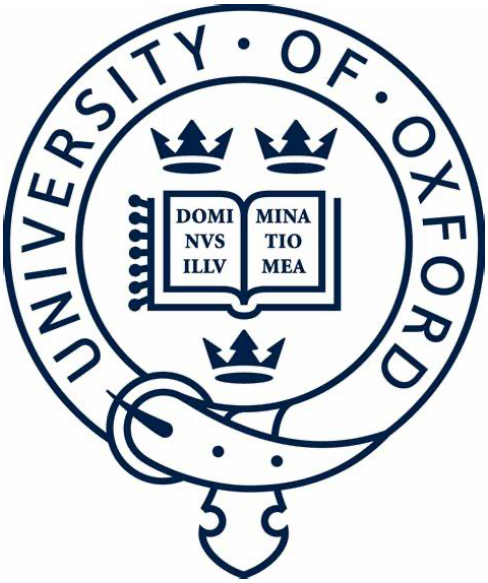
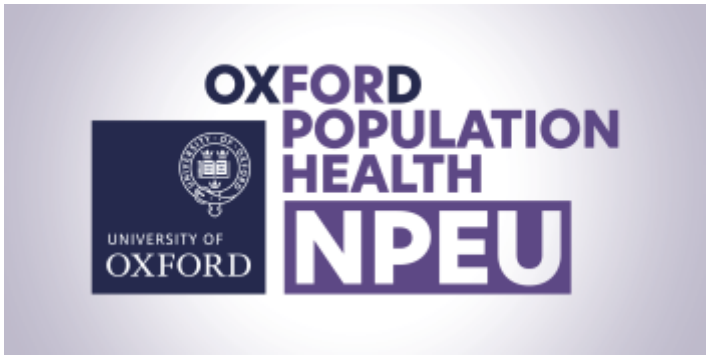
Inequalities in maternal health outcomes: In a developed country which elements of socioeconomic disadvantage are associated with an increased risk of severe maternal morbidity?





Dorothea Miranda Geddes-Barton

National Perinatal Epidemiology Unit, University of Oxford

Submission for the degree of Doctorate of Philosophy

Word count 44,117

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List of Publications

Geddes-Barton D, Baldelli S, Karthikappallil R, Bentley T, Omorodion B, Thompson L, Roberts NW, Goldacre R, Knight M, Ramakrishnan R. Association between socioeconomic disadvantage and severe maternal morbidity and mortality in high-income countries: a systematic review. J Epidemiol Community Health. 2025 Mar 1;79(3):207-15

Geddes-Barton D, Ramakrishnan R, Goldacre R, Knight M. The association between the different domains of the Index of Multiple Deprivation and severe maternal morbidity. (*Under review in Social Science and Medicine*)

Acronyms

Acronyms	Full Term
AIMS	Addressing Inequalities in Maternity Services
AIHW	The Australian Institute of Health and Welfare
AMMOI	Australian Maternal Morbidity Outcome Indicator
BMI	Body Mass Index
C4	Four largest cities, The Netherlands
CDC	Centres for Disease Control and Prevention
CI	Confidence Interval
DIAPER	Data-InfrAstructure for ParEnts and childRen
EFA	Exploratory Factor Analysis
EMMOI	English Maternal Morbidity Outcome Indicator
HES APC	Hospital Episode Statistics Admitted Patient Care
ICD-10	International Classification of Diseases, Tenth Revision
ICC	Intra-class Correlation Coefficient
IMD	Index of Multiple Deprivation
IRR	Incidence Rate Ratio
LB M 3.0	Leefbaarometer version 3
LSOA	Lower Layer Super Output Area
MCA	Multiple Correspondence Analysis
MM	Maternal Mortality
MMR	Maternal Mortality Ratio
NHS	National Health Service
NMMSP	National Maternal Mortality Surveillance Programs
ONS	Office for National Statistics
OPCS-4	Office of Population Censuses and Surveys Classification of Interventions and Procedures, Version 4
OR	Odds Ratio
PAF	Population Attributable Fraction
PC4	4-digit postcode area, The Netherlands
PMMRC	Perinatal and Maternal Mortality Review Committee
RD	Risk Difference
RR	Risk Ratio
SES	Socioeconomic Status (chosen by the Addressing Inequalities in Maternity Services lived experience group to describe income, employment and education measures)
SES-WOA	Socioeconomic Status Prosperity, Education and Work (in Dutch)
SMM	Severe Maternal Morbidity
UK	United Kingdom (including England, Wales, Scotland and Northern Ireland)
US	United States of America
WHO	World Health Organisation

Glossary

Term	Definition
Average Adjusted Predictive Margin (AAPM)	A method in regression analysis to estimate the effect of a predictor variable while adjusting for other variables.
Case-control study	A type of observational study where two groups are compared. One group with the condition (cases) and another group without the condition (controls). The goal is to identify factors that may contribute to the condition.
Causal Mediation Analysis	A statistical method to evaluate how an independent variable influences an outcome through one or more mediator variables.
Cohort study	A type of longitudinal study that follows a group of people (cohort) over a period of time to study the effects of certain exposures or interventions on outcomes.
Confidence Interval	The confidence interval uses the sample to estimate the interval of probable values of the population. It shows the range of values in which the true estimate would fall if the study is repeated many times.
Cross-sectional study	A type of observational study that analyses data from a population at a specific point in time. It is often used to identify the prevalence of a condition or characteristic within a defined population.
Effect Modification	A situation where the effect of a primary exposure on an outcome differs depending on the level of another variable (moderator).
Ethnicity	Refers to the social group a person belongs to and is defined by shared characteristics such as culture, language, traditions and often a shared history.
Exploratory Factor Analysis (EFA)	A statistical method used to identify underlying relationships between observed variables by grouping them into factors based on unobserved variables.
Fixed Effects Model	Effects that are constant across different groups or subjects in a study, often representing the individual-level parameters in multi-level models.
Index of Heterogeneity (I^2)	A statistic used in meta-analysis to measure the percentage of variation across studies due to heterogeneity rather than chance. A higher I^2 indicates more variation.
Intra-class Correlation Coefficient (ICC)	A measure of the proportion of variance in a dependent variable that is explained by group-level differences.
Latent Variable/ Factor	An underlying construct inferred from the relationship between observed variables in an exploratory factor analysis.
Maternal Mortality Ratio (MMR)	The number of women who die from pregnancy-related causes while pregnant or within 42 days of pregnancy termination per 100,000 live births (World Health Organisation).
Maternity	A pregnancy resulting the in birth of one or more child (live or still birth)

Term	Definition
Meta-Analysis	A statistical technique that combines the results of multiple studies to arrive at a more precise estimate of the overall effect or relationship.
Multilevel Modelling	A statistical technique used to analyse data with multiple levels (e.g., individuals within groups). It accounts for the hierarchical structure of the data.
Multivariable Analysis	A statistical analysis method examining multiple variables simultaneously to understand their collective influence on an outcome.
Multiple Correspondence Analysis (MCA)	A statistical technique for analysing patterns in categorical data, identifying relationships between variables.
Multiparous	Having two or more pregnancies which resulted in birth to a viable fetus.
National Maternal Mortality Surveillance Report	A report that tracks and analyses maternal mortality data on a national level.
Nulliparous	Having never given birth to a viable infant.
P value	The p-value shows the likelihood of your data occurring under the null hypothesis. P-values help determine statistical significance.
Population Attributable Fraction (PAF)	A measure quantifying the proportion of a health outcome in the population attributed to a specific risk factor.
Prediction Interval	A range of values that estimates where future individual observations are likely to fall, based on existing data. It incorporates both within-study and between-study variability.
Primiparous	Having one pregnancy having never borne a child.
Random Effects Model	Variability in the data that is attributed to differences between groups, often modelled as random variables in multi-level models.
Risk	The probability of an event occurring within a specified time period in a given population, expressed as the proportion of individuals who experience the event out of the total at risk.
Risk Ratio	A measure of the relative risk of an event occurring in one group compared to another.
Severe Maternal Morbidity (SMM)	Unexpected outcomes of labour and delivery that can result in significant short- or long-term health consequences (Centres for Disease Control and Prevention definition).
Socioeconomic Deprivation	A condition where individuals or groups lack access to essential resources such as income, education, or a safe living environment compared to others in the same society. Used specifically in this thesis to describe deprivation measured using the Index of Multiple Deprivation.

Term	Definition
Socioeconomic Disadvantage	A more general term commonly used in the literature and policy to describe having less favourable social and economic circumstances than others in the same society. The term 'socioeconomic disadvantage' has increasingly replaced 'socioeconomic status' because it focuses more on the challenges and barriers faced by individuals or groups due to their economic and social conditions, rather than simply measuring their position in society.
Socioeconomic Position	An aggregate concept that includes both resource-based and prestige-based measures, as linked to both childhood and adult social class position.
Socioeconomic Status	An individual's or group's position within a hierarchical social structure, typically determined by factors such as income, education, occupation and access to resources, which influence their overall quality of life and opportunities. Socioeconomic status was used by the Addressing Inequalities in Maternity Services lived experience group in the labelling of one of the exploratory factor analysis variables as they discussed how it was easier to understand than 'socioeconomic disadvantage'.
Univariable Analysis	A statistical analysis examining one variable at a time, often used for summarising basic characteristics or trends.

Abstract

Background

Socioeconomic disadvantage is associated with severe maternal morbidity (SMM) and maternal mortality in high-income countries. However, previous studies in England primarily rely on neighbourhood-level deprivation data, which may lead to underestimating this association due to misclassification. The specific aspects of disadvantage contributing to the increased risk and the modifiable factors that could be targeted for intervention remain unclear.

Methods

A systematic review examined the relationship between socioeconomic disadvantage and SMM across high-income countries. Three analyses followed. First, English national Hospital Episode Statistics Admitted Patient Care (HES APC) data were used to assess how different Index of Multiple Deprivation (IMD) domains/subdomains are associated with SMM. Secondly, an exploratory factor analysis (EFA) was conducted using the separate indicators which constitute the IMD to facilitate a clear understanding of mediating pathways and examine the role of modifiable risk factors such as obesity, pre-existing medical and mental health problems and engagement with care. Finally, a nationwide database from the Netherlands, the Data InfrAstructure for ParEnts and childRen (DIAPER), was used to compare the findings from England to a second high-income country and to assess the role of neighbourhood- versus individual-level socioeconomic disadvantage in SMM risk.

Results

The review demonstrated a relatively consistent positive association between socioeconomic disadvantage and SMM across high-income countries, regardless of the level of the measure of disadvantage. English data showed that income and employment IMD domains were most

strongly associated with SMM, with adjusted risk ratios (RR) of 1.16 (95% confidence interval (CI) 1.12-1.20) and 1.15 (95% CI 1.11-1.19) in the neighbourhoods with the lowest income and employment rates compared to the highest, respectively. The EFA revealed two disadvantage dimensions: Traditional Socioeconomic status (SES) (income, employment and education) and Urban Deprivation (homelessness, household overcrowding, air pollution, road traffic accidents, English language proficiency and geographical barriers to services). The adjusted RR was 1.15 (95% CI 1.11-1.18) and 1.20 (95% CI 1.16-1.24) for women living in the most compared to the least Traditional SES and Urban Deprived areas, respectively. In the Dutch data analysis, the individual-level measure of disadvantage had a stronger association with SMM than neighbourhood-level measures, with low individual educational attainment showing the strongest association with SMM (aRR 1.41 95% CI 1.33-1.50). Obesity and pre-existing medical conditions mediated 20% and 14% of the Traditional SES-SMM relationship in England, respectively, and pre-existing conditions mediated 22% of the education-SMM association in the Netherlands. The association between disadvantage and SMM varied by ethnicity and migration status depending on the measure used.

Discussion

This study indicates that neighbourhood-level measures likely underestimate the association between socioeconomic disadvantage and SMM in England. Additionally, interventions addressing obesity and pre-existing medical problems could be important for reducing SMM disparities. Further research is necessary, focusing on more accurate disadvantage metrics in England, alongside studies which focus on interventions to address the modifiable risk factors identified in this thesis.

Acknowledgements

I would like to express my gratitude to my supervisors, Dr. Ramakrishnan, Dr. Goldacre, and Professor Knight. Completing this thesis would not have been possible without the time, effort and guidance they each provided. Their invaluable discussions, feedback and thorough reviews of my work were essential throughout the DPhil. Professor Knight has been a mentor from the very beginning, from offering encouragement during our first phone call right through until completion of this thesis. Dr. Goldacre's has consistently provided thoughtful insights, reviewed my work meticulously and played a key role in strengthening my programming skills. Dr. Ramakrishnan's support has been instrumental in me completing the DPhil. Whether offering statistical advice, reviewing my work or providing invaluable pastoral care, Dr. Ramakrishnan has always been there to guide me, not only academically but also personally. I would also like to extend my thanks to the lived experience group, whose insights and guidance played a crucial role in shaping and steering this project.

I want to express gratitude to my parents for their constant support and belief in my abilities. I am especially grateful to my sister Maddie, whose encouragement to apply for a DPhil at the University of Oxford helped me take that leap, without her advice, I might never have pursued this path. Finally, I would like to thank my husband, Alex. His support, whether taking on domestic tasks during busy periods, offering a calm presence or encouraging a healthy work-life balance, has made this experience much more manageable and enjoyable.

Chapter 1: Introduction

1.1 Background

1.1.1 Socioeconomic Position and Health Disparities

Socioeconomic position is frequently implicated as contributing to disparate health outcomes. Mueller and Parcel (1) defined socioeconomic position as 'the relative position of a family or individual on a hierarchical social structure, based on their access to or control over wealth, prestige and power'. Socioeconomic position encompasses a range of concepts including income, education, employment or neighbourhood environment which researchers can measure at multiple levels such as the individual-, neighbourhood- or regional-level.

Individuals with a higher socioeconomic position consistently exhibit better health outcomes than those of lower socioeconomic position, including in high-income countries with well-developed healthcare systems (2). Different mechanisms can explain this association and the pathways linking socioeconomic position and health are complex and often intersect. Material deprivation limits access to resources such as money for food or safe, warm housing. Individuals with a lower socioeconomic position are also more likely to experience stress (3) such as job insecurity, unemployment and crime exposure, which has been linked to poor mental and physical health (4). Individuals with a lower education may have lower health literacy through difficulties in information processing and critical thinking (5) and are more likely to be socialised into participating in unhealthy behaviours such as smoking or substance misuse (6). Environmental- and community-level mechanisms may also impact health outcomes. Individuals living in a disadvantaged neighbourhood are more likely to be exposed to environmental hazards such as unhealthy food environments, poor housing and air pollution (7). Stigma may also contribute, with healthcare workers behaving differently or providing different medical care based on their implicit bias and cultural stereotypes (8). These biases

can lower trust in the medical profession and reduce participation in healthcare, which compounds any increased risk (9).

1.1.2 Measuring Socioeconomic Position

Researchers and policymakers use various approaches to measure different dimensions of socioeconomic disadvantage, and the available data often determine the choice of measure. However, there is often little, if any, discussion of the specific way socioeconomic position might have exerted its influence within the context of the study outcomes (5). Furthermore, studies also show variation in the health impact of specific socioeconomic position measures among groups commonly examined in health disparities research. For example, in a study in the United States (US), mortality rates decreased with lower neighbourhood poverty levels, but the decrease varied by ethnicity (10). The various approaches to measuring socioeconomic position can be categorised as compositional, contextual or composite (5) and have different strengths and weaknesses, depending on the research question and the population under study.

1.1.2.1 Compositional Measures

Compositional measures are individual socioeconomic characteristics, such as income, education or occupation. These are often the measurements of choice as they can directly measure an individual's access to resources and social capital (11). However, compositional measures are also limited as they may not always capture community- and neighbourhood-level factors influencing health. Furthermore, compositional measures such as income or wealth include personal and sensitive data that an individual may not want to reveal due to the stigma or social norms (5).

There are strengths and limitations within each of the compositional socioeconomic position measures. Relative income allows access to material goods and services, which may influence health. However, income levels differ at different life course stages and do not vary monotonically with either prestige or power (1). Additionally, individual income may not necessarily reflect household income or wealth (1, 5, 12). Income is also often unavailable in administrative databases and has a higher nonresponse rate than other socioeconomic position measures (5). Education levels, on the other hand, are easy to measure, are stable beyond later adulthood and are less affected by diseases in adulthood than other individual-level measures. Educational attainment is especially likely to capture aspects of lifestyle and behaviours (5). However, education levels may differ across generations as education access has evolved. Older individuals typically have lower levels of higher education, which may not reflect their socioeconomic position (12). Education levels may also have different social meanings and consequences across cultures (5). Furthermore, there is considerable heterogeneity in income and occupation within each education level, which has also been shown to vary by ethnicity (1, 5). Employment status also has limitations where individuals may be unemployed because they have financial resources, allowing them not to work, or they may choose to be the primary caregivers for their children (13). This may be especially true when the employment status of a woman of childbearing age is used as a marker of socioeconomic position. Contrastingly, occupation may be a better measure of socioeconomic position and has been described as a greater structural link between education and income. Furthermore, occupation measures environmental and working conditions and the psychological demands of a job (5). However, occupational classes are comprised of heterogenous occupations with variations in income, education and prestige and most classifications were developed and validated on working men (1). Occupation measures may be particularly problematic in maternity research as they exclude homemakers and teenage mothers.

1.1.2.2 Contextual Measures

Contextual measures measure the socioeconomic characteristics of the environments in which individuals live, such as neighbourhoods. These ecological measures often use area-based indicators, such as the percentage of residents living below the poverty line. Contextual measures capture the wider social determinants of health and how living in a disadvantaged area may affect health outcomes beyond individual circumstances (5, 12). However, contextual measures are limited if they are used as proxies for individual socioeconomic position. This can lead to misclassification, where individuals with high individual socioeconomic position may be incorrectly categorised as having a low socioeconomic position if they reside in disadvantaged neighbourhoods. This is especially true for people who live in socioeconomically heterogeneous neighbourhoods such as London. They can vary in their accuracy depending upon the amount of time that has passed since these data were collected and the dynamic nature of the geographic area of interest (5). In addition, there is evidence of a higher rate of underreporting for minoritised ethnicities in census data, highlighting that the reliability of these data may differ among ethnic groups (5).

Despite this limitation, contextual measures are valuable in their own right, as the environment may lead to additional effects on health outcomes beyond individual disadvantage. For example, deprived areas are often associated with limited access to healthcare services, a poorer environment with less green space and reduced opportunities for physical or social activities, all of which contribute to worse health outcomes, even among those with relatively high individual socioeconomic position. Contextual disadvantage may further modify the effects of individual disadvantage, with individuals with lower individual socioeconomic position who live in deprived areas experiencing worse health outcomes than individuals with disadvantage at only one of these levels (14).

1.1.2.3 Composite Measures

Composite measures combine elements of compositional measures (such as individual income or employment status) and contextual measures (such as air pollution or neighbourhood housing quality) to provide a broader understanding of socioeconomic position (5). These measures help capture the multifaceted nature of socioeconomic position and may reflect both personal circumstances and the broader social or environmental contexts. However, like contextual measures, they are often measured at the neighbourhood level and, therefore, if used in research as a proxy for individual socioeconomic position, result in misclassification. Furthermore, composite measures may be challenging to interpret as they can hide heterogeneity within populations and also combine data from different levels. It has been argued (5), therefore, that using composite measures to design interventions is limited, as the specific characteristics associated with living in a disadvantaged area that might underlie disparities in health outcomes are unclear.

1.1.3 Maternal Mortality

Maternal mortality, defined as the death of a woman during pregnancy, birth or postnatally, serves as a window into the broader shortcomings of a healthcare system and society. Therefore, it not only devastates entire families, but its study is crucial for improving health equity and outcomes (15). The Maternal Mortality Ratio (MMR) measures the number of maternal deaths per 100,000 live births (16), which is directly or indirectly related to pregnancy. The MMR varies across countries with different levels of economic development. The MMR is less than ten in high-income countries such as Norway and Japan. In contrast, low-income countries such as Sierra Leone and the Central African Republic have an MMR of 1,360 and 860 per 100,000 live births, respectively (16). These stark global variations are driven by differences in healthcare access, infrastructure and socioeconomic challenges (16). However,

even within high-income countries with universal health systems free at the point of access and reliable resources, disparities between different social groups persist, with many high-income countries reporting minoritised ethnic and socioeconomically disadvantaged women at greater risk (16-21). However, as there are fortunately low numbers of maternal deaths in such countries, the study of the factors driving these disparities in maternal mortality is limited. Furthermore, a purely quantitative understanding of maternal mortality is insufficient. These numbers should be complemented by qualitative analyses, such as those found in confidential enquiries into maternal deaths, to explore the underlying factors contributing to the increased risk.

1.1.4 Severe Maternal Morbidity (SMM)

The World Health Organisation (22) recommends using SMM, rather than maternal mortality, as a more comprehensive indicator for monitoring healthcare quality across high-income countries. For every woman who dies from pregnancy-related complications, many more experience life-threatening injuries, such as postpartum haemorrhage, organ failure or eclampsia. These conditions are associated with high healthcare costs and also have both long-term physical and psychological impacts for women. As SMM cases are more frequent, studying SMM trends provides greater statistical power than maternal mortality. This allows for a more robust and granular level study of disparities in maternal health outcomes. The rate of SMM also varies across high-income countries. Studies in the US have shown that SMM occurs in 5-29 out of every 1000 live births (23, 24), while in the United Kingdom (UK) it is approximately 12-16 cases of SMM per 1000 maternities (a pregnancy resulting in the birth of one of more child) (25-27). These variations may be explained by differences in healthcare systems, demographics of the population, differing SMM definitions and how the data are compiled. As different countries and studies use different definitions of SMM, comparison

between countries is challenging (28). The World Health Organisation (WHO) developed the near-miss approach as a measure to identify and analyse cases in which women nearly died but survived a life-threatening complication in maternal health. The WHO defines a maternal near-miss using specific clinical, laboratory and management-based criteria, providing a standardised method to facilitate comparisons across settings and over time (29). However, the near-miss approach has several limitations. One major challenge is the reliance on access to detailed clinical data and diagnostic capacity, which may be limited in low-income countries (30), leading to under-identification or inconsistent reporting. Moreover, a study found that in the Netherlands, where advanced laboratory and clinical monitoring are available, organ dysfunction-based criteria of the maternal near-miss tool failed to identify nearly two-thirds of severe acute maternal morbidity cases and more than one-third of maternal deaths (31), highlighting that even in high-income countries, current WHO criteria may lack sufficient sensitivity to capture the full spectrum of life-threatening maternal complications.

In the UK, the Royal College of Obstetrics and Gynaecology (RCOG) uses process-focused maternal indicators (32). However, these indicators are limited, as process measures do not always reflect actual health outcomes and often fail to capture the broader context of the care setting. Alternatively, the UK Obstetric Surveillance System (UKOSS) records rare serious conditions or near-miss events through direct reporting from hospitals (33). While valuable, this approach also has limitations. The conditions it monitors are rare by definition and therefore it may have limited capacity to assess overall quality of maternity care or have sufficient power to detect trends.

Routinely collected administrative data may provide a resource-efficient alternative and SMM definitions have been designed to be used in such data, including the English Maternal

Morbidity Outcome Indicator (EMMOI) (27). The EMMOI is a list of procedures and diagnoses based on a validated Australian SMM indicator. It has been designed to capture various conditions whilst minimising false negatives as it is a composite outcome. However, the EMMOI has not been validated with clinical notes and omits certain key SMM conditions, such as postpartum haemorrhage, due to reliability concerns, as well as mental health-related morbidities, which were not included in the Australian indicator. Even though the EMMOI may not be fully comprehensive or reliable for the absolute incidence of SMM, it remains useful for trend monitoring and is relevant to high-income countries and has been designed to be used in English routinely collected data and was therefore chosen as the measure of SMM in this thesis.

1.1.5 Socioeconomic Position, Maternal Mortality and SMM

There are many known risk factors for maternal mortality and SMM in high-income countries, which may be associated with socioeconomic position. Pre-existing medical conditions such as diabetes, hypertension and cardiac disease are risk factors for maternal mortality and SMM (34). They are associated with health behaviours which may be more prevalent in women with a lower socioeconomic position, such as poor nutrition and smoking (3, 35). Obesity, which also disproportionately affects women with a lower socioeconomic position, further influences obstetric conditions such as venous thromboembolism, preeclampsia and gestational diabetes and is associated with increased rates of caesarean birth and surgical complications (36). Furthermore, women from disadvantaged socioeconomic backgrounds are more likely to experience psychosocial adversity, including exposure to domestic violence, mental health disorders and substance misuse, which have been shown to increase the risk of SMM and maternal mortality (17, 37, 38). Women with lower socioeconomic position may also receive poorer care or be treated disrespectfully by healthcare providers, further exacerbating poor maternal outcomes (39).

However, some factors associated with socioeconomic position may also be protective against maternal morbidity and mortality. Women of lower socioeconomic position tend to be younger, have singleton pregnancies and are likelier to be multiparous (40). Both primiparity and grand multiparity are regarded as risk factors for SMM and maternal mortality. Consequently, the fact that women of lower socioeconomic positions tend to have larger families may offer some reduction in SMM risk, but only up to a certain number of pregnancies. Advanced maternal age increases the risk of conditions such as gestational diabetes, preeclampsia and caesarean birth, all of which may contribute to higher morbidity and mortality rates (41). Furthermore, a greater proportion of women with a higher socioeconomic position undergo fertility treatment, which increases the risk of multiple pregnancies. This, in turn, elevates the risk of SMM and maternal mortality (42).

Women from minoritised ethnic groups are at an elevated risk of both SMM and maternal mortality, with studies consistently showing that they face poorer maternal health outcomes compared to White women (17, 26, 43, 44). The specific causes of the increased risk of maternal mortality for minoritised ethnic women are complex and thought to be driven by a combination of genetic, cultural and structural determinants (44). Furthermore, in many high-income countries, including the UK and the US, people from minoritised ethnic groups are more likely to experience socioeconomic disadvantage (45). In England, for White women, a dose-response relationship has been demonstrated between increasing levels of deprivation and risk of maternal mortality (44). However, there is insufficient evidence to indicate a dose-response relationship for women from minoritised ethnic backgrounds, although this may be due to low statistical power given the small number of women who died in each of the minoritised ethnic groups. Moreover, various measures of socioeconomic disadvantage have

been described in the literature as reflecting how different measures of disadvantage may vary in their application to different ethnic groups (5). However, the ways in which different socioeconomic position measures intersect with ethnicity concerning any increased risk of adverse maternal health outcomes are currently unknown.

