 8 (see Supplement 3). Despite these relatively high NOS quality ratings many studies did not provide detailed information on the geographical areas included (e.g. population density of each geographical area) or operationalise terms such as “rural” or “urban”. A quarter of the studies used official Census data to define geographical areas. Most analyses adjusted for age and sex and all cohort studies implemented a follow-up period of >1 year bar one study⁴. One study⁶ reported wide confidence intervals for the association between area-level factors and mortality. This may be due to a limited number of mortality events within the samples which may make it more difficult to estimate the true effect of the area-level variable. One study⁷ used verbal autopsy with close family members of the deceased to identify links with the cause of death. However, this method was not supplemented with official mortality records and relied on the relatives’ recall which may be affected by recall bias.

Geographical measures

Around three quarters of included studies did not report or reported incomplete information about the geographical measurements of the areas included in their investigation. Two studies^{1, 2} provided geographical area measurements using the UK census derived Lower and Middle Super Output Areas (LSOA and MSOA).

Individual-level covariates

Most studies^{1-4, 6-8} controlled for participants' age and sex within subsequent statistical analyses and a quarter of the studies^{1,2} included ethnicity variables. No investigation provided comprehensive statistical models adjusting for all significant covariates.

Mortality outcomes

Most studies^{1-5, 7} investigated all-cause mortality outcomes. Most studies¹⁻⁶ derived the mortality variable from official datasets bar one study⁷ which used a verbal autopsy method. Mortality in the SMI cohorts ranged from 0.3 %⁶ to 12.4%⁷.

Discussion

This review is, to our knowledge, the first to provide a synthesis of the current evidence base in relation to area-level factors and mortality in SMI using systematic inclusion criteria across many databases (including a grey literature database). The review revealed limited studies investigating this association which made it difficult to draw firm conclusions. Of the studies identified, most were conducted in the UK, with other studies conducted in Spain and Ethiopia, therefore the findings may be less generalisable to populations outside of these settings.

We identified only 7 studies (8 papers) exploring the association between mortality and area level factors which highlights the dearth of literature on this topic. Our findings suggest research to date is inconclusive on the nature and magnitude, if any, of associations between area-level factors and risk of mortality in people with SMI. For those studies that adjusted for an urbanicity variable in their statistical models, no consistent associations were reported between residence in either rural / urban areas and mortality in SMI. There was no evidence of an association between mortality and other area-level factors which included social fragmentation. However, one study suggested a protective effect of area-level ethnic density and mortality in an ethnically diverse SMI cohort (Das-Munshi et al., 2019). None of the included studies investigated built environment attributes such as green and blue spaces and pollution.

Three studies reported an association between increasing area-level deprivation and an increased risk of mortality in SMI. The two UK-based studies which found an association between deprivation and suicide-related mortality may suggest that areas of high deprivation confer additional risk factors for people with SMI in the form of socio-economic disadvantages (e.g. unemployment, poor housing conditions, limited access to resources) that may exacerbate this risk. This finding is consistent with other investigations conducted using samples from the general population (Office for National Statistics, 2019). Interestingly, additional analyses conducted by Osborn and colleagues (2008) using data from the UK, revealed a lower risk of suicide mortality among people with SMI living in areas of high deprivation compared to those with the same diagnoses living in the least deprived areas. The difficulties in interpreting this finding arise from the lack of individual level information provided by the study. For example, this study did not control for individual-level socio-economic status and therefore it is difficult to determine the extent to which the study findings are linked to contextual or individual level factors. However, these findings may indicate a non-linear association between deprivation and suicide mortality in SMI which may warrant further investigation.

Two studies reported no association between all-cause mortality and deprivation. These findings may reflect underlying contextual factors related to the areas sampled within the investigations. For example, two studies were conducted almost primarily in areas with high levels of deprivation relative to other areas in England (Das-Munshi et al., 2019; Hayes et al., 2012). Therefore, it may have been more difficult to detect differences in mortality by area-level deprivation compared to other studies which found associations between deprivation and mortality outcomes that included a more diverse range of areas with both higher and lower levels of deprivation (Martin et al., 2014; Osborn, Levy, Nazareth, & King, 2008). Given the mixed findings, it is important to bear in mind the variation in measures used to derive the deprivation variables. These measures included the English and Scottish Indexes of Multiple Deprivation

(IMD) and the Carstairs index which measure deprivation using different domains and are weighted differently. Hence, comparison of findings between studies using different measures may increase the difficulty of making comparisons.

One study found a positive association between ethnic density and mortality in SMI in England. The study reported that racially minoritized participants with SMI living in areas with higher proportions of other resident racially minoritized groups had lowered risk of mortality compared to White British participants with similar diagnoses. This finding is similar to those found in previous investigations looking at the link between ethnic density and mental health (Bécares, Dewey, & Das-Munshi, 2018). Racially minoritized groups with SMI may accrue benefits by living in areas with higher ethnic density potentially through social mechanisms (e.g. increased levels of social support and being less likely to be socially isolated) that may be associated with a reduced risk of mortality (Das-Munshi et al., 2019). However, this finding has not been replicated and therefore it would be beneficial to investigate this in more depth.

Although these studies lay the groundwork for more detailed follow-up investigations, there are several limitations which should be taken into consideration. Firstly, the lack of consistency in findings may reflect differences in study methodologies including the definition and measurement of environmental exposure variables (e.g. “urban” and “rural” areas). The varied geographical boundaries / units used within the studies prevents comparative analysis between studies and the geographical area units chosen may have had an impact on summary values (e.g. population density, mortality rates) which vary according to the shape and scale of the geographical unit (Arcaya et al., 2016). This is known as the Modifiable Areal Unit Problem (MAUP). Although the use of census-defined geographical areas is a favourable method for reducing the risk of MAUP, a potential difficulty is that these areas may not accurately represent the participants’ experiences of their neighbourhoods. Participants’ views of their neighbourhood (including the boundaries) may differ from the official measures and therefore crucial information about their travel and access to neighbourhood features that may be associated with their health may be missed due to using only census-defined geographical boundaries.

Secondly, few studies accounted for the clustered nature of the data using appropriate approaches such as multilevel modelling (MLM) methods. In traditional regression analyses, it is assumed that all observational data are independent of each other. Many of the studies did not account for clustering of individuals within neighbourhoods using appropriate frameworks such as multilevel modelling or other approaches. MLM has an advantage over traditional regression models in that the total variance can be partitioned between variances observed both between neighbourhoods and within neighbourhoods which can lead to more accurate estimation of these effects and may enable better understanding of the geographical contexts which affect health outcomes (Merlo, Chaix, Yang, Lynch, & Råstam, 2005). Hence, future research could benefit from inclusion of these statistical methods within studies investigating these associations.

Some studies tended to include area-level deprivation variables as the only area-level exposure variable - these deprivation measures are a composite measure of aggregated properties of individuals (e.g. unemployment, income, education, and training) from censuses and other population surveys which means that area-level factors that appear to be relevant may be an artefact of area indices acting as a proxy for individual-level factors not included in the statistical analyses (e.g. individual-level socioeconomic status vs area-level deprivation). Moreover, given the

aggregated properties (i.e. individual-level factors) of these measures, this may not be the best indicator of the quantity and quality of other physical/built features within neighbourhoods (e.g. green spaces, access to transport) that may influence mortality in SMI.

Another limitation is that over two thirds of included studies investigated all-cause mortality as the only mortality outcome. Recent reviews of research conducted with the general population have found weak to moderate associations between various area-level factors and cause-specific mortality outcomes (Gascon et al., 2016; Hoek et al., 2013) which enables researchers to develop more targeted hypotheses about the mechanisms underlying these associations. Therefore, future research conducted with SMI cohorts could benefit from inclusion of similar investigations into associations between cause-specific mortality outcomes and area-level factors.

The majority of included studies were conducted in high income settings and did not support an association between residing in increasingly urbanised locations and higher mortality risks in people with SMI. One Ethiopian study provided evidence of an association between residence in urban areas and a higher risk of all-cause mortality within an SMI cohort (Teferra et al., 2011). Future investigations could benefit from further exploration of the role of area-level factors in mortality among people with SMI, which may also differ according to whether the setting is a high- or low or middle income country.

Strengths and limitations of the review

To our knowledge, this is the first review to investigate the relationship between area-level factors and the risk of mortality in SMI. While previous reviews have primarily focused on examining geographic disparities in mortality among individuals with SMI (Patel et al., 2006) and the widening mortality gap (Hjorthøj et al., 2017; Hayes et al., 2017), the specific aim of this review was to explore the impact of environmental factors at the area level on mortality risk in this population. The findings of this narrative review highlight a significant research gap in this particular area, which future studies should address. Due to the small number of studies identified and heterogeneity of the included studies, which include differing approaches to the measurement of area-level exposures and adjustment of confounders, conducting a meta-analysis was not feasible. Furthermore, the review did not provide a comparison of the risk of mortality between affective and non-affective disorders since the included studies did not report separate statistical analyses for these subgroups. We adhered to the criteria outlined in the risk of bias measure (Newcastle-Ottawa Scale), which stipulated that cohort studies should have a minimum follow-up period of 1 year for a 'high' quality rating. We recognize that the latency period for mortality outcomes could extend beyond this specified criterion. However, all studies in this review had a follow up period exceeding one year (ranging from 3-15 years) and most studies (with the exception of one study) utilised methods (e.g. deriving rate of death over time) which are insensitive to the period of follow up, and assume rate is constant over time, or take into account non-proportional hazards over time. A further strength is that we developed search terms in this review from existing literature, with expert input from a librarian. The search terms were kept broad to enable identification of potentially suitable studies.

Conclusion

In conclusion, across all studies the association between deprivation and mortality in SMI was most consistently demonstrated and is also consistent with research conducted within the general population. One study suggested a link between urbanicity and mortality in SMI in a low to middle income setting - other studies conducted in high income countries have not found similar associations with urbanicity variables. Another study suggested a protective effect of area-level ethnic density on mortality in SMI within high income settings which covered an urbanised area with ethnically diverse populations. Lastly, none of the included studies included built/physical environment variables (e.g. green spaces, pollution) and therefore the association between these factors and mortality could not be ascertained in this review. The extent to which the included studies offer hypotheses regarding potential factors and mechanisms driving previously reported geographical variations in the risk of mortality in SMI (Hjorthøj et al., 2017) are limited due to methodological limitations.

Currently, a large proportion of interventions tend to focus on individual-level factors as informed by the existing evidence base that have linked these factors to premature mortality in SMI. However, despite the implementation of these interventions there remains a significant gap in life expectancy between the general population and the SMI population (Hjorthøj et al., 2017) which indicates that solely targeting individual-level factors may not be the most effective way to reduce excess mortality in this population. In future, research in this area would benefit from more targeted analyses of area-level factors (particularly physical environment factors) and cause-specific mortality outcomes. The findings could inform interventions with SMI in terms of multilevel frameworks that take into account both individual- and area-level factors. Also, future investigations could benefit from investigating these associations in LAMICs to enable future comparative analyses between different countries and contexts. Premature mortality remains a pervasive health inequality in SMI and given more recent reports of an increasing gap in life expectancy, it is of the utmost importance to address this inequality in order to improve the quality of life for this population.

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References

- Alter, D. A., & Eny, K. (2005). The relationship between the supply of fast-food chains and cardiovascular outcomes. *Can J Public Health*, 96(3), 173-177. doi:10.1007/bf03403684
- Arcaya, M. C., Tucker-Seeley, R. D., Kim, R., Schnake-Mahl, A., So, M., & Subramanian, S. V. (2016). Research on neighborhood effects on health in the United States: A systematic review of study characteristics. *Soc Sci Med*, 168, 16-29. doi:10.1016/j.socscimed.2016.08.047
- Bécares, L., Dewey, M. E., & Das-Munshi, J. (2018). Ethnic density effects for adult mental health: systematic review and meta-analysis of international studies. *Psychological medicine*, 48(12), 2054-2072. doi:10.1017/s0033291717003580
- Bécares, L., Shaw, R., Nazroo, J., Stafford, M., Albor, C., Atkin, K., Kiernan, K., Wilkinson, R., & Pickett, K. (2012). Ethnic density effects on physical morbidity, mortality, and health behaviors: a systematic review of the literature. *American journal of public health*, 102(12), e33-e66.
- Carnegie, E. R., Inglis, G., Taylor, A., Bak-Klimek, A., & Okoye, O. (2022). Is Population Density Associated with Non-Communicable Disease in Western Developed Countries? A Systematic Review. *International Journal of Environmental Research and Public Health*, 19(5), 2638.
- Collings, S., Ivory, V., Blakely, T., & Atkinson, J. (2009). Are neighbourhood social fragmentation and suicide associated in New Zealand? A national multilevel cohort study. *J Epidemiol Community Health*, 63(12), 1035-1042. doi:10.1136/jech.2009.090985
- Cumpston M., & Chandler J. (2022). Chapter IV: Updating a review. In: Higgins JPT, Thomas J, Chandler J, Cumpston M, Li T, Page MJ, Welch VA (editors). *Cochrane Handbook for Systematic Reviews of Interventions* version 6.3 (updated February 2022). Cochrane, 2022. Available from: www.training.cochrane.org/handbook.
- Das-Munshi, J., Chang, C.-K., Dutta, R., Morgan, C., Nazroo, J., Stewart, R., & Prince, M. (2017). Ethnicity and excess mortality in severe mental illness: A cohort study. *The Lancet Psychiatry*, 4. doi:10.1016/S2215-0366(17)30097-4
- Das-Munshi, J., Schofield, P., Bhavsar, V., Chang, C.-K., Dewey, M. E., Morgan, C., Stewart, R., Thornicroft, G., & Prince, M. J. (2019). Ethnic density and other neighbourhood associations for mortality in severe mental illness: a retrospective cohort study with multi-level analysis from an urbanised and ethnically diverse location in the UK. *The Lancet Psychiatry*, 6(6), 506-517.
- Diez Roux, A. V. (2016). Neighborhoods and Health: What Do We Know? What Should We Do? *Am J Public Health*, 106(3), 430-431. doi:10.2105/ajph.2016.303064
- Faris, R., & Dunham, W. (1939). *Mental Disorders in Urban Areas: An Ecological Study of Schizophrenia and Other Psychoses*. Chicago: University of Chicago Press.
- Faustini, A., Rapp, R., & Forastiere, F. (2014). Nitrogen dioxide and mortality: review and meta-analysis of long-term studies. *European Respiratory Journal*, 44(3), 744-753. doi:10.1183/09031936.00114713
- Gascon, M., Triguero-Mas, M., Martínez, D., Dadvand, P., Rojas-Rueda, D., Plasència, A., & Nieuwenhuijsen, M. J. (2016). Residential green spaces and mortality: A systematic review. *Environ Int*, 86, 60-67. doi:10.1016/j.envint.2015.10.013
- Halpern, D. (1993). Minorities and mental health. *Social science & medicine*, 36(5), 597-607.
- Hayes, J. F., Marston, L., Walters, K., King, M. B., & Osborn, D. P. J. (2017). Mortality gap for people with bipolar disorder and schizophrenia: UK-based cohort study 2000-2014. *Br J Psychiatry*, 211(3), 175-181. doi:10.1192/bjp.bp.117.202606
- Hayes, R. D., Chang, C. K., Fernandes, A. C., Begum, A., To, D., Broadbent, M., Hotopf, M., & Stewart, R. (2012). Functional status and all-cause mortality in serious mental illness. *PLoS One*, 7(9), e44613. doi:10.1371/journal.pone.0044613
- Hernandez, L. M., & Blazer, D. G. (2006). *Genes, Behavior, and the Social Environment: Moving Beyond the Nature/Nurture Debate*.