1.2 Research Rationale

In high-income countries, the associations between socioeconomic disadvantage and adverse maternal health outcomes such as maternal mortality and SMM appear to be widening (17, 22, 46). Researchers frequently rely on administrative data to explore these disparities, as such datasets provide large, representative samples and are a cost-effective research resource. Despite this, there are significant gaps in our understanding. Specifically, it is unclear whether the neighbourhood-level composite measures of socioeconomic position often available in such databases are sufficient to capture the full extent of the disparities related to socioeconomic position. Furthermore, it is currently unclear which groups of women with a lower socioeconomic position are most at risk, what factors amplify these risks and the mediating pathways driving adverse outcomes. Moreover, the intersection between socioeconomic position and ethnicity remains poorly understood. Addressing these knowledge gaps is essential to developing targeted interventions and policies to mitigate maternal health inequities.

1.3 Aim and Objectives of Thesis

1.3.1 Aim

The aim of this thesis is to determine the association between socioeconomic disadvantage and SMM in high-income countries, focusing on England and the Netherlands. It will compare the strength of the association between the different measures of socioeconomic disadvantage and SMM, and how the association between each disadvantage measure and SMM may vary across

different ethnic groups. This aims to identify the groups of women who are most at risk of SMM and therefore may benefit most from an intervention. Additionally, the thesis aims to identify the role of modifiable risk factors that could inform targeted public health interventions to reduce any increased risk of SMM in the most at risk populations.

1.3.2 Objectives

1. To synthesise and critically evaluate the evidence regarding disparities in SMM and maternal mortality between socioeconomically disadvantaged women and those from more advantaged socioeconomic backgrounds in high-income countries through a systematic review and meta-analysis. Additionally, to identify the strength of the association between different measures of socioeconomic disadvantage, and SMM and maternal mortality.

2. To investigate the relationship between different aspects of neighbourhood deprivation (such as income, employment, education and housing) and SMM in England, identifying which specific aspects of neighbourhood-level deprivation most strongly contribute to an increased SMM risk.

3. To explore whether the neighbourhood-level socioeconomic trends observed in England are replicated in a similar high-income European country, the Netherlands.

4. To investigate the impact of neighbourhood-level versus individual-level socioeconomic disadvantage on the risk of SMM in the Netherlands, with the aim of better understanding the limitations of using neighbourhood-level disadvantage measures in SMM research.

5. To investigate how the association between socioeconomic disadvantage and SMM varies across ethnic groups in England, and ethnic and migrant groups in the Netherlands, exploring whether certain socioeconomic measures have a stronger or weaker association with SMM in different ethnic or migrant populations.

6. To quantify the proportion of SMM attributable to each measure of socioeconomic disadvantage**,** as well as the combined effects of socioeconomic disadvantage and ethnicity in England, and socioeconomic disadvantage, ethnicity and migration status in the Netherlands.

7. To explore the role of modifiable factors, such as obesity, pre-existing medical and mental health problems and engagement with care that may be mediators on the pathway between socioeconomic disadvantage and SMM, that could be targeted for public health interventions in high-income countries.

Chapter 2: Lived Experience Group: Addressing Inequalities in Maternity Services (AIMS)

2.1 Background

A lived experience group was established, consisting of six women with recent pregnancies who had faced multiple forms of socioeconomic disadvantage, to guide and develop this research. This group was formed through collaboration with Birth Companions (47). This charity works to improve the lives of pregnant women and babies experiencing disadvantage, including involvement in the criminal justice system, refugees, asylum seekers or social care involvement. The same six women were involved throughout the study and met every four to six months. The recruitment and involvement of the lived experience group used the United Kingdom (UK) standards for public involvement framework (48), which emphasises inclusive opportunities, collaboration, support and learning, governance, communications, and impact. Birth Companions recruited the women and provided travel and childcare expenses, translation services, and additional psychological support for the women if required. A research facilitator was also present at all meetings to ensure women felt safe and supported during the meetings.

2.2 Methods

The women were initially trained on the strengths and limitations of routine healthcare data. This allowed for a discussion regarding the use of such data for research purposes and the ethical implications of using anonymised social data, such as data on income, domestic abuse, neighbourhood deprivation, mental health, employment and education status, collected as part of routine care without explicit consent.

The lived experience group have identified future research priorities and will assist with disseminating the study findings. They have guided the creation of an infographic to make the

findings accessible. The women have been consulted on how the research should be shared through various communication channels, including social media platforms, to help the results be understood and accessible to the communities most impacted by the issues explored in this study.

2.3 Results

The women chose the name AIMS (Addressing Inequalities in Maternity Services) for their group and developed a logo. They expressed satisfaction with the study design and described how they were comfortable with routinely collected administrative data being used and shared for this study. The women provided feedback on the objectives of the thesis and emphasised how a better understanding of the intersection of socioeconomic position with ethnicity was a priority. The objectives to explore whether the association between socioeconomic disadvantage and SMM varied by ethnic group (**Objective 5**), and to calculate population attributable fractions using White least deprived women as the reference group (**Objective 6**) was subsequently added to thesis based on this recommendation. They also helped name the factors identified from the exploratory factor analysis (EFA) described in more detail in **Chapter 5**.

When the collection of individual-level measures of socioeconomic position was discussed, they explained how they would be willing to share personal information if it could assist in their treatment or for research purposes, provided this could lead to better outcomes for other women. The group discussed what type of socioeconomic information they would feel the most comfortable disclosing. They described their preference for discreet methods of collecting sensitive personal information, such as social factors, which could be gathered via an iPad in

the waiting room rather than be directly asked by maternity staff. However, the women expressed that they wanted to directly understand the purpose of collecting such data.

2.4 Reflection

Including a lived experience group in this research was valuable and challenging. Engaging a third-party organisation such as Birth Companions proved highly beneficial, as they assisted with logistics, and the women also had trust in this organisation. Many of the women had faced negative experiences with public institutions, including in hospitals, as well as from healthcare workers during pregnancy and childbirth. Consequently, ensuring they felt comfortable discussing difficult issues with me, both a doctor and a researcher, was essential.

Planning how the women would participate in the research posed challenges, as there is often limited scope in certain aspects of data-driven research to adapt the study design. Moreover, consulting with the group on the nuances of the data required careful and clear communication, which was particularly challenging given that the participants had varying levels of familiarity with healthcare systems and data use. Nevertheless, the time invested in training the group on the strengths and limitations of routine healthcare data seemed beneficial, and the women grew more confident in discussing how their information would be used.

The women described their own experiences of pregnancy and childbirth whilst facing multiple disadvantages such as homelessness or being involved in the criminal justice system, and how their experience of socioeconomic disadvantage intersected with their ethnicity. Their input, therefore, not only validated the acceptability of using the data for this type of research and

added context to the data, but also identified areas for further exploration, which resulted in significant revisions to the thesis objectives.

Chapter 3: The Association Between Socioeconomic Disadvantage and Severe Maternal Morbidity (SMM) and Mortality in High-Income Countries: A Systematic Review

3.1 Background

Across high-income countries, the rates of adverse maternal health outcomes, including SMM and maternal mortality, have declined (22). However, studies have shown that disparities in outcomes between women of different social circumstances are widening (17, 46). Most research examining the association between socioeconomic position and adverse maternal health outcomes has tended to treat socioeconomic position as a singular construct, often measured using only one indicator at a single level (e.g. regional-, neighbourhood- or individual-level). Individual-level measures of socioeconomic position help reflect personal circumstances, while neighbourhood-level measures may measure broader structural and environmental influences. However, as described previously, neighbourhood-level measures may misclassify women if used as a proxy for individual socioeconomic disadvantage, as their surrounding area may not accurately capture an individual's socioeconomic position. Therefore, the strength of the association may be biased towards the null. Moreover, even individual-level measures such as low income, low educational attainment, or unemployment may have different causal pathways and varying associations with adverse maternal outcomes. Currently, it remains unclear which disadvantage measures are most strongly associated with severe maternal morbidity (SMM) and maternal mortality and the impact of whether the measurement is at the individual or neighbourhood level.

3.2 Aim and Objectives

3.2.1 Aim

This systematic review, therefore, aims to summarise and critically evaluate the evidence regarding the association between socioeconomic disadvantage and maternal mortality across various high-income settings. The study aims to clarify how various measures of socioeconomic disadvantage are associated with maternal mortality and SMM, seeking to better understand which aspects of disadvantage are most affective to target for evidence-based interventions to reduce disparities in maternal health outcomes.

3.3.2 Objectives

1. To synthesise the evidence for the association between socioeconomic disadvantage and SMM and maternal mortality in high-income settings, and to evaluate whether there was a consistent direction of association across different countries, populations, political, welfare and healthcare systems, and study designs (**Thesis Objective 1**).

2. To determine whether any specific aspect of socioeconomic disadvantage is more strongly associated with SMM and maternal mortality, with a specific focus on a comparison between individual-level and neighbourhood-level disadvantages (**Thesis Objective 1**).

3.3 Methods

The systematic review was registered with the International Prospective Register of Systematic Reviews (PROSPERO) CRD42023399267. This database is where systematic reviews and meta-analyses are registered to ensure transparency and avoid duplication in research efforts. Methods for the review were based on the Cochrane Collaboration's Handbook for Systematic Reviews of Health Promotion and Public Health Interventions. They followed Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) and Meta-analyses of Observational Studies in Epidemiology guidelines for systematic review and meta-analysis.

3.3.1 Study Inclusion and Exclusion Criteria

The population, intervention/exposure, comparator, outcome, and study design for the study are shown in **Table 3.1**. The population were women who were either pregnant or up to 1 year postpartum in a high-income (Organisation for Economic Co-operation and Development (OECD)) country. The OECD is a forum where most countries have high-income economies, are ranked as 'very high' in the Human Development Index and are regarded as developed countries. Studies that reported the association between socioeconomic disadvantage measured using Shavers'(5) definition (**Appendix Table 3.1)** and maternal mortality or SMM were included. The study exclusion criteria are shown in **Table 3.1**.

Peer-reviewed papers from observational (cohort, cross-sectional or case-control) studies were included if they reported an association between socioeconomic disadvantage and SMM or maternal mortality, included a comparator group, and followed the Population, Exposure, Comparison, Outcome, Study Design (PECOS) framework. Reports from National Maternal Mortality Surveillance Programmes and peer-reviewed published posters and conference proceedings were included.

Table 3.1. Population, Exposure, Comparison, Outcome, Study Design (PECOS)

Population	Inclusion criteria: Women who were either pregnant or up to 1 year postpartum in a high-income country. A high-income country was defined as a country belonging to the OECD. Exclusion criteria: To focus on interventions in the context of universal health coverage such as the National Health Service (NHS), studies/ interventions related to health insurance cover/ eligibility for Medicaid were excluded. Studies undertaken in low- or middle- income countries (not OECD) were also excluded.
Exposure	Inclusion criteria: Studies that reported socioeconomic disadvantage using the definition by Shavers (5) which encompasses compositional, contextual and composite measures of socioeconomic position. A more detailed breakdown of this definition is provided in **Appendix Table 3.1**. Exclusion criteria: Studies that focused exclusively on broader geographical areas, such as states or countries, were excluded from the review. This was because the focus of this review is on the association between individual-, household- and neighbourhood-level socioeconomic disadvantage and SMM and maternal mortality, rather than directly comparing the association between socioeconomic disadvantage and SMM and mortality related to different social and political systems. Studies were excluded if the focused exclusively on migration, refugee/asylum seeker status, ethnicity, urban/rural or distance to hospital as these risk factors are not direct measures of socioeconomic position.
Comparison	Studies with individual-level, household-level or neighbourhood-level exposures that compare low to high socioeconomic disadvantage.
Outcome	Primary Outcome: SMM. Variant terms and synonymous terminologies of SMM and maternal near-miss were included (**Appendix Table 3.2**). Studies were only included if they used a composite outcome of two or more life-threating maternal conditions. The list of the conditions was based on the World Health Organisation (WHO) near-miss criteria (29) and the list of the procedures and diagnoses from the English Maternal Morbidity Outcome Indicator (27) (EMMOI). Secondary Outcome: Maternal mortality. The WHO definition for maternal mortality was used which includes a female death of any cause related to or aggravated by pregnancy and its management (excluding accidental or incidental causes) during pregnancy or childbirth or within 42 days of terminating a pregnancy (16). However, if a study also included accidental/incidental deaths as well as deaths which can be defined as maternal mortality using the WHO definition, the study was included as it was assumed that the number of accidental/incidental deaths would be low. Furthermore, studies that reported 'late maternal deaths'- any pregnancy related deaths from 42 days up to one-year post-partum were also included. Studies which used the outcome of 'late maternal deaths' or accidental/incidental deaths alone were excluded.

Table 3.1. (Continued)

Study type	Inclusion criteria: Studies were included if they were observational (cohort, cross-sectional or case-control studies) and included a comparator group. These studies were only included if they had been peer-reviewed and followed the PECOS framework. Reports from National Maternal Mortality Surveillance Programmes were also included. Published posters and conference proceedings were included if they have been published in peer-reviewed format. For articles published in a language other than English, the authors were contacted for English-language summaries; if unavailable, the abstracts were translated and the English-language abstracts were included in the review. Exclusion criteria: Case series/reports, editorial reviews, letter of communications, commentaries, studies with small sample size (n<10), and qualitative studies. If a report from a National Maternal Mortality Surveillance Programme included data which was also included in full in another study, it was excluded.

3.3.2 Database Search

A comprehensive search was conducted in MEDLINE, EMBASE, CINAHL and PsycINFO databases alongside OECD country National Maternal Mortality Surveillance Programmes. The start date was 1 January 2000, as this coincided with the introduction of the Millennium Development Goals (49). Studies were limited to humans with no language limits and full-text availability. Reference lists were screened for studies not included in the database search, and relevant systematic reviews were assessed. Google Scholar was used to search for grey literature. Search strategies were built using controlled vocabulary and free-text terms, with input from an experienced clinical librarian. See **Appendix Table 3.2** for details of the search strategy.

3.3.3 Data Management

Studies were extracted to Covidence (50) and duplicates were removed. For all review stages, the author of this thesis was the first reviewer, and BO, SB, LT, TB, and RK[1] were the second

[1] Blessing Omorodion, Sofia Baldelli, Lucy Thompson, Thomas Bentley, Roshan Karthikappallil,

reviewers. MK and RR[2] acted as the third reviewers, resolving disputes. Titles and abstracts were screened, and the full text of potentially eligible studies was retrieved and independently assessed by two reviewers. Translations were used for abstract screening for articles published in a language other than English.

A standardised form was used to extract data to assess study quality and evidence synthesis (**Appendix Table 3.3**). Where a study did not report a relative measure of effect (e.g., risk ratio (RR)), this was calculated where sufficient information was provided.

3.3.4 Risk of Bias Assessment

The risk of bias was assessed using a modified Newcastle-Ottawa scale (51) applicable to pregnancy research (52) and cross-sectional studies and assessed the risk of bias of the result rather than the study quality. For each domain, studies were rated as having either *low, some concerns, high* or *unknown* risk of bias based on the selection of the study population, measurement of exposure and outcomes, comparability and missing data (**Appendix Tables 3.4, 3.5 and 3.6**).

3.3.5 Data Analysis

Meta-analysis was performed for studies with the same measure of socioeconomic disadvantage, comparator and outcome of either SMM or maternal mortality if the data were available. If a study reported the result for SMM combined with maternal mortality as the outcome, it was included in the SMM analysis only. If two studies with overlapping cohorts used the same exposure and outcome, the study with the largest population was included. A random effects model using the DerSimonian and Laird approach was used due to the high heterogeneity between studies. Odds ratios (ORs) and their associated 95% confidence

[2] Marian Knight, Rema Ramakrishnan

intervals (95% CI) are presented for binary outcomes, as this was the most frequently reported measure. Where required, ORs were recalculated using reported frequency data into more comparable socioeconomic disadvantage categories. Given the availability of the data, only unadjusted summary ORs were calculated.

Heterogeneity was assessed using the I^2 statistic and prediction interval. An I^2 value greater than 50% indicated substantial heterogeneity, and 75% was considered considerable heterogeneity (53). A prediction interval is well suited to evaluate the variability of an intervention's effect over different settings because it provides a predicted range for the actual treatment effect in a future individual study (54).

A narrative synthesis of the findings from the included studies, structured around the different definitions of socioeconomic disadvantage and type of outcome, was undertaken, with key findings tabulated. Summaries of exposure effects for each study were presented as ORs or RRs for dichotomous outcomes and standardised mean differences for continuous outcomes, depending on what was most appropriate based on the availability of studies. Relationships between studies were reported by discussing similarities and contradictions, including the statistical significance and direction of effect. For the narrative summary, if two studies had overlapping cohorts but were not identical in the study design, both results were reported.

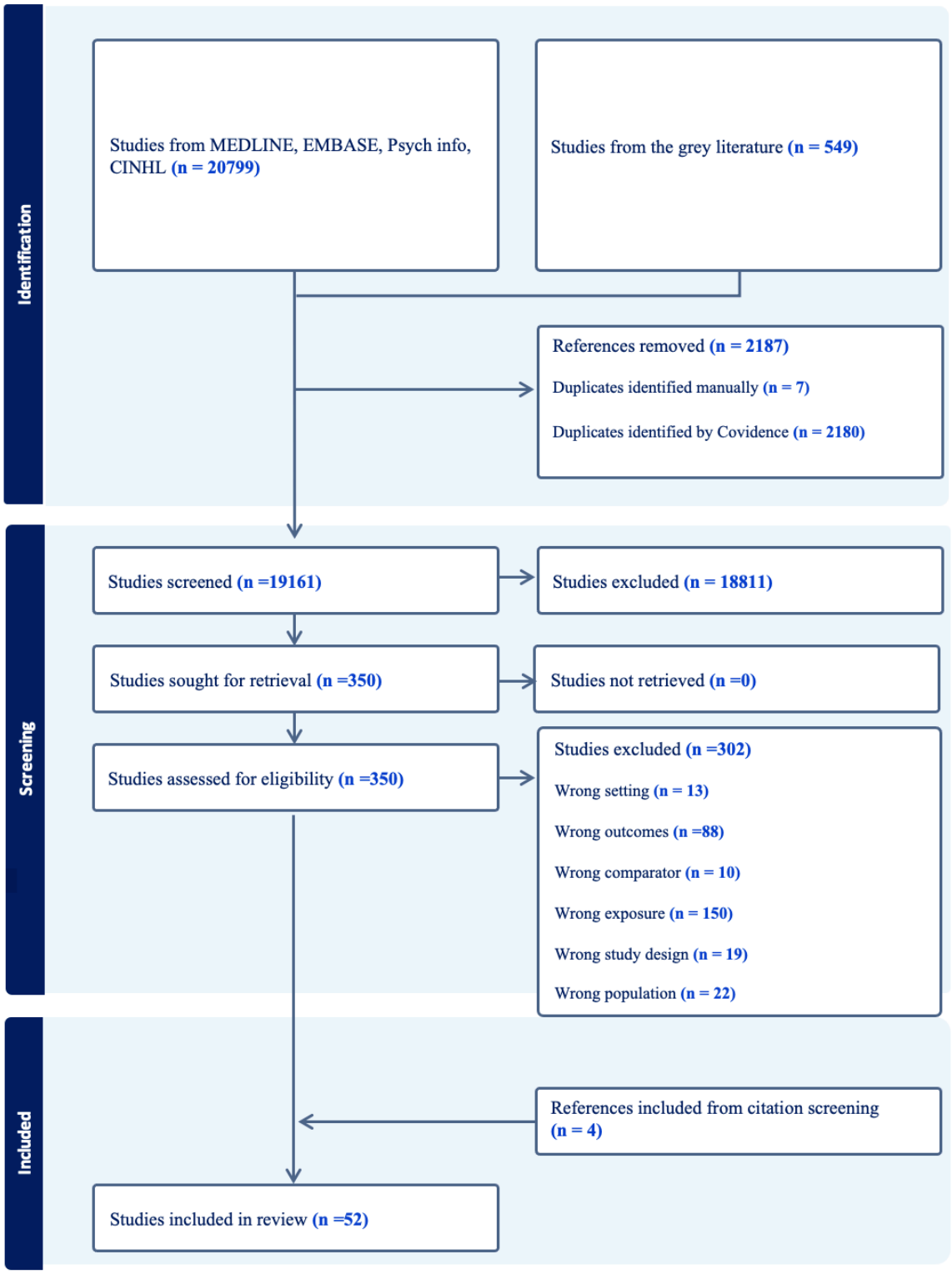
A harvest plot was used to summarise the findings from all the studies, including those that could not be included in the meta-analysis. The plots were stratified by statistical significance, and the height of the bar corresponded to the percentage measure of association. Summaries for each study were presented as a percentage change in the ORs or RRs depending on what was most appropriate based on the availability of studies. A narrative summary was used to report the findings from studies that did not have a dichotomous outcome and, therefore, could not be included in the harvest plot or the meta-analysis.

Meta-analyses were conducted using Stata V.17.0 (Stata Corp. 2021, Stata Statistical Software: Release 17, College Station, Texas, USA: StataCorp LLC).

3.4 Results

After removing duplicates, 18,612 studies were identified from database searches. A further 549 articles from grey literature were screened. 18,811 were excluded after title and abstract screening. Four additional studies were added to the final list from citation searching. In the final review, 52 studies were included, 40 of which were included in the meta-analysis. Ten studies reported data from overlapping cohorts and were included in the harvest plot if there was no perfect overlap between studies. The PRISMA flow diagram is shown in **Figure 3.1**.

Figure 3.1. PRISMA flow diagram



3.4.1 Characteristics of Included Studies

Tables 3.2 and Appendix Table 3.7 summarise the characteristics of the included studies. 34 studies reported SMM as the outcome, and 20 reported maternal mortality (two studies reported both maternal mortality and SMM independently). There were 31 cohort studies, 10 case-control studies, four cross-sectional studies, and seven National Maternal Mortality Surveillance Programmes. The studies were conducted in various countries, with the highest number (26) from the United States (US).

The studies used a range of measures of socioeconomic disadvantage, with the most common being neighbourhood deprivation (15 studies), individual educational attainment (13 studies) and neighbourhood income (13 studies). Different definitions were reported for SMM and maternal mortality, with the most common being the Centre for Disease Control and Prevention (CDC) definition (23 studies) and the International Statistical Classification of Diseases, 10th Revision definition (ICD-10) (11 studies) for SMM and maternal mortality, respectively (**Table 3**).

Table 3.2. Descriptive statistics of the exposure and outcome of included studies (Studies in italics had overlapping cohorts with other studies in the systematic review and had smaller sample sizes and, therefore, not included in the meta-analysis). If maternal deaths were included in the outcome with SMM and for this review, the study was counted as reporting SMM only as the number of maternal mortality was small compared to the number of SMM. Abbreviations in a footnote at the end of the table.

Country	Author, year	Description of exposure	Definition: SMM/ maternal mortality	Total number of participants	Prevalence of SMM
Australia	Adane, 2020 (55)	Neighbourhood deprivation - IRSD	AMMOI - modified to include blood transfusion	410043	2.29%
	AIHW, 2020 (19)	Neighbourhood deprivation – IRSD	ICD-10 maternal mortality	915610	MMR 6.4/100000; 59 deaths
	Lindquist (a), 2015 (56)	Neighbourhood deprivation – IRSD	Composite of five SMM conditions	1443	623 cases, 820 controls
	Lindquist (b), 2015 (57)	Neighbourhood deprivation - IRSD	AMMOI	211060	1119 cases, 209941 controls
Canada	Aoyama, 2019 (58)	Neighbourhood median household income from zip code	SMM - Canadian Perinatal Surveillance System (34 conditions); ICD-10 maternal mortality	3162303	SMM 17.7/ 1000 ; MMR 6.2/100000
	Ray, 2018 (59)	Neighbourhood median household income from zip code	All cause maternal mortality at birth or up to 42 days after	1953943	181 deaths
	Snelgrove, 2021 (60)	Neighbourhood poverty	Composite of conditions of SMM (+ direct obstetric death)	1048845	SMM 18/1000
France	Azria, 2016 (61)	Composite of social deprivation	Composite of 13 SMM conditions (+ maternal mortality)	9312	Deprivation: SMM 7.5% No deprivation: 8.4%
	Sante Publique, 2021 (62)	Composite of social vulnerability	ICD-10 maternal mortality and 1 year	2431552	MMR 10.8/1000000
	Saucedo, 2012 (63)	Employment	maternal mortality - Postnatal death within 42 days	14497	286 cases, 14211 controls
Germany	David, 2019 (64)	Educational attainment	Composite of SMM conditions	7100	n/a

Table 3.2. (Continued)

Country	Author, year	Description of exposure	Definition: SMM/ maternal mortality	Total number of participants	Prevalence of SMM
Ireland	Lutomski, 2012 (65)	Medical card status (proxy for low income)	AMMOI	330955	SMM 13/10000
Italy	Donati, 2018 (66)	Educational attainment	ICD-10 maternal mortality	301288	MMR 9.18/1000000 320 deaths
Mexico	Romero-Gutierrez, 2007 (67)	Employment	ICD-10 maternal mortality	550	110 cases, 440 controls
New Zealand	PMMRC, 2022 (20)	Neighbourhood Deprivation - NZDep 2006	ICD-10 maternal mortality	930021	MMR 7.75/100000; 35 deaths
South Korea	Jeong, 2020 (68)	Household income, employment	ICD-10 maternal mortality (and within 1 year but ICD-10 maternal mortality result reported in this systematic review)	3334663	MMR 10.59/100000; 353 deaths
	Nam, 2022 (69)	Household income	CDC ICD 9 / ICD-10 SMM, ACOG SMM (excluded prolonged length of hospital stay) and Zwart et al SMM, EURONET-SAMM	6421091	CDC: 151533 events (2.36%) ACOG: 200090 events (3.12%) Zwart et al: 20084 events (0.3%) Euro Peristat: 87452 events (1.36%)
The Netherlands	De Graaf, 2012 (18)	Neighbourhood deprivation - 40 neighbourhoods labelled as deprived by Dutch government	ICD-10 maternal mortality	3108235	MMR 10.8/100000
United Kingdom	Lewis, 2004 (70)	Occupation – (NE-SEC partners occupation)	ICD-10 maternal mortality	1997472	MMR 13.1/100000
	Lewis, 2007 (71)	Employment, occupation (NS-SEC from partner), Deprivation (IMD)	ICD-10 maternal mortality	1753760	MMR 14/100000
	Lewis, 2011 (72)	Employment, occupation (NS-SEC from woman), Deprivation (IMD)	ICD-10 maternal mortality	2248000	MMR 11.39/100000

Table 3.2. (Continued)

Country	Author, year	Description of exposure	Definition: SMM/ maternal mortality	Total number of participants	Prevalence of SMM
United Kingdom (continued)	*Knight, 2009* (73)	*Occupation - NS-SEC (woman, if unemployed then partners occupation)*	*Composite of five SMM conditions*	*1913*	*686 cases, 1227 controls*
	Knight, 2020 (74)	Neighbourhood deprivation - IMD	ICD-10 maternal mortality	1741005	2009-2011: 10.63/100000; 253 deaths 2012-2014: 8.5/100000; 241 deaths 2015-2017: 9.2/100000; 240 deaths
	Lindquist, 2013 (75)	Occupation - NS-SEC (woman)	Composite of six SMM conditions	3400	1144 cases, 2256 controls
	Knight, 2022 (76)	Neighbourhood deprivation - IMD	ICD-10 maternal mortality	1681020	MMR 10.9/100000; 229 deaths
	Nair, 2016 (77)	Employment	ICD-10 maternal mortality	1899	383 cases, 1516 controls
United States	Campbell, 2013 (78)	Employment, education	Maternal mortality at delivery hospitalisation	1084862	MMR 12.12/100000; 132 deaths
	Creanga, 2014 (79)	Neighbourhood income - Neighbourhood median household income quintile from zip code	CDC ICD 9 SMM	3476392	SMM 150.7/10000**
	Frederiksen, 2017 (80)	Educational attainment	CDC ICD 9 SMM (accounting for hospital length of stay)	196788	SMM 105/10000**
	Freese, 2020 (81)	Educational attainment	CDC ICD 9 SMM	86429	SMM 2.00%
	Friedman, 2016 (23)	*Neighbourhood income – Neighbourhood median household income quintile from zip code*	*Composite of 15 SMM conditions*	*50433539*	*SMM 0.57%*
	Frolich, 2014 (82)	Neighbourhood income - Neighbourhood median household income quartile from zipcode	ICD-10 maternal mortality (also included coincidental)	231	77 cases ,154 controls

Table 3.2. (Continued)

Country	Author, year	Description of exposure	Definition: SMM/ maternal mortality	Total number of participants	Prevalence of SMM
United States (continued)	Goffman, 2007 *(83)*	Educational attainment	Composite of SMM conditions including admission to intensive care (+ maternal mortality up to 1-year postpartum)	308	77 cases, 231 controls; (8 deaths and 69 SMM)
	Gray, 2012 (84)	Educational attainment	CDC ICD 9 SMM + 3 day hospital stay	50597	9485 cases, 41112 controls
	Guglielminotti, 2021 (85)	*Neighbourhood income - Neighbourhood median household income quartile from zipcode*	*CDC ICD 9 SMM*	*2286975*	*SMM 13.4/1000*
	Howland, 2019 (86)	Educational attainment, neighbourhood poverty (% of residents living below the federal poverty level)	CDC ICD 9 SMM (if length of stay in the 90th centile for delivery method or transferred or died)	588232	SMM: 229.6/10000
	Huang, 2023 (87)	Housing insecurity	*CDC ICD-10 SMM* maternal mortality during hospitalisation	539950	SMM: *Housing secure**: 2.3%* *Housing insecure**: 4.8%* MMR 26.3/1000000
	Janevic, 2020 (88)	The Index of Concentration at the Extremes (Neighbourhood income)	CDC ICD 9 SMM	316600	2.6%
	Kozhimannil, 2019 (89)	*Neighbourhood median household income quartile from zipcode*	*CDC ICD 9 SMM*	*6793342*	*SMM: Rural: 140/10000; SMM: Urban: 135/10000*
	Leonard, 2022 (90)	*Individual educational attainment*	*CDC ICD-10 SMM*	*3308554*	*SMM 1.61%*
	Leonard, 2019 (91)	Individual educational attainment	CDC ICD-10 SMM	3556206	SMM: 1.35%
	Luke, 2020 (92)	Neighbourhood median household income quartile from zipcode	CDC ICD 9/ ICD-10 SMM (+ ICD-10 maternal mortality)	4494089	SMM: Lowest quartile: (2.14%) SMM: Top three quartiles: (1.64%)
	Matas, 2021 (93)	Neighbourhood median household income quartile from zipcode	CDC ICD-10 SMM	6193852	101757 events (1.64%)

Table 3.2. (Continued)

Country	Author, year	Description of exposure	Definition: SMM/ maternal mortality	Total number of participants	Prevalence of SMM
United States (continued)	Meeker, 2021 (94)	Neighbourhood crime (%), housing (% housing violations and percent of owner occupied housing), education (% women graduate high school), income (% women receiving public assistance income), poverty (% women below the 100% poverty level), and employment (% women who are in the labour force)	CDC ICD 9/ ICD-10 SMM	63334	11726 events (2.73%)
	Muchomba, 2021 (95)	Educational attainment, municipality level deprivation	CDC ICD9/ ICD-10 SMM	1001410	SMM 199/10000
	Muchomba, 2022 (96)	Municipal-level housing - Municipal-level rental costs relative to income (housing cost burden)	CDC ICD 9/ ICD-10 SMM	1004000	SMM 199/10000
	Oot, 2021 (24)	Neighbourhood poverty - ZCTA % of poverty households	CDC ICD-10 SMM	421426	2.8%
	Petersen, 2019 (97)	Educational attainment	maternal mortality during pregnancy or 1 year after delivery		N/A
	Reid, 2018 (98)	Neighbourhood income (median household income quartile from zipcode), poverty (ZCTA % of poverty households), and educational attainment (%women no high school diploma)	CDC ICD 9 SMM	364113	SMM: 197/10000
	Snowden, 2021 (28)	Educational attainment	CDC ICD-10 SMM	3049774	1.3%
	Staniczenko, 2022 (99)	Unstable housing	CDC ICD 9/ ICD-10 SMM	73100000	N/A
	Tipre, 2022 (100)	Neighbourhood deprivation - Area deprivation index (ADI)	ICD-10 SMM	32909	SMM 9.8% – 26 were maternal mortality

Abbreivations: IRSD: Index of Relative Socioeconomic Deprivation, AMMOI: Australian maternal morbidity outcome indicator, SMM: Severe maternal morbidity, ICD-9/10: International Statistical Classification of Diseases and Related Health Problems 9th or 10th Revision. MMR: maternal mortality ratio, N/A: unavailable, ACOG: The American College of Obstetrics and gynaecology, IMD: Index of Multiple Deprivation, NS-SEC: National Statistics Socio-economic Classification, CDC: Centres for Disease Control and Prevention, ZCTA: zip code area

***Worked out from rate and N study population.*

Table 3.3. Characteristics of included studies

	SMM	Maternal mortality
Study design	- 24 Cohort - 6 Case Control - 4 Cross Sectional	- 8 Cohort - 5 Case Control - 7 National Maternal Mortality Surveillance Programs
Location	- 3 Australia - 2 Canada - 1 Germany - 1 France - 1 Ireland - 1 South Korea - 2 United Kingdom - 23 United States	- 1 Australia - 2 Canada - 2 France - 1 Italy - 1 Mexico - 1 New Zealand - 1 South Korea - 1 The Netherlands - 6 United Kingdom - 4 United States
Population characteristics	- 31 All women giving birth - 2 Primiparous women giving birth - 1 Postnatal woman	- 7 All women giving birth - 13 All maternities
Definition of outcome	- 3 AMMOI - 22 CDC - 9 Other	- 11 ICD-10 maternal mortality - 2 ICD-10 maternal mortality + 1 year - 1 Postnatal death up to 42 days - 6 Other
Exposure	- 6 Neighbourhood deprivation - 10 Neighbourhood income - 4 Neighbourhood poverty - 2 Neighbourhood educational attainment - 10 Individual educational attainment - 2 Individual/ household income - 2 Individual housing - 2 Neighbourhood housing - 1 Neighbourhood crime - 1 Neighbourhood employment - 2 Individual occupation - 1 Individual social deprivation	- 9 Neighbourhood deprivation - 2 Neighbourhood income - 3 Individual education - 1 Household income - 3 Individual occupation - 7 Individual employment - 1 Individual social vulnerability - 1 Individual housing

**Abbreviations: ICD-10: International Statistical Classification of Diseases and Related Health Problems 10th Revision., AMMOI: Australian maternal morbidity outcome indicator, CDC: Centres for Disease Control and Prevention*

3.4.2 Narrative Summary of Findings

3.4.2.1 Neighbourhood Measures and SMM

3.4.2.1.1 Neighbourhood Deprivation

Six studies (55-57, 60, 95, 100) examined the association between neighbourhood deprivation and SMM (**Appendix Table 3.8)**. Among these, each used a different definition of SMM except two studies set in the US, which used the CDC definition. Neighbourhood deprivation was assessed using composite scores based on different domains of deprivation across different countries, with four out of the six studies (55-57, 60) measuring deprivation at the postcode level. In one study conducted in the US (95), deprivation was evaluated at the New Jersey municipality level, and a second study, also conducted in the US measured deprivation at the census tract level (100). The results of the meta-analysis of the crude ORs of the comparable studies are presented in **Figure 3.2**. Across all the comparable studies, there was a 1.45-fold increase in the odds of SMM (95% CI: 1.13-1.85) for women living in the most deprived areas compared to those who live in the least. There was considerable heterogeneity observed among the studies (I^2=96.8%, P<0.001), with a prediction interval spanning from 0.57 to 3.68. In the multivariable analysis, Adane et al. (55), Lindquist et al. (56), Snelgrove et al. (60), Muchomba et al. (95) and Tipre et al. (100) showed an increase in the odds of SMM in the most deprived neighbourhoods when compared to the least deprived neighbourhoods, with ORs of 1.29 (95% CI 1.20-1.39), 2.00 (95% CI 1.29-3.10), 1.16 (95% CI 1.11 - 1.21), 1.09 (95% CI 1.06-1.12), 1.78 (95% CI 1.22-2.59) respectively. In contrast, Lindquist et al. (57) reported different findings in a case-control study of all births in Victoria, Australia. This study indicated that the odds of SMM were significant only in the fourth most deprived neighbourhood compared to the least deprived neighbourhood (OR: 1.55 (95% CI 1.28-1.87)) after conducting a multivariable analysis.

3.4.2.1.2 Neighbourhood Educational Attainment

Two studies (94, 98) conducted in the US described the association between neighbourhood educational attainment and SMM (**Appendix Table 3.9)**. Both studies used the percentage of women who graduated high school in the neighbourhood as the exposure, and the CDC definition of SMM as the outcome. Using univariable analysis, Meeker et al. (94) reported a 0.29 (95% CI 0.10-0.47) percentage increase per one-unit change in neighbourhood education. Reid et al. (98) reported an increased RR of 1.38 (95% CI 1.16-1.65) in neighbourhoods where 10.2-100% of the women had a high school diploma, compared to neighbourhoods where <1.9% of the women had no high school diploma, using multivariable analysis.

3.4.2.1.3 Neighbourhood Employment

One study (94) reported the association between neighbourhood employment at the zip code level and SMM (**Appendix Table 3.10)**. This study was conducted in the US and used the CDC definition of SMM as the outcome. Using univariable analysis, the study did not find an association between the percentage of women in the labour force in the neighbourhood and the risk of SMM.

3.4.2.1.4 Neighbourhood Poverty

Four studies (24, 86, 94, 98) described the association between neighbourhood poverty and SMM (**Appendix Table 3.11)**. All the studies were conducted in the US and used the CDC definition of SMM as the outcome. Neighbourhood poverty was measured using the percentage of residents living below the poverty level. The results of the meta-analysis of the crude ORs across the comparable studies are shown in **Figure 3.2**. Across all the comparable studies, there was a 1.61-fold increase in the odds of SMM (95% CI: 0.97-2.66) for women residing in neighbourhoods with the highest percentage of people living in poverty compared to those residing in neighbourhoods with the lowest percentage. There was considerable heterogeneity

between the studies (I^2=99.1% P<0.001) with a prediction interval spanning between 0.001 and 1074.39. The two studies (24, 86) which conducted multivariable analysis did not show an association between neighbourhood poverty and risk of SMM.

3.4.2.1.5 Neighbourhood Income

A total of ten studies (23, 58, 79, 85, 88, 89, 92-94, 98) investigated the relationship between neighbourhood income and SMM (**Appendix Table 3.12**). Among the studies, one (58) was conducted in Canada, and the remaining nine were conducted in the US. In all the studies, the exposure was measured as the median household income at the zip code level. Within the US studies, eight (79, 85, 88, 89, 92-94, 98) used the CDC definition to classify SMM. The results of the meta-analysis of the crude ORs, where the population was consistently pregnant women giving birth, are displayed in **Figure 3.2**. Across all the comparable studies, the overall effect of residing in neighbourhoods with the lowest median household income, when compared to the highest, indicated a 1.48-fold increase in the odds of SMM (95% CI: 1.34-1.63). There was considerable heterogeneity among the studies (I^2=98.4%, P<0.001) with prediction intervals spanning from 1.02 to 2.14. Among the studies that performed multivariable analyses, Aoyama et al.(58), Luke et al. (92) and Janevic et al. (88) showed a significant increase in the odds of SMM for women who lived in areas with the lowest income compared to the highest, with ORs of 1.19 (95% CI 1.14-1.22), 1.09 (95% CI 1.06-1.11) and a risk difference of 0.40 (95% CI 0.20-0.60) respectively. Creanga et al. (79), and Friedman et al. (23), also upheld the significant positive association between neighbourhood income and SMM with RRs of 0.80 (95% CI 0.80-0.80) and 0.96 (95% CI 0.95-0.97), for women who lived in areas with the highest median income compared to the lowest. Only one study (98) showed no association after adjusting for covariates that could lie on the causal pathway, such as lack of health insurance or medical comorbidities.

3.4.2.1.6 Neighbourhood Housing

Two studies (94, 96) examined the association between housing-related factors and SMM (**Appendix Table 3.13)**. Both studies were conducted in the US and used the CDC definition of SMM as the outcome. Muchomba et al. (96), showed using a multivariable model, there was an increased odds of SMM of 1.27 (95% CI 1.01-1.60) per 1% increase in the housing cost burden, 1.38 (95% CI 1.04-1.82) per 1% increase in the severe housing cost burden and 1.73 (95% CI 1.15-2.59) per 1% increase in the median rent to income ratio. Similarly, Meeker et al. (94), using univariable analysis, identified an association between neighbourhood housing violations (housing quality law violations) and the risk of SMM with a 3.90 (95% CI 1.40-6.21) per cent increase in SMM per one unit change in the number of housing violations in the neighbourhood. However, no statistically significant association was observed between the percentage or number of owner-occupied or renter-occupied housing and the risk of SMM in this study.

3.4.2.1.7 Neighbourhood Crime

A single study (94) conducted in the US explored the association between neighbourhood crime and SMM (**Appendix Table 3.14)**. This study used the percentage of neighbourhood crimes as the exposure and the CDC definition of SMM as the outcome. Using univariable analysis, Meeker et al. (94) showed a 4.90 (95%CI 2.02-7.83) per cent increase in SMM per one-unit change in the number of violent crimes in the neighbourhood. However, there was no longer an association after adjusting for ethnicity. There was no observed association between non-violent crimes and the percentage change in SMM.

3.4.2.2 Individual Measures and SMM

3.4.2.2.1 Individual Educational Attainment

A total of ten studies (28, 64, 80, 81, 83, 84, 86, 90, 91, 95) investigated the relationship between individual educational attainment and SMM (**Appendix Table 3.15)**. Among these studies, nine were conducted in the US, while one (64) was conducted in Germany. Eight studies (28, 80, 81, 84, 86, 90, 91, 95) used the CDC definition of SMM; one (83) combined the CDC definition with pregnancy and birth-related intensive care unit admissions, and one (64) employed a list of eight specific SMM conditions as the outcome. The results of the meta-analysis crude ORs from comparable studies are displayed in **Figure 3.2.** Across all comparable studies, there was a 1.29-fold increase in the odds of SMM (95% CI 1.22-1.37) in women who were categorised as having a lower education compared to those who were categorised as having a higher education. There was considerable heterogeneity observed among the studies (I^2=94.8%, P<0.001) with a prediction interval spanning from 1.04 to 1.60. The two studies (64, 83) that did not identify an association in the univariable analysis were case-control studies with few study participants. Among the studies that conducted multivariable analysis, four out of six (81, 86, 90, 95) identified a significant positive association between the risk of SMM and individual educational level. Freese et al. (81) showed that women with no college degree, compared to those who had a college degree, had a RR of SMM of 1.20 (95% CI 1.10-1.40). Leonard et al. (90) showed that women with less than a high school education, compared to those who had a college degree, had a RR of SMM of 1.28 (95% CI 1.25-1.32) for SMM. Howland et al. (86) showed that women with less than a high school education, compared to women with a college degree, had an OR of SMM of 1.27 (95% CI 1.19-1.27) for SMM. Muchomba et al. (95) chose women who had not completed high school as the baseline group and showed that women with a college degree or greater had an OR of 0.75 (95% CI 0.71-0.80). Frederiksen et al. (80) and Goffman et al. (83) did not show a statistically significant

association, the former after multivariable analysis adjusting for factors likely to be on the causal pathway, and the latter a case-control study with only 77 cases.

3.4.2.2.2 Individual Occupation

Two studies (73, 75) reported the association between the woman's occupation (or her partner's occupation if the information for the woman was unavailable) and SMM (**Appendix Table 3.16)**. Both studies were conducted in the United Kingdom (UK) and used the same cohort of women from the United Kingdom Obstetric Surveillance System (UKOSS) database with overlapping dates. Knight et al. (73) conducted a case-control study using UKOSS data from 2005 and 2006 and showed in the unadjusted model, there was no statistically significant association between all other occupations and risk of SMM, compared to women with professional/managerial occupations. However, in the multivariable model, there was a 1.32 (95% CI 1.02-1.69) increase in the odds of SMM in women from all other occupations compared to those who had professional/managerial occupations. Lindquist et al. (75) conducted a case-control study using UKOSS data from 2005-2010. They did not find an association with the risk of SMM in any occupational category compared to women who had a professional/managerial occupation in either the unadjusted or multivariable models.

3.4.2.2.3 Individual/Household Income

Two (65, 69) studies looked at the association between income at the individual/household level and SMM (**Appendix Table 3.17)**. One study was based in Ireland (65) and used individual low income as the exposure and the Australian Maternal Morbidity Outcome Indicator (AMMOI) as the outcome to measure SMM. One study was based in South Korea (69) and used household income as the exposure. It compared four measures of SMM, including the CDC (101), American College of Obstetricians and Gynaecologists (ACOG) (102), Zwart et al. (103), and EURO-Peristat (104), as the outcome. In Ireland (65), there was

no association between individual income and risk of SMM in the unadjusted model. In South Korea (69), in the multivariable model, the CDC SMM definition had an increased RR of 1.17 (95% CI 1.15-1.19), ACOG 1.14 (95% CI 1.13-1.16), Zwart et al. 1.30 (95% CI 1.24-1.36) and Euro-Peristat 1.13 (95% CI 1.10-1.15) for the lowest income quartile compared to the highest.

3.4.2.2.4 Individual Housing

Two studies (87, 99) examined the relationship between individual-level housing insecurity and SMM (**Appendix Table 3.18)**. Both studies were conducted in the US and used the same cohort of women from the National Inpatient Sample (NIS) database, representing a stratified sample of women giving birth nationwide. Staniczenko (99) included data from 2008 to 2018, while Huang (87) included data from 2016 to 2018. Both studies used the housing insecurity ICD codes as the exposure and the CDC definition of SMM as the outcome. Huang et al. (87) and Staniczenko et al. (99) both showed, using univariable analysis, that women with insecure housing, compared to women with secure housing, had an increased odds of SMM of 2.17 (95% CI 1.75-2.68) and 2.73 (95% CI 2.50-2.97), respectively. However, Huang et al. (87) demonstrated that there was no longer an association after adjusting for covariates, which could be on the causal pathway, such as pre-existing comorbidities and neighbourhood median income.

3.4.2.2.5 Individual Social Vulnerability

One study (61) , conducted in four hospitals in Paris, France, investigated the association between a composite of social vulnerability and a composite of thirteen SMM conditions. Compared to those without social vulnerability, women with social vulnerability had an adjusted RR of 1.30 (95% CI 1.01-1.69) (**Appendix Table 3.19)**.

3.4.2.3 Neighbourhood Measures and Maternal Mortality

3.4.2.3.1 Neighbourhood Deprivation

Seven studies (18-20, 71, 72, 74, 76) investigated the association between neighbourhood deprivation and maternal mortality (**Appendix Table 3.20)**. These studies included confidential inquiries from New Zealand (20), Australia (19) and four from the UK (71, 72, 74, 76), along with a nationwide cohort study conducted in the Netherlands (18). All of these studies conducted univariable analysis only. Each different country included different domains in the composite measure of neighbourhood deprivation. The studies conducted in Australia (19) and the Netherlands (18) did not show any association between women residing in a deprived neighbourhood compared to those living in the least and an increased risk of maternal mortality. In contrast, in the UK, for women living in the most deprived neighbourhoods compared to those living in the least, the National Maternal Mortality Surveillance Programmes conducted between 2003-2005 (71), 2006-2008 (72), 2009-2011(74), 2015-2017 (74) and 2018-2020 (76), showed there was an increase in the odds of maternal mortality of 5.10 (95% CI 3.20-8.10), 1.69 (95% CI 1.11-1.69), 1.69 (95% CI 1.03-2.87), 2.23 (95% CI 1.23-4.33) and 2.52 (95% CI 1.50-4.47), respectively. The National Maternal Mortality Surveillance Programme, conducted in the UK between 2012 and 2014 (74), did not show any association. The results of the meta-analysis of crude ORs from comparable studies are displayed in **Figure 3.3.** Across all the comparable studies, there was a 2.10-fold increase (95% CI 1.57-2.81) in the odds of maternal mortality for women living in the most deprived neighbourhoods compared to those living in the least. There was substantial heterogeneity between the studies (I^2=62.3% P=0.007), with a prediction interval spanning from 0.87 to 5.09.

3.4.2.3.2 Neighbourhood Income

Three studies (58, 59, 82) examined the association between median neighbourhood household income and maternal mortality (**Appendix Table 3.21)**. Among these studies, one was

conducted in the US (82) and two in Canada (58, 59). Two studies (58, 59) used cohorts comprising all pregnant women giving birth. One of these studies (58) was conducted using all women giving birth in hospitals in Canada (excluding Quebec) and revealed an adjusted OR of 4.14 (95%CI 2.03-8.05) for maternal mortality for women who reside in neighbourhoods with the lowest quintile of medium income compared to those in the highest. A second study (59), also conducted in Canada and included every woman giving birth in Ontario, showed an increased odds of maternal mortality of 1.63 (95%CI 1.21-2.18) for women in the lowest two income quintiles compared to the those in the highest two income quintiles using univariable analysis. Conversely, a study conducted in the US (82) did not identify an association between neighbourhood income and the risk of maternal mortality. This study was a case-control design, with cases and controls selected from a single hospital.

3.4.2.4 Individual Measures and Maternal Mortality

3.4.2.4.1 Individual Employment

Seven studies (63, 67, 68, 71, 72, 77, 78) examined the association between individual-level recorded employment and maternal mortality (**Appendix Table 3.22)**. These studies were conducted in France (63), Mexico (67), the US (78), South Korea (68) and three in the UK (71, 72, 77). Most of the studies evaluated the woman's own employment status, except for two National Maternal Mortality Surveillance Programs conducted in the UK (71, 72), which focused on the employment status of the woman's partner. Two of the studies in the UK had overlapping cohorts. The crude ORs from the meta-analysis of comparable studies are displayed in **Figure 3.3** Across all the comparable studies, there was a 1.86-fold increase (95% CI 0.95-3.66) in the odds of maternal mortality if a woman or her partner were unemployed compared to those who were employed. There was considerable heterogeneity between the studies (I^2=96.7% P<0.001), with prediction intervals spanning from 0.20 to 18.47. Both the

study conducted in South Korea (68) and the study that used maternal mortality data from the UK from 2009 to 2013 (77) indicated that after adjusting for covariates such as maternal age and medical comorbidities, there was no longer an association between employment status and maternal mortality.

3.4.2.4.2 Individual Housing

A single study by Huang et al. (87) investigated the relationship between individual-level housing insecurity and maternal mortality (**Appendix Table 3.23)**. This study used a stratified sample from all hospital births in the US. Huang et al. demonstrated that women with housing insecurity had a 2.17-fold (95% CI 1.75-2.68) increase in the odds of maternal mortality compared to women with stable housing conditions. However, after adjusting for confounding factors such as comorbidities, neighbourhood income, and rurality, there was no longer an association between housing insecurity and maternal mortality

3.4.2.4.3 Individual Occupation

Three National Maternal Mortality Surveillance Programmes (70-72), all based in the UK, explored the association between a woman's partner or husband's occupation and maternal death (**Appendix Table 3.24)**. These inquiries encompassed data from the time periods 2000-2002 (70), 2003-2005 (71), and 2006-2008 (72). The results of the meta-analysis of crude ORs from comparable studies are displayed in **Figure 3.3.** Across all comparable studies, the overall effect of a partner/husband with a routine/manual occupation compared to a professional/managerial occupation was a 1.61-fold increase (95% CI: 1.03-2.51) in the odds of maternal death in the UK. There was substantial heterogeneity between the studies (I^2=70.9%, P=0.032) with a prediction interval spanning from 0.01 to 261.50.

3.4.2.4.4 Individual Education

Three studies (66, 78, 97) examined the association between education and maternal mortality, two set in the US and one in Italy. These studies performed univariable analyses only (**Appendix Table 3.25**). The results of the meta-analysis of crude ORs from comparable studies are displayed in **Figure 3.3.** In all the studies, the overall increase in odds of maternal mortality for women with higher education compared to those with lower education was 1.90 (95% CI 1.29-2.79). There was considerable heterogeneity between the studies, with an I^2 of 82.6% (p=0.003) with an estimated 95% predictive interval of 0.02 to 188.89.

3.4.3 Meta-Analysis

Neighbourhood deprivation, neighbourhood income and individual education were associated with an increased odds of SMM, with summary ORs of 1.45 (95% CI 1.13 to 1.85), 1.48 (95% CI 1.34 to 1.63) and 1.29 (95% CI 1.22 to 1.37), respectively. However, there was no evidence of an association between neighbourhood poverty and SMM (**Figure 3.2**). Neighbourhood deprivation, individual occupation and individual education meta-analyses were associated with maternal mortality, with summary ORs of 2.10 (95% CI 1.57 to 2.81), 1.61 (95% CI 1.03 to 2.51) and 1.90 (95% CI 1.29 to 2.79), respectively. There was no evidence for an association between individual employment and maternal mortality (**Figure 3.3**).