- Hjorthøj, C., Stürup, A. E., McGrath, J. J., & Nordentoft, M. (2017). Years of potential life lost and life expectancy in schizophrenia: a systematic review and meta-analysis. *Lancet Psychiatry*, 4(4), 295-301. doi:10.1016/s2215-0366(17)30078-0
- Hoek, G., Krishnan, R. M., Beelen, R., Peters, A., Ostro, B., Brunekreef, B., & Kaufman, J. D. (2013). Long-term air pollution exposure and cardio-respiratory mortality: a review. *Environmental health*, 12(1), 1-16.
- Hopper, K., & Wanderling, J. (2000). Revisiting the Developed Versus Developing Country Distinction in Course and Outcome in Schizophrenia: Results From ISO, the WHO Collaborative Followup Project. *Schizophrenia Bulletin*, 26(4), 835-846. doi:10.1093/oxfordjournals.schbul.a033498
- Institute of Medicine (US). (2002). The future of the Public's Health in the 21st Century. Retrieved from <https://www.ncbi.nlm.nih.gov/books/NBK221239/>
- Jablensky, A., & Sartorius, N. (2008). What did the WHO studies really find? *Schizophrenia Bulletin*, 34(2), 253-255. doi:10.1093/schbul/sbm151
- Lomholt, L. H., Andersen, D. V., Sejrsgaard-Jacobsen, C., Øzdemir, C. M., Graff, C., Schjerning, O., Jensen, S. E., Straszek, S. P. V., Licht, R. W., Grøntved, S., & Nielsen, R. E. (2019). Mortality rate trends in patients diagnosed with schizophrenia or bipolar disorder: a nationwide study with 20 years of follow-up. *Int J Bipolar Disord*, 7(1), 6. doi:10.1186/s40345-018-0140-x
- Luo, Y., Pang, L., Guo, C., Zhang, L., & Zheng, X. (2021). Association of Urbanicity with Schizophrenia and Related Mortality in China: Association de l'urbanité avec la schizophrénie et la mortalité qui y est reliée en Chine. *Can J Psychiatry*, 66(4), 385-394. doi:10.1177/0706743720954059
- Martin, J. L., McLean, G., Park, J., Martin, D. J., Connolly, M., Mercer, S. W., & Smith, D. J. (2014). Impact of socioeconomic deprivation on rate and cause of death in severe mental illness. *BMC psychiatry*, 14, 261. doi:10.1186/s12888-014-0261-4
- Merlo, J., Chaix, B., Yang, M., Lynch, J., & Råstam, L. (2005). A brief conceptual tutorial of multilevel analysis in social epidemiology: linking the statistical concept of clustering to the idea of contextual phenomenon. *Journal of Epidemiology & Community Health*, 59(6), 443-449.
- Mok, P. L., Leyland, A. H., Kapur, N., Windfuhr, K., Appleby, L., Platt, S., & Webb, R. T. (2013). Why does Scotland have a higher suicide rate than England? An area-level investigation of health and social factors. *J Epidemiol Community Health*, 67(1), 63-70. doi:10.1136/jech-2011-200855
- Moreno-Küstner, B., Guzman-Parra, J., Pardo, Y., Sanchidrián, Y., Díaz-Ruiz, S., & Mayoral-Cleries, F. (2021). Excess mortality in patients with schizophrenia spectrum disorders in Malaga (Spain): A cohort study. *Epidemiol Psychiatr Sci*, 30, e11. doi:10.1017/s2045796020001146
- Office For National Statistics (2019). Socioeconomic inequalities in avoidable mortality, England and Wales: 2001 to 2017. <https://www.ons.gov.uk/peoplepopulationandcommunity/healthandsocialcare/causesofdeath/articles/measuringsocioeconomicinequalitiesinavoidablemortalityinenglandandwales/2001to2016>.
- Osborn, D., Levy, G., Nazareth, I., & King, M. (2008). Suicide and severe mental illnesses. Cohort study within the UK general practice research database. *Schizophr Res*, 99(1-3), 134-138. doi:10.1016/j.schres.2007.11.025
- Patel, V., Cohen, A., Thara, R., & Gureje, O. (2006). Is the outcome of schizophrenia really better in developing countries? *Brazilian Journal of Psychiatry*, 28(2), 149-152.
- Roof, K., & Oleru, N. (2008). Public health: Seattle and King County's push for the built environment. *Journal of environmental health*, 71(1), 24-27.
- Saha, S., Chant, D., & McGrath, J. (2007). A systematic review of mortality in schizophrenia: is the differential mortality gap worsening over time? *Arch Gen Psychiatry*, 64(10), 1123-1131. doi:10.1001/archpsyc.64.10.1123
- Travert, A.-S., Sidney Annerstedt, K., & Daivadanam, M. (2019). Built environment and health behaviors: deconstructing the black box of interactions—a review of reviews. *International Journal of Environmental Research and Public Health*, 16(8), 1454.

- Teferra, S., Shibre, T., Fekadu, A., Medhin, G., Wakwoya, A., Alem, A., Kullgren, G., & Jacobsson, L. (2011). Five-year mortality in a cohort of people with schizophrenia in Ethiopia. *BMC psychiatry*, 11(1), 165. doi:10.1186/1471-244X-11-165
- Wells, G., Shea, B., O'Connell, D., Peterson, J., Welch, V., Losos, M., & Tugwell, P. (2012). *The Newcastle-Ottawa Scale (NOS) for assessing the quality of nonrandomised studies in meta-analyses*. Ottawa: Ottawa Hospital Research Institute.

Figure 1 PRISMA flow diagram

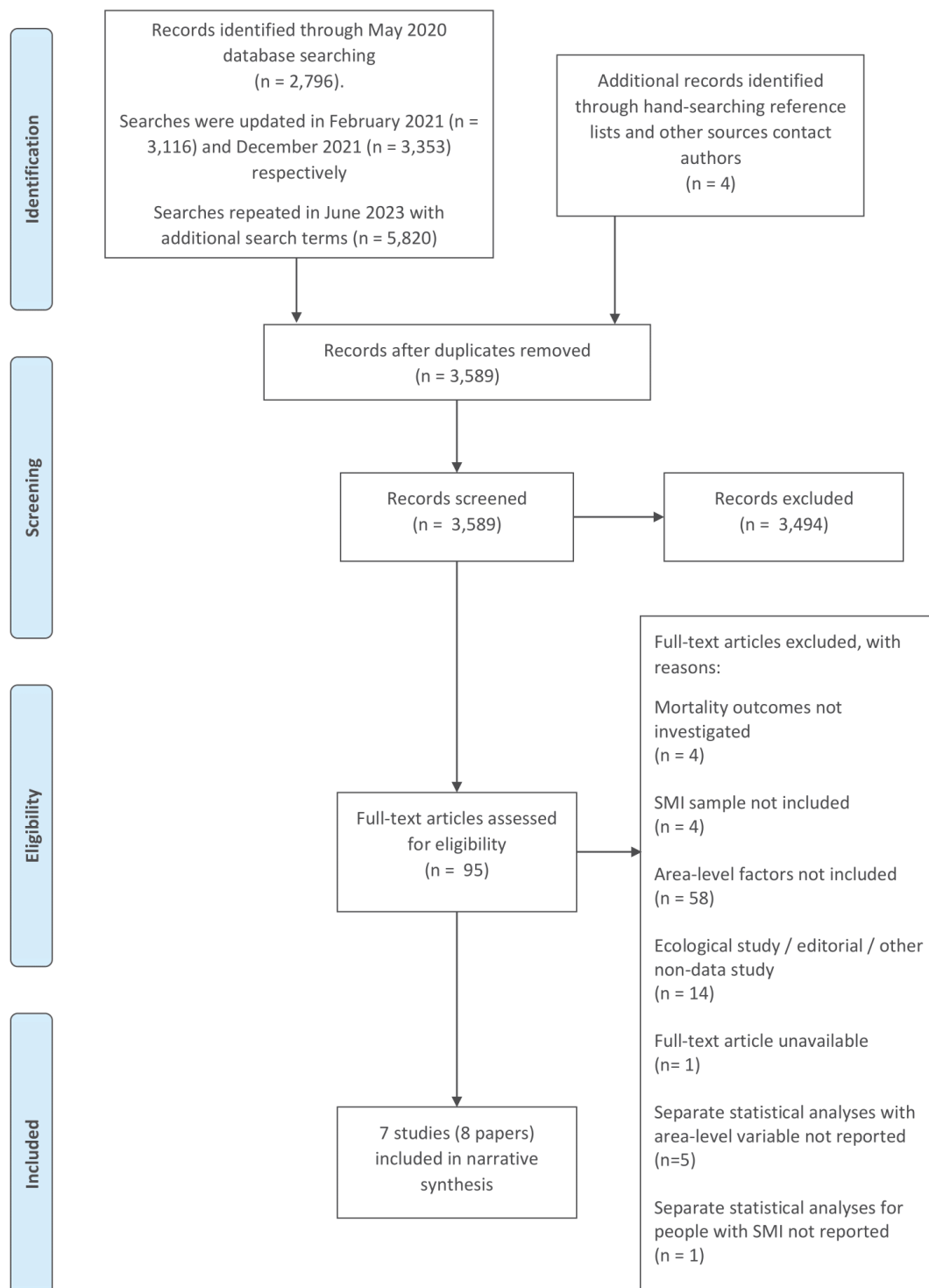


Table 1. Demographic overview of included studies

Study characteristics	No. of studies (n = 7)	%
Country		
UK	4	57.1
China	1	14.3
Ethiopia	1	14.3
Spain	1	14.3
Population		
Clinical	2	28.6
Population-based	5	71.4
Sample age		
≥15	4	57.1
≥18	3	42.9
SMI		
Bipolar disorder and schizophreniform disorders	5	71.4
Schizophreniform disorders only	2	28.6
Area-level exposures		
Area-level deprivation	4	57.1
Rural / urbanised areas	3	42.9
Population density (urbanicity)	1	14.3
Ethnic density	1	14.3
Social fragmentation	1	14.3
Geographical area measure		
Not specified	5	71.4
Census derived LSOA and MSOA (average 1,500 and 7,200 residents per area respectively)	2	28.6
Mortality outcome		
All-cause mortality	5	71.4
Unnatural mortality, including suicide	2	28.6
Natural mortality	1	14.3
Follow-up period		
3 years	1	14.3
4 years	1	14.3
5 years	1	14.3
7 years	1	14.3
>10 years	2	28.6
Individual-level covariates		
Age	6	85.7
Sex	5	71.4
Marital status	4	57.4
Psychiatric diagnosis	2	28.6
Ethnicity	2	28.6
Education/ employment status	3	42.9
Substance / alcohol misuse	2	28.6
Calendar period	1	14.3
Physical health comorbidity	1	14.3
Smoking status	1	14.3
Other	5	71.4

Abbreviations: MSOA = Middle Super Output Area, LSOA = Lower Super Output Area, SMI = Severe Mental Illness

Table 2. Longitudinal studies included in the review

No.	Author(s), Year, Country	Sample, Follow up period	Area-level exposure/s	Mortality outcome	Statistical analysis	Individual-level covariates	Findings
1	Das-Munshi et al., 2019 and Das-Munshi et al., 2017 England	Sample age: ≥ 15 Clinical population N = 18,201 (diagnosed with schizophrenia-spectrum disorders or bipolar disorders) FU: 7 years	2019 study: <i>Deprivation</i> Assessed using IMD	All-cause	2019 study: SWR Poisson regression 2017 study: Cox regression	Age, sex, ethnicity, diagnosis (ICD-10), marital status, substance use disorders	2019 study: Lowered all-cause mortality rate ratios for racially minoritized participants with SMI living in areas of higher ethnic density compared to their White British counterparts after adjusting for other covariates (aRR = 0.52, 95% CI 0.38 - 0.71, $p < .0001$). No associations reported for other area-level exposures. 2017 study No association reported between area-level deprivation and mortality in this cohort (aHR = 0.98, 95% CI = 0.85 - 1.14, $p = .080$).
			<i>Social fragmentation</i> Assessed using Congdon Index <i>Urbanicity</i> Assessed using persons per hectare of land <i>Ethnic density</i> Percentage of the total population accounted for by each racialised minority group resident in the area at the time of the 2011 Census 2017 study: <i>Deprivation</i> Assessed using IMD				
2	Hayes et al., 2012 England	Sample age: 15 - 94 Clinical population N = 6,880 (diagnosed with schizophreniform disorders or bipolar disorder) FU: 4 years	<i>Deprivation</i> Assessed using IMD	All-cause	Cox regression	Age, sex, ethnicity, diagnosis (ICD-10), marital status, no. of face-to-face mental health contacts Problem drinking / drug taking, problematic social relationships, employment, non-accidental self-injury, physical illness or disability, depressed mood, daily life functioning, sub-optimal living conditions assessed by HoNOS	No significant associations were observed in the hazard ratios between the deprivation tertiles and mortality in the SMI cohort.

3	Luo et al., 2021 China	Sample age: ≥18 Population-based cohort N = 2,071 (diagnosed with schizophrenia) N = 1,909,205 (controls) FU: 3 years	<i>Urbanicity</i> Assessed using the ratio of non-agricultural population to total population (%)	All-cause	Cox regression	Age, sex, marital status, residence, household size, education, household income per capita, employment status	No significant association indicated between increasing urbanicity and all-cause mortality (aHR, 0.63, 95% CI 0.25–1.58; p > 0.05)
4	Martin et al., 2014 Scotland	Sample age: 18 - 65 Population-based cohort N = 230 (deaths among those diagnosed with	<i>Deprivation</i> Assessed using SIMD	All-cause Natural-cause Unnatural-cause	Descriptive statistics Chi square	N/A	Elevated all-cause mortality reported among people with SMI living in the most deprived quintiles relative to the general Scottish population (46.1% vs 31.9%, p < .001). Conversely, lower proportion of deaths were observed in the SMI cohort compared to the local Glaswegian population living in the most deprived areas (46.1% vs 66.3%, p < .001).

		bipolar disorder or schizophrenia) N = 8,094 (deaths in local Glaswegian population) N = 24,590 (deaths in wider Scottish population) FU: 5 years						Elevated drug-related deaths observed in the SMI cohort living in the most deprived areas compared to the local Glaswegian (12.3% vs. 5.9%, $p < 0.001$) and wider Scottish population (12.3% vs. 5.1%, $p < 0.001$). Differences observed in suicide-related deaths between the SMI cohort and (1) the local Glaswegian population (12.3% vs 6.9%, $p = .054$) and (2) the wider Scottish population (12.33% vs 6.9%, $p = .05$) living in the most deprived quintiles were significant. Lower cancer- and alcohol-related deaths observed in the SMI cohort compared to the local Glaswegian (12.3% vs. 25.1%, $p = .013$) and the wider Scottish population (12.3% vs. 26.3%, $p = .008$) living in the most deprived quintiles. Reported higher risk for all-cause mortality risk in participants with SMI living in deprived urban areas compared to those with similar diagnoses residing in non-deprived urban areas (aHR, 1.46, 95% CI 1.04–2.05; $p = 0.028$). No association for risk of all-cause mortality between participants with SMI living in rural areas and compared to those with similar diagnoses who lived in non-deprived urban areas (aHR, 0.74, 95% CI 0.45–1.24; $p = 0.055$). Elevated risk of suicide mortality observed in cohort diagnosed with SMI who lived in the most deprived areas compared to the control group living in similarly deprived areas (adjusted HR 5.30, 95% CI 2.77 - 10.15). Elevated risk of suicide mortality for the SMI cohort living in the least deprived quintiles compared to the control group living in
5	Moreno-Küstner et al., (2020) Spain	Sample age: ≥ 15 Population-based cohort N = 1,418 (diagnosed with schizophrenia-spectrum disorders or non-organic psychoses) FU: 13 years	Area of residence: • Non-deprived urban • Deprived urban • Rural No measure specified	All-cause	SMR YLL Cox regression	Age, sex, civil (marital) status, education, type of living arrangement, employment, psychiatric diagnosis (ICD-10)		
6	Osborn et al., 2008 England	Sample age: ≥ 18 Population-based cohort N = 46,136 (diagnosed with bipolar disorder, schizophrenia or	Deprivation Assessed with Carstairs Index	Suicide	Cox regression PAR	Age, calendar period, antidepressant prescription in last 6 months and smoking		

		delusional disorder) N = 300,426 (control) FU: 15 years						similarly deprived quintiles (aHR 10.52, 95% CI 4.25 - 26.05). Lowered risk of suicide mortality for people with SMI living in the most deprived quintile compared to people with similar SMI diagnoses living in the least deprived quintiles (aHR 0.54, 95% CI 0.30 - 0.99) Reported lowered risk for all-cause mortality in participants living in rural areas compared to those who resided in urban areas (aHR, 0.34, 95% CI 0.14 - 0.80; p = 0.014).
7	Teferri et al., 2011 Ethiopia	Sample age: ≥15 Population-based cohort N = 307 (diagnosed with schizophrenia) FU: 5 years	Rural and urban areas No measure specified	All-cause	Cox regression Years of life lost	Age, sex, marital status, education, age of illness onset, duration of illness, speed of onset of mental illness, schizophrenia diagnosis (ICD-10, CIDI and SCAN), medication		

Abbreviations:

aHR = Adjusted Hazard Ratio, aRR = Adjusted rate ratio, aHR = Adjusted hazard ratio, CHD = Coronary Heart Disease, CVD = Cardiovascular mortality, CIDI = Composite International Diagnostic Interview, FU = Follow up period, HoNOS = Health of the Nation Outcome Scales, HR = Hazard ratio, ICD = International Classification of Diseases, IMD = Index of Multiple Deprivation, PAR = Population Attributable Risk, SCAN = Schedules for Clinical Assessment in Neuropsychiatry, SIMD = Scottish Index of Multiple Deprivation, SMI = Severe mental illness, SMR = Standardised mortality ratio, YLL = potential years of life lost

Table 3. Direction of association between area-level exposures and all-cause and cause-specific mortality outcomes

All-cause mortality outcomes		Area-level exposure			
Author(s), Year		Increasing deprivation	Increasing ethnic density	Increasing urbanicity (ranging from more rural to more urban areas)	Increasing social fragmentation
Moreno-Küstner et al., 2020		X	-	X	-
Martin et al., 2014	X ¹	X ²	-	-	-
Das-Munshi et al., 2019; 2017	X	X	X	X	X
Teferra et al., 2011	-	-	-	X	-
Hayes et al., 2012	X	X	-	-	-
Luo et al 2021				X	
Cause-specific mortality outcomes					
Mortality outcome		Area-level exposure			
		Increasing deprivation			
Osborn et al., 2008	Suicide	X ³	X ⁴		
Martin et al., 2014	Suicide	X			
	Drug-related	X			
	Cancer	X			
	Alcohol-related	X			

Key:

- No association between area-level exposure and mortality outcome
- Association between area-level exposure and an **increase** in mortality outcome
- Association between area-level exposure and a **decrease** in mortality outcome

¹ Compared to the general Scottish population living in similarly deprived areas
² Compared to the local Glaswegian population living in similarly deprived areas
³ Compared to the control group without SMI diagnoses living in similarly deprived areas
⁴ Compared to group with SMI living in the least deprived areas

Acknowledgements

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Appendix 2. Study 1 Search terms

EMBASE

1. exp catatonic schizophrenia/ or exp schizophrenia spectrum disorder/ or exp latent schizophrenia/ or exp paranoid schizophrenia/ or exp schizophrenia/
2. exp bipolar disorder/
3. exp affective psychosis/ or exp acute psychosis/ or exp puerperal psychosis/ or exp manic psychosis/ or exp schizoaffective psychosis/ or exp paranoid psychosis/ or exp psychosis/
4. (severe mental disorde* or severe mental illne* or serious mental illnes* or serious mental disorde* or psychotic disorde* or psychoses or psychosis or schizophrenia or schizophrenia spectrum disorde* or bipolar disorde* or schizophreniform disorde* or schizoaffective disorde* or schiz * or psychotic disorde*).mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word]
5. 1 or 2 or 3 or 4
6. exp mortality risk/ or exp all cause mortality/ or exp mortality/ or exp mortality rate/ or exp standardized mortality ratio/ or exp premature mortality/ or exp suicide/
7. excess mortality or death or life expectancy .mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word]
8. 6 or 7
9. (area-level deprivation or urbanicity or ethnic density or built environment or natural environment or multi-level analys* or community or green spaces or blue spaces or pollution or social fragmentation or social environment or social cohesion or social networ * or social capital or population density or food environment or population density or fast food outlet or fast-food outlet or takeaway outlet or food swamp or food desert).mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word]
10. 5 and 8 and 9

NB: exp [search term]/ denotes exploding a subject heading; mp searching for references where the words appear in several specific fields, including the title, abstract, subject heading, author keywords, and more; * denotes truncation. Words in [blue](#) are the search terms that were added to the search conducted in June 2023.

Medline

1. exp Catatonic Schizophrenia/ or exp Undifferentiated Schizophrenia/ or exp "Schizophrenia (Disorganized Type)"/ or exp Acute Schizophrenia/ or exp Schizophrenia/ or exp Process Schizophrenia/ or exp Paranoid Schizophrenia/
2. exp Psychosis/ or exp Affective Psychosis/ or exp Acute Psychosis/ or exp Chronic Psychosis/ or exp Postpartum Psychosis/ or exp Reactive Psychosis/
3. exp Schizophrenia, Paranoid/ or exp Schizophrenia, Disorganized/ or exp Schizophrenia/ or exp Schizophrenia, Catatonic/
4. exp Psychotic Disorders/
5. exp Bipolar Disorder/
6. (severe mental disorde* or severe mental illne* or serious mental illnes* or serious mental disorde* or psychotic disorde* or psychoses or psychosis or schizophrenia or schizophrenia spectrum disorde* or bipolar disorde* or schizophreniform disorde* or schizoaffective disorde* or schiz* or psychotic disorde*).mp. [mp=title, book title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms, population supplementary concept word, anatomy supplementary concept word]
7. exp "Death and Dying"/ or exp Mortality Rate/
8. exp Suicide/
9. (premature mortality or life expectancy or excess mortality or all-cause mortality or cause-specific mortality or early death or death or cardiovascular mortality or cancer mortality or respiratory mortality).mp. [mp=title, book title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms, population supplementary concept word, anatomy supplementary concept word]
10. (area-level deprivation or urbanicity or ethnic density or built environment or natural environment or multi-level analys* or community or green spaces or blue spaces or pollution or social fragmentation or social environment or social cohesion or social networ* or social capital or population density or food environment or population density or fast food outlet or fast-food outlet or takeaway outlet or food swamp or food desert). mp. [mp=title, book title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms, population supplementary concept word, anatomy supplementary concept word]
11. 1 or 2 or 3 or 4 or 5 or 6
12. 7 or 8 or 9
13. 10 and 11 and 12

NB: exp [search term]/ denotes exploding a subject heading; mp searching for references where the words appear in several specific fields, including the title, abstract, subject heading, author keywords, and more; * denotes truncation. Words in **blue** are the search terms that were added to the search conducted in June 2023.

1. exp Catatonic Schizophrenia/ or exp Undifferentiated Schizophrenia/ or exp "Schizophrenia (Disorganized Type)"/ or exp Acute Schizophrenia/ or exp Schizophrenia/ or exp Process Schizophrenia/ or exp Paranoid Schizophrenia/
2. exp Psychosis/ or exp Affective Psychosis/ or exp Acute Psychosis/ or exp Chronic Psychosis/ or exp Postpartum Psychosis/ or exp Reactive Psychosis/
3. exp Bipolar Disorder/
4. (severe mental disorde* or severe mental illne* or serious mental illnes* or serious mental disorde* or psychotic disorde* or psychoses or psychosis or schizophrenia or schizophrenia spectrum disorde* or bipolar disorde* or schizophreniform disorde* or schizoaffective disorde* or schiz* or psychotic disorde*).mp. [mp=title, abstract, heading word, table of contents, key concepts, original title, tests & measures, mesh]
5. exp "Death and Dying"/ or exp Mortality Rate/
6. exp Suicide/
7. (premature mortality or life expectancy or excess mortality or all-cause mortality or cause-specific mortality or early death or cardiovascular mortality or cancer mortality or respiratory mortality or death).mp. [mp=title, abstract, heading word, table of contents, key concepts, original title, tests & measures, mesh]
8. (area-level deprivation or urbanicity or ethnic density or built environment or natural environment or multi-level analys* or community or green spaces or blue spaces or pollution or social fragmentation or social environment or social cohesion or social networ* or social capital or population density or food environment or population density or fast food outlet or fast-food outlet or takeaway outlet or food swamp or food desert).mp. [mp=title, abstract, heading word, table of contents, key concepts, original title, tests & measures, mesh word]
9. 1 or 2 or 3 or 4
10. 5 or 6 or 7
11. 8 and 9 and 10

NB: exp [search term]/ denotes exploding a subject heading; mp searching for references where the words appear in several specific fields, including the title, abstract, subject heading, author keywords, and more; * denotes truncation. Words in [blue](#) are the search terms that were added to the search conducted in June 2023.

Social Policy and Practice

1. (severe mental disorde* or severe mental illne* or serious mental illnes* or serious mental disorde* or psychotic disorde* or psychoses or psychosis or schizophrenia or schizophrenia spectrum disorde* or bipolar disorde* or schizophreniform disorde* or schizoaffective disorde* or schiz* or psychotic disorde*).mp. [mp=abstract, title, publication type, heading word, accession number]
2. (mortality or premature mortality or excess mortality or mortality rate or mortality risk or all cause mortality or cause specific mortality or life expectancy or sudden death or early death or suicid* risk or standardized mortality ratio or cardiovascular mortality or respiratory mortality or cancer mortality or death).mp. [mp=abstract, title, publication type, heading word, accession number]
3. (area-level deprivation or urbanicity or ethnic density or built environment or natural environment or multi-level analys* or community or green spaces or blue spaces or pollution or social fragmentation or social environment or social cohesion or social networ* or social capital or population density or food environment or population density or fast food outlet or fast-food outlet or takeaway outlet or food swamp or food desert).mp. [mp=abstract, title, publication type, heading word, accession number]
4. 1 and 2 and 3

NB: mp searching for references where the words appear in several specific fields, including the title, abstract, subject heading, author keywords, and more; * denotes truncation. Words in [blue](#) are the search terms that were added to the search conducted in June 2023.

Web of Science Core Collection

# 4	#3 AND #2 AND #1 Indexes=SCI-EXPANDED Timespan=All years
# 3	TS=(area-level deprivation or urbanicity or ethnic density or built environment or natural environment or multi-level analys* or community or green spaces or blue spaces or pollution or social fragmentation or social environment or social cohesion or social network* or social capital or population density or food environment or population density or fast food outlet or fast-food outlet or takeaway outlet or food swamp or food desert) Indexes=SCI-EXPANDED Timespan=All years
# 2	TS (severe mental disorde* or severe mental illne* or serious mental illnes* or serious mental disorde* or psychotic disorde* or psychoses or psychosis or schizophrenia or schizophrenia spectrum disorde* or bipolar disorde* or schizophreniform disorde* or schizoaffective disorde* or schiz* or psychotic disorde*) Indexes=SCI-EXPANDED Timespan=All years
# 1	TS=(mortality or premature mortality or mortality rate or mortality risk or all cause mortality or cause specific mortality or life expectancy or sudden death or early death or suicide or cardiovascular mortality or cancer mortality or respiratory mortality or death) Indexes=SCI-EXPANDED Timespan=All years

NB: TS [search term]/ denotes topic search which is performed within the Title, Abstract and Keywords and Keyword Plus fields; * denotes truncation. Words in [blue](#) are the search terms that were added to the search conducted in June 2023.

OpenGrey

1. severe mental illnes* AND death AND environment
2. severe mental illnes* AND mortality AND environment
3. severe mental disorde* AND death AND environment
4. severe mental disorde* AND mortality AND environment
5. psychos* AND death AND environment
6. psychos* AND mortality AND environment
7. schizophren* AND mortality AND environment
8. schizophren* AND death AND environment
9. mood disorde* AND mortality AND environment
10. mood disorde* AND death AND environment
11. bipolar disorder* AND mortality AND environment
12. bipolar disorder* AND death AND environment

NB: search terms were kept broad due to the limited number of hits within this database with specific search terms used in previous databases.

Appendix 3. Study 1 - PRISMA guidelines for systematic review



PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	Title page
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	1
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	2-3
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	3
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	1, 4
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	4
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	4
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	Supplement
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	4
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	4-5
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and	4-5

Section/topic	#	Checklist item	Reported on page #
		simplifications made.	
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	5
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	N/A
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	4-5
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	N/A
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	N/A
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	6 Figure 1
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	Table 1 References
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	Supplement
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	6-8 Table 2
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	N/A
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	N/A
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	N/A
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	9-10
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	11
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	11-12

Section/topic	#	Checklist item	Reported on page #
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	Title page

NB: From Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097

For more information, visit: www.prisma-statement.or

Appendix 4. Methods - Worked example (Ministry of Housing Communities & Local Government, 2015)

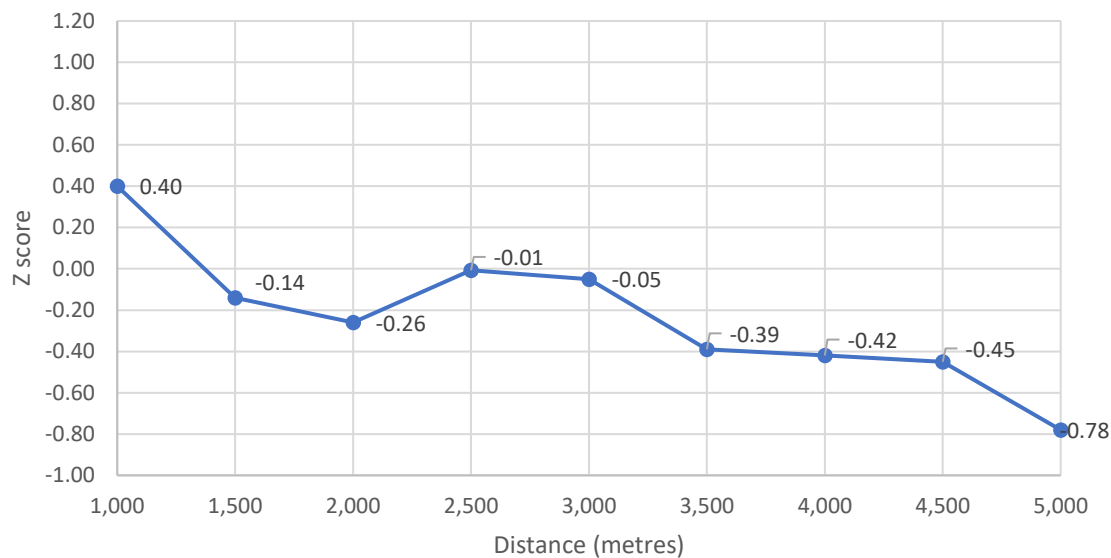
To calculate the average IMD score for MSOA X in a Local Authority District. It has been identified that MSOA X has five LSOAs. These five LSOAs have populations of 1,200, 1,800, 1,400, 1,500 and 1,700, giving a total population of 7,600, and have Index of Multiple Deprivation scores of 44.81, 26.75, 64.58, 59.43 and 14.34 respectively.