9 Forest plots of unadjusted odds ratios (and their 95% confidence intervals) for SMM among women who (A) had less than or equal to high school education only compared with those who had a higher education, (B) lived in the most deprived versus least deprived neighbourhoods, (C) lived in neighbourhoods with the highest versus least household median income and (D) lived in neighbourhoods with the highest versus least amount of poverty. Data have been collapsed into comparable categories

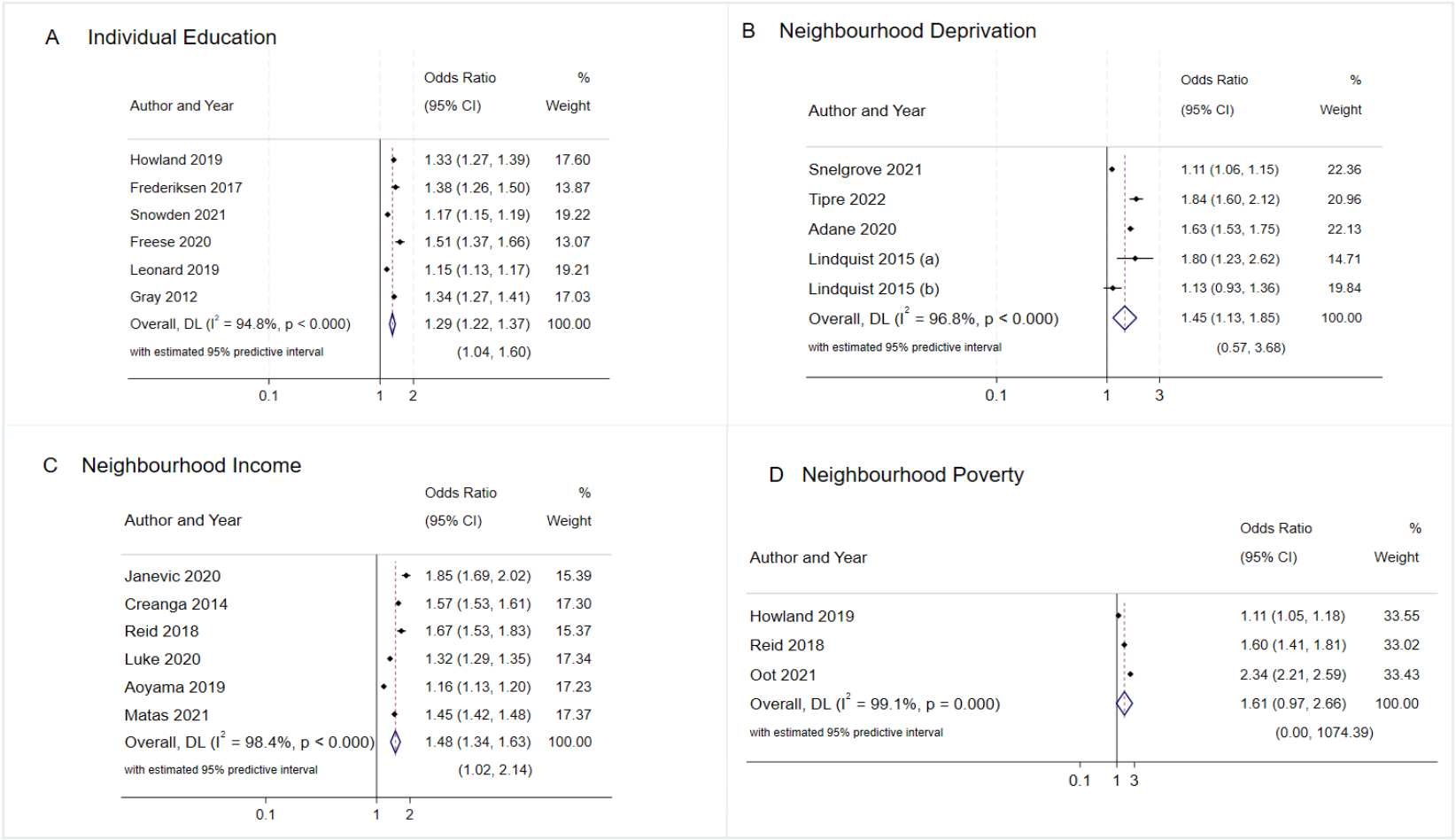
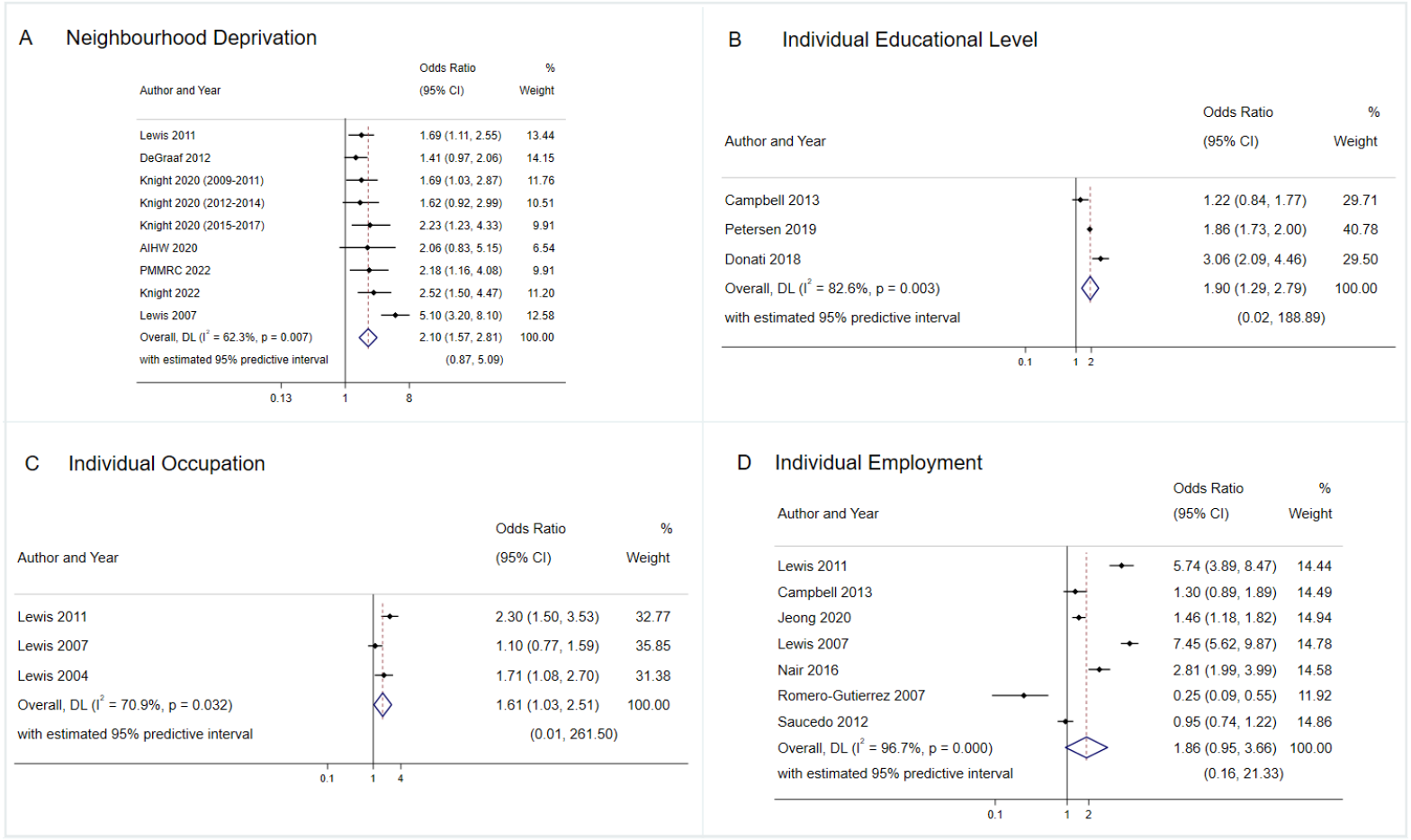


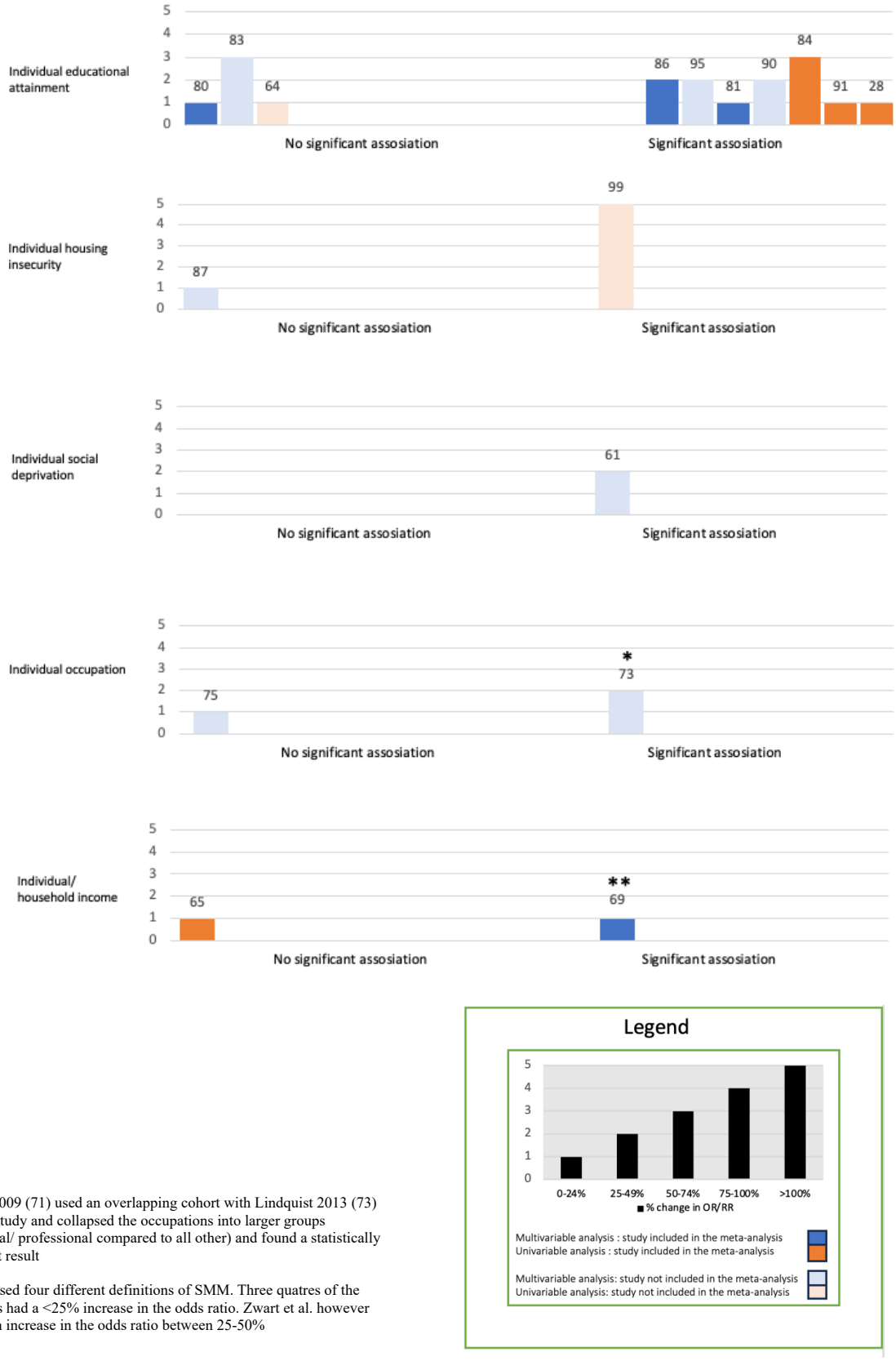
Figure 3.3. Forest plots of unadjusted odds ratios (and their 95% confidence intervals) for maternal mortality among women (A) who lived in the most deprived versus least deprived neighbourhoods, (B) who had the highest versus lowest level of educational attainment measured at the individual level, (C) whose husband or partner had a routine/manual occupation versus professional/managerial occupation and (D) who (or whose husband) were employed compared with those who were unemployed measured at the individual level. Data have been collapsed into comparable categories.



3.4.4 Harvest Plot

The studies that reported dichotomous outcomes are displayed in **Figures 3.4, 3.5 and 3.6** using a harvest plot. These studies showed different measures of socioeconomic disadvantage associated with increased risk or odds for SMM and maternal mortality - the percentage increase ranged from 4% to 510%. The studies that did not find evidence for an association were more likely to be case-control studies (57, 63, 75, 77, 82-84). No study showed a significantly decreased association between socioeconomic disadvantage and SMM.

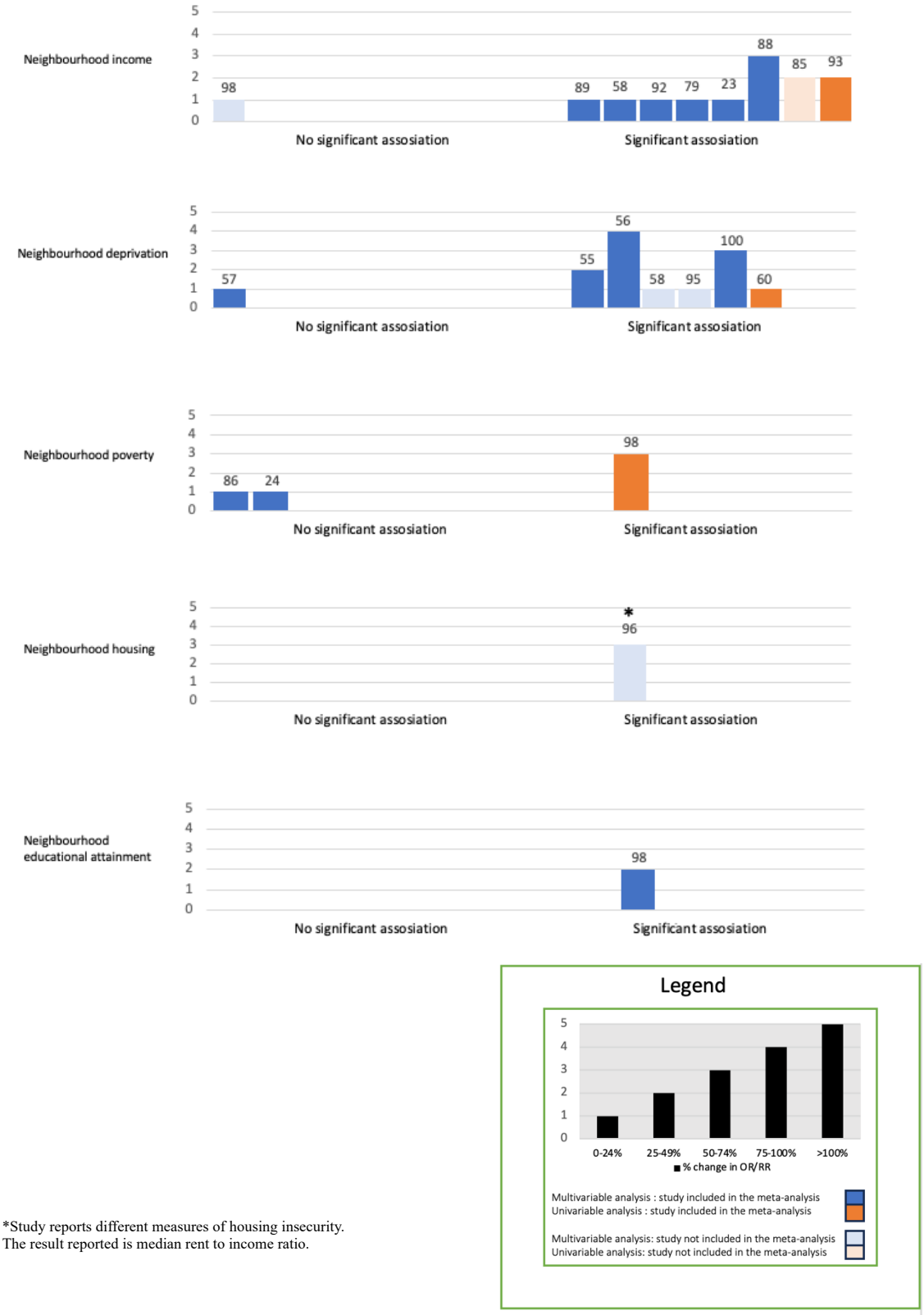
Figure 3.4. Harvest plot of the association between individual-level socioeconomic disadvantage and SMM stratified by measure of socioeconomic disadvantage. If a study was included in the meta-analysis but also reported a result of a multivariable model, this result was included in the harvest plot. Numbers are study references.



*Knight 2009 (71) used an overlapping cohort with Lindquist 2013 (73) with this study and collapsed the occupations into larger groups (managerial/ professional compared to all other) and found a statistically significant result

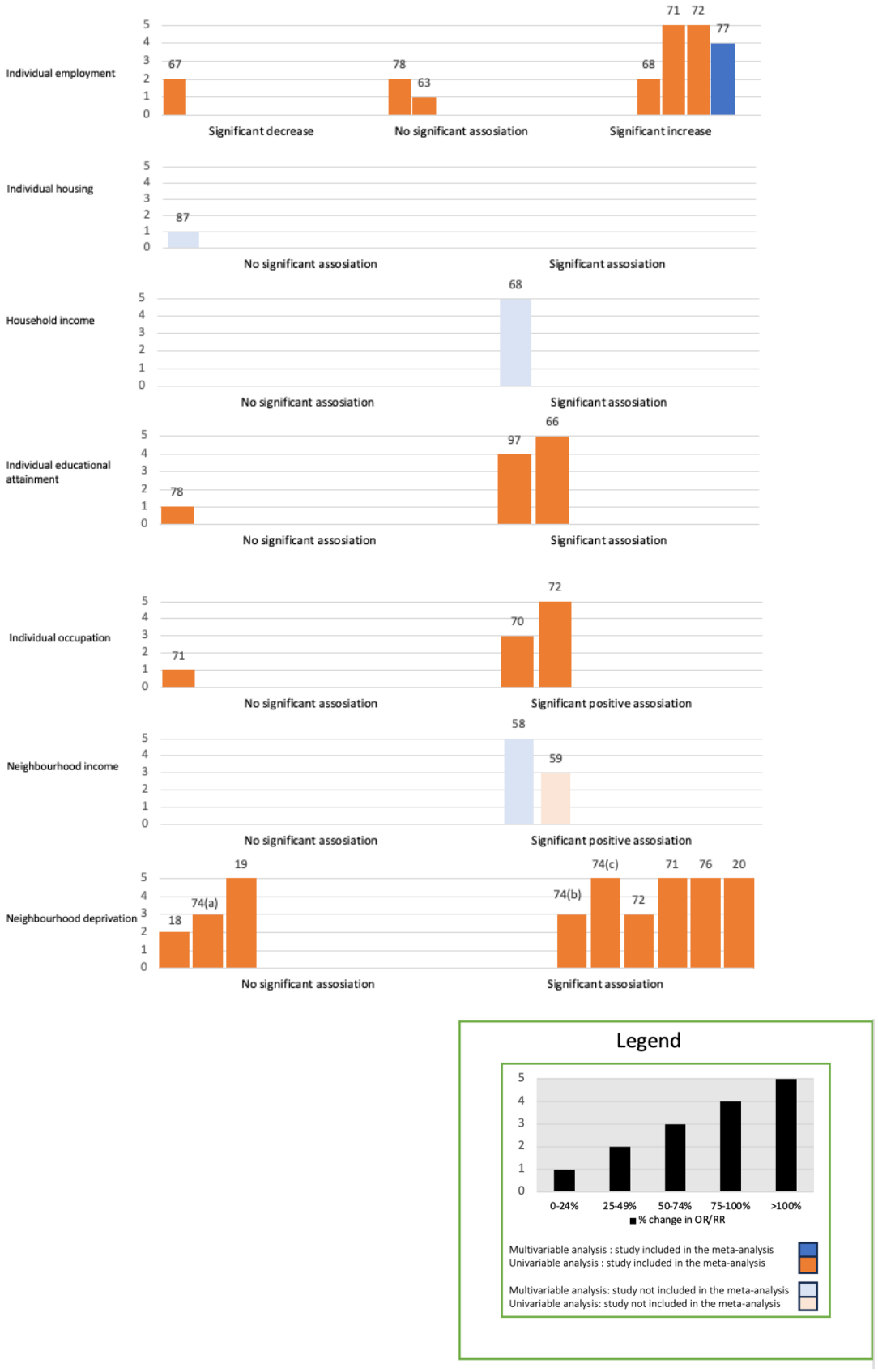
**Study used four different definitions of SMM. Three quatres of the definitions had a <25% increase in the odds ratio. Zwart et al. however showed an increase in the odds ratio between 25-50%

Figure 3.5. Harvest plot of the association between neighbourhood socioeconomic disadvantage and SMM stratified by measure of socioeconomic disadvantage. If a study was included in the meta-analysis but also reported a result of a multivariable model, this result was included in the harvest plot. Numbers are study references.



*Study reports different measures of housing insecurity.
The result reported is median rent to income ratio.

Figure 3.6. Harvest plot of the association between individual and neighbourhood-level socioeconomic disadvantage and maternal mortality stratified by measure of socioeconomic disadvantage. If a study was included in the meta-analysis but also reported a result of a multivariable model, this result was included in the harvest plot. Numbers are study references.



3.4.5 Risk of Bias

The results of the modified Newcastle-Ottawa Score were divided into study types (**Tables 3.4, 3.5 and 3.6**); the justification for the score is shown in **Appendix Tables 3.26, 3.27 and 3.28**. None of the studies had low risk of bias scores across all the items. The greatest risk of bias was seen in the *comparability* domain, with all but one study scoring high. These studies conducted univariable analysis or adjusted for covariates on the causal pathway. 17 studies did not provide sufficient information to gauge the completeness of the data. These studies, therefore, were scored as 'unknown' for risk of bias in the *adequacy of follow-up of cohort/missing data* heading. Six studies had a high risk for selection bias due to the poor representativeness of the cohort to the population. 32 studies that used record linkage to determine SMM/maternal mortality scored 'some concerns' for risk if bias for assessment of the outcome (cohort studies) or the case (case-control studies). Other potential sources of bias (e.g., relating to other aspects of selection or the exposure and outcome) were less of a concern because the data from most studies were routinely collected, and the outcome was objective.

Table 3.4. Modified Newcastle-Ottawa Score for cohort studies and National Maternal Mortality Surveillance Programmes

Study author, year and country	SELECTION - representative	Selection of the Non-Exposed Cohort	Ascertainment of Exposure	COMPARABILITY	OUTCOME - assessment	Was Follow-Up Long Enough for Outcomes to Occur	Adequacy of Follow Up of Cohorts/ Missing data
Adane 2020, Australia	low	low	low	high	some concerns	low	low
AIHW 2020, Australia	low	low	low	high	low	low	unknown
Aoyama 2019, Canada	low	low	low	high	some concerns	low	low
Snelgrove 2021, Canada	low	low	low	high	some concerns	low	low
Ray 2018 , Canada	low	low	low	high	low	low	low
Azria 2016, France	low	low	some concerns	high	low	unknown	unknown
Sante Publique 2021, France	low	low	unknown	high	some concerns	low	high
David 2019, Germany	low	low	low	high	some concerns	low	low
Lutomski 2012, Ireland	low	low	low	high	some concerns	low	low
Donati 2018, Italy	low	low	unknown	high	low	low	unknown
PMMRC 2022, New Zealand	low	low	low	high	low	low	low
Jeong 2020, South Korea	low	low	low	high	some concerns	low	low
Nam 2022, South Korea	low	low	low	high	some concerns	low	low
DeGraaf 2012, The Netherlands	low	low	low	high	low	low	unknown
Lewis 2004, UK	low	low	unknown	high	low	low	unknown
Lewis 2007, UK	low	low	unknown	high	low	low	unknown

Table 3.4. (Continued)

Lewis 2011, UK	low	low	unknown	high	low	low	unknown
Knight 2020, UK	low	low	low	high	low	low	unknown
Knight 2022, UK	low	low	low	high	low	low	unknown
Campbell 2013, US	low	low	unknown	high	some concerns	low	unknown
Creanga 2014, US	low	low	low	high	some concerns	low	low
Frederiksen 2017, US	low	low	unknown	high	some concerns	low	low
Freese 2020, US	high	low	some concerns	high	some concerns	unknown	low
Friedman 2016, US	low	low	low	high	some concerns	low	low
Guglielminotti 2021, US	low	low	low	high	some concerns	low	low
Howland 2019, US	low	low	unknown	high	some concerns	low	unknown
Huang 2023, US	low	low	low	high	some concerns	low	unknown
Kozhimanni 2019, US	low	low	low	high	some concerns	low	low
Leonard 2019, US	low	low	some concerns	high	some concerns	low	unknown
Leonard 2021, US	low	low	some concerns	high	some concerns	low	low
Luke 2020, US	low	low	low	high	some concerns	low	unknown
Matas 2021, US	low	low	low	high	some concerns	low	low
Meeker 2021, US	low	low	low	high	some concerns	low	unknown
Oot 2021, US	low	low	low	high	some concerns	low	unknown

Table 3.4. (Continued)

Petersen 2019, US	low	low	unknown	high	low	low	high
Reid 2018, US	low	low	low	high	some concerns	low	low
Snowden 2021, US	low	low	unknown	high	some concerns	low	low
Tipre 2022, US	high	low	low	high	some concerns	low	low

Table 3.5. Modified Newcastle-Ottawa Score for case-control studies

Study author, year and country	SELECTION - case definition	Representativeness of the Cases	Selection of controls	COMPARABILITY	EXPOSURE- Ascertainment of Exposure	Method of ascertainment of exposure	Non-response rate	Missing data
Lindquist 2015 (a), Australia	low	low	low	high	low	low	unknown	low
Lindquist 2015 (b), Australia	some concerns	low	low	high	low	low	low	low
Saucedo 2012, France	low	high	low	high	high	high	unknown	high
Romero-Gutierrez 2007, Mexico	low	high	low	high	high	high	unknown	unknown
Knight 2009, UK	low	low	low	high	unknown	low	low	unknown
Lindquist 2013, UK	low	low	low	high	unknown	low	low	high
Nair 2016, UK	low	low	low	high	unknown	high	low	high
Gray 2012, US	some concerns	high	low	high	unknown	low	low	high
Frolich 2014, US	low	high	low	high	low	low	low	low
Goffman 2007, US	low	high	low	high	unknown	low	low	low

Table 3.6. Modified Newcastle-Ottawa Score for cross-sectional studies

Study ID	SELECTION representativeness	Sample size	Non respondents	Ascertainment of the exposure	COMPARABILITY	OUTCOME assessment
Janevic 2020, US	low	low	low	low	high	some concerns
Muchomba 2021, US	low	low	low	unknown	low	some concerns
Muchomba 2022, US	low	low	low	low	high	some concerns
Staniczenko 2022, US	low	low	low	high	high	some concerns

3.5 Discussion

3.5.1 Main findings

This review is the first to systematically synthesise the current evidence of socioeconomic disadvantage across various definitions measured at the individual- and neighbourhood-level and SMM and maternal mortality. The findings demonstrate that there is a consistent positive association with socioeconomic disadvantage and an increased risk of SMM and maternal mortality across diverse populations, healthcare systems and social contexts. This review incorporated studies from high-income countries such as Australia, the US, South Korea, the UK and various European countries, with differences in study design, population characteristics and definitions of socioeconomic disadvantage, SMM and maternal mortality.