To calculate the average IMD score for MSOA X, each LSOA score is multiplied by the LSOA population. These values are then summed, before dividing by the population for MSOA X to create the average score for MSOA X. Thus, the average score for MSOA X would be calculated as:

Average score calculation for MSOA X	$(44.81 \times 1,200 + 26.75 \times 1,800 + 64.58 \times 1,400 + 59.43 \times 1,500 + 14.34 \times 1,700) \div 7,600$
--------------------------------------	---

Average score for MSOA X =	40.24
----------------------------	--------------

Appendix 5. Study 2 - Selecting a distance threshold for hot spot analysis using Global Moran's I statistic



Key: ● Z score

P-values corresponding to the displayed z scores were all greater than .05

Nb: Global Moran's I analysis was performed to determine the suitable distance for conducting Getis-Ord GI* (hot spot) analyses. The highest peaks in the graph show the distances where spatial clustering of the standardised mortality ratios are most pronounced. One way of determining an appropriate scale of analysis is to choose the distance linked to a statistically significant peak that most accurately matches the scale of your inquiry. Typically, this corresponds to the first statistically significant peak in the z-scores which in this case would be 1,000 metres. However, it's important to note that there isn't a definitive "right" threshold to select. The choice of threshold is ultimately up to the researcher's judgment (ESRI, 2010).

Appendix 6. Study 2 - Unadjusted OLS regression models for SMR and built environment exposure variables

Built environment exposure	β coef.	t	95% CI	p	R^2
Index of multiple deprivation rank score					
Reference group: Least deprived quintile	-	-	-		
2 nd quintile	-0.02	-0.10	-0.44 , 0.39	.10	.05
3 rd quintile	0.01	0.05	-0.43 , 0.45		
4 th quintile	0.60	2.30	0.08 , 1.11		
Most deprived quintile	0.31	0.99	-0.31 , 0.93		
Neighbourhood walkability (z score)					
Ref: Least walkable quintile	-	-	-		
2 nd quintile	0.01	0.04	-0.51 , 0.53	.78	.01
3 rd quintile	-0.01	-0.06	-0.49 , 0.46		
4 th quintile	0.24	0.79	-0.36 , 0.84		
Most walkable quintile	0.21	0.89	-0.26 , 0.68		
Population density (persons per hectare)					
Ref: Least populous quintile	-	-	-		
2 nd quintile	0.35	1.22	-0.22 , 0.93	.63	.02
3 rd quintile	-0.05	-0.23	-0.52 , 0.41		
4 th quintile	-0.04	-0.14	-0.58 , 0.50		
Most populous quintile	-0.03	-0.14	-0.49 , 0.42		
Green spaces (% per hectare)					
Ref: Least vegetation	-	-	-		
2 nd quintile	0.32	1.33	-0.16 , 0.80	.43	.02
3 rd quintile	-0.12	-0.57	-0.52 , 0.29		
4 th quintile	0.18	0.75	-0.29 , 0.64		
Most vegetation	0.01	0.05	-0.52 , 0.55		
Convenience stores [‡]					
Ref: lowest no. of outlets	-	-	-		
2 nd quintile	0.39	1.48	-0.13 , 0.90	.08	.05
3 rd quintile	-0.00	-0.00	-0.44 , 0.44		
4 th quintile	0.45	1.78	-0.05 , 0.95		
Highest no. of outlets	0.57	2.21	0.06 , 1.07		
Supermarkets [‡]					
Ref: Lowest no. of outlets	-	-	-		
2 nd tertile	0.16	0.77	-0.26 , 0.58	.69	<.001
Highest no. of outlets	-0.04	-0.18	-0.46 , 0.39		
Off-licences [‡]					
Ref: lowest no. of outlets	-	-	-		
2 nd quintile	-0.30	-1.02	-0.88 , 0.28	.68	.02
3 rd quintile	-0.27	-1.00	-0.81 , 0.26		
4 th quintile	-0.39	-1.38	-0.94 , 0.17		
Highest no. of outlets	-0.14	-0.51	-0.71 , 0.42		
Fast food outlet [‡]					
Ref: lowest no. of outlets	-	-	-		
2 nd quintile	0.29	1.00	-0.28 , 0.85	.31	.03
3 rd quintile	-0.03	-0.12	-0.55 , 0.49		
4 th quintile	-0.25	-1.16	-0.66 , 0.17		
Highest no. of outlets	0.14	0.59	-0.33 , 0.61		

[‡] Services and retail outlets per 100,000 population; P values are for linear trend

Appendix 6. Study 2 - Unadjusted OLS regression models for SMR and social environment exposure variables

Social environment exposure	β coef.	<i>t</i>	95% CI	<i>p</i>	R^2
Social fragmentation (z score)					
Reference group: Least fragmented quintile	-	-	-		
2 nd quintile	0.41	1.49	-0.13 , 0.95	.53	.02
3 rd quintile	0.28	1.14	-0.20 , 0.76		
4 th quintile	0.34	1.25	-0.20 , 0.88		
Most fragmented quintile	0.15	0.69	-0.27 , 0.56		
Ethnic density (%)					
Ref group: Least ethnically dense	-	-	-		
2 nd quintile	0.35	1.54	-0.10 , 0.81	.09	.06
3 rd quintile	-0.07	-0.31	-0.48 , 0.35		
4 th quintile	0.61	2.07	0.03 , 1.20		
Most ethnically dense	0.17	0.65	-0.35 , 0.69		
Places of worship (PW) [‡]					
Ref group: lowest no. of PWs	-	-	-		
2 nd quintile	0.05	0.19	-0.45 , 0.54	.82	.01
3 rd quintile	0.25	0.85	-0.34 , 0.84		
4 th quintile	0.17	0.64	-0.36 , 0.71		
Highest no. of PWs	0.19	0.83	-0.26 , 0.63		

[‡]Places of worship per 100,000 population; P value is for linear trend

Appendix 7. Study 3 - Associations between all-cause mortality and the individual-level covariates in SMI cohort (n = 22,689)

	Model A7.a				Model A7.b		Model A7.c		Model A7.d		Model A7.e		Model A7.f	
	Died (n) / Alive (n)	Crude IRR (95% CI)	<i>p</i>	Adjusted (deprivation) IRR (95%CI)	<i>p</i>	Adjusted (deprivation & built environment) IRR (95%CI)	<i>p</i>	Adjusted (deprivation & social environment) IRR (95%CI)	<i>p</i>	Fully adjusted (deprivation & built environment) IRR (95%CI)	<i>p</i>	Fully adjusted (deprivation & social environment) IRR (95%CI)	<i>p</i>	
Individual-level covariates														
Sociodemographic														
Age (at diagnosis)														
Ref group: 15-24	78 / 3,558	-		-		-		-		-		-		-
25-34	196 / 5,539	1.42 (1.06 - 1.89)	<.0001	1.42 (1.07 - 1.89)	<.0001	1.42 (1.07 - 1.89)	<.0001	1.42 (1.07 - 1.89)	<.0001	1.46 (1.10 - 1.95)	<.0001	1.46 (1.10 - 1.93)	<.0001	
35-44	375 / 5,269	2.31 (1.74 - 3.07)		2.31 (1.74 - 3.07)		2.32 (1.74 - 3.08)		2.32 (1.74 - 3.08)		2.39 (1.81 - 3.17)		2.38 (1.80 - 3.15)		
45-54	456 / 3,811	3.25 (2.35 - 4.49)		3.25 (2.35 - 4.48)		3.23 (2.34 - 4.45)		3.23 (2.34 - 4.45)		3.35 (2.44 - 4.60)		3.36 (2.44 - 4.61)		
55-64	495 / 2,015	5.25 (3.63 - 7.60)		5.25 (3.64 - 7.58)		5.22 (3.62 - 7.52)		5.22 (3.62 - 7.52)		5.39 (3.77 - 7.70)		5.42 (3.77 - 7.78)		
65-74	606 / 1,372	7.23 (4.58 - 11.43)		7.22 (4.57 - 11.39)		7.15 (4.54 - 11.26)		7.15 (4.54 - 11.26)		7.64 (4.88 - 11.96)		7.68 (4.87 - 12.12)		
75-84	533 / 906	7.30 (4.19 - 12.70)		7.29 (4.20 - 12.66)		7.13 (4.11 - 12.35)		7.13 (4.11 - 12.35)		7.65 (4.44 - 13.20)		7.81 (4.49 - 13.61)		
85 & over	172 / 219	9.97 (5.17 - 19.22)		9.95 (5.17 - 19.13)		9.72 (5.06 - 18.66)		9.72 (5.06 - 18.66)		10.36 (5.44 - 19.72)		10.63 (5.52 - 20.50)		
Sex														
Ref: Male	1,477 / 11,655	-		-		-		-		-		-		-
Female	1,434 / 11,034	1.06 (0.99 - 1.14)	.12	1.06 (0.98 - 1.14)	.12	1.05 (0.98 - 1.13)	.16	1.05 (0.98 - 1.13)	.15	0.76 (0.71 - 0.81)	<.0001	0.76 (0.71 - 0.80)	<.0001	
Marital status														
Ref: Single	1,524 / 15,800	-		-		-		-		-		-		-
Married or cohabitating	457 / 3,547	1.37 (1.23 - 1.53)	<.0001	1.37 (1.22 - 1.53)	<.0001	1.35 (1.21 - 1.51)	<.0001	1.37 (1.22 - 1.53)	<.0001	0.79 (0.72 - 0.87)	<.0001	0.80 (0.73 - 0.88)	<.0001	
Divorced , separated or widowed	930 / 3,342	2.89 (2.66 - 3.14)		2.89 (2.66 - 3.14)		2.89 (2.65 - 3.14)		2.89 (2.66 - 3.14)		1.01 (0.93 - 1.09)		1.01 (0.94 - 1.09)		
Ethnicity														
Ref: White British	1,771 / 10,868	-		-		-		-		-		-		-
Racialized minority group	1,140 / 11,821	0.58 (0.53 - 0.62)	<.0001	0.58 (0.53 - 0.62)	<.0001	0.58 (0.54 - 0.63)	<.0001	0.58 (0.53 - 0.63)	<.0001	0.80 (0.75 - 0.86)	<.0001	0.80 (0.74 - 0.85)	<.0001	
Clinical variables														
Substance misuse														
Ref: No substance misuse	1,771 / 10,868	-		-		-		-		-		-		-
Lifetime substance misuse	356 / 3,700	0.71 (0.63 - 0.80)	<.0001	0.71 (0.63 - 0.80)	<.0001	0.71 (0.63 - 0.81)	<.0001	0.71 (0.63 - 0.81)	<.0001	1.22 (1.09 - 1.37)	.0006	1.23 (1.09 - 1.38)	.0005	
Diagnosis														
Ref: Non-affective	2,555 / 16,444	-		-		-		-		-		-		-
Affective	656 / 6,245	0.79 (0.72 - 0.87)	<.0001	0.79 (0.72 - 0.86)	<.0001	0.78 (0.71 - 0.86)	<.0001	0.79 (0.72 - 0.86)	<.0001	0.87 (0.80 - 0.94)	.0007	0.87 (0.80 - 0.94)	.0007	

Model A7.a is crude estimates; Model A7.b is adjusted for area-level deprivation; Model A7.c is adjusted for area-level deprivation and built environment variables (i.e. neighbourhood walkability, population density, green spaces, convenience stores, supermarkets, off-licences and fast food outlets); ; Model A7.c is adjusted for area-level deprivation and social environment factors (i.e. social fragmentation, ethnic density and places of worship); Model A7.e is adjusted for area-level deprivation, built environment factors and all other individual-level variables; Model A7.f is adjusted for area-level deprivation, social environment factors and all other individual-level variables; *P* values are for linear trend; Age modelled as a quadratic term across all models; Robust standard errors used to adjust for clustering at the Middle Super Output Area across all models.

Appendix 8. Study 3 - Associations between natural-cause mortality and the individual-level covariates in SMI cohort (n = 22,466)

	Model A8.a			Model A8.b		Model A8.c		Model A8.d		Model A8.e		Model A8.f	
	Died (n) / Alive (n)	Crude IRR (95% CI)	p	Adjusted (deprivation) IRR (95%CI)	p	Adjusted (deprivation & built environment) IRR (95%CI)	p	Adjusted (deprivation & social environment) IRR (95%CI)	p	Fully adjusted (deprivation & built environment) IRR (95%CI)	p	Fully adjusted (deprivation & social environment) IRR (95%CI)	p
Individual-level covariates													
Sociodemographic													
Age (at diagnosis)													
Ref group: 15-24	23 / 3,558	-		-		-		-		-		-	
25-34	108 / 5,539	2.07 (1.36 - 3.17)	<.0001	2.08 (1.36 - 3.17)	<.0001	2.09 (1.37 - 3.19)	<.0001	2.07 (1.36 - 3.17)	<.0001	2.15 (1.41 - 3.28)	<.0001	2.13 (1.39 - 3.25)	<.0001
35-44	281 / 5,269	3.42 (2.26 - 5.18)		3.42 (2.26 - 5.18)		3.45 (2.27 - 5.24)		3.42 (2.26 - 5.20)		3.57 (2.34 - 5.43)		3.54 (2.33 - 5.38)	
45-54	395 / 3,811	4.12 (2.64 - 6.42)		4.11 (2.64 - 6.40)		4.14 (2.64 - 6.50)		4.13 (2.64 - 6.46)		4.32 (2.75 - 6.78)		4.28 (2.73 - 6.72)	
55-64	458 / 2,015	5.26 (3.24 - 8.56)		5.26 (3.24 - 8.53)		5.32 (3.25 - 8.71)		5.33 (3.26 - 8.69)		5.49 (3.35 - 8.99)		5.45 (3.33 - 8.92)	
65-74	535 / 1,372	5.09 (2.81 - 9.23)		5.06 (2.80 - 9.14)		5.22 (2.85 - 9.57)		5.17 (2.84 - 9.41)		5.61 (3.06 - 10.30)		5.52 (3.02 - 10.08)	
75-84	426 / 906	3.72 (1.81 - 7.67)		3.70 (1.81 - 7.59)		3.80 (1.82 - 7.95)		3.79 (1.84 - 7.84)		4.10 (1.94 - 8.63)		4.06 (1.94 - 8.48)	
85 & over	126 / 219	3.19 (1.36 - 7.49)		3.14 (1.34 - 7.36)		3.34 (1.39 - 8.02)		3.29 (1.39 - 7.78)		3.54 (1.47 - 8.50)		3.44 (1.45 - 8.18)	
Sex													
Ref: Male	1,175 / 11,655	-		-		-		-		-		-	
Female	1,177 / 11,034	1.15 (1.05 - 1.25)	.001	1.14 (1.05 - 1.24)	.002	1.13 (1.04 - 1.23)	.002	1.14 (1.05 - 1.23)	.003	0.75 (0.69 - 0.81)	<.0001	0.75 (0.70 - 0.81)	<.0001
Marital status													
Ref: Single	1,190 / 15,800	-		-		-		-		-		-	
Married or cohabitating	380 / 3,547	1.50 (1.33 - 1.69)	<.0001	1.49 (1.32 - 1.68)	<.0001	1.47 (1.30 - 1.66)	<.0001	1.49 (1.32 - 1.68)	<.0001	0.78 (0.69 - 0.88)	.0001	0.78 (0.69 - 0.88)	.0002
Divorced, separated or widowed	782 / 3,342	3.21 (2.92 - 3.53)		3.22 (2.93 - 3.54)		3.22 (2.92 - 3.55)		3.22 (2.93 - 3.54)		0.97 (0.86 - 1.08)		0.97 (0.87 - 1.08)	
Ethnicity													
Ref: White British	1,430 / 10,868	-		-		-		-		-		-	
Racialized minority group	922 / 11,821	0.56 (0.52 - 0.61)	<.0001	0.56 (0.52 - 0.62)	<.0001	0.57 (0.52 - 0.63)	<.0001	0.57 (0.52 - 0.62)	<.0001	0.80 (0.73 - 0.87)	<.0001	0.79 (0.73 - 0.86)	<.0001
Clinical variables													
Substance misuse													
Ref: No substance misuse	2,118 / 10,868	-		-		-		-		-		-	
Lifetime substance misuse	234 / 3,700	0.55 (0.48 - 0.64)	<.0001	0.56 (0.48 - 0.64)	<.0001	0.56 (0.48 - 0.64)	<.0001	0.56 (0.48 - 0.64)	<.0001	1.06 (0.92 - 1.22)	.42	1.07 (0.93 - 1.24)	.35
Diagnosis													
Ref: Non-affective	1,824 / 16,444	-		-		-		-		-		-	
Affective	528 / 6,245	0.81 (0.73 - 0.89)	<.0001	0.80 (0.73 - 0.88)	<.0001	0.80 (0.73 - 0.88)	<.0001	0.80 (0.73 - 0.88)	<.0001	0.87 (0.78 - 0.96)	.004	0.86 (0.78 - 0.95)	.003

¹ 223 cohort members were classified as not otherwise specified (R00-R99) and therefore were **not** included in the analyses for cause-specific mortality; Model A8.a is crude estimates; Model A8.b is adjusted for area-level deprivation; Model A8.c is adjusted for area-level deprivation and built environment variables (i.e. neighbourhood walkability, population density, green spaces, convenience stores, supermarkets, off-licences and fast food outlets); ; Model A8.c is adjusted for area-level deprivation and social environment factors (i.e. social fragmentation, ethnic density and places of worship); Model A8.e is adjusted for area-level deprivation, built environment factors and all other individual-level variables; Model A8.f is adjusted for area-level deprivation, social environment factors and all other individual-level variables; *P* values are for linear trend; Age modelled as a quadratic term across all models; Robust standard errors used to adjust for clustering at the Middle Super Output Area across all models.

Appendix 9. Study 3 - Associations between unnatural-cause mortality and the individual-level covariates in SMI cohort (n = 22,466)

	Model A9.a			Model A9.b		Model A9.c		Model A9.d		Model A9.e		Model A9.f	
	Died (n) / Alive (n)	Crude IRR (95% CI)	p	Adjusted (deprivation) IRR (95%CI)	p	Adjusted (deprivation & built environment) IRR (95%CI)	p	Adjusted (deprivation & social environment) IRR (95%CI)	p	Fully adjusted (deprivation & built environment) IRR (95%CI)	p	Fully adjusted (deprivation & social environment) IRR (95%CI)	p
Individual-level covariates													
Sociodemographic													
Age (at diagnosis)													
Ref group: 15-24	52 / 3,558	-		-		-		-		-		-	
25-34	84 / 5,539	0.99 (0.64 - 1.51)	.77	0.98 (0.64 - 1.51)	.76	0.99 (0.64 - 1.52)	.81	0.99 (0.64 - 1.51)	.76	1.00 (0.65 - 1.52)	.81	0.99 (0.65 - 1.51)	.75
35-44	84 / 5,269	0.99 (0.52 - 1.89)		0.99 (0.52 - 1.89)		1.00 (0.53 - 1.89)		1.00 (0.53 - 1.89)		1.03 (0.55 - 1.90)		1.01 (0.55 - 1.88)	
45-54	57 / 3,811	1.00 (0.36 - 2.74)		0.99 (0.36 - 2.73)		0.98 (0.36 - 2.69)		1.00 (0.37 - 2.75)		1.01 (0.38 - 2.68)		1.02 (0.38 - 2.71)	
55-64	25 / 2,015	0.91 (0.21 - 3.98)		0.91 (0.21 - 3.98)		0.88 (0.21 - 3.82)		0.92 (0.21 - 4.00)		0.92 (0.23 - 3.77)		0.94 (0.23 - 3.87)	
65-74	16 / 1,372	0.99 (0.13 - 7.41)		0.99 (0.13 - 7.38)		0.95 (0.13 - 7.03)		0.99 (0.13 - 7.36)		1.07 (0.16 - 7.31)		1.09 (0.16 - 7.52)	
75-84	15 / 906	1.79 (0.13 - 25.70)		1.79 (0.13 - 25.59)		1.64 (0.12 - 23.21)		1.82 (0.13 - 25.71)		1.90 (0.15 - 24.43)		2.04 (0.16 - 26.66)	
85 & over	3 / 219	1.93 (0.04 - 85.13)		1.94 (0.04 - 85.51)		1.73 (0.04 - 74.24)		1.96 (0.04 - 85.26)		1.94 (0.05 - 74.09)		2.08 (0.05 - 81.48)	
Sex													
Ref group: Male	226 / 11,655	-		-		-		-		-		-	
Female	110 / 11,034	0.54 (0.41 - 0.72)	<.0001	0.54 (0.41 - 0.72)	<.0001	0.54 (0.41 - 0.71)	<.0001	0.54 (0.41 - 0.71)	<.0001	0.62 (0.46 - 0.82)	.0009	0.62 (0.46 - 0.82)	.0009
Marital status													
Ref: Single	259 / 15,800	-		-		-		-		-		-	
Married or cohabitating	35 / 3,547	0.61 (0.43 - 0.88)	.01	0.62 (0.43 - 0.88)	.01	0.61 (0.43 - 0.88)	.01	0.61 (0.43 - 0.88)	.01	0.74 (0.52 - 1.05)	.15	0.74 (0.52 - 1.05)	.14
Divorced, separated or widowed	42 / 3,342	0.72 (0.51 - 1.02)		0.72 (0.51 - 1.02)		0.72 (0.51 - 1.02)		0.72 (0.50 - 1.02)		0.81 (0.57 - 1.15)		0.80 (0.56 - 1.13)	
Ethnicity													
Ref: White British	203 / 10,868	-		-		-		-		-		-	
Racialized minority group	133 / 11,821	0.60 (0.48 - 0.74)	<.0001	0.58 (0.47 - 0.73)	<.0001	0.58 (0.46 - 0.73)	<.0001	0.57 (0.45 - 0.71)	<.0001	0.60 (0.48 - 0.76)	<.0001	0.59 (0.47 - 0.74)	<.0001
Clinical variables													
Substance misuse													
Ref: No substance misuse	211 / 10,868	-		-		-		-		-		-	
Lifetime substance misuse	115 / 3,700	2.72 (2.19 - 3.38)	<.0001	2.71 (2.18 - 3.37)	<.0001	2.75 (2.21 - 3.42)	<.0001	2.72 (2.18 - 3.39)	<.0001	2.40 (1.91 - 3.01)	<.0001	2.36 (1.88 - 2.95)	<.0001
Diagnosis													
Ref: Non-affective	248 / 16,444	-		-		-		-		-		-	
Affective	88 / 6,245	0.98 (0.76 - 1.27)	.90	0.99 (0.77 - 1.28)	.92	0.99 (0.77 - 1.27)	.92	0.99 (0.77 - 1.28)	.96	1.03 (0.78 - 1.36)	.82	1.04 (0.79 - 1.37)	.77

¹ 223 cohort members were classified as not otherwise specified (R00-R99) and therefore were **not** included in the analyses for cause-specific mortality; Model A9.a is crude estimates; Model A9.b is adjusted for area-level deprivation; Model A9.c is adjusted for area-level deprivation and built environment variables (i.e. neighbourhood walkability, population density, green spaces, convenience stores, supermarkets, off-licences and fast food outlets); ; Model A9.c is adjusted for area-level deprivation and social environment factors (i.e. social fragmentation, ethnic density and places of worship); Model A9.e is adjusted for area-level deprivation, built environment factors and all other individual-level variables; Model A9.f is adjusted for area-level deprivation, social environment factors and all other individual-level variables; *P* values are for linear trend; Age modelled as a quadratic term across all models; Robust standard errors used to adjust for clustering at the Middle Super Output Area across all models.

Appendix 10. Study 3 - Variance partition coefficients (VPC) for associations between all-cause mortality and built environment variables

Table shows components of variance and variance partition coefficient (VPC) from multilevel regression analyses assessing the association between built environment variables and all-cause mortality for [Table 6.2](#) in main text

Model A10.a Empty model								
Level 2 (between-MSOA)								
Variance	.0003	-	-	-	-	-	-	-
VPC (%)	.4	-	-	-	-	-	-	-
Fit statistic								
Deviance†	20952.08	-	-	-	-	-	-	-
Model A10.b (crude)								
	Dep	Nwalk	PopD	GrnS	Cstore	Smkts	OLicnce	Ffood
Level 2 (between-MSOA)								
Variance	.0003	.0003	.0003	.0003	.0003	.0003	.0003	.0003
VPC (%)	.4	.4	.4	.4	.4	.4	.4	.4
Fit statistic								
Deviance	20949.62	20943.07	20941.64	20947.92	20942.34	20950.80	20945.52	20945.01
Model A10.c (adjusted for deprivation)								
	Dep	Nwalk	PopD	GrnS	Cstore	Smkts	OLicnce	Ffood
Level 2 (between-MSOA)								
Variance	-	.0003	.0004	.0003	.0003	.0003	.0004	.0003
VPC (%)	-	.4	.4	.4	.4	.4	.4	.4
Fit statistic								
Deviance	-	20941.08	20940.63	20945.63	20939.21	20948.31	20943.09	20943.82
Model A10.d (adjusted for deprivation & sociodemographic indicators)								
	Dep	Nwalk	PopD	GrnS	Cstore	Smkts	OLicnce	Ffood
Level 2 (between-MSOA)								
Variance	0.000001	.0000008	.000006	.000001	.0000009	.000001	.000001	.0000009
VPC (%)	.009	.006	.005	.007	.007	.008	.008	.007
Fit statistic								

	Deviance	17382.32	17379.21	17377.47	17377.86	17378.67	17381.33	17380.08	17378.07
Model A10.e (adjusted for deprivation & clinical indicators)									
	Dep	Nwalk	PopD	GrnS	Cstore	Smkts	OLicnce	Ffood	
Level 2 (between-MSOA)									
	Variance	.0004	.0004	.0004	.0003	.0004	.0004	.0004	.0004
	VPC (%)	.5	.4	.4	.4	.4	.4	.4	.4
Fit statistic									
	Deviance	20879.57	20871.94	20870.33	20875.13	20869.02	20878.24	20872.98	20873.86
Model A10.f (adjusted for deprivation, sociodemographic indicators & clinical indicators)									
	Dep	Nwalk	PopD	GrnS	Cstore	Smkts	OLicnce	Ffood	
Level 2 (between-MSOA)									
	Variance	.000001	.0000008	.0000005	.0000008	.0000008	.0000009	.000001	.0000008
	VPC (%)	.007	.005	.004	.006	.006	.007	.007	.006
Fit statistic									
	Deviance	17361.89	17359.05	17356.83	17357.08	17358.58	17360.78	17359.774	17357.42
Model A10.g (fully adjusted)									
Level 2 (between-MSOA)									
	Variance	0	-	-	-	-	-	-	-
	VPC (%)	0	-	-	-	-	-	-	-
Fit statistic									
	Deviance	17332.55	-	-	-	-	-	-	-

Key: **Dep** = area-level deprivation, **Nwalk** = neighbourhood walkability, **PopD** = population density, **GrnS** = green spaces, **CStore** = convenience stores, **Smkts** = supermarkets, **OLicence** = off-licences, **Ffood** = fast food outlets

Model A10.a is an empty model (no predictor variables have been added); Model A10.b is crude estimates; Model A10.c is adjusted for area-level deprivation; Model A10.d is adjusted for area-level deprivation and sociodemographic factors (i.e. age, sex, ethnicity and marital status); Model A10.e is adjusted for area-level deprivation and clinical factors (i.e. substance misuse and SMI diagnosis); Model A10.f is adjusted for area-level deprivation, sociodemographic and clinical factors; Model A10.g is adjusted for area-level deprivation, sociodemographic and clinical factors and all other area-level variables predictor variables; † Deviance statistic is a measure used to assess the fit of the model to the data - generally the lower the deviance, the better the fit of the model; * Variance partition coefficient (VPC) quantifies the impact of clusters on all-cause mortality, which, in this case, refers to how much the middle super output areas (MSOAs) influence mortality outcomes beyond the effects of the modelled cohort member and MSOA characteristics; Level 2 Variance represents the variation of all-cause mortality between the different MSOAs

Appendix 11. Study 3 - Variance partition coefficients (VPC) for associations between all-cause mortality and social environment variables

Table shows components of variance and variance partition coefficient (VPC) from multilevel regression analyses assessing the association between built environment variables and all-cause mortality in [Table 6.3](#) in the main text

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Model A11.a Empty model				
Level 2 (between-MSOA)				
Variance	.0003			
VPC (%)	.4			
Fit statistic				
Deviance†	20952.08			
Model A11.b (Crude)				
	Social frag.	Ethnic density	Places of worship	
Level 2 (between-MSOA)				
Variance	.0003	.0003	.0003	
VPC (%)	.4	.4	.4	
Fit statistic				
Deviance†	20948.40	20947.88	20951.32	
Model A11.c (adjusted for area deprivation)				
	Social frag.	Ethnic density	Places of worship	
Level 2 (between-MSOA)				
Variance	.0004	.0003	.0003	
VPC (%)	.4	.4	.4	
Fit statistic				
Deviance†	20947.02	20945.80	20948.66	
Model A11.d (adjusted for deprivation & sociodemographic indicators)				
	Social frag.	Ethnic density	Places of worship	
Level 2 (between-MSOA)				
Variance	.0000003	.0000004	.0000004	
VPC (%)	.004	.004	.004	
Fit statistic				
Deviance†	17011.70	17011.88	17010.44	
Model A11.e (adjusted for deprivation & clinical indicators)				
	Social frag.	Ethnic density	Places of worship	
Level 2 (between-MSOA)				
Variance	.0004	.0004	.0004	
VPC (%)	.4	.4	.4	
Fit statistic				
Deviance	20877.30	20875.09	20878.65	
Model A11.f (adjusted for deprivation, sociodemographic indicators & clinical indicators)				
	Social frag.	Ethnic density	Places of worship	
Level 2 (between-MSOA)				
Variance	.0000004	.0000004	.0000004	
VPC (%)	.004	.004	.003	
Fit statistic				
Deviance	16988.93	16989.01	16987.67	
Model A11.g (fully adjusted)				

Level 2 (between-MSOA)			
Variance	.0000003	-	-
VPC (%)	.003	-	-
Fit statistic			
Deviance	16984.35	-	-

Key: Social frag. = social fragmentation

Model A11.a is an empty model (no predictor variables have been added); Model A11.b is crude estimates; Model A11.c is adjusted for area-level deprivation; Model A11.d is adjusted for area-level deprivation and sociodemographic factors (i.e. age, sex, ethnicity and marital status); Model A11.e is adjusted for area-level deprivation and clinical factors (i.e. substance misuse and SMI diagnosis); Model A11.f is adjusted for area-level deprivation, sociodemographic and clinical factors; Model A11.g is adjusted for area-level deprivation, sociodemographic and clinical factors and all other area-level variables predictor variables; † Deviance statistic is a measure used to assess the fit of the model to the data - generally the lower the deviance, the better the fit of the model; * Variance partition coefficient (VPC) quantifies the impact of clusters on all-cause mortality, which, in this case, refers to how much the middle super output areas (MSOAs) influence mortality outcomes beyond the effects of the modelled cohort member and MSOA characteristics; Level 2 Variance represents the variation of all-cause mortality between the different MSOAs.