Importantly, no studies indicated a significant negative association between socioeconomic disadvantage and SMM, and only one study (67) suggested a protective effect of unemployment on maternal mortality. This outlier study was conducted in Mexico, which has a low female employment rate (105), indicating limited comparability to other high-income settings. Furthermore, this case-control study was conducted in a single hospital, and the analysis was unadjusted. Therefore, this result has a high risk of selection bias and confounding.

However, despite consistency in the direction of association, many studies still did not show a significant association, possibly due to a lack of power. This was primarily seen in non-population-based case-control studies or cohort studies conducted in a single or a small number of medical institutions. Furthermore, all but one of the studies (95) had a high risk of bias scores for comparability, as the result was either univariable analysis only or if the authors conducted multivariable analysis, they controlled for multiple and potentially highly correlated psychosocial, behavioural and medical variables that might lie on the causal pathway, resulting

in over adjustment. Regardless of the measure used, most studies included socioeconomic position variables without justifying why a given measure was selected, without explaining its meaning, and without fully considering appropriate confounding factors.

In this systematic review, the association between socioeconomic disadvantage and SMM and maternal mortality remained even when socioeconomic position was measured at the neighbourhood level. It has been argued that neighbourhood-level measures are a poor proxy for individual socioeconomic position as there may be misclassification of the exposure, for only some living in a deprived area are individually deprived, which may have biased results towards the null (106). A possible explanation of the study's findings is that individuals living in the same area are not only likely to share characteristics, but the contextual impact of living in a deprived area is a risk factor for poor outcomes beyond the individual-level impact and may describe a unique inequity. However, no studies using the same cohort directly compared the impact of individual- and neighbourhood-level socioeconomic position measures. Therefore, it was not possible to draw conclusions on the similarities or differences in the strength of the association between the two measurement levels because of variations in populations and study design.

3.5.2 Strengths and limitations

The review captured studies from various high-income countries, populations and study designs and demonstrated a relatively consistent direction of association throughout. The search strategy was broad and included multiple databases supplemented by searching citations and reference lists. Studies were included if information on the prevalence of SMM or maternal mortality in each socioeconomic disadvantage category was presented as raw data only, and the ORs were subsequently calculated. Studies were also included if the association between socioeconomic disadvantage and SMM or maternal mortality was not the study's primary aim.

This allowed more studies to be included and reduced publication bias. The grey literature sources included several Nationwide Maternal Mortality Surveillance Reports. Including these nationwide databases and other large cohort studies resulted in large sample sizes for some socioeconomic disadvantage/outcome combinations. All screening, data extraction and risk of bias assessment were duplicated to minimise human error.

The review also faced several significant limitations. A primary issue was the large amount of statistical heterogeneity between the studies, even within the same socioeconomic disadvantage or outcome categories, and it was not possible to assess potential reasons for heterogeneity. All but one meta-analysis exhibited considerable heterogeneity, likely due to differences in how exposures (socioeconomic position markers) and outcomes (SMM and maternal mortality) were defined and measured. The heterogeneity was further compounded by differences in the population between countries, measurement of exposure and definitions of the outcome. Another major limitation was the reliance on unadjusted ORs. The results of any univariable analysis of the relationship between socioeconomic disadvantage and SMM and maternal mortality are likely confounded by maternal age and ethnicity, which are both strongly associated with SMM and maternal mortality (44, 107, 108). Moreover, there was a limited number of comparable studies in each exposure/outcome category, so it was impossible to assess publication bias. Therefore, selective reporting cannot be ruled out. It was also not possible to conduct any of the planned sensitivity analyses such as the effect of study quality.

A further limitation was the disproportionate representation of studies from the US, approximately half of the included studies. Health inequities in the US are often more pronounced than in other high-income countries (109), and the limited data from different settings made it difficult to assess whether findings were consistent across diverse healthcare systems.

Finally, as randomised control trials are not ethically or logistically feasible for this topic, this review only included observational studies. Therefore, it is impossible to make any inferences regarding the causal relationship between socioeconomic disadvantage and the outcomes. There is also little understanding of etiological factors mediating any relationship and what could be amenable to interventions to reduce the demonstrated unequal outcomes. Causal meditation analysis is one way of exploring mediators using observational data, but this was not undertaken in any of the studies. Finally, as large sample sizes are typically required to examine socioeconomic health disparities, many studies used routinely collected healthcare data that cannot capture information about socioeconomic experiences over time. Socioeconomic factors across a woman's lifetime may have more of an influence on adverse health outcomes than do her socioeconomic circumstances around the time of childbirth (110).

3.5.3 Conclusion

This systematic review showed socioeconomic disadvantage to be associated with an increased risk for SMM and maternal mortality across many high-income countries with different healthcare, political and welfare systems (**Thesis Objective 1**). Although estimates of the magnitude of the relative differences in the adverse outcomes associated with socioeconomic disadvantage are small, the size of the population who experience socioeconomic disadvantage is substantial. Therefore, even a modest difference in the risk can have a significant public health impact. Nevertheless, uncertainty exists in the summary estimates due to the high heterogeneity demonstrated in the meta-analyses. Neighbourhood-level measures of socioeconomic position did not show a weaker association than individual-level measures (**Thesis Objective 1**); therefore, they may still be helpful for research using administrative data. However, no studies directly compared the strength of association between individual-

and neighbourhood-level socioeconomic position measures within the same study. Therefore, this thesis attempts to address the limitations in the current literature by comparing the association with SMM between different measures of disadvantage within the same cohort (**Chapters 4, 5 and 6**) including at both the individual- and neighbourhood-level (**Chapter 6**), adjusting appropriately for relevant confounding factors (**Chapters 4, 5 and 6**), and identifying mediating factors amenable to interventions (**Chapters 5 and 6**) to reduce the inequality gap demonstrated in this systematic review.

Chapter 4: The Association Between the Different Domains of the Index of Multiple Deprivation (IMD) and SMM, in England, 2013-2023

4.1 Background

This analysis used the Hospital Episode Statistics Admitted Patient Care (HES APC) data, a nationwide English secondary care administrative database to explore the relationship between various aspects of socioeconomic disadvantage and SMM within the same English cohort. This database provides detailed information on neighbourhood-level deprivation across multiple measures, enabling an in-depth analysis of which aspects of deprivation contribute to an increased risk of severe maternal morbidity (SMM), to help understand which aspects of disadvantage would benefit most from a targeted intervention.

4.1.1 Trends in Maternal Mortality and SMM in the United Kingdom

In the most recent confidential enquiry into maternal death in the United Kingdom (UK), the maternal mortality rate was 13.6 per 100,000 maternities from 2020-2022 (111). Black women had three times greater risk of dying, and Asian women had twice the risk compared to White women. In addition, women who lived in the most deprived areas had twice the risk of dying compared with those living in the least deprived areas. However, this enquiry did not find a dose-response relationship between deprivation and the risk of dying, as the women living in the third most deprived quintile area had a higher maternal mortality rate than those living in the second most deprived quintile. Furthermore, 9% of deaths were associated with women with severe multiple disadvantages such as mental health problems, substance misuse and domestic violence.

Risk factors for SMM in the UK follow similar trends to maternal mortality. The incidence of SMM is higher in older and younger women, women from minoritised ethnicities, women with multiple pregnancies, women with a past or current history of hypertension, parity > 3, anaemia in the current pregnancy, previous pregnancy problems or a previous postpartum haemorrhage. Social exclusion, living in a deprived area, inadequate utilisation of antenatal care, pre-existing medical conditions and unemployment have also been shown to increase the risk (25, 26, 112). However, there is currently insufficient evidence for how these factors are related to each other and their role in the association between socioeconomic position and SMM risk in England.

4.1.2 Neighbourhood Deprivation and SMM in the United Kingdom

A nationwide cohort study using English routinely collected hospital data, which included all primiparous women who gave birth in England from 2012 to 2019, identified socioeconomic deprivation as a significant risk factor for SMM (26). The study found an overall SMM incidence rate of 1.6% at the time of birth, with a linear trend indicating progressively higher odds of SMM with increase in levels of the Index of Multiple Deprivation (IMD). However, this study was limited as the cohort was restricted to primiparous women, and it only explored the association between a composite deprivation measure (IMD) and SMM rather than singular aspects of deprivation (or deprivation domains). Therefore, the association between deprivation types such as education, housing or income, and SMM remains poorly understood. A more nuanced understanding of the relationship between the specific aspects of deprivation and SMM is required to provide more information for targeted interventions.

4.1.3 Neighbourhood Deprivation and Ethnicity

Minoritised ethnic groups are overrepresented in the UK's most deprived areas (26, 44) and are also more likely to experience adverse maternal health outcomes such as mortality and

SMM (17, 26, 43, 44). Although a recent study showed no evidence of an association between deprivation and SMM in any specific ethnic group (26) the modifying effects of ethnicity with the different aspects of deprivation, such as education or housing problems, are not known.

4.2 Aim and Objectives

4.2.1 Aim

This analysis aims to explore the relationship between specific aspects of neighbourhood deprivation and the risk of SMM at birth in England and how this may vary across different ethnic groups.

4.2.2 Objectives

1. To examine the trend in the incidence rate of SMM in England from 2013 to 2023 and to investigate which specific SMM conditions or procedures contribute to changes in the risk of SMM during this time period, if applicable.

2. To examine the associations between IMD, both the composite measure and individual domains/subdomains, and the risk of SMM and to explore the contribution of specific aspects of socioeconomic deprivation, such as income, education, employment, and housing, to any increased risk of SMM (**Thesis Objective 2**).

3. To explore if the association between individual IMD domains/subdomains and the risk of SMM varied across different ethnic groups (**Thesis Objective 5**).

4. To assess the contribution of various measures of socioeconomic disadvantage to SMM risk using population attributable fractions (PAFs). PAFs will enable the estimation of

the proportion of SMM cases that could be prevented if all women face the same SMM risk as the reference group, defined as women in the highest socioeconomic group for the overall analysis and White women in the highest socioeconomic group for the analysis by ethnicity, in order to quantify the overall socioeconomic and ethnic disparities in SMM (**Thesis Objective 6**).

4.3 Methods

4.3.1 Data source

The HES APC dataset is a routinely collected data source. When a patient is discharged from the hospital, the clinician completes a discharge summary containing the diagnoses and procedures which occurred during the admission. This information, and administrative and demographic details, are entered into a local electronic database by trained clinical coders, which is then processed and validated by National Health Service (NHS) Digital (replaced by NHS England in February 2023) (113). Although HES APC was not initially intended for research, it is frequently used for research and service evaluation because of its ability to track individuals over time, comprehensive coverage and long data collection period (113).

The HES APC database contains all hospital admissions within the NHS, including about 97% of all births in England (114). It includes patient demographics, clinical information and hospital administrative data. Additionally, the HES APC contains pregnancy and birth-specific information, such as mode of birth, birth weight, gestational age at childbirth, maternal age, the status of the person conducting the birth and the birth location in an additional maternity section. However, as this additional section is not mandatory, it has varying quality and completeness (113). Diagnoses are coded using the International Classification of Diseases, 10th edition (ICD-10), and procedures are coded using the UK Office for Population Censuses

and Surveys classification, fourth revision (OPCS-4). For this analysis, data on all birth episodes (pregnancy loss, live or stillbirth) between January 1, 2003, and March 31, 2023, were extracted. These were linked to all hospital admissions for any reason over this period.

4.3.2 Creating a Cohort of Birth 'Superspells'

The cohort was formed using all birth 'superspells' from January 1, 2013, to March 31, 2023. A 'spell' is one continuous admission period, which can be a combination of different 'episodes' of care under different consultants. A 'superspell' is a period of care that includes transfer between hospitals. The dataset was adjusted so that each row represented an individual woman and her birth 'superspell'. Each patient has a unique encrypted ID number that links all episodes of care for the same patient, which allows hospital episodes to be linked. A 'look back' approach was used to incorporate confounding factors from prior to the index birth. This method flagged records containing pre-selected diagnosis or procedure codes, and the diagnosis dates were then linked to all matching 'superspells' under the same encrypted HES ID. Women were assumed not to have the above confounding factors if they were not coded in any of the hospital records from the time listed in **Appendix Table 4.1**. The time varied based on the time each condition was considered relevant to an increased risk of SMM. All hospital 'superspells' without a birth code (R17-R25) were removed to create a birth cohort.

4.3.2.1 Duplicate 'Superspells'

Exact duplicate 'superspells' were dropped. If identical 'superspell' IDs had conflicting information on gestational age at birth, birthweight, mode of birth or maternal age these records were dropped. If variables were missing on one but present on an identical 'superspell' ID, the information was copied over and one of the duplicated 'superspells' was dropped.

4.3.2.2 Study Population

4.3.2.2.1 Defining Gestational Age at Childbirth

Only birth 'superspells' which resulted in a pregnancy loss, live or stillbirth ≥ 20 weeks' gestation were included. The data on pregnancy loss < 20 weeks' gestation in the HES APC is unreliable as many of these miscarriages do not occur in hospital. Therefore, data for these pregnancies are not captured HES APC, leading to an underestimated denominator (115). The cut-off of 20 weeks and beyond was selected because most births occur in hospitals after 20 weeks.

Gestational age at childbirth and birthweight of the baby were used to determine a cohort of women with a gestational age ≥ 20 weeks at childbirth. Gestational age at childbirth is thought to be reliably recorded in HES APC. A 94% agreement of gestational age at childbirth within 1 week was found between the HES APC and self-reported gestational age at childbirth in the Millennium Cohort study (116). The reliability of birthweight in HES has not been investigated by linking and comparing it to a second database. Therefore, birthweight was recoded as implausible if it was greater than five standard deviations (SD) away from the median for the corresponding gestational age (117). If data on gestational age at birth was missing (25% in the current dataset), it was assumed to be ≥ 20 weeks if birthweight was recorded and > 360g which is the median birthweight for 20 weeks (118).

There were 13.1% missing data on both birthweight and gestational age at childbirth. These women were included in the cohort because only 0.5% of those with complete data had a gestational age at childbirth of < 20 weeks. Therefore, if the distribution of gestational age at childbirth for women with missing data on this variable is comparable to those with complete data, the likelihood of including women with a gestational age at childbirth < 20 weeks is low.

Furthermore, the women who had missing information on both gestational age at childbirth and birthweight were more likely to be from minoritised ethnic groups (Risk ratio (RR) 1.10 (95% confidence interval (CI) 1.09-1.10)), be older (p_{trend} p<0.001) and have SMM (RR 1.20 (95% CI 1.17-1.21)) (**Appendix Table 4.2).** Therefore, excluding these women may introduce bias to the cohort by excluding disadvantaged groups.

Gestational age at childbirth was not only used to determine the study denominator but was also used to estimate the start of pregnancy for determining timing for variables as either occurring before or after the start of pregnancy. Women with a missing value for gestational age at childbirth were assigned a gestational age of 35 weeks if they had a preterm code, and 39 weeks if they had not. This method has been shown to correctly estimate 45% of gestational ages within one week and 70.1% within three weeks (119). Using this method for estimating gestational age at childbirth for those with missing data, the proportion of preterm births (7.46% of births <37 week) is similar to the incidence in other nationwide cohort studies (120).

4.3.3 Population

The study population was every woman who had given birth or had a pregnancy loss in a hospital between 1 January 2013 and 1 March 2023, aged 10-55 years, with gestational age at childbirth ≥ 20 weeks in England. Women were excluded if they had missing information on their lower-layer super output areas (LSOA). If a woman had two separate pregnancies and births in the study period, one of the births was randomly selected to avoid within individual clustering. Both singleton and multiple births were included.

4.3.4 Exposure

Index of Multiple Deprivation (IMD)

The IMD is widely used in England to measure neighbourhood socioeconomic deprivation (121). It was created by a team at the University of Oxford who were commissioned by the British government in 2000, to aid the targeting of regeneration programmes and to provide a more robust understanding of multidimensional deprivation (122). The IMD framework is grounded in the work of Townsend (123), who defined deprivation in relative terms, arguing that 'people can be said to be deprived if they lack the types of diet, clothing, housing, household facilities and fuel and environmental, educational, working and social conditions, activities and facilities which are customary.' However, it was developed to address the limitations of the Townsend Index, which relied on only four census-based indicators: unemployment, non-car ownership, non-home ownership and overcrowding. In contrast, the IMD incorporates seven weighted domains based on thirty-nine indicators (income, employment, education, health, crime, barriers to housing and services and living environment) and uses a mix of administrative and census data, updated more frequently to reflect current conditions. These domains were selected to reflect deprivation across a range of dimensions as well as on the availability of indicators. Each domain is assigned a weighted value relative to its importance in overall deprivation, derived from consideration of the academic literature on poverty and deprivation, as well as consideration of the levels of robustness of the indicators. Since its initial release, the IMD has been periodically updated (in 2004, 2007, 2010, 2015 and 2019) and has become the leading tool for measuring and addressing spatial inequalities in England.

This study selected deprivation at the smallest neighbourhood measure of LSOAs which are neighbourhoods of approximately 1,500 people. The overall deprivation level in an LSOA is

measured by the extent to which people within the LSOA experience different domains of deprivation, which are measured by separate indices. The areas (LSOAs) are then ranked nationally, with 1 being the least deprived and 32,844 being the most. Higher scores on any deprivation domain indicate more deprived areas.

In this analysis, the primary exposure was the composite IMD and the secondary exposures were the nine domains and subdomains. The health deprivation and disability domain was not included because its rankings are based on health outcomes data from HES APC. This creates a risk of 'mathematical coupling,' where the same data are used in both parts of the correlation analysis, potentially leading to an artificially strong relationship. The exposures were defined based on the 2019 and 2015 releases of the IMD. If the birth was before 1 January 2015, the 2015 IMD release was used. If the birth was on the 1 of January 2015 or after, the 2019 IMD release was used. The domains are listed below, and the indices that comprise the 2019 and 2015 IMD domains are shown in **Table 4.1**. For this study, so that the domains could be compared with each other, the national rankings were categorised into population-level quintiles, with the first quintile being the least deprived and the fifth the most.

Table 4.1. IMD domains, subdomains and indices and the proportion each domain contributes to the composite score (124)

Domain (% contribution to the composite score)*	**Indices**	**Additional Information**
Income 22.5%	Adults and children in income support families Adults and children in income-based Jobseeker's Allowance families Adults and children in income-based Employment and Support Allowance families Adults and children in Pension credit families Adults and children in Working Tax Credit and Child Tax Credit families, below 60% median income and not already counted Asylum seekers in England in receipt of subsistence support, accommodation support, or both Adults and Children in Universal Credit families where no adults in 'Working – no requirements' conditionally regime**	The totals are calculated by subtracting the prison population to avoid overlap. Shrinkage techniques were applied to improve the reliability and precision of the score where data may be sparse or subject to random variation.
Employment 22.5%	Claimants of Jobseeker's Allowance, aged 18-59/64 Claimants of Employment and Support Allowance, aged 18-59/64 Claimants of Incapacity Benefit, aged 18-59/64 Claimants of Carer's Allowance, aged 18-59/64 Claimants of Universal Credit in 'Searching for work' and 'No work requirements' conditionality group**	The score is calculated by dividing the seasonally-adjusted number of employment-deprived individuals by the working-age population, excluding the prison population.
Education Skills and Training 13.5%	**Children and Young People** Key stage 2 attainment Key stage 4 attainment Secondary school absence Staying on in education post 16 Entry to higher education	
	Adult Skills Adults with no or low qualifications, aged 25-59/64 Adults who cannot speak English or cannot speak English well, aged 25-59/64	
Health Deprivation and Disability 13.5%***	Years of potential life lost Comparative illness and disability ratio Acute morbidity Mood and anxiety disorders	
Crime 9.3%	Recorded crime rates for: violence, burglary, theft and criminal damage	These indicators are standardised, and factor analysis was used to combine them into a domain score.

Table 4.1 (Continued)

Domain (% contribution to the composite score)*	Indices	Additional information
Barriers to Housing and Services 9.3%	**Geographical Barriers** Road distance to a post office, primary school, general store or supermarket and GP surgery	
	Wider Barriers Household overcrowding Homelessness Housing affordability	
Living Environment 9.3%	**Indoors Living Environment** Houses without central heating Housing in poor condition	
	Outdoors Living Environment Air quality Road traffic accidents	

* Each domain of the IMD was assigned a specific weight that reflects its perceived contribution to overall deprivation. These weights were decided through expert consultation, statistical analysis, and, in some cases, through public or stakeholder input to ensure they captured the multidimensional nature of deprivation (124).
** Not included in the 2015 IMD
***The Health Deprivation and Disability domain was not included in the analysis where each domain/sub-domain was an exposure, nor the exploratory factor analysis in Chapter 5, because of the risk of 'mathematical coupling'

4.3.5 Outcome

SMM was defined using a modified English Maternal Morbidity Outcome Indicator (EMMOI) (125). This is a composite outcome which includes 21 diagnoses and 16 procedures, adapted from the original EMMOI (27), which can be used as a single measure of severe morbidity during childbirth using data from HES APC. The list of the relevant diagnoses/procedures and their codes are included in the **Appendix Table 4.3**.

4.3.6 Covariates

For each of the domains/subdomains, a Directed Acyclic Graph (DAG) (**Appendix Figures 4.1-4.9**) was used to conceptually represent which variables were confounders or mediators based on both existing literature and clinical knowledge *a priori*. The confounders identified were age, parity, ethnicity, year of childbirth, neighbourhood-level country of birth,

neighbourhood-level adult qualifications, neighbourhood-level English language proficiency, urban/rural, pre-existing medical and mental health conditions and smoking and substance misuse.

4.3.6.1 Parity

In the additional HES APC maternity section, there is a large amount of missing data on parity (35.7%) and these women were not excluded from the cohort. Missing data is more common in certain hospitals (126) as well as in women who are younger (p_{trend} $p<0.001$), from a minoritised ethnicity (RR 1.08 (95% CI 1.07-1.08)) and have SMM (RR 1.07 (95% CI 1.06-1.09)) (**Appendix Table 4.4)**. Therefore, dropping all women with missing data on parity may introduce selection bias into the cohort. This could reduce both the internal and external validity of the analysis, as women would be disproportionally excluded who had characteristics which were important in the study and the results would no longer be nationally representative. Secondly, there is evidence that even when it has been recorded this could be incorrect in certain hospitals. For instance, some hospitals reported that nearly all their mothers were first-time mothers, or nearly all second-time mothers.

For all women in the dataset the following algorithm was applied to identify and correct inconsistent parity, or to provide a value when it was unknown. Firstly, any trust that had a percentage of nulliparous women outside the range 20–70% had all their parity data set to 'unknown'. A total of 20 hospitals or 438,440 women (7.45% of women) had their parity data set to 'unknown' using this method. Parity was then determined using a combination of the value provided in the field NUMPREG and a 'look back' method. A woman was labelled as multiparous if she had a parity greater than zero, a code suggesting a previous birth (for example a code for previous caesarean birth) during this pregnancy (O34.2, O75.7, Z35.4, Z87.6 and Z87.5), or it was not the first birth 'superspell' in the database (a code of R17-R25

before this pregnancy). If she was not flagged as being multiparous by the method above, she was assumed to be primiparous. **Appendix Table 4.5** shows the number of women who were labelled as primiparous in the additional HES APC maternity section (NUMPREG=0) who had evidence of a previous pregnancy using the other methods for determining parity. **Appendix Table 4.6** shows how many women by each method were assigned their parity scores. According to this method, 41.4% of the women were coded as primiparous and 58.6% multiparous which aligns with the parity distribution in the gold standard, Office for National Statistics (ONS) data (120).

4.3.6.2 Neighbourhood-level Socioeconomic Variables

2011 Census data was used to derive neighbourhood-level socioeconomic variables for each LSOA. The proportions of each were calculated and then the LSOAs were subsequently ranked based on these proportions.

- Neighbourhood country of birth: The proportion of women born outside of the UK was computed using all residents born outside of the UK as the numerator and all residents as the denominator.

- Neighbourhood adult qualifications: The proportion of neighbourhood adult qualifications was computed using all working-age adults with no or low qualifications as the numerator and all working-age adults as the denominator.

- Neighbourhood English language proficiency: The proportion of neighbourhood English language proficiency was computed using all working-age adults who cannot speak English as the numerator and all working-age adults as the denominator

4.3.6.3 Ethnicity

Ethnicity was defined using the ONS categorisation system (127) and then collapsed into ten groups based on the categories used for the MBRRACE-UK perinatal mortality surveillance report (128): White, Black or Black British - African, Black or Black British - Caribbean, Asian or Asian British - Indian, Asian or Asian British - Pakistani, Asian or Asian British - Bangladeshi, Mixed, Other, Other Black and Other Asian. The ONS made person-level comparisons between ethnicity coded in HES and self-reported ethnicity in the 2011 census (considered gold standard). Out of the 66% of the total population recorded in the 2011 census which could both be linked with HES and had their ethnicity recorded, there was 90.7% agreement when ethnicity was divided into 18 ethnic categories and 95.8% agreement when it was divided into five ethnic categories between the two data sources (127). In this cohort, there was 15% missing data on ethnicity. This was reduced to 5% by copying ethnicity from any hospital admission in the database prior to creating the final cohort of solely delivery episodes.

4.3.6.4 Age

Maternal age at childbirth was grouped into five-year categories except for ages younger than 20 or older than 40 years which were grouped into single categories.

4.3.6.5 Urban/ Rural

The ONS Rural Urban Classification (129) was used to distinguish rural and urban areas based on 2011 LSOAs.