Appendix 12. Study 3 - Post-hoc sensitivity testing for associations between all-cause mortality and built environment variables with cohort emigration

Table 13. Post-hoc sensitivity analyses for the association between all-cause mortality and the built environment variables with cohort emigration as a competing risk in SMI cohort (n = 22,689)

	Model A12.a			Model A12.b		Model A12.c		Model A12.d		Model A12.e		Model A12.f	
	Died (n) / Alive (n)	Crude SHR (95% CI)	p	Adjusted (deprivation) SHR (95%CI)	p	Adjusted (deprivation & sociodemographic) SHR (95%CI)	p	Adjusted (deprivation & clinical) SHR (95%CI)	p	Adjusted (deprivation, sociodemographi c & clinical) SHR (95%CI)	p	Fully adjusted SHR (95% CI)	p
Built environment variables													
Area-level deprivation (rank score)													
Ref. group: Least deprived quintile	635 / 4,035	-		-		-		-		-		-	
2 nd quintile	586 / 3,981	0.91 (0.78 - 1.06)	.55	-	-	1.01 (0.90 - 1.15)	.37	0.91 (0.78 - 1.06)	.54	1.01 (0.89 - 1.14)	.48	1.07 (0.98 - 1.23)	.27
3 rd quintile	543 / 3,936	0.87 (0.73 - 1.03)		-		0.99 (0.87 - 1.14)		0.87 (0.73 - 1.03)		0.98 (0.86 - 1.13)		1.06 (0.91 - 1.23)	
4 th quintile	580 / 3,863	0.94 (0.80 - 1.11)		-		1.12 (0.98 - 1.28)		0.95 (0.73 - 1.03)		1.10 (0.96 - 1.26)		1.18 (1.00 - 1.39)	
Most deprived quintile	567 / 3,964	0.90 (0.75 - 1.07)		-		1.06 (0.91 - 1.23)		0.90 (0.75 - 1.07)		1.04 (0.89 - 1.21)		1.09 (0.92 - 1.29)	
N'hood walkability (z score)													
Ref: Least walkable quintile	635 / 3,895	-		-		-		-		-		-	
2 nd quintile	611 / 3,862	0.95 (0.81 - 1.12)	.01	0.96 (0.81 - 1.13)	.03	1.00 (0.87 - 1.15)	.11	0.96 (0.81 - 1.14)	.04	0.99 (0.86 - 1.15)	.13	1.00 (0.88 - 1.13)	.22
3 rd quintile	538 / 4,059	0.79 (0.69 - 0.91)		0.77 (0.66 - 0.91)		0.88 (0.77 - 1.00)		0.78 (0.66 - 0.92)		0.87 (0.76 - 1.00)		0.87 (0.75 - 1.01)	
4 th quintile	533 / 3,843	0.84 (0.71 - 1.01)		0.81 (0.65 - 1.00)		0.98 (0.82 - 1.17)		0.82 (0.66 - 1.01)		0.96 (0.81 - 1.15)		0.98 (0.81 - 1.20)	
Most walkable quintile	594 / 4,119	0.86 (0.74 - 1.00)		0.82 (0.69 - 0.98)		0.99 (0.85 - 1.14)		0.84 (0.70 - 1.00)		0.97 (0.84 - 1.12)		0.96 (0.79 - 1.16)	
Population density													
Ref: Least populous quintile	647 / 3,845	-		-		-		-		-		-	
2 nd quintile	582 / 3,936	0.84 (0.72 - 0.99)	.003	0.84 (0.72 - 0.99)	.007	1.06 (0.92 - 1.21)	.37	0.84 (0.72 - 0.99)	.01	1.05 (0.92 - 1.21)	.33	1.12 (0.98 - 1.27)	.09
3 rd quintile	546 / 4,018	0.78 (0.67 - 0.91)		0.78 (0.67 - 0.91)		0.95 (0.84 - 1.08)		0.78 (0.66 - 0.91)		0.95 (0.84 - 1.07)		0.94 (0.82 - 1.09)	
4 th quintile	549 / 3,891	0.78 (0.67 - 0.92)		0.79 (0.66 - 0.93)		0.92 (0.80 - 1.04)		0.79 (0.67 - 0.93)		0.91 (0.80 - 1.04)		0.87 (0.74 - 1.02)	
Most populous quintile	587 / 4,088	0.78 (0.67 - 0.92)		0.78 (0.66 - 0.93)		0.96 (0.83 - 1.10)		0.78 (0.66 - 0.93)		0.95 (0.83 - 1.09)		0.93 (0.79 - 1.09)	
Green spaces (%)													
Ref: Least vegetation	550 / 3,957	-		-		-		-		-		-	
2 nd quintile	594 / 3,873	1.09 (0.92 - 1.29)	.43	1.11 (0.94 - 1.30)	.43	1.05 (0.91 - 1.21)	.45	1.12 (0.95 - 1.31)	.49	1.06 (0.92 - 1.22)	.43	1.09 (0.95 - 1.25)	.28
3 rd quintile	557 / 3,932	1.04 (0.88 - 1.24)		1.06 (0.89 - 1.27)		0.98 (0.86 - 1.12)		1.06 (0.89 - 1.27)		0.98 (0.86 - 1.13)		1.03 (0.90 - 1.18)	
4 th quintile	631 / 4,038	1.17 (0.99 - 1.38)		1.18 (0.99 - 1.39)		1.08 (0.94 - 1.24)		1.18 (1.00 - 1.40)		1.09 (0.95 - 1.25)		1.01 (0.88 - 1.16)	
Most vegetation	579 / 3,978	1.08 (0.91 - 1.29)		1.09 (0.92 - 1.29)		0.97 (0.84 - 1.13)		1.09 (0.93 - 1.29)		0.98 (0.84 - 1.13)		0.91 (0.76 - 1.08)	
Convenience stores[†]													
Ref: lowest no. of outlets	601 / 3,921	-		-		-		-		-		-	

	Model A12.a			Model A12.b		Model A12.c		Model A12.d		Model A12.e		Model A12.f	
	Died (n) / Alive (n)	Crude SHR (95% CI)	<i>p</i>	Adjusted (deprivation) SHR (95%CI)	<i>p</i>	Adjusted (deprivation & sociodemographic) SHR (95%CI)	<i>p</i>	Adjusted (deprivation & clinical) SHR (95%CI)	<i>p</i>	Adjusted (deprivation, sociodemographi c & clinical) SHR (95%CI)	<i>p</i>	Fully adjusted SHR (95% CI)	<i>p</i>
2 nd quintile	621 / 3,904	1.05 (0.90 - 1.24)	.06	1.05 (0.90 - 1.24)	.05	1.11 (0.98 - 1.26)	.32	1.05 (0.90 - 1.24)	.05	1.11 (0.98 - 1.26)	.35	1.19 (1.04 - 1.36)	.03
3 rd quintile	528 / 3,934	0.89 (0.74 - 1.06)		0.87 (0.72 - 1.05)		0.97 (0.84 - 1.12)		0.87 (0.72 - 1.04)		0.97 (0.84 - 1.12)		1.06 (0.91 - 1.22)	
4 th quintile	624 / 3,952	1.05 (0.89 - 1.24)		1.07 (0.91 - 1.26)		1.08 (0.95 - 1.23)		1.07 (0.91 - 1.26)		1.07 (0.94 - 1.22)		1.18 (1.02 - 1.36)	
Highest no. of outlets	537 / 4,067	0.88 (0.75 - 1.03)		0.89 (0.76 - 1.03)		1.06 (0.93 - 1.21)		0.89 (0.77 - 1.04)		1.05 (0.92 - 1.20)		1.20 (0.98 - 1.46)	
Supermarkets[†]													
Ref: Lowest no. of outlets	1,709 / 11,836	-		-		-		-		-		-	
2 nd tertile	577 / 3,951	1.02 (0.90 - 1.17)	.35	1.03 (0.90 - 1.18)	.32	1.05 (0.95 - 1.17)	.48	1.03 (0.90 - 1.18)	.32	1.05 (0.95 - 1.17)	.43	1.09 (0.98 - 1.21)	.23
Highest no. of outlets	625 / 3,991	1.10 (0.97 - 1.24)		1.10 (0.97 - 1.24)		1.06 (0.95 - 1.17)		1.10 (0.97 - 1.24)		1.06 (0.95 - 1.18)		1.07 (0.96 - 1.20)	
Off-licences[†]													
Ref: lowest no. of outlets	603 / 3,825	-		-		-		-		-		-	
2 nd quintile	550 / 4,034	0.85 (0.73 - 0.99)	.13	0.85 (0.74 - 0.99)	.12	0.94 (0.82 - 1.08)	.49	0.85 (0.74 - 0.99)	.12	0.94 (0.82 - 1.08)	.53	0.97 (0.85 - 1.10)	.49
3 rd quintile	616 / 3,880	0.99 (0.84 - 1.17)		1.00 (0.85 - 1.18)		1.00 (0.87 - 1.15)		1.00 (0.85 - 1.18)		1.00 (0.87 - 1.15)		1.04 (0.90 - 1.19)	
4 th quintile	548 / 3,977	0.85 (0.72 - 1.01)		0.85 (0.72 - 1.00)		0.90 (0.79 - 1.03)		0.85 (0.73 - 1.01)		0.90 (0.79 - 1.03)		0.94 (0.82 - 1.08)	
Highest no. of outlets	594 / 4,062	0.90 (0.77 - 1.05)		0.90 (0.77 - 1.05)		0.95 (0.84 - 1.09)		0.85 (0.74 - 0.99)		0.94 (0.82 - 1.08)		1.02 (0.87 - 1.19)	
Fast-food outlets[†]													
Ref: lowest no. of outlets	629 / 3,832	-		-		-		-		-		-	
2 nd quintile	583 / 3,980	0.91 (0.77 - 1.08)	.21	0.93 (0.79 - 1.09)	.32	0.98 (0.86 - 1.11)	.36	0.93 (0.79 - 1.10)	.31	0.98 (0.86 - 1.11)	.33	0.95 (0.82 - 1.09)	.10
3 rd quintile	608 / 3,941	0.94 (0.79 - 1.12)		0.95 (0.81 - 1.13)		1.00 (0.87 - 1.14)		0.95 (0.81 - 1.12)		0.99 (0.87 - 1.14)		0.94 (0.81 - 1.08)	
4 th quintile	556 / 4,014	0.85 (0.72 - 1.01)		0.87 (0.73 - 1.03)		0.89 (0.78 - 1.01)		0.87 (0.74 - 1.03)		0.88 (0.77 - 1.01)		0.84 (0.72 - 0.97)	
Highest no. of outlets	535 / 4,011	0.84 (0.71 - 0.99)		0.85 (0.73 - 1.00)		0.94 (0.83 - 1.07)		0.85 (0.73 - 1.00)		0.94 (0.83 - 1.07)		0.81 (0.68 - 0.95)	

†Number of outlets per 100,000 population; Model A12.a is crude estimates; Model A12.b is adjusted for area-level deprivation; Model A12.c is adjusted for area-level deprivation and sociodemographic factors (i.e. age, sex, ethnicity and marital status); ; Model A12.c is adjusted for area-level deprivation and clinical factors (i.e. substance misuse and mental health diagnosis); Model A12.e is adjusted for area-level deprivation, sociodemographic factors and clinical factors (i.e. SMI diagnosis and substance misuse); Model A12.f is adjusted for area-level deprivation, sociodemographic and clinical factors and all other area-level variables predictor variables ; *P* values are for linear trend; Age modelled as a quadratic term across all models; Robust standard errors used to adjust for clustering at the Middle Super Output Area across all models.