4.3.6.6 Year of Childbirth

Year was determined from the year of birth of the baby.

4.3.6.7 Other Variables

The following conditions were derived from ICD-10 codes:

- Pre-existing medical conditions
- Pre-existing mental health conditions
- Substance misuse and smoking

A list of confounding pre-existing medical conditions relevant to SMM has been devised by D'Arcy et al (125). The list was modified to include the conditions which can be appropriately coded in the HES APC, are related to SMM and are associated with socioeconomic disadvantage. A list and their corresponding ICD-10 codes for pre-existing mental health conditions, smoking and substance misuse has been devised by Harron et al (130). The full list of all the conditions for the covariates and their corresponding ICD-10 codes are shown in **Appendix Table 4.1**. Women were assumed not to have the above covariates if they were not coded in any of the hospital records from the preceding length of time listed in **Appendix Table 4.1**.

4.3.6.8 Other Covariates

The following covariates were not used as confounding factors in the model but were used to describe the cohort:

- **Mode of Labour Onset**

  Mode of labour onset was derived from the DELONSET variable in the HES APC additional maternity section and was categorised into spontaneous, any caesarean birth, surgical induction by amniotomy, medical induction and combination of surgical and medical induction.

- **Mode of Birth**

  Mode of birth was derived using the variable DELMETH in HES APC additional maternity section and was categorised into unassisted vaginal vertex birth, instrumental birth, breech birth, elective caesarean birth, emergency caesarean birth and other modes of birth. Mode of birth in the additional maternity section (if not missing) has a high level of agreement with procedure codes (**Appendix Table 4.7)**. If there were missing data in the additional maternity section (15.7%), procedure codes were used (R17-R25).

4.3.7 Statistical Analysis

Statistical analysis was performed using Stata version 18 (StataCorp. 2023. Stata Statistical Software: Release 18. College Station, TX: StataCorp LLC). Statistical significance was assumed to be a two-tailed p value of less than 0.05.

4.3.7.1 Descriptive Statistics

The data were checked for implausible values and these were recoded as missing. The characteristics of the women in the study population are presented as number and percentage stratified by the composite IMD quintile. The frequency and proportion of each SMM condition in the final composite outcome was calculated.

4.3.7.2 Change in Rate of SMM Over Time

The annual frequency and incidence rate and their 95% CIs of the composite SMM outcome per 1000 maternities were computed. Cochran-Armitage's test for trend was used to describe the trend over time. Joinpoint analysis (131) was used to identify points where there was a significant change in trend over time, providing statistics such as the rate of change (slope) for each segment, the number and location of joinpoints, and the statistical significance of these

changes. The incidence rate of SMM stratified by the composite IMD quintile of SMM per 1000 maternities (women with either live or stillbirths) per year were calculated. The frequency and proportion of the individual conditions of the composite SMM indicator were calculated stratifying by year of birth. Poisson regression with robust standard errors was used to calculate incidence rate ratios (and their 95% CIs) per year of the diagnoses/procedures which contributed the largest proportion of the composite outcome to explore whether any change in rate over time was driven by a single condition.

4.3.7.3 Multi-level Modelling

Multi-level Poisson regression with a random intercept was used to calculate the risk ratios (RR) (and 95% CI) to account for clustering between individuals who shared the same postcode (LSOA). Level 1 was defined as the individual woman and level 2, her LSOA. A fixed effects null model was compared to a model which included both fixed and random effects using a likelihood ratio test. A caterpillar plot was used to visualise the estimated random effects (and 95% CI). The Intra Class Coefficient (ICC) was used to quantify the proportion of the total variance that is due to differences between individuals (Level 1) compared to differences between groups (Level 2).

4.3.7.4 Univariable Analysis

The baseline group (the reference category) was the least deprived quintile. Multi-level Poisson regression modelling was used to estimate the RR for SMM and their 95% CI for each level of the exposure.

4.3.7.5 Multivariable Analysis

Three models were built using multi-level multivariable Poisson regression to estimate the RR of SMM (and their 95% CI) in the different quintiles of deprivation compared to the least deprived quintile using a complete case analysis excluding 200,950 women with missing information on ethnicity. Model 1 included the variables identified as confounders which were consistent across all the different exposures; age, year, parity and ethnicity. Likelihood ratio testing for linearity was used to determine whether age should be modelled as continuous or as a categorical variable. Model 2 included any additional variables which were identified as confounders for that specific domain/subdomain. Model 3 included additional adjustment for the pre-existing medical and mental health conditions and smoking/substance misuse. Model 2 was used as the final model as the covariates in Model 3 could be either confounders or mediators and therefore there is a risk of over adjustment. There was no Model 3 for the children and young people subdomain as pre-existing medical and mental health conditions and smoking/substance misuse were not identified as potential confounders in the DAG. RR (and their 95% CI) were calculated separately for the major components of the composite SMM outcome using Model 2 in the most deprived composite IMD quintile compared to the least.

4.3.7.6 Missing Data

The outcome was classified using procedure and diagnosis codes and, therefore, had no quantifiable missing information. As there were less than 5% missing data on the exposure and other covariates a complete case analysis was chosen. **Appendix Table 4.8 and 4.9** shows the characteristics of the women in the HES APC with missing data.

4.3.7.7 Effect Modification by Ethnicity

Likelihood ratio testing was used to test for effect modification by ethnicity. It was decided *a prioi* to test for an effect modification between each measure of disadvantage and ethnicity. A p-value for interaction ($P_{interaction}$) <0.05 was considered statistically significant. If there was evidence of effect modification by ethnicity, all ethnic groups were compared to a standard reference point (the least deprived White women category) to provide a consistent baseline across all comparisons. Absolute measures were then calculated using average adjusted predictive margins which provide an average probability of SMM for each combined category of ethnicity and socioeconomic position.

4.3.7.8 Population Attributable Fraction (PAFs)

Univariable and multivariable (using Model 2) population attributable fractions (PAFs) and their 95% CIs were calculated using the *punaf* command in Stata in each measure of socioeconomic disadvantage. Attributable fraction was defined as the difference in the observed and expected number of women with SMM, divided by the observed number. The attributable fraction describes the proportion of SMM which would not have occurred were the risk of SMM the same as in the women in the reference group and depends on the proportion of the population exposed to the risk factors (deprivation) and the effect size. The data were used for women in each highest socioeconomic group as the reference group for the overall analysis or those from a White ethnic background in the highest socioeconomic group as the reference group for the analysis by ethnicity, which was then applied to the women in the entire cohort.

4.3.7.9 Sensitivity Analyses

A sensitivity analysis was conducted which excluded women with both missing gestational age at birth and birthweight (13.1%). A second sensitivity analysis defined SMM using only ICD-10 codes as to be able to compare to the results of the DIAPER analysis (**Chapter 6**), as the Dutch DIAPER database does not have OPCS-4 codes to define SMM. A third sensitivity analysis excluded sepsis from the outcome, as sepsis made up the greatest proportion of the outcome and is potentially more subject to differential diagnostic criteria and coding practices between hospitals with the incidence rate fluctuating from 1 in 1000 births to 33 in 1000 births between hospitals. Finally, a sensitivity analysis included sepsis in the outcome only if the length of hospital stay was three days or more, which aimed to reduce the likelihood of non-sepsis events such as prophylactic antibiotics given in labour being misclassified as sepsis (132).

4.4 Results

4.4.1 Descriptive Statistics

The study population consisted of 4,040,106 women with a mean age at childbirth of 30 years. The identification of the study population is shown in **Figure 4.1**. The characteristics of the women in the study population are shown in **Table 4.2**. The overall incidence of SMM was 17.7 (95% CI 17.6-17.8) per 1000 maternities. Women who lived in the most deprived quintiles were more likely to have SMM, be younger, be from a minoritised ethnic group, live in urban areas, live in areas with a higher percentage of people who were not born in the UK, live in Yorkshire and the Humber, the North West, the West Midlands or London, be multiparous, have a history of smoking or substance misuse, be obese and have pre-existing mental health conditions. They were also more likely to have had an unassisted vertex vaginal birth and to have registered their pregnancy with the midwife on or later than 12 weeks. The conditions

which made up the greatest proportion of the modified EMMOI were sepsis (40%), acute renal failure (14.4%) and the management of intra-abdominal or vaginal collection (14.7%) (**Figure 4.2)**. **Appendix Table 4.10** showed that the proportion of the composite SMM outcome was higher for sepsis, sickle cell crisis or an embolic event for women living in the most deprived areas and was higher for management of a collection, acute renal failure or management of a vulval/vaginal haematoma for women living in the least deprived areas.

Figure 4.1. Flow chart showing the identification of the cohort

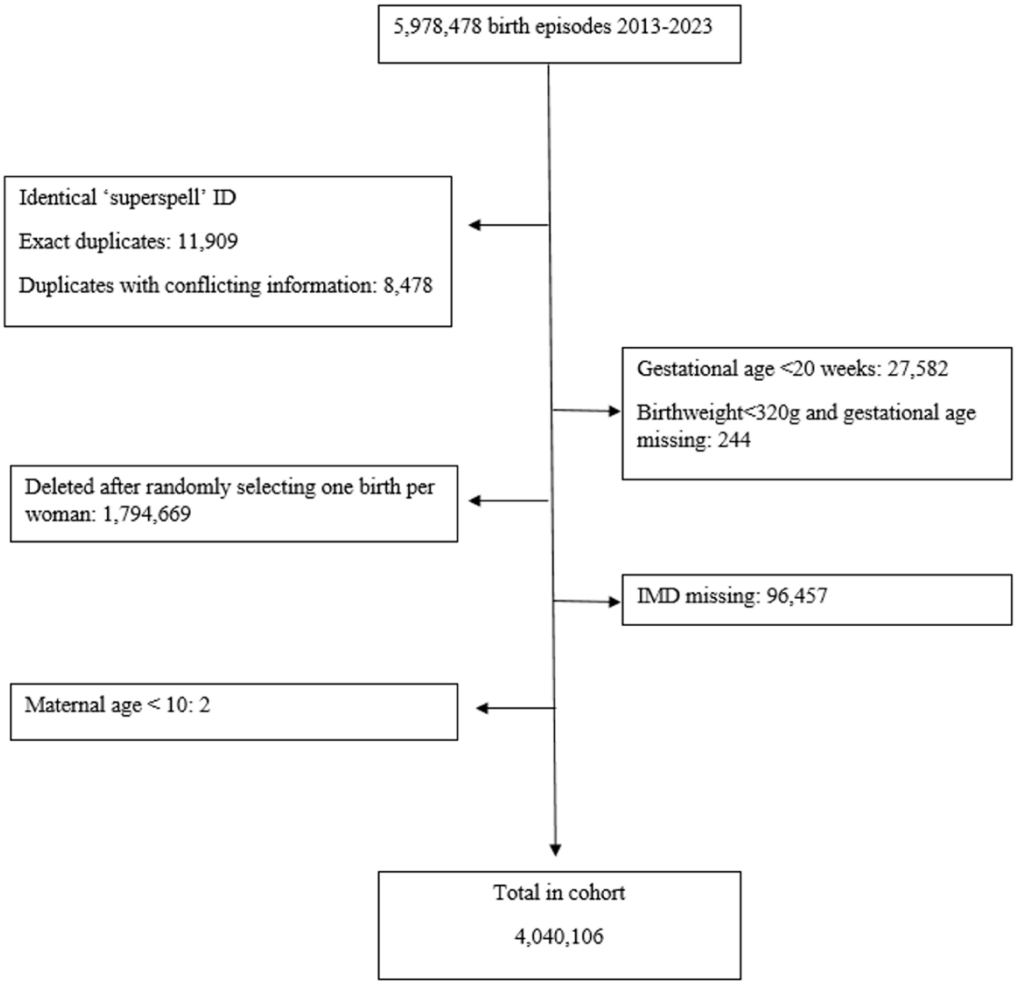


Table 4.2. Characteristics of the study population stratified by composite Index of Multiple Deprivation quintile, number and percentage (N (%)).

	Index of Multiple Deprivation Quintile					
	Most deprived 20%	**More deprived 20-40%**	**Less deprived 40-60%**	**Less deprived 60-80%**	**Least deprived 80-100%**	**Total**
	N(%)	**N(%)**	**N(%)**	**N(%)**	**N(%)**	**N(%)**
Total	**1,048,387 (25.9)**	**916,418 (22.7)**	**778,629 (19.3)**	**686,228 (17.0)**	**610,444 (15.1)**	**4,040,106 (100.0)**
SMM						
No	1,028,362 (98.1)	899,119 (98.1)	765,055 (98.3)	675,001 (98.4)	601,151 (98.5)	3,968,688 (98.2)
Yes	20,025 (1.9)	17,299 (1.9)	13,574 (1.7)	11,227 (1.6)	9,293 (1.5)	71,418 (1.8)
Age group						
<20	55,363 (5.3)	30,243 (3.3)	18,850 (2.4)	12,006 (1.7)	7,394 (1.2)	123,856 (3.1)
20-25	207,037 (19.7)	140,181 (15.3)	95,759 (12.3)	66,879 (9.7)	43,695 (7.2)	553,551 (13.7)
25-30	313,768 (29.9)	262,243 (28.6)	209,558 (26.9)	170,878 (24.9)	130,874 (21.4)	1,087,321 (26.9)
30-35	281,696 (26.9)	284,168 (31.0)	263,127 (33.8)	248,454 (36.2)	233,664 (38.3)	1,311,109 (32.5)
35-40	149,881 (14.3)	158,938 (17.3)	153,684 (19.7)	150,808 (22.0)	156,400 (25.6)	769,711 (19.1)
>40	40,642 (3.9)	40,645 (4.4)	37,651 (4.8)	37,203 (5.4)	38,417 (6.3)	194,558 (4.8)
Ethnicity						
White	665,971 (66.5)	623,508 (71.7)	590,306 (80.0)	554,122 (85.2)	505,782 (87.2)	2,939,689 (76.6)
Black or Black British - Caribbean	16,363 (1.6)	11,260 (1.3)	5,304 (0.7)	2,602 (0.4)	1,517 (0.3)	37,046 (1.0)
Black or Black British - African	56,529 (5.6)	33,764 (3.9)	15,279 (2.1)	8,403 (1.3)	5,516 (1.0)	119,491 (3.1)
Asian or Asian British - Indian	28,995 (2.9)	39,187 (4.5)	29,243 (4.0)	20,346 (3.1)	17,720 (3.1)	135,491 (3.5)
Asian or Asian British - Pakistani	76,829 (7.7)	37,538 (4.3)	18,864 (2.6)	10,219 (1.6)	6,430 (1.1)	149,880 (3.9)
Asian or Asian British - Bangladeshi	29,469 (2.9)	16,301 (1.9)	6,208 (0.8)	2,968 (0.5)	1,700 (0.3)	56,646 (1.5)
Mixed	24,810 (2.5)	18,537 (2.1)	12,763 (1.7)	10,025 (1.5)	8,207 (1.4)	74,342 (1.9)
Other	60,266 (6.0)	49,783 (5.7)	34,359 (4.7)	25,299 (3.9)	20,908 (3.6)	190,615 (5.0)
Other Asian	26,605 (2.7)	28,187 (3.2)	20,346 (2.8)	13,833 (2.1)	10,527 (1.8)	99,498 (2.6)
Other Black	15,569 (1.6)	11,312 (1.3)	5,177 (0.7)	2,652 (0.4)	1,748 (0.3)	36,458 (0.9)
Parity						
Multiparous	659,764 (62.9)	537,140 (58.6)	438,060 (56.3)	382,215 (55.7)	351,669 (57.6)	2,368,848 (58.6)
Primiparous	388,623 (37.1)	379,278 (41.4)	340,569 (43.7)	304,013 (44.3)	258,775 (42.4)	1,671,258 (41.4)
Rural/Urban						
Urban	1,029,343 (98.2)	850,301 (92.8)	637,753 (81.9)	529,929 (77.2)	480,662 (78.7)	3,527,988 (87.3)
Rural	19,044 (1.8)	66,117 (7.2)	140,876 (18.1)	156,299 (22.8)	129,782 (21.3)	512,118 (12.7)

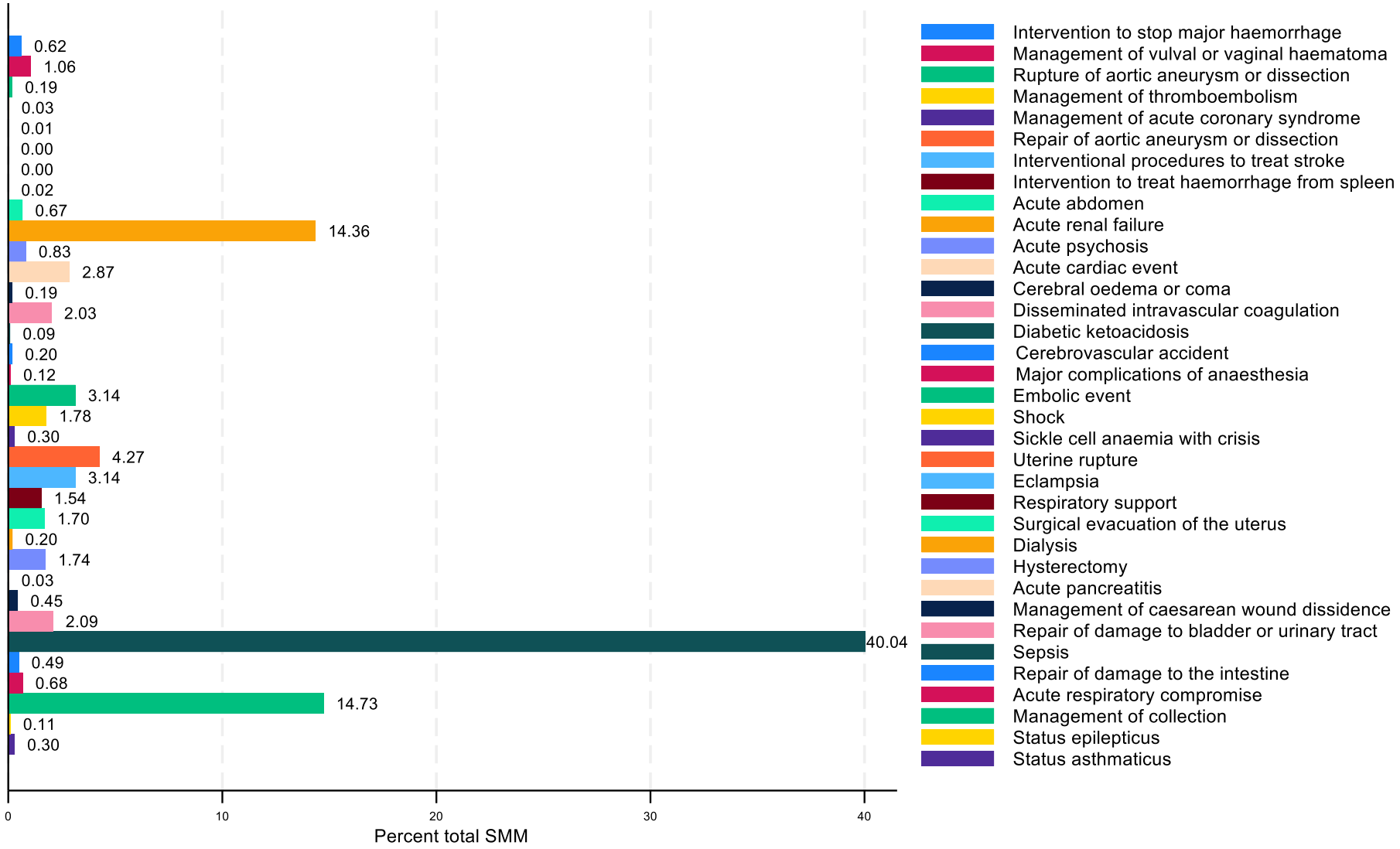
Table 4.2. (Continued)

	Index of Multiple Deprivation Quintile					
	Most deprived 20%	**More deprived 20-40%**	**Less deprived 40-60%**	**Less deprived 60-80%**	**Least deprived 80-100%**	**Total**
	N(%)	**N(%)**	**N(%)**	**N(%)**	**N(%)**	**N(%)**
Neighbourhood % not born in the United Kingdom (UK)						
Lowest 20%	143,288 (13.7)	135,365 (14.8)	135,550 (17.4)	129,127 (18.8)	90,309 (14.8)	633,639 (15.7)
Lower 20-40%	130,863 (12.5)	122,910 (13.4)	139,272 (17.9)	151,051 (22.0)	128,930 (21.1)	673,026 (16.7)
Middle 40-60%	149,684 (14.3)	126,040 (13.8)	144,984 (18.6)	149,809 (21.8)	175,144 (28.7)	745,661 (18.5)
Higher 60-80%	211,775 (20.2)	176,726 (19.3)	158,326 (20.3)	151,993 (22.1)	168,844 (27.7)	867,664 (21.5)
Highest 80-100%	412,777 (39.4)	355,377 (38.8)	200,497 (25.8)	104,248 (15.2)	47,217 (7.7)	1,120,116 (27.7)
Region						
North East	72,751 (6.9)	42,623 (4.7)	23,564 (3.0)	20,435 (3.0)	18,176 (3.0)	177,549 (4.4)
North West	227,447 (21.7)	104,346 (11.4)	74,650 (9.6)	70,271 (10.2)	54,952 (9.0)	531,666 (13.2)
Yorkshire and Humber	149,996 (14.3)	74,309 (8.1)	60,442 (7.8)	61,144 (8.9)	42,613 (7.0)	388,504 (9.6)
East Midlands	74,323 (7.1)	69,764 (7.6)	57,667 (7.4)	58,831 (8.6)	57,998 (9.5)	318,583 (7.9)
West Midlands	170,289 (16.2)	85,624 (9.3)	74,546 (9.6)	59,378 (8.7)	43,414 (7.1)	433,251 (10.7)
East of England	56,811 (5.4)	90,618 (9.9)	103,793 (13.3)	94,706 (13.8)	96,879 (15.9)	442,807 (11.0)
London	183,610 (17.5)	260,984 (28.5)	162,303 (20.8)	105,007 (15.3)	56,304 (9.2)	768,208 (19.0)
South East	64,190 (6.1)	114,435 (12.5)	133,841 (17.2)	137,657 (20.1)	179,889 (29.5)	630,012 (15.6)
South West	48,970 (4.7)	73,715 (8.0)	87,823 (11.3)	78,799 (11.5)	60,219 (9.9)	349,526 (8.7)
Substance misuse or Smoking						
No	727,128 (69.4)	683,531 (74.6)	603,359 (77.5)	550,446 (80.2)	510,651 (83.7)	3,075,115 (76.1)
Yes	321,259 (30.6)	232,887 (25.4)	175,270 (22.5)	135,782 (19.8)	99,793 (16.3)	964,991 (23.9)
Pre-existing medical conditions						
No	824,213 (78.6)	726,596 (79.3)	616,128 (79.1)	542,836 (79.1)	484,860 (79.4)	3,194,633 (79.1)
Yes	224,174 (21.4)	189,822 (20.7)	162,501 (20.9)	143,392 (20.9)	125,584 (20.6)	845,473 (20.9)
Pre-existing mental health problems						
No	906,066 (86.4)	804,865 (87.8)	686,335 (88.1)	607,381 (88.5)	545,308 (89.3)	3,549,955 (87.9)
Yes	142,321 (13.6)	111,553 (12.2)	92,294 (11.9)	78,847 (11.5)	65,136 (10.7)	490,151 (12.1)

Table 4.2. (Continued)

	Index of Multiple Deprivation Quintile					
	Most deprived 20%	**More deprived 20-40%**	**Less deprived 40-60%**	**Less deprived 60-80%**	**Least deprived 80-100%**	**Total**
	N(%)	**N(%)**	**N(%)**	**N(%)**	**N(%)**	**N(%)**
Obesity/ overweight						
No	779,597 (78.5)	714,653 (81.5)	622,088 (83.0)	559,458 (84.3)	514,193 (86.7)	3,189,989 (82.3)
Yes	213,613 (21.5)	161,788 (18.5)	127,704 (17.0)	104,319 (15.7)	78,886 (13.3)	686,310 (17.7)
Mode of birth						
Unassisted vaginal vertex birth	609,611 (58.2)	505,708 (55.3)	421,923 (54.3)	366,773 (53.6)	323,502 (53.1)	2,227,517 (55.3)
Instrumental birth	122,666 (11.7)	124,866 (13.7)	108,112 (13.9)	96,084 (14.0)	85,292 (14.0)	537,020 (13.3)
Breech birth	4,624 (0.4)	3,964 (0.4)	3,502 (0.5)	2,858 (0.4)	3,158 (0.5)	18,106 (0.4)
Elective caesarean birth	124,545 (11.9)	114,158 (12.5)	104,524 (13.5)	99,477 (14.5)	93,263 (15.3)	535,967 (13.3)
Emergency caesarean birth	179,325 (17.1)	159,238 (17.4)	132,985 (17.1)	113,814 (16.6)	97,796 (16.1)	683,158 (16.9)
Other modes of birth	6,069 (0.6)	6,680 (0.7)	5,574 (0.7)	5,529 (0.8)	5,821 (1.0)	29,673 (0.7)
Birth onset method						
Spontaneous: the onset of regular contractions whether or not preceded by spontaneous rupture of the membranes	449,318 (52.0)	398,247 (53.1)	339,729 (53.0)	298,449 (52.8)	271,827 (53.4)	1,757,570 (52.8)
Any caesarean section carried out immediately following the onset of labour, when the decision was made before labour	140,541 (16.3)	120,828 (16.1)	105,774 (16.5)	97,175 (17.2)	91,233 (17.9)	555,551 (16.7)
Surgical induction by amniotomy	47,538 (5.5)	40,232 (5.4)	35,785 (5.6)	30,227 (5.3)	27,532 (5.4)	181,314 (5.4)
Medical induction	159,652 (18.5)	139,533 (18.6)	116,190 (18.1)	101,196 (17.9)	86,914 (17.1)	603,485 (18.1)
Combination of surgical induction and medical induction	67,818 (7.8)	51,134 (6.8)	43,410 (6.8)	38,612 (6.8)	31,077 (6.1)	232,051 (7.0)
Booked antenatal care ≥12 weeks						
No	378,100 (71.4)	362,636 (76.2)	320,175 (79.3)	289,469 (81.2)	270,547 (82.4)	1,620,927 (77.4)
Yes	151,239 (28.6)	113,349 (23.8)	83,758 (20.7)	67,055 (18.8)	57,816 (17.6)	473,217 (22.6)

Figure 4.2. The proportion (%) of each SMM diagnosis (ICD-10) or procedure (OPCS-4) in the final composite outcome



4.4.2 Change in Rate of SMM Over Time

The incidence rate per 1000 maternities per year for the composite SMM outcome increased over time (**Figure 4.3)**. There was a linear trend ($p<0.001$) in the incidence rate of SMM from 2013 to 2019 with an 18.2% annual percentage change (**Appendix Figure 4.10**). SMM rates across the IMD quintiles began to diverge over time, with the largest increase occurring in the 20-40% more deprived quintile with an incidence of SMM of 9 in 1000 maternities in 2013 compared to an incidence of SMM of 31 in 1000 births maternities in 2022 (**Figure 4.4**). The annual frequency and proportion of individual SMM conditions are summarised in **Appendix Table 4.11**. The increase in rate over time was particularly pronounced for sepsis and acute renal failure (**Appendix Figure 4.11**), which contributed an increasing proportion of the overall SMM outcome over time, with an increase in the incidence of 2 to 13 in 1000 maternities for sepsis and 1 to 7 in 1000 maternities for acute renal failure from 2013 to 2022. However, both conditions showed a subsequent flattening of the increase in 2020 (for sepsis) and 2021 (for acute renal failure**)** (**Appendix Figure 4.11**) which may explain the flattening of the increase in rate of the composite outcome from 2019.