Appendix 13. Study 3 - Post-hoc sensitivity testing for associations between all-cause mortality and social environment variables with cohort emigration

Post-hoc sensitivity analyses for the association between all-cause mortality and the social environment variables with cohort emigration as a competing risk in SMI cohort (n = 22,689)

	Model A13.a			Model A13.b		Model A13.c			Model A13.d		Model A13.e		Model A13.f	
	Died (n) / Alive (n)	Crude IRR (95% CI)	<i>p</i>	Adjusted (deprivation) IRR (95%CI)	<i>p</i>	Adjusted (deprivation & sociodemographic) IRR (95%CI)	<i>p</i>	Adjusted (deprivation & clinical) IRR (95%CI)	<i>P</i>	Adjusted (deprivation, sociodemographic & clinical) IRR (95%CI)	<i>p</i>	Fully adjusted IRR (95% CI)	<i>p</i>	
Social environment variables														
Social fragmentation (z score)														
Ref: Least fragmented	610 / 3,927	-												
2 nd quintile	598 / 3,980	0.92 (0.77 - 1.10)	.26	0.94 (0.78 - 1.12)	.47	1.05 (0.91 - 1.20)	.95	0.94 (0.79 - 1.12)	.52	1.04 (0.91 - 1.19)	.95	1.04 (0.91 - 1.19)	.86	
3 rd quintile	572 / 3,886	0.89 (0.74 - 1.06)		0.89 (0.74 - 1.07)		1.01 (0.86 - 1.18)		0.89 (0.74 - 1.07)		1.00 (0.86 - 1.17)		0.99 (0.85 - 1.15)		
4 th quintile	580 / 4,028	0.88 (0.75 - 1.03)		0.90 (0.76 - 1.06)		1.02 (0.89 - 1.18)		0.91 (0.77 - 1.07)		1.02 (0.89 - 1.17)		1.00 (0.86 - 1.16)		
Most fragmented	551 / 4,007	0.82 (0.70 - 0.98)		0.84 (0.70 - 1.02)		1.00 (0.85 - 1.17)		0.85 (0.71 - 1.02)		0.98 (0.84 - 1.15)		0.95 (0.80 - 1.12)		
Ethnic density (%)														
Ref: Least ethnically dense	580 / 3,793													
2 nd quintile	617 / 4,066	0.99 (0.83 - 1.18)	.57	1.08 (0.83 - 1.40)	.59	1.14 (0.93 - 1.41)	.67	1.07 (0.83 - 1.39)	.54	1.14 (0.93 - 1.41)	.64	1.14 (0.92 - 1.40)	.57	
3 rd quintile	591 / 3,927	0.96 (0.79 - 1.17)		1.07 (0.83 - 1.39)		1.07 (0.88 - 1.31)		1.06 (0.82 - 1.38)		1.07 (0.88 - 1.30)		1.06 (0.87 - 1.30)		
4 th quintile	586 / 3,889	0.97 (0.83 - 1.14)		1.04 (0.81 - 1.34)		1.10 (0.91 - 1.33)		1.03 (0.80 - 1.32)		1.11 (0.92 - 1.34)		1.12 (0.92 - 1.37)		
Most ethnically dense	537 / 4,103	0.88 (0.73 - 1.05)		0.94 (0.70 - 1.25)		1.06 (0.85 - 1.31)		0.92 (0.69 - 1.22)		1.06 (0.85 - 1.32)		1.05 (0.84 - 1.31)		
Places of worship [†]														
Ref: lowest no. of outlets	580 / 3,806													
2 nd quintile	562 / 4,059	0.92 (0.78 - 1.07)	.83	0.92 (0.78 - 1.07)	.81	0.97 (0.85 - 1.10)	.61	0.92 (0.79 - 1.08)	.83	0.97 (0.85 - 1.10)	.64	0.98 (0.86 - 1.10)	.54	
3 rd quintile	587 / 3,968	0.94 (0.79 - 1.12)		0.95 (0.80 - 1.13)		1.01 (0.88 - 1.16)		0.95 (0.80 - 1.13)		1.01 (0.87 - 1.16)		1.01 (0.87 - 1.17)		
4 th quintile	610 / 3,974	0.97 (0.82 - 1.15)		0.99 (0.84 - 1.17)		1.07 (0.94 - 1.22)		0.99 (0.84 - 1.17)		1.07 (0.93 - 1.22)		1.09 (0.94 - 1.26)		
Highest no. of outlets	572 / 3,971	0.93 (0.77 - 1.12)		0.95 (0.79 - 1.13)		1.05 (0.91 - 1.20)		0.95 (0.80 - 1.14)		1.04 (0.91 - 1.19)		1.07 (0.93 - 1.23)		

†Number of places of worship per 100,000 population; Model A13.a is crude estimates; Model A13.b is adjusted for area-level deprivation; Model A13.c is adjusted for area-level deprivation and sociodemographic factors (i.e. age, sex, ethnicity and marital status); ; Model A13.c is adjusted for area-level deprivation and clinical factors (i.e. substance misuse and mental health diagnosis); Model A13.e is adjusted for area-level deprivation, sociodemographic factors and clinical factors (i.e. SMI diagnosis and substance misuse); Model A13.f is adjusted for area-level deprivation, sociodemographic and clinical factors and all other area-level variables predictor variables ; *P* values are for linear trend; Age modelled as a quadratic term across all models; Robust standard errors used to adjust for clustering at the Middle Super Output Area across all models.

Appendix 14. Study 4 - Associations between all-cause mortality and the individual-level covariates in SMI cohort (n = 22,564)

Associations between all-cause mortality and the individual-level covariates in SMI cohort (n = 22,564)

	Model A14.a			Model A14.b		Model A14.c		Model A14.d	
	Died (n) / Alive (n)	Crude IRR (95% CI)	p	Adjusted (deprivation) IRR (95%CI)	p	Adjusted (deprivation & distance variables) IRR (95%CI)	p	Fully adjusted IRR (95%CI)	P
Individual-level covariates									
Sociodemographic									
Age (at diagnosis)									
Ref group: 15-24	76 / 3,457	-		-		-		-	
25-34	193 / 5,309	1.43 (1.08 - 1.91)	<.0001	1.44 (1.08 - 1.91)	<.0001	1.44 (1.08 - 1.91)	<.0001	1.48 (1.12 - 1.97)	<.0001
35-44	374 / 4,868	2.37 (1.79 - 3.13)		2.36 (1.78 - 3.13)		2.36 (1.78 - 3.13)		2.46 (1.86 - 3.25)	
45-54	453 / 3,335	3.31 (2.41 - 4.56)		3.30 (2.40 - 4.55)		3.30 (2.40 - 4.55)		3.45 (2.51 - 4.74)	
55-64	492 / 1,512	5.35 (3.71 - 7.73)		5.34 (3.70 - 7.72)		5.34 (3.70 - 7.72)		5.58 (3.87 - 8.04)	
65-74	605 / 765	7.38 (4.67 - 11.67)		7.33 (4.64 - 11.58)		7.33 (4.64 - 11.58)		7.92 (5.03 - 12.47)	
75-84	533 / 373	7.46 (4.29 - 12.96)		7.40 (4.26 - 12.87)		7.40 (4.26 - 12.87)		8.11 (4.66 - 14.11)	
85 & over	172 / 47	10.20 (5.30 - 19.62)		10.16 (5.28 - 19.52)		10.16 (5.28 - 19.52)		11.11 (5.80 - 21.26)	
Sex									
Ref: Male	1,467 / 10,097	-		-		-		-	
Female	1,431 / 9,569	1.06 (0.99 - 1.14)	.12	1.06 (0.98 - 1.13)	.12	1.06 (0.98 - 1.13)	.14	0.76 (0.71 - 0.81)	<.0001
Marital status									
Ref: Single	1,517 / 14,182	-		-		-		-	
Married or cohabitating	455 / 3,083	1.37 (1.22 - 1.53)	<.0001	1.36 (1.22 - 1.52)	<.0001	1.36 (1.22 - 1.52)	<.0001	0.79 (0.72 - 0.87)	<.0001
Divorced, separated or widowed	926 / 2,401	2.88 (2.65 - 3.14)		2.87 (2.64 - 3.12)		2.87 (2.64 - 3.12)		1.01 (0.93 - 1.09)	
Ethnicity									
Ref: White British	1,763 / 9,044	-		-		-		-	
Racialized minority group	1,135 / 10,622	0.58 (0.53 - 0.62)	<.0001	0.58 (0.54 - 0.63)	<.0001	0.58 (0.54 - 0.63)	<.0001	0.81 (0.75 - 0.86)	<.0001
Clinical variables									
Substance misuse									
Ref: No substance misuse	2,544 / 16,353	-		-		-		-	
Lifetime substance misuse	354 / 3,313	0.71 (0.63 - 0.80)	<.0001	0.72 (0.63 - 0.81)	<.0001	0.72 (0.63 - 0.81)	<.0001	1.24 (1.10 - 1.39)	<.001
Diagnosis									
Ref: Non-affective	2,243 / 14,094	-		-		-		-	
Affective	655 / 5,572	0.79 (0.72 - 0.87)	<.0001	0.79 (0.72 - 0.86)	<.0001	0.79 (0.72 - 0.86)	<.0001	0.88 (0.81 - 0.95)	.001

Model A14.a is crude estimates; Model A14.b is adjusted for area-level deprivation; Model A14.c is adjusted for area-level deprivation and built environment variables (i.e. neighbourhood walkability, population density, green spaces, convenience stores, supermarkets, off-licences and fast food outlets); ; Model A14.c is adjusted for area-level deprivation and social environment factors (i.e. social fragmentation, ethnic density and places of worship); Model A14.e is adjusted for area-level deprivation, built environment factors and all other individual-level variables; Model A14.f is adjusted for area-level deprivation, social environment factors and all other individual-level variables; P values are for linear trend; Age modelled as a quadratic term across all models; Robust standard errors used to adjust for clustering at the Middle Super Output Area across all models.

Appendix 15. Study 4 - Associations between natural-cause mortality and the individual-level covariates in SMI cohort (n = 22,341)

Associations between natural-cause mortality and the individual-level covariates in SMI cohort (n = 22,341)

	Model A15.a			Model A15.b		Model A15.c		Model A15.d	
	Died (n) / Alive (n)	Crude IRR (95% CI)	p	Adjusted (deprivation) IRR (95%CI)	p	Adjusted (deprivation & distance variables) IRR (95%CI)	p	Fully adjusted IRR (95%CI)	P
Individual-level covariates									
Sociodemographic									
Age (at diagnosis)									
Ref group: 15-24	22 / 3,457	-		-		-		-	
25-34	107 / 5,309	2.15 (1.42 - 3.26)	<.0001	2.22 (1.46 - 3.38)	<.0001	2.22 (1.46 - 3.38)	<.0001	2.28 (1.50 - 3.46)	<.0001
35-44	281 / 4,868	3.57 (2.37 - 5.38)		3.85 (2.53 - 5.85)		3.85 (2.53 - 5.85)		3.98 (2.62 - 6.06)	
45-54	392 / 3,335	4.26 (2.74 - 6.61)		4.87 (3.09 - 7.68)		4.87 (3.09 - 7.68)		5.08 (3.21 - 8.02)	
55-64	455 / 1,512	5.44 (3.35 - 8.83)		6.68 (4.03 - 11.08)		6.68 (4.03 - 11.08)		6.91 (4.15 - 11.51)	
65-74	534 / 765	5.28 (2.91 - 9.56)		6.77 (3.63 - 12.65)		6.77 (3.63 - 12.65)		7.29 (3.88 - 13.70)	
75-84	426 / 373	3.86 (1.88 - 7.91)		5.09 (2.37 - 10.90)		5.09 (2.37 - 10.90)		5.50 (2.54 - 11.94)	
85 & over	126 / 47	3.30 (1.41 - 7.75)		4.03 (1.65 - 9.86)		4.03 (1.65 - 9.86)		4.29 (1.73 - 10.61)	
Sex									
Ref: Male	1,168 / 10,097	-		-		-		-	
Female	1,175 / 9,569	1.15 (1.05 - 1.24)	.002	1.13 (1.04 - 1.23)	.003	1.13 (1.04 - 1.23)	.004	0.74 (0.68 - 0.80)	<.0001
Marital status									
Ref: Single	1,187 / 14,182	-		-		-		-	
Married or cohabitating	378 / 3,083	1.49 (1.32 - 1.68)	<.0001	1.47 (1.30 - 1.66)	<.0001	1.47 (1.30 - 1.65)	<.0001	0.78 (0.69 - 0.88)	.0002
Divorced, separated or widowed	778 / 2,401	3.19 (2.90 - 3.52)		3.13 (2.85 - 3.44)		3.12 (2.83 - 3.43)		0.95 (0.85 - 1.06)	
Ethnicity									
Ref: White British	1,425 / 9,044	-		-		-		-	
Racialized minority group	918 / 10,622	0.56 (0.52 - 0.61)	<.0001	0.56 (0.52 - 0.62)	<.0001	0.57 (0.52 - 0.62)	<.0001	0.80 (0.73 - 0.87)	<.0001
Clinical variables									
Substance misuse									
Ref: No substance misuse	2,110 / 16,353	-		-		-		-	
Lifetime substance misuse	233 / 3,313	0.56 (0.48 - 0.64)	<.0001	0.56 (0.49 - 0.65)	<.0001	0.57 (0.49 - 0.65)	<.0001	1.08 (0.93 - 1.24)	.31
Diagnosis									
Ref: Non-affective	1,816 / 14,094	-		-		-		-	
Affective	527 / 5,572	0.81 (0.73 - 0.89)	<.0001	0.80 (0.73 - 0.88)	<.0001	0.80 (0.73 - 0.88)	<.0001	0.88 (0.80 - 0.97)	.01

Model A15.a is crude estimates; Model A15.b is adjusted for area-level deprivation; Model A15.c is adjusted for area-level deprivation and built environment variables (i.e. neighbourhood walkability, population density, green spaces, convenience stores, supermarkets, off-licences and fast food outlets); ; Model A15.c is adjusted for area-level deprivation and social environment factors (i.e. social fragmentation, ethnic density and places of worship); Model A15.e is adjusted for area-level deprivation, built environment factors and all other individual-level variables; Model A15.f is adjusted for area-level deprivation, social environment factors and all other individual-level variables; P values are for linear trend; Age modelled as a quadratic term across all models; Robust standard errors used to adjust for clustering at the Middle Super Output Area across all models.

Appendix 16. Study 4 - Associations between unnatural-cause mortality and the individual-level covariates in SMI cohort (n = 22,341)

Associations between unnatural-cause mortality and the individual-level covariates in SMI cohort (n = 22,341)

	Model A16.a			Model A16.b		Model A16.c		Model A16.d	
	Died (n) / Alive (n)	Crude IRR (95% CI)	p	Adjusted (deprivation) IRR (95%CI)	p	Adjusted (deprivation & distance variables) IRR (95%CI)	p	Fully adjusted IRR (95%CI)	p
Individual-level covariates									
Sociodemographic									
Age (at diagnosis)									
Ref group: 15-24	51 / 3,457	-		-		-		-	
25-34	82 / 5,309	0.99 (0.64 - 1.52)	.79	0.99 (0.65 - 1.52)	.85	0.99 (0.65 - 1.52)	.86	1.00 (0.65 - 1.52)	.83
35-44	83 / 4,868	1.01 (0.53 - 1.92)		1.03 (0.54 - 1.95)		1.03 (0.54 - 1.95)		1.05 (0.56 - 1.96)	
45-54	57 / 3,335	1.03 (0.38 - 2.85)		1.06 (0.39 - 2.92)		1.06 (0.39 - 2.92)		1.06 (0.39 - 2.87)	
55-64	25 / 1,512	0.96 (0.22 - 4.19)		1.00 (0.23 - 4.37)		1.00 (0.23 - 4.37)		0.99 (0.24 - 4.18)	
65-74	16 / 765	1.04 (0.14 - 7.88)		1.08 (0.14 - 8.16)		1.08 (0.14 - 8.16)		1.17 (0.16 - 8.43)	
75-84	15 / 373	1.91 (0.13 - 27.73)		1.92 (0.13 - 27.96)		1.92 (0.13 - 27.96)		2.14 (0.15 - 29.63)	
85 & over	3 / 47	2.08 (0.05 - 93.57)		2.05 (0.05 - 93.11)		2.05 (0.05 - 93.11)		2.24 (0.05 - 96.55)	
Sex									
Ref: Male	223 / 10,097	-		-		-		-	
Female	109 / 9,569	0.54 (0.41 - 0.72)	<.0001	0.54 (0.41 - 0.71)	<.0001	0.54 (0.41 - 0.71)	<.0001	0.62 (0.46 - 0.83)	.001
Marital status									
Ref: Single	255 / 14,182	-		-		-		-	
Married or cohabitating	35 / 3,083	0.62 (0.43 - 0.88)	.01	0.62 (0.44 - 0.89)	.01	0.62 (0.43 - 0.88)	.01	0.75 (0.52 - 1.06)	.17
Divorced, separated or widowed	42 / 2,401	0.73 (0.52 - 1.04)		0.72 (0.50 - 1.02)		0.72 (0.51 - 1.02)		0.81 (0.57 - 1.16)	
Ethnicity									
Ref: White British	200 / 9,044	-		-		-		-	
Racialized minority group	132 / 10,622	0.60 (0.48 - 0.75)	<.0001	0.59 (0.47 - 0.73)	<.0001	0.59 (0.47 - 0.75)	<.0001	0.62 (0.49 - 0.78)	.0001
Clinical variables									
Substance misuse									
Ref: No substance misuse	218 / 16,353	-		-		-		-	
Lifetime substance misuse	114 / 3,313	2.74 (2.21 - 3.41)	<.0001	2.76 (2.22 - 3.43)	<.0001	2.78 (2.24 - 3.45)	<.0001	2.43 (1.93 - 3.04)	<.0001
Diagnosis									
Ref: Non-affective	244 / 14,094	-		-		-		-	
Affective	88 / 5,572	1.00 (0.77 - 1.29)	.97	1.01 (0.78 - 1.30)	.97	1.00 (0.78 - 1.29)	.98	1.04 (0.79 - 1.38)	.76

Model A16.a is crude estimates; Model A16.b is adjusted for area-level deprivation; Model A16.c is adjusted for area-level deprivation and built environment variables (i.e. neighbourhood walkability, population density, green spaces, convenience stores, supermarkets, off-licences and fast food outlets); ; Model A16.c is adjusted for area-level deprivation and social environment factors (i.e. social fragmentation, ethnic density and places of worship); Model A16.e is adjusted for area-level deprivation, built environment factors and all other individual-level variables; Model A16.f is adjusted for area-level deprivation, social environment factors and all other individual-level variables; P values are for linear trend; Age modelled as a quadratic term across all models; Robust standard errors used to adjust for clustering at the Middle Super Output Area across all models.

Appendix 17. Study 4 - Variance partition coefficients (VPC) for associations between all-cause mortality and distance to the nearest built environment variable

Components of variance and variance partition coefficient (VPC) from multilevel regression analyses assessing the association between proximity to environment variables and all-cause mortality for [Table 7.2](#) in the main text

Model A17.a Empty model							
Level 2 (between-MSOA)							
Variance	.0003	-	-	-	-	-	-
VPC (%)	.4	-	-	-	-	-	-
Fit statistic							
Deviance†	20853.78	-	-	-	-	-	-
Model A17.b (crude)							
	Supermarket	Convenience store	Off-licence	Fast-food outlets	Green spaces	Places of worship	
Level 2 (between-MSOA)							
Variance	.0003	.0003	.0002	.0002	.0003	.0003	
VPC (%)	.4	.4	.3	.3	.4	.4	
Fit statistic							
Deviance	20849.52	20853.73	20847.67	20848.38	20850.39	20853.74	
Model A17.c (adjusted for deprivation)							
	Supermarket	Convenience store	Off-licence	Fast-food outlets	Green spaces	Places of worship	
Level 2 (between-MSOA)							
Variance	.0003	.0003	.0003	.0003	.0003	.0003	
VPC (%)	.3	.4	.4	.4	.4	.4	
Fit statistic							
Deviance	20847.33	20851.25	20845.63	20846.58	20848.34	20851.25	
Model A17.d (adjusted for deprivation & sociodemographic indicators)							
	Supermarket	Convenience store	Off-licence	Fast-food outlets	Green spaces	Places of worship	
Level 2 (between-MSOA)							
Variance	.0000009	.000001	.000001	.000001	.000001	.000001	
VPC (%)	.007	.007	.007	.007	.007	.007	

Fit statistic							
	Deviance	17283.90	17282.16	17285.70	17285.67	17284.85	17285.45
Model A17.e (adjusted for deprivation & clinical indicators)							
	Supermarket	Convenience store	Off-licence	Fast-food outlets	Green spaces	Places of worship	
Level 2 (between-MSOA)							
	Variance	.0003	.0004	.0003	.0003	.0003	.0004
	VPC (%)	.4	.4	.4	.4	.4	.4
Fit statistic							
	Deviance	20778.24	20782.07	20776.94	20777.63	20779.23	20782.07
Model A17.f (adjusted for deprivation, sociodemographic & clinical indicators)							
	Supermarket	Convenience store	Off-licence	Fast-food outlets	Green spaces	Places of worship	
Level 2 (between-MSOA)							
	Variance	.0000008	.000001	.0000009	.0000009	.0000009	.0000009
	VPC (%)	.006	.007	.006	.007	.007	.006
Fit statistic							
	Deviance	17263.27	17262.49	17265.29	17265.33	17264.22	17264.94
Model A17.g (fully adjusted)							
Level 2 (between-MSOA)							
	Variance	.0000006	-	-	-	-	-
	VPC (%)	.005	-	-	-	-	-
Fit statistic							
	Deviance	17255.92	-	-	-	-	-

Key: VPC = variance partition coefficient, MSOA = middle super output area

Model A17.a is an empty model (no predictor variables have been added); Model A17.b is crude estimates; Model A17.c is adjusted for area-level deprivation; Model A17.d is adjusted for area-level deprivation and sociodemographic factors (i.e. age, sex, ethnicity and marital status); Model A17.e is adjusted for area-level deprivation and clinical factors (i.e. substance misuse and SMI diagnosis); Model A17.f is adjusted for area-level deprivation, sociodemographic and clinical factors; Model A17.g is adjusted for area-level deprivation, sociodemographic and clinical factors and all other area-level variables predictor variables; † Deviance statistic is a measure used to assess the fit of the model to the data - generally the lower the deviance, the better the fit of the model; * Variance partition coefficient (VPC) quantifies the impact of clusters on all-cause mortality, which, in this case, refers to how much the middle super output areas (MSOAs) influence mortality outcomes beyond the effects of the modelled cohort member and MSOA characteristics; Level 2 Variance represents the variation of all-cause mortality between the different MSOAs.

Appendix 18. Study 4 - Post-hoc sensitivity testing for associations between all-cause mortality and distance to the nearest built environment variables with cohort emigration

Post-hoc sensitivity analyses for the association between all-cause mortality and the distance variables with cohort emigration as a competing risk in SMI cohort (n = 22,564)

	Model A18.a			Model A18.b		Model A18.c		Model A18.d		Model A18.e		Model A18.f	
	Died (n) / Alive (n)	Crude SHR (95% CI)	p	Adjusted (deprivation) SHR (95%CI)	p	Adjusted (deprivation & sociodemographic) SHR (95%CI)	p	Adjusted (deprivation & clinical) SHR (95%CI)	p	Adjusted (deprivation, sociodemographi c & clinical) SHR (95%CI)	p	Fully adjusted SHR (95% CI)	p
Nearest distance variables†													
Supermarket													
Ref. group: <0.32 km	551 / 3,940	-		-		-		-		-		-	
0.32 - 0.47 km	571 / 3,976	1.01 (0.87 - 1.17)	.35	1.01 (0.87 - 1.18)	.34	1.03 (0.91 - 1.18)	.32	1.01 (0.87 - 1.17)	.35	1.03 (0.90 - 1.17)	.32	1.05 (0.92 - 1.21)	.27
0.48 - 0.65 km	562 / 3,934	1.02 (0.88 - 1.19)		1.03 (0.88 - 1.20)		0.96 (0.86 - 1.08)		1.02 (0.88 - 1.20)		0.96 (0.86 - 1.08)		0.96 (0.85 - 1.08)	
0.66 - 0.88 km	583 / 3,933	1.05 (0.91 - 1.21)		1.05 (0.91 - 1.21)		1.04 (0.93 - 1.15)		1.05 (0.91 - 1.21)		1.03 (0.93 - 1.15)		1.03 (0.92 - 1.16)	
≥0.89 km	631 / 3,883	1.15 (0.99 - 1.33)		1.14 (0.99 - 1.32)		1.08 (0.96 - 1.21)		1.14 (0.99 - 1.32)		1.09 (0.97 - 1.22)		1.08 (0.96 - 1.23)	
Convenience store													
Ref. group: <0.09 km	587 / 3,927	-		-		-		-		-		-	
0.09 - 0.14 km	574 / 3,954	0.94 (0.83 - 1.07)	.12	0.94 (0.83 - 1.07)	.15	0.94 (0.84 - 1.06)	.02	0.94 (0.82 - 1.07)	.14	0.94 (0.84 - 1.06)	.03	0.92 (0.82 - 1.04)	.11
0.15 - 0.19 km	579 / 3,978	0.94 (0.82 - 1.08)		0.94 (0.82 - 1.08)		0.90 (0.81 - 1.00)		0.94 (0.81 - 1.08)		0.91 (0.82 - 1.01)		0.89 (0.79 - 1.00)	
0.20 - 0.28 km	543 / 3,951	0.90 (0.79 - 1.02)		0.90 (0.79 - 1.02)		0.84 (0.76 - 0.93)		0.89 (0.79 - 1.01)		0.85 (0.76 - 0.94)		0.84 (0.73 - 0.96)	
≥0.29 km	615 / 3,856	1.09 (0.94 - 1.26)		1.07 (0.92 - 1.25)		0.91 (0.82 - 1.02)		1.07 (0.91 - 1.24)		0.92 (0.83 - 1.03)		0.84 (0.73 - 0.98)	
Off-licence													
Ref. group: <0.18 km	552 / 3,967	-		-		-		-		-		-	
0.18 - 0.27 km	549 / 3,939	1.00 (0.88 - 1.14)	.04	1.00 (0.88 - 1.14)	.04	0.90 (0.79 - 1.01)	.32	1.00 (0.88 - 1.13)	.04	0.90 (0.80 - 1.02)	.30	0.96 (0.84 - 1.09)	.68
0.28 - 0.38 km	572 / 3,985	1.04 (0.90 - 1.20)		1.04 (0.90 - 1.20)		0.95 (0.84 - 1.07)		1.04 (0.90 - 1.20)		0.95 (0.85 - 1.07)		1.00 (0.88 - 1.14)	
0.39 - 0.56 km	585 / 3,925	1.07 (0.94 - 1.21)		1.07 (0.94 - 1.22)		0.93 (0.82 - 1.04)		1.06 (0.93 - 1.21)		0.93 (0.82 - 1.04)		0.96 (0.85 - 1.08)	
≥0.57 km	640 / 3,850	1.24 (1.07 - 1.44)		1.23 (1.07 - 1.42)		1.00 (0.88 - 1.12)		1.23 (1.06 - 1.41)		1.00 (0.89 - 1.13)		1.04 (0.90 - 1.18)	
Fast-food outlet													
Ref. group: <0.10 km	516 / 3,970	-		-		-		-		-		-	
0.11 - 0.17 km	619 / 3,878	1.20 (1.04 - 1.38)	.0007	1.20 (1.04 - 1.38)	.001	1.04 (0.92 - 1.16)	.08	1.19 (1.03 - 1.36)	.002	1.04 (0.93 - 1.17)	.08	1.10 (0.97 - 1.24)	.37
0.18 - 0.25 km	541 / 4,021	1.02 (0.88 - 1.17)		1.01 (0.88 - 1.17)		0.88 (0.78 - 0.98)		1.01 (0.87 - 1.16)		0.88 (0.78 - 0.99)		0.96 (0.83 - 1.11)	
0.26 - 0.36 km	572 / 3,985	1.09 (0.96 - 1.24)		1.09 (0.96 - 1.24)		0.96 (0.85 - 1.07)		1.08 (0.96 - 1.23)		0.96 (0.85 - 1.08)		1.04 (0.89 - 1.22)	
≥0.37 km	650 / 3,812	1.31 (1.12 - 1.53)		1.29 (1.11 - 1.51)		0.99 (0.87 - 1.13)		1.29 (1.10 - 1.50)		1.00 (0.88 - 1.14)		1.06 (0.90 - 1.27)	
Green spaces													
Ref. group: <0.07 km	531 / 4,030	-		-		-		-		-		-	
0.07 - 0.11 km	560 / 3,967	1.08 (0.93 - 1.25)	.008	1.08 (0.93 - 1.25)	.01	0.99 (0.87 - 1.12)	.03	1.08 (0.93 - 1.25)	.009	0.99 (0.88 - 1.12)	.02	0.99 (0.87 - 1.12)	.04
0.12 - 0.16 km	672 / 3,873	1.30 (1.12 - 1.51)		1.30 (1.12 - 1.50)		1.17 (1.03 - 1.32)		1.30 (1.12 - 1.50)		1.17 (1.04 - 1.32)		1.15 (1.02 - 1.30)	
0.17 - 0.23 km	554 / 3,907	1.11 (0.95 - 1.30)		1.11 (0.94 - 1.30)		1.04 (0.90 - 1.19)		1.11 (0.95 - 1.30)		1.04 (0.91 - 1.20)		1.03 (0.89 - 1.18)	
≥0.24 km	581 / 3,889	1.15 (1.00 - 1.33)		1.15 (0.98 - 1.33)		1.07 (0.94 - 1.23)		1.13 (0.98 - 1.32)		1.09 (0.95 - 1.24)		1.07 (0.94 - 1.23)	
Place of worship													

	Model A18.a			Model A18.b		Model A18.c		Model A18.d		Model A18.e		Model A18.f	
	Died (n) / Alive (n)	Crude SHR (95% CI)	p	Adjusted (deprivation) SHR (95%CI)	p	Adjusted (deprivation & sociodemographic) SHR (95%CI)	p	Adjusted (deprivation & clinical) SHR (95%CI)	p	Adjusted (deprivation, sociodemographi c & clinical) SHR (95%CI)	p	Fully adjusted SHR (95% CI)	p
Ref. group: <0.12 km	585 / 3,918	-	-	-	-	-	-	-	-	-	-	-	-
0.12 - 0.18 km	574 / 3,985	0.96 (0.83 - 1.10)	.55	0.95 (0.83 - 1.09)	.64	0.98 (0.87 - 1.11)	.21	0.95 (0.83 - 1.10)	.67	0.98 (0.87 - 1.11)	.19	0.98 (0.87 - 1.10)	.16
0.19 - 0.25 km	558 / 3,979	0.93 (0.81 - 1.08)		0.93 (0.81 - 1.07)		0.95 (0.84 - 1.06)		0.93 (0.81 - 1.07)		0.95 (0.84 - 1.06)		0.95 (0.85 - 1.07)	
0.26 - 0.34 km	591 / 3,930	1.01 (0.89 - 1.16)		1.01 (0.89 - 1.15)		1.07 (0.96 - 1.20)		1.01 (0.89 - 1.15)		1.07 (0.96 - 1.21)		1.08 (0.96 - 1.21)	
≥0.35 km	590 / 3,881	1.05 (0.90 - 1.22)		1.03 (0.89 - 1.18)		1.02 (0.90 - 1.15)		1.02 (0.89 - 1.18)		1.03 (0.91 - 1.16)		1.02 (0.91 - 1.15)	

†Distance (km) to the nearest neighbourhood amenity; ‡publicly accessible green spaces; Model A18.a is crude estimates; Model A18.b is adjusted for area-level deprivation; Model A18.c is adjusted for area-level deprivation and sociodemographic factors (i.e. age, sex, ethnicity and marital status); ; Model A18.c is adjusted for area-level deprivation and clinical factors (i.e. substance misuse and mental health diagnosis); Model A18.e is adjusted for area-level deprivation, sociodemographic factors and clinical factors (i.e. SMI diagnosis and substance misuse); Model A18.f is adjusted for area-level deprivation, sociodemographic and clinical factors and all other area-level variables predictor variables ; P values are for linear trend; Age modelled as a quadratic term across all models; Robust standard errors used to adjust for clustering at the Middle Super Output Area across all models; VPC = Variance Partition Coefficient.