Figure 4.3. The crude incidence rate (N per 1000 maternities) and 95% confidence interval per year for SMM

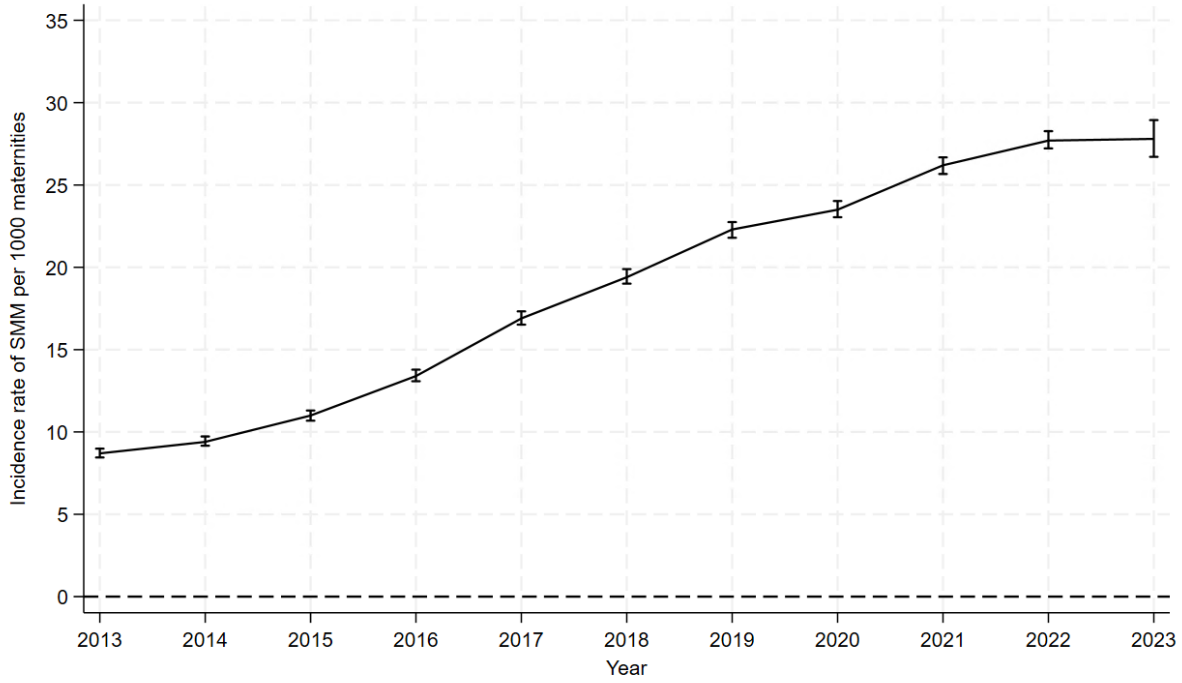
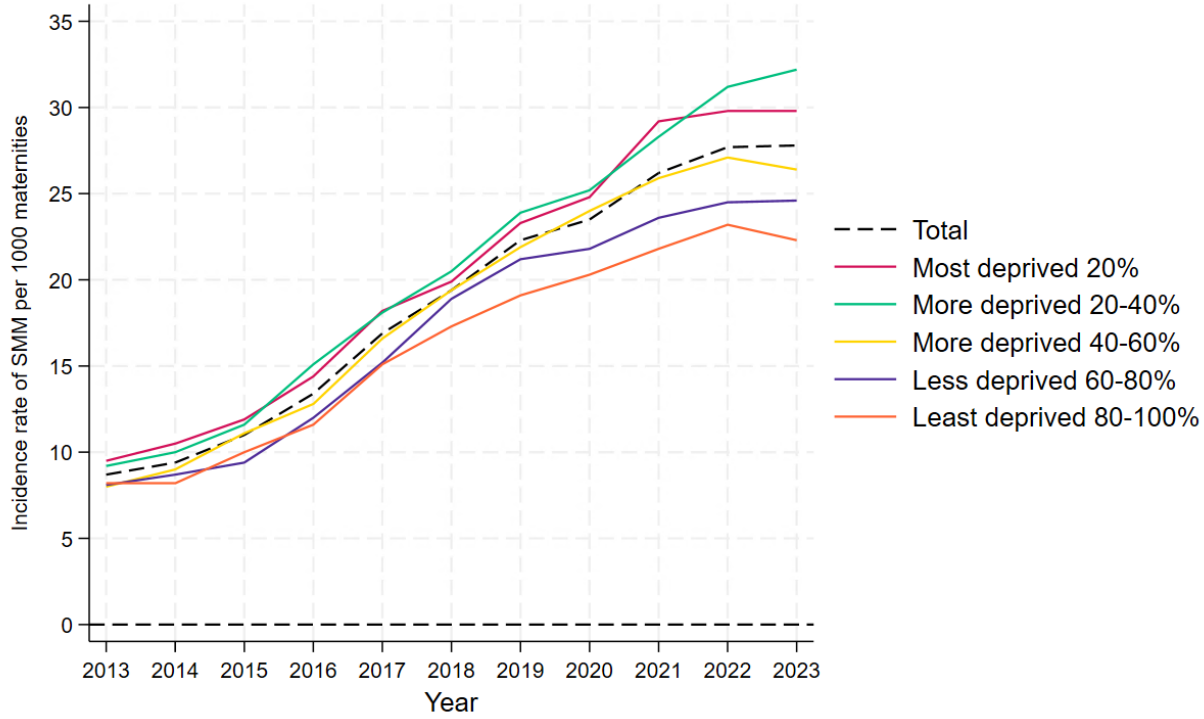


Figure 4.4. The crude incidence rate (N per 1000 births) of SMM per year stratified by the Index of Multiple Deprivation



4.4.3 Multilevel Modelling

There were 33,977 different neighbourhoods modelled at the LSOA level with a range of maternities per neighbourhood of between 1 and 1,001, with an average of 120. Multi-level modelling was chosen to model all the neighbourhood disadvantage measures as in the null model (containing the outcome and LSOA level only with no explanatory variable), the multi-level model had a better fit than the fixed effect model. Differences between neighbourhoods (Level 2) contributed to 3.8% (95% CI 3.5%-4.0%) of the variance compared to the remaining 96.2% (95% CI 96.0%-96.5%) which was from the variance between individuals within neighbourhoods (Level 1). The caterpillar plot describing the predictive probability (and their 95% CI) of SMM (%) in each LSOA is shown in **Appendix Figure 4.12** which shows only small variation in the risk of SMM across the different neighbourhoods.

4.4.4 Univariable Analysis

There was a positive association between the composite IMD and SMM with a similar risk seen in the most deprived quintile (RR 1.24 (95% CI 1.20-1.27)) and fourth most deprived quintile (RR 1.23 (95% CI 1.20-1.27)) compared to the least deprived quintile. There was a positive association between eight out of the nine subdomains with the greatest association seen in the outdoor living environment and the wider barriers subdomains where the RR was 1.38 (95% CI 1.34-1.42) and 1.49 (95% CI 1.45-1.53) in the most deprived quintile compared to the least deprived quintile respectively (**Tables 4.3-4.14**). The geographical barriers subdomain appeared to be associated with a reduced risk of SMM, with a RR of 0.73 (95% CI 0.71-0.75) in the most deprived quintile compared to the least deprived quintile.

4.4.5 Multivariable Analysis

There was a dose-response relationship between composite IMD and risk of SMM in the final model which adjusted for age, year, parity and ethnicity (Model 2) (**Table 4.3, Figure 4.5**.) The adjusted RR was 1.21 (95% CI 1.17-1.24) in the most deprived IMD quintile compared to the least. Women who lived in the most deprived IMD areas compared to those living in the least deprived areas had an increased risk of sepsis, acute renal failure, 'all other SMM conditions', but not for the management of a pelvic or intra-abdominal collection (**Figure 4.6**). In a more detailed breakdown (**Appendix Figure 4.13)** of the association between deprivation and the conditions with the highest prevalence in 'all other SMM conditions' (embolic and cardiac events, uterine rupture and eclampsia), there was a dose-response relationship, with an increased risk with increasing deprivation of an acute cardiac or embolic event. The strongest association was between deprivation and embolic events, with an adjusted RR of 1.97 (95% CI 1.69-2.29) in the most compared to the least deprived IMD quintile.

The results of the multivariable models for each of the nine domains/subdomains are shown in **Tables 4.4-4.14** and the results of the final model (Model 2) across the different domains are shown in **Figure 4.7**. There was a dose-response relationship for neighbourhood income, neighbourhood employment, outdoor living environment and adult skills, although the magnitude of risk between outdoor living environment and SMM was small (adjusted RR 1.06 (95% CI 1.03-1.10)) for women living in the most deprived quintile compared to those living in the least. The association between the geographical barriers and SMM remained after multivariable adjustment, although it was attenuated, with an adjusted RR of 0.92 (95% CI 0.89-0.95) for women living in the most deprived quintile compared to those living in the least. The subdomain, wider barriers, was only a statistically significant risk for SMM in the most deprived quintile (adjusted RR 1.15 (95% 1.10-1.20)) with all the remaining quintiles not

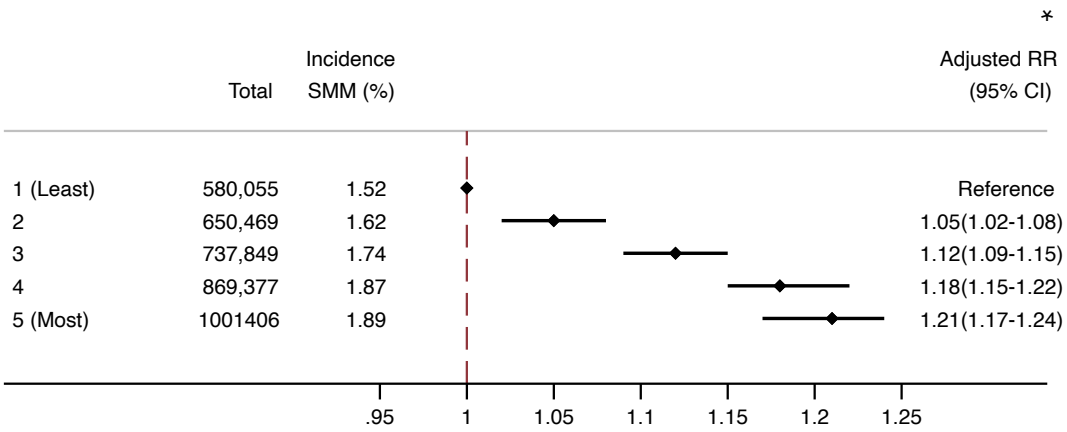
showing a statistically significant result, when compared to the least deprived quintile. There was no evidence for an association between crime and SMM.

Table 4.3. Univariable and multivariable analysis showing risk ratios (and their 95% confidence intervals) between the **composite IMD** and SMM compared to the least deprived IMD quintile. There is no Model 1 as Model 2 did not require any additional adjustments based on the DAG *Model 2: Adjusted for year, age, parity and ethnicity. **Model 3: Model 2 additionally adjusted for substance misuse/ smoking/ pre-existing medical conditions/ pre-existing mental health conditions.

	Unadjusted	**Model 2* (final model)**	**Model 3****
Composite Index of Multiple Deprivation quintile	Risk ratio (95% CI)	Risk ratio (95% CI)	Risk ratio (95% CI)
Most deprived 20%	1.24 (1.20-1.27)	1.21 (1.17-1.24)	1.19 (1.16-1.22)
More deprived 20- 40%	1.23 (1.20-1.27)	1.18 (1.15-1.21)	1.17 (1.14-1.20)
Less deprived 40-60%	1.15 (1.11-1.18)	1.11 (1.08-1.14)	1.10 (1.07-1.14)
Less deprived 60-80%	1.07 (1.04-1.11)	1.05 (1.02-1.09)	1.05 (1.02-1.08)
Least deprived 80-100%	1(ref)	1(ref)	1(ref)
ICC	0.036 (0.033-0.038)	0.027 (0.025-0.030)	0.027 (0.025-0.030)

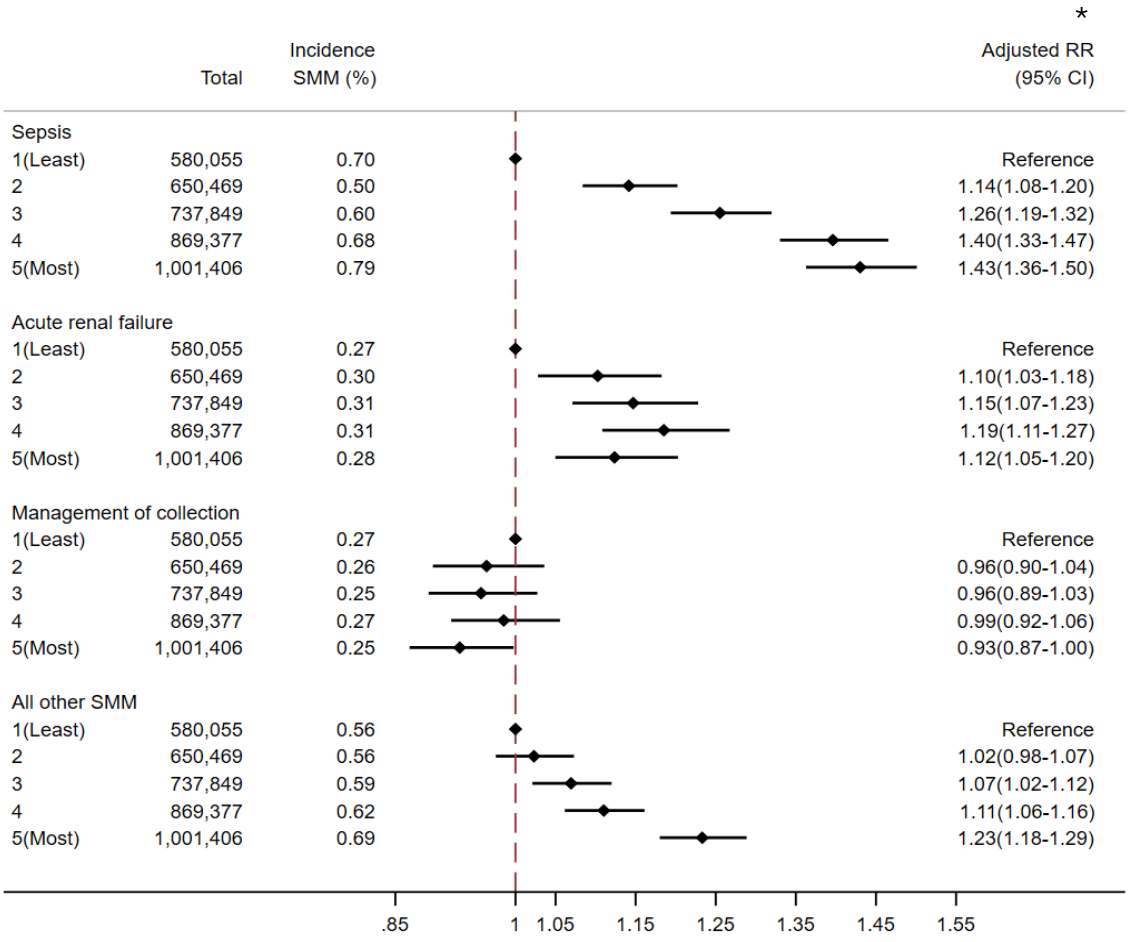
Abbreviations: CI, confidence interval; ICC, Intra-class Correlation Coefficient

Figure 4.5. Adjusted risk ratios (and their 95% confidence intervals) of SMM in each of the composite IMD quintiles compared to the least deprived quintile.



* *Adjusted for age, year, parity and ethnicity*

Figure 4.6. Adjusted risk ratios (and their 95% confidence intervals) of sepsis, acute renal failure, management of collection and 'all other SMM' conditions in each of the composite IMD quintiles compared to the least deprived quintile.



* *Adjusted for age, year, parity and ethnicity*

Table 4.4. Univariable and multivariable analysis showing risk ratios (and their 95% confidence intervals) between **income** and SMM compared to the least deprived income quintile. *Model 1: Adjusted for year, age, parity and ethnicity **Model 2: Model 1 + additionally adjusted for % neighbourhood country of birth/ neighbourhood English language proficiency ***Model 3: Model 2 + additionally adjusted for substance misuse/ smoking/ pre-existing medical conditions/ pre-existing mental health conditions.

	Unadjusted	**Model 1***	**Model 2 (final model)****	**Model 3*****
Income quintile	Risk ratio (95% CI)	Risk ratio (95% CI)	Risk ratio (95% CI)	Risk ratio (95% CI)
Most deprived 20%	1.23 (1.19-1.26)	1.21 (1.18-1.24)	1.16 (1.12-1.20)	1.14 (1.10-1.17)
More deprived 20-40%	1.19 (1.16-1.22)	1.16 (1.13-1.19)	1.12 (1.08-1.15)	1.10 (1.06-1.13)
Less deprived 40-60%	1.12 (1.09-1.16)	1.10 (1.07-1.13)	1.07 (1.04-1.10)	1.06 (1.03-1.10)
Less deprived 60-80%	1.04 (1.01-1.08)	1.04 (1.01-1.08)	1.04 (1.00-1.07)	1.03 (1.00-1.06)
Least deprived 80-100%	1(ref)	1(ref)	1(ref)	1(ref)
ICC	0.035 (0.033-0.038)	0.028 (0.025-0.030)	0.027 (0.025-0.030)	0.027 (0.025-0.029)

Abbreviations: CI, confidence interval; ICC, Intra-class Correlation Coefficient

Table 4.5. Univariable and multivariable analysis showing risk ratios (and their 95% confidence intervals) between **employment** and SMM compared to the least deprived employment quintile. *Model 1: Adjusted for year, age, parity and ethnicity **Model 2: Model 1 + additionally adjusted for %neighbourhood country of birth/ neighbourhood English language proficiency ***Model 3: Model 2 + additionally adjusted for substance misuse/ smoking/ pre-existing medical conditions/ pre-existing mental health conditions.

	Unadjusted	**Model 1***	**Model 2 (final model)****	**Model 3*****
Employment quintile	Risk ratio (95% CI)	Risk ratio (95% CI)	Risk ratio (95% CI)	Risk ratio (95% CI)
Most deprived 20%	1.15 (1.11-1.18)	1.16 (1.13-1.20)	1.15 (1.11-1.19)	1.12 (1.09-1.16)
More deprived 20-40%	1.15 (1.12-1.18)	1.15 (1.11-1.18)	1.13 (1.09-1.16)	1.11 (1.07-1.14)
Less deprived 40-60%	1.11 (1.08-1.15)	1.10 (1.07-1.13)	1.08 (1.05-1.11)	1.07 (1.04-1.10)
Less deprived 60-80%	1.07 (1.03-1.10)	1.06 (1.03-1.09)	1.08 (1.04-1.11)	1.07 (1.04-1.10)
Least deprived 80-100%	1(ref)	1(ref)	1(ref)	1(ref)
ICC	0.036 (0.034-0.039)	0.028 (0.026-0.030)	0.027 (0.025-0.030)	0.027 (0.025-0.30)

Abbreviations: CI, confidence interval; ICC, Intra-class Correlation Coefficient

Table 4.6. Univariable and multivariable analysis showing risk ratios (and their 95% confidence intervals) between **indoor living environment** and SMM compared to the least deprived indoor living environment quintile. *Model 1: Adjusted for year, age, parity and ethnicity **Model 2: Model 1 + additionally adjusted for neighbourhood income and English language proficiency ***Model 3: Model 2 + additionally adjusted for substance misuse/ smoking/ pre-existing mental health conditions.

	Unadjusted	**Model 1***	**Model 2 (final model)****	**Model 3*****
Indoors Living Environment quintile	Risk ratio (95% CI)	Risk ratio (95% CI)	Risk ratio (95% CI)	Risk ratio (95% CI)
Most deprived 20%	1.10 (1.07-1.13)	1.09 (1.06-1.12)	1.05 (1.02-1.08)	1.04 (1.03-1.07)
More deprived 20-40%	1.12 (1.09-1.15)	1.08 (1.06-1.11)	1.05 (1.02-1.08)	1.05 (1.02-1.07)
Less deprived 40-60%	1.10 (1.07-1.13)	1.06 (1.04-1.09)	1.04 (1.01-1.07)	1.02 (0.99-1.05)
Less deprived 60-80%	1.07 (1.04-1.10)	1.05 (1.02-1.07)	1.03 (1.00-1.06)	1.03 (1.00-1.05)
Least deprived 80-100%	1(ref)	1(ref)	1(ref)	1(ref)
ICC	0.037 (0.035-0.040)	0.028 (0.026-0.031)	0.028 (0.025-0.030)	0.028 (0.025-0.030)

Abbreviations: CI, confidence interval; ICC, Intra-class Correlation Coefficient

Table 4.7. Univariable and multivariable analysis showing risk ratios (and their 95% confidence intervals) between **outdoor living environment** and SMM compared to the least deprived outdoor living environment living environment quintile. *Model 1: Adjusted for year, age, parity and ethnicity **Model 2: Model 1 + additionally adjusted for %neighbourhood country of birth/ neighbourhood English language proficiency and neighbourhood income ***Model 3: Model 2 + additionally adjusted for substance misuse/ smoking/ pre-existing mental health conditions.

	Unadjusted	**Model 1***	**Model 2 (final model)****	**Model 3*****
Outdoor Living Environment quintile	Risk ratio (95% CI)	Risk ratio (95% CI)	Risk ratio (95% CI)	Risk ratio (95% CI)
Most deprived 20%	1.38 (1.34-1.42)	1.20 (1.16-1.23)	1.06 (1.03-1.10)	1.06 (1.03-1.10)
More deprived 20-40%	1.17 (1.14-1.20)	1.10 (1.07-1.14)	1.03 (1.00-1.06)	1.02 (1.00-1.05)
Less deprived 40-60%	1.08 (1.05-1.11)	1.06 (1.03-1.09)	1.02 (0.99-1.05)	1.01 (0.98-1.04)
Less deprived 60-80%	1.03 (1.00-1.06)	1.02 (0.99-1.05)	1.00 (0.97-1.03)	1.00 (0.97-1.03)
Least deprived 80-100%	1(ref)	1(ref)	1(ref)	1(ref)
ICC	0.031 (0.029-0.034)	0.027 (0.025-0.029)	0.027 (0.024-0.029)	0.027 (0.024-0.029)

Abbreviations: CI, confidence interval; ICC, Intra-class Correlation Coefficient

Table 4.8. Univariable and multivariable analysis showing risk ratios (and their 95% confidence intervals) between **adult skills** and SMM compared to the least deprived adult skills quintile. There is no Model 1 as Model 2 did not require any additional adjustments based on the DAG *Model 2: Adjusted for year, age, parity and ethnicity. **Model 3: Model 2 + additionally adjusted for substance misuse/ smoking/ pre-existing medical conditions/ pre-existing mental health conditions.

	Unadjusted	**Model 2 (final model)***	**Model 3****
Adult Skills quintile	Risk ratio (95% CI)	Risk ratio (95% CI)	Risk ratio (95% CI)
Most deprived 20%	1.02 (0.99-1.05)	1.10 (1.06-1.13)	1.07 (1.04-1.10)
More deprived 20-40%	1.04 (1.01-1.07)	1.09 (1.06-1.12)	1.08 (1.05-1.11)
Less deprived 40-60%	1.00 (0.97-1.03)	1.05 (1.02-1.08)	1.04 (1.01-1.07)
Less deprived 60-80%	0.97 (0.95-1.00)	1.02 (0.99-1.05)	1.01 (0.98-1.04)
Least deprived 80-100%	1(ref)	1(ref)	1(ref)
ICC	0.037 (0.035-0.040)	0.028 (0.026-0.031)	0.028 (0.026-0.031)

Abbreviations: CI, confidence interval; ICC, Intra-class Correlation Coefficient

Table 4.9. Univariable and multivariable analysis showing risk ratios (and their 95% confidence intervals) between **children and young people** and SMM compared to the least deprived children and young people quintile. *Model 1: Adjusted for year, age, parity and ethnicity **Model 2: Model 1 + additionally adjusted for %neighbourhood country of birth/ neighbourhood English language proficiency.

	Unadjusted	**Model 1***	**Model 2 (final model)****
Children and Young People quintile	Risk ratio (95% CI)	Risk ratio (95% CI)	Risk ratio (95% CI)
Most deprived 20%	1.00 (0.97-1.02)	1.07 (1.04-1.10)	1.06 (1.03-1.09)
More deprived 20-40%	1.06 (1.03-1.09)	1.09 (1.06-1.12)	1.07 (1.04-1.10)
Less deprived 40-60%	1.08 (1.05-1.11)	1.07 (1.04-1.10)	1.05 (1.02-1.08)
Less deprived 60-80%	1.06 (1.03-1.09)	1.05 (1.02-1.08)	1.05 (1.01-1.07)
Least deprived 80-100%	1(ref)	1(ref)	1(ref)
ICC	0.037 (0.034-0.039)	0.029 (0.026-0.031)	0.028 (0.025-0.030)

Abbreviations: CI, confidence interval; ICC, Intra-class Correlation Coefficient

Table 4.10. Univariable and multivariable analysis showing risk ratios (and their 95% confidence intervals) between **wider barriers** and SMM compared to the least deprived wider barriers quintile. *Model 1: Adjusted for year, age, parity and ethnicity **Model 2: Model 1 + additionally adjusted for %neighbourhood country of birth/ neighbourhood income/ neighbourhood English language proficiency and urban/rural ***Model 3: Model 2 + additionally adjusted for substance misuse/ smoking/ pre-existing medical conditions/ pre-existing mental health conditions.

	Unadjusted	**Model 1***	**Model 2 (final model)****	**Model 3*****
Wide Barriers quintile	Risk ratio (95% CI)	Risk ratio (95% CI)	Risk ratio (95% CI)	Risk ratio (95% CI)
Most deprived 20%	1.49 (1.45-1.53)	1.26 (1.23-1.30)	1.14 (1.10-1.20)	1.14 (1.10-1.20)
More deprived 20-40%	1.14 (1.11-1.17)	1.08 (1.05-1.11)	1.01 (0.98-1.05)	1.01 (0.98-1.05)
Less deprived 40-60%	1.07 (1.04-1.10)	1.05 (1.02-1.08)	1.01 (0.98-1.05)	1.01 (0.97-1.05)
Less deprived 60-80%	1.03 (1.00-1.06)	1.03 (1.00-1.06)	1.01 (0.98-1.04)	1.01 (0.98-1.04)
Least deprived 80-100%	1(ref)	1(ref)	1(ref)	1(ref)
ICC	0.030 (0.028-0.032)	0.027 (0.025-0.029)	0.026 (0.024-0.029)	0.026 (0.024-0.029)

Abbreviations: CI, confidence interval; ICC, Intra-class Correlation Coefficient

Table 4.11. Univariable and multivariable analysis showing risk ratios (and their 95% confidence intervals) between **geographical barriers to services** and SMM compared to the least deprived geographical barriers quintile. *Model 1: Adjusted for year, age, parity and ethnicity **Model 2: Model 1 + additionally adjusted for %neighbourhood country of birth/ neighbourhood income, air pollution and urban/rural ***Model 3: Model 2 + additionally adjusted for substance misuse/ smoking/ pre-existing mental health conditions.

	Unadjusted	**Model 1***	**Model 2 (final model)****	**Model 3*****
Geographical Barriers quintile	Risk ratio (95% CI)	Risk ratio (95% CI)	Risk ratio (95% CI)	Risk ratio (95% CI)
Most deprived 20%	0.73 (0.71-0.75)	0.83 (0.81-0.85)	0.92 (0.89-0.95)	0.92 (0.89-0.95)
More deprived 20-40%	0.78 (0.76-0.80)	0.87 (0.85-0.89)	0.94 (0.91-0.96)	0.93 (0.90-0.95)
Less deprived 40-60%	0.83 (0.81-0.86)	0.91 (0.89-0.94)	0.96 (0.94-0.99)	0.96 (0.94-1.00)
Less deprived 60-80%	0.87 (0.85-0.89)	0.92 (0.90-0.94)	0.95 (0.93-0.97)	0.95 (0.93-0.98)
Least deprived 80-100%	1(ref)	1(ref)	1(ref)	1(ref)
ICC	0.039 (0.036-0.043)	0.028 (0.025-0.030)	0.027 (0.025-0.029)	0.027 (0.025-0.029)

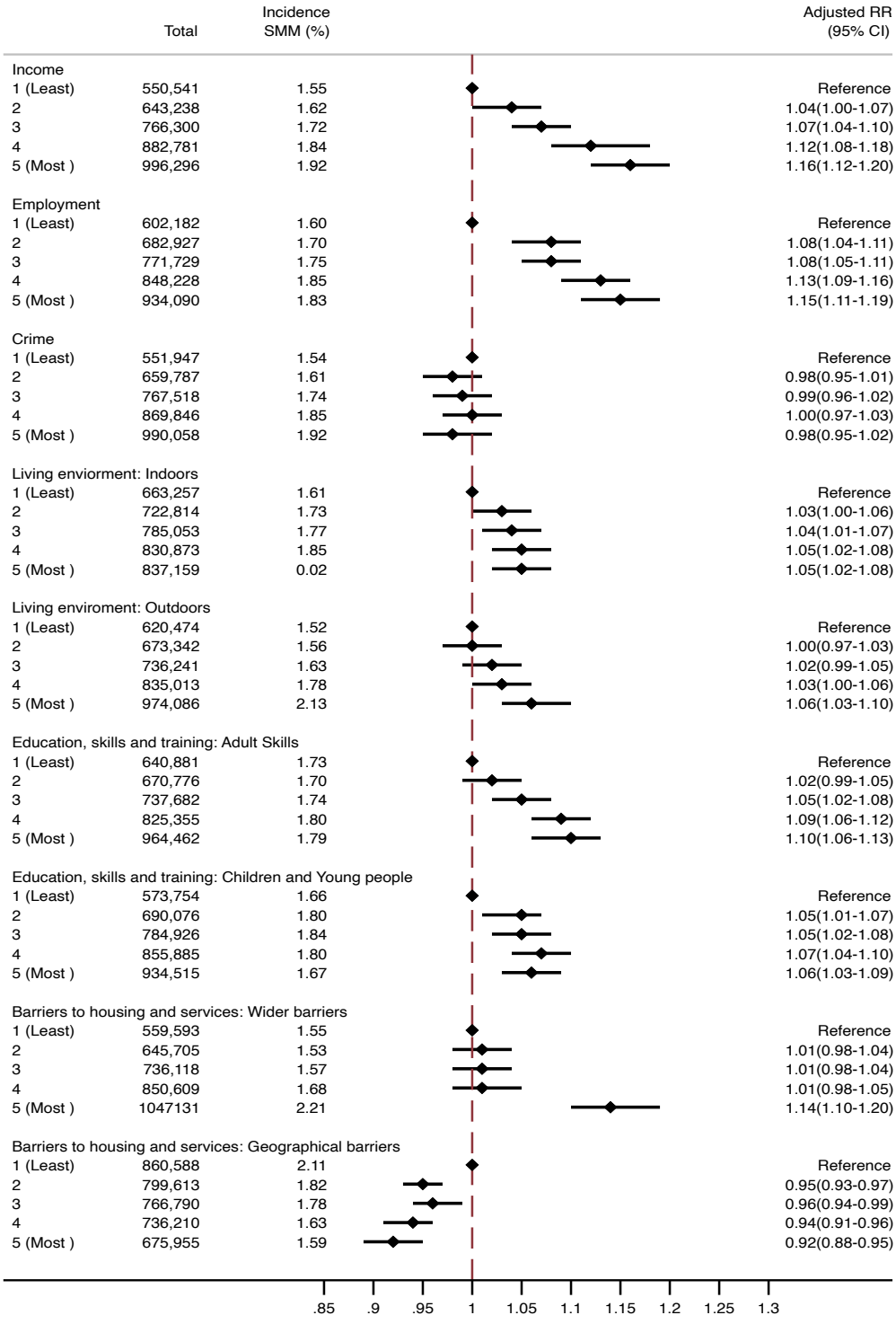
Abbreviations: CI, confidence interval; ICC, Intra-class Correlation Coefficient

Table 4.12. Univariable and multivariable analysis showing risk ratios (and their 95% confidence intervals) between **crime** and SMM compared to the least deprived crime quintile. *Model 1: Adjusted for year, age, parity and ethnicity **Model 2: Model 1 + additionally adjusted for %neighbourhood country of birth/ neighbourhood income/ English language proficiency and urban/rural ***Model 3: Model 2 Additionally adjusted for substance misuse/ smoking/ pre-existing medical and mental health conditions.

	Unadjusted	**Model 1***	**Model 2 (final model)****	**Model 3*****
Crime quintile	Risk ratio (95% CI)	Risk ratio (95% CI)	Risk ratio (95% CI)	Risk ratio (95% CI)
Most deprived 20%	1.23 (1.19-1.26)	1.14 (1.11-1.17)	0.98 (0.95-1.02)	0.98 (0.94-1.01)
More deprived 20-40%	1.21 (1.17-1.24)	1.13 (1.10-1.16)	1.00 (0.97-1.03)	0.99 (0.96-1.03)
Less deprived 40-60%	1.14 (1.11-1.18)	1.08 (1.05-1.11)	0.99 (0.96-1.02)	0.99 (0.96-1.02)
Less deprived 60-80%	1.05 (1.02-1.09)	1.03 (1.00-1.06)	0.98 (0.95-1.01)	0.98 (0.95-1.01)
Least deprived 80-100%	1(ref)	1(ref)	1(ref)	1(ref)
ICC	0.035 (0.033-0.038)	0.028 (0.026-0.031)	0.027 (0.025-0.030)	0.027 (0.025-0.030)

Abbreviations: CI, confidence interval; ICC, Intra-class Correlation Coefficient

Figure 4.7. The risk ratios (and their 95% confidence intervals) of SMM in each quintile of deprivation in each of the domains compared to the least deprived quintile. Q1=Least deprived IMD quintile and Q5= most deprived IMD quintile.



**All domains are adjusted for age, year, parity and ethnicity. Income and employment are additionally adjusted for neighbourhood % not born in the UK and neighbourhood English language proficiency. Indoor living environment is additionally adjusted for neighbourhood income and neighbourhood English language proficiency. Outdoor living environment is additionally adjusted for neighbourhood income, neighbourhood English language proficiency and neighbourhood % not born in the UK. Children and young people is additionally adjusted for % not born in the UK and neighbourhood English language proficiency. Wider barriers is additionally adjusted for neighbourhood income, neighbourhood English language proficiency, neighbourhood % not born in the UK and urban/rural. Geographical barriers is additionally adjusted for neighbourhood income, neighbourhood % not born in the UK, urban/rural and air pollution. Crime is additionally adjusted for neighbourhood income, neighbourhood % not born in the UK, neighbourhood English language proficiency and urban/rural.*

4.4.6 Effect Modification by Ethnicity

There was effect modification between the adult skills ($P_{interaction}$=0.048), and children and young people domains ($P_{interaction}$=0.01) and ethnicity, and SMM. The number of women, the incidence (%) of SMM and the adjusted RR (and their 95% CI) in each of the subdomain quintiles compared to the least deprived quintile stratified by ethnic group are shown in **Appendix Table 4.12-4.14**. There were low numbers of women living in the least deprived education quintiles, and an even lower number of these women who experienced SMM in some of the minoritised ethnic groups such as Asian or Asian British Bangladeshi women or Black or Black British Caribbean women. **Figures 4.8 and 4.9** show the average adjusted predictive margins of each ethnic group stratified by neighbourhood adult skills or children and young people quintile, compared to White women in the highest quintile of each exposure. There was a dose-response relationship between living in areas with lower adult skills and children's educational attainment and risk of SMM for White women but not for any other ethnic group, with White women living in areas with the lowest adult skills and children's educational attainment having a 1.65% (95% CI 1.62%-1.69%) and 1.59% (95% CI 1.56%-1.62%) prediction of SMM respectively. The average predictive margins (and their 95% CI) were higher for all the minoritised ethnic groups regardless of the neighbourhood that they live in than for White women living in any quintile of educational attainment deprivation. British or Asian British Bangladeshi women living in the areas with the highest adult skills and second highest of children's educational attainment had the highest overall risk of SMM, with adjusted predictive margins of 3.46% (95% CI 2.93%-4.00%) and 2.93% (95% CI 2.44%-3.42%), respectively.

4.4.7 Population Attributable Fractions (PAFs)

The population attributable fraction (PAF) indicated that 13.2% (95% CI 11.4%-15.1%) of SMM could be attributed to socioeconomic deprivation measured using the composite IMD, and this fraction was reduced in the adjusted model to 11.4% (95% CI 9.5%-13.2%). In the separate IMD domains, neighbourhood income and employment had the highest adjusted PAFs with 8.2% (95% CI 6.1%-10.3%) and 7.8% (95% CI 5.8%-9.8%) of SMM attributable to these neighbourhood factors, respectively.

The PAF indicated that 17.8% (95% CI 15.9%-19.7%) of SMM could be attributed to both socioeconomic deprivation (measured using the composite IMD) and ethnic inequality which increased to 19.6% (95% CI 17.7%-21.4%) in the adjusted model. In the separate IMD domains, neighbourhood income and employment again had the highest adjusted PAFS with 16.5% (95% CI 14.4%-18.6%) and 15.9% (95% CI 13.9%-17.9%) of SMM attributable to the combination of ethnic inequality and these neighbourhood factors, respectively (**Table 13**).

4.4.8 Sensitivity Analyses

The sensitivity analyses did not show material differences when women with both missing gestational age at birth and birthweight were excluded from the cohort (**Appendix Table 4.15**) or when ICD-10 codes only were included in the outcome (**Appendix Table 4.16**).

When sepsis was excluded from the outcome, a dose-response between increasing composite deprivation and SMM risk remained although was attenuated with the most deprived IMD quintile having a 14% (95% CI 1.10-1.17) increased risk of SMM compared to the least deprived IMD quintile (**Appendix Table 4.17**). This reduction in the effect size was mainly driven by the indoor and outdoor living environment domains, where there was no longer any evidence for an association with SMM. The geographical barriers domain also showed no

evidence of an association. However, the association between neighbourhood income, neighbourhood employment and neighbourhood education, skills and training domains and SMM remained similar, although there was no longer evidence of effect modification by ethnicity in the adult skills ($P_{interaction}$=0.34) and children and young people ($P_{interaction}$=0.52) subdomains. When the sepsis diagnosis was restricted to include women who had a hospital stay of three days or more, 2,369 (8.7%) sepsis cases were excluded from the outcome, and there were no notable changes from the original analysis (**Appendix Table 4.18-4.20).**

Figure 4.8. The average adjusted predictive margins (and their 95% confidence intervals) of SMM for women living in each adult skills quintile stratified by ethnicity

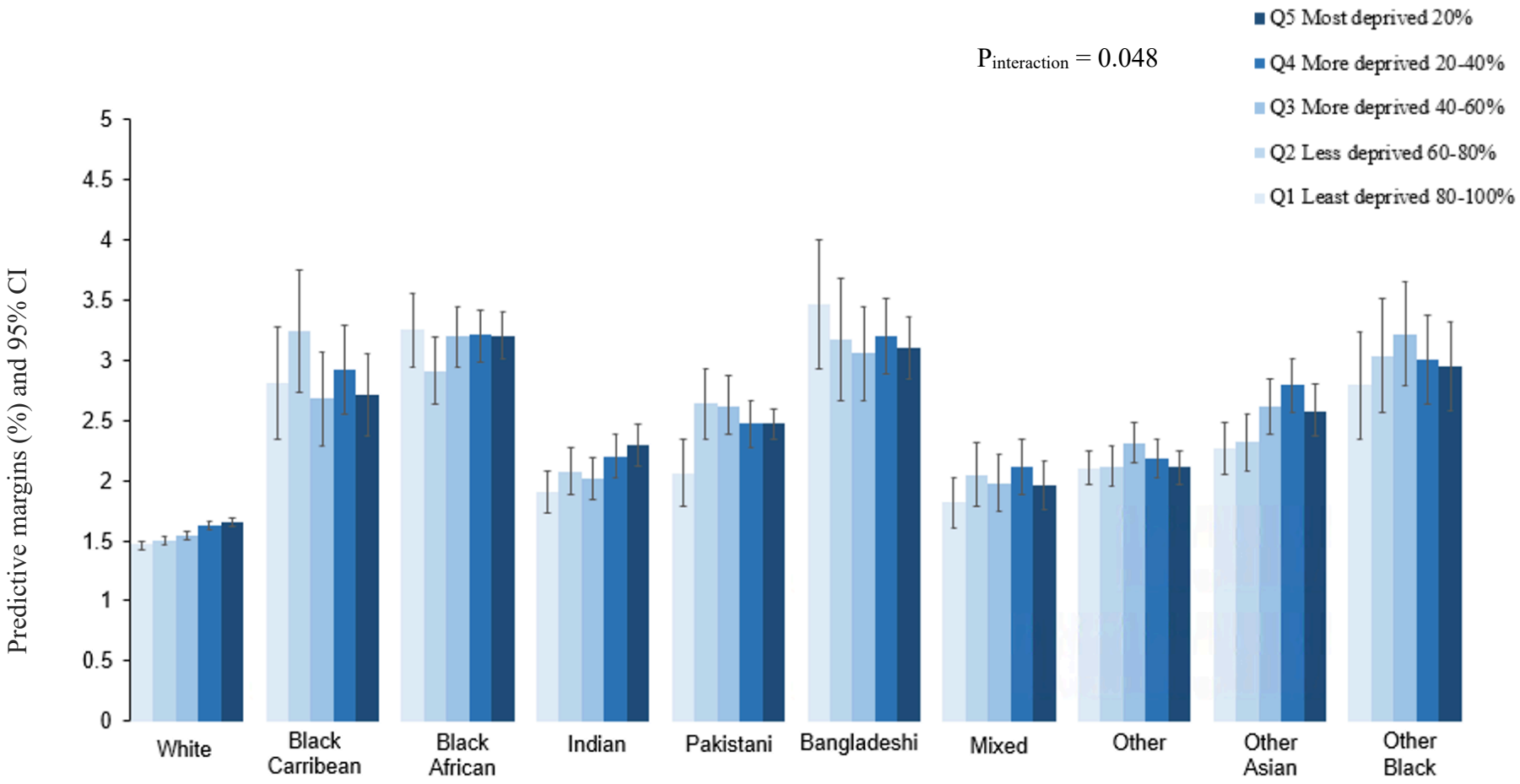


Figure 4.9. The average adjusted predictive margins (and their 95% confidence intervals) of SMM for women living in each children and young people quintile stratified by ethnicity

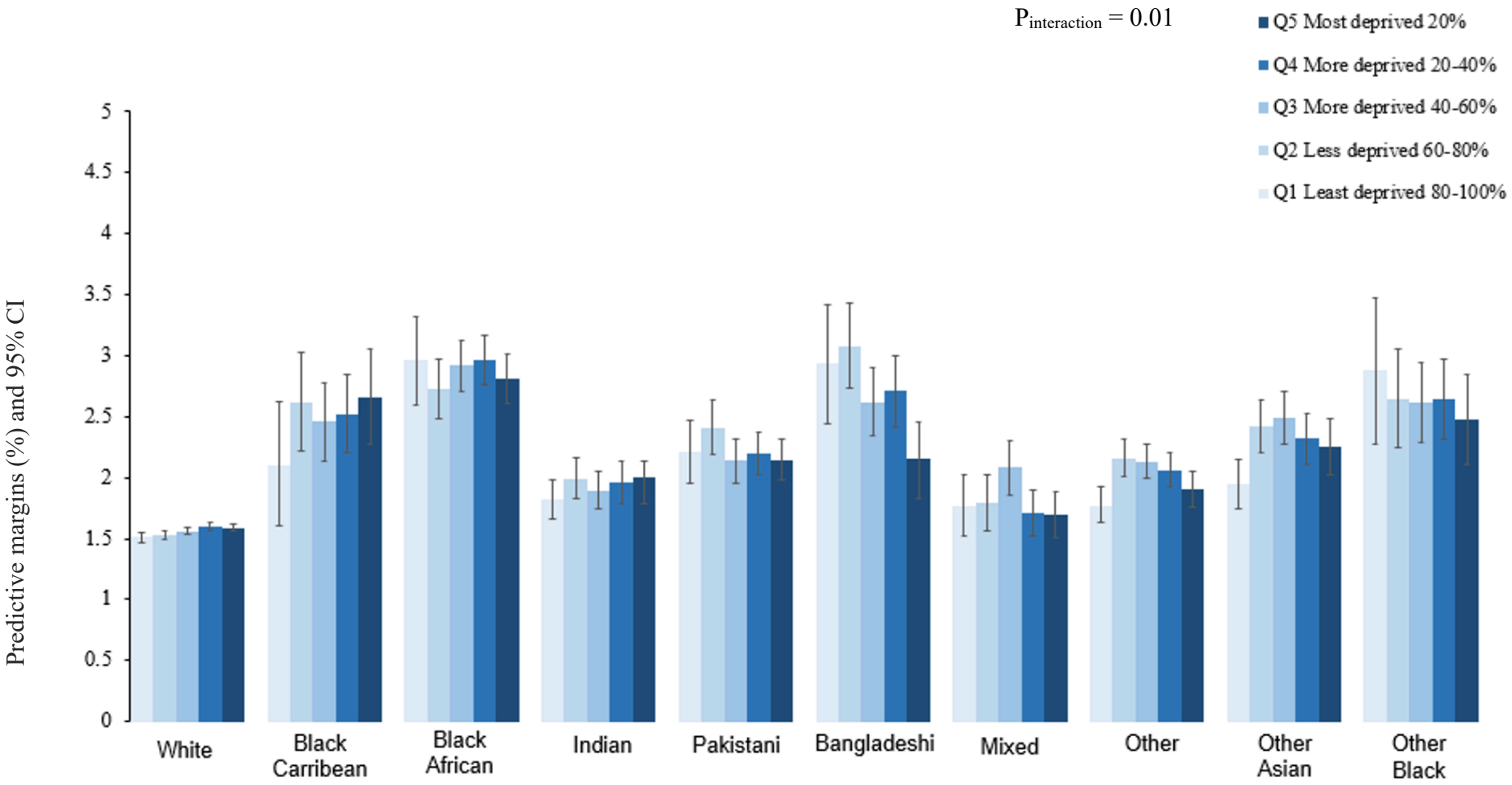


Table 4.13. Univariable and multivariable population attributable fractions (PAFs) of the composite IMD and each domain/subdomain of IMD using both the least deprived 20% of women across all ethnicities and least deprived 20% of White women as the baseline group. The multivariable analysis uses Model 2 from each domain/subdomain.

	PAF (95% CI)									
	Income	**Employment**	**Crime**	**Adult Skills**	**Children and Young People**	**Geographical Barriers**	**Wider Barriers**	**Indoor Living Environment**	**Outdoor Living Environment**	**Composite**
Univariable analysis using the least deprived 20% of White women as the baseline group	17.2 (15.2-19.1)	15.9 (14.0-17.8)	16.6 (14.7-18.5)	10.6 (8.6-12.5)	12.0 (10.0-14.0)	1.7 (-0.0-3.6)	17.7 (15.9-19.5)	15.5 (13.7-17.3)	15.8 (14.1-17.5)	17.8 (15.9-19.7)
Multivariable analysis using the least deprived 20% of White women as the baseline group	16.5 (14.4-18.6)	15.9 (13.9-17.9)	8.7 (5.6-10.5)	15.0 (13.1-16.9)	12.1 (9.9-14.2)	5.1 (3.1-7.0)	13.5 (11.0-15.9)	13.9 (12.0-15.7)	11.2 (9.0-13.2)	19.6 (17.7-21.4)
Univariable analysis using the least deprived 20% of all women as the baseline group	11.9 (10.0-13.8)	9.4 (7.5-11.2)	12.6 (10.7-14.4)	0.8 (-1.1-2.7)	3.9 (1.9-5.8)	-16.5 (-18.1 to -14.9)	15.2 (13.4-16.9)	7.4 (5.7-9.3)	13.3 (11.5-15.0)	13.2 (11.4-15.1)
Multivariable analysis using the least deprived 20% of all women as the baseline group	8.2 (6.1-10.3)	7.8 (5.8-9.8)	-1.1 (-3.7-1.4)	5.0 (3.2-6.8)	4.3 (2.3-6.2)	-4.5 (-6.1 to -2.9)	5.0 (2.4-7.5)	3.6 (1.6-5.4)	2.9 (1.0-5.1)	11.4 (9.5-13.2)

4.5 Discussion

4.5.1 Main Findings

This analysis used routinely collected hospital admissions data of 4,040,106 maternities from 2013-2023 in England and showed an overall incidence of SMM of 18 per 1000 maternities. There was a dose-response with increasing SMM risk as composite deprivation increased, with women living in the most deprived areas having a 21% greater risk of SMM compared to those living in the least. For the individual domains, the association with SMM varied, with income and employment having the strongest association. There was no evidence for effect modification by ethnicity for the association between the composite deprivation index (IMD) and SMM. However, the relationship between SMM and the education, skills, and training subdomains varied across ethnic groups, where only White women showed a dose-response to this disadvantage. The proportion of SMM attributable to ethnic and socioeconomic disadvantage was approximately double that of the proportion attributable to disadvantage alone, highlighting the importance of considering both ethnic and socioeconomic inequalities when designing interventions to reduce SMM.

4.5.1.1 Patterns in SMM

Throughout the study period, the incidence rate of SMM increased. This was mostly driven by sepsis and acute kidney injury, although there was also a more moderate increase in the incidence of ‘all other SMM conditions’ over this time. From the literature, it appears that the population of women giving birth is becoming older, more obese and with a greater number of medical complexities (107, 133). There is also a greater number of medical interventions, such as induction of labour or caesarean birth, which may also explain this finding (134, 135). However, it was not possible from this analysis to determine whether this was a true finding with a rise in clinical cases, increased recognition or a change in coding practices.

SMM declined during the COVID-19 pandemic (2020-2021) which was particularly driven by a decline in sepsis. This may be explained by increased infection control measures, disruptions in healthcare access and changes in clinical management protocols (136, 137). Alternatively, this could be due to a change in recording practices, such as women with suspected infections being recorded as Covid-19 rather than sepsis. Finally, SMM might have been underreported, as completing thorough discharge summaries may have been deprioritised during the pandemic.

Over time, the SMM risk gap between the most and least deprived quintiles appeared to widen, with the most significant increase in risk observed in the most deprived and second most deprived groups. This trend highlights the widening gap in maternal health outcomes, which is also reflected in the most recent MBRRACE-UK report (2021-2023), where there was a non-statistically significant increase in the disparities between women living in the most and least deprived neighbourhoods compared to 2019-2021(17).

4.5.1.2 Risk of SMM by the Composite IMD and Specific IMD Domains

There was a 21% (95% CI 17%-24%) increased risk in SMM for women living in the most deprived compared to the least deprived areas using the composite IMD measure. Sepsis played a key role in the association between composite deprivation and SMM as it contributed to the greatest proportion of the SMM composite (40%), particularly for women living in the most deprived areas. The association between living in the most deprived area and sepsis (adjusted RR 1.43 (95% CI 1.36-1.50)) could be driven by factors such as differences in antenatal care uptake and continuity (138), delayed medical attention (139, 140), increased risk of pre-existing conditions such as diabetes and hypertension (141) and the increased labour induction rate (141, 142) for women living deprived areas, all increasing susceptibility to infections. Poor

housing and overcrowded living conditions in deprived areas may also contribute to infection risks (143, 144). In this analysis, other conditions, such as acute cardiac and embolic events were also associated with living in a deprived area, with adjusted RR of 1.24 (95% CI 1.09-1.41) for acute cardiac events and 1.97 (95% CI 1.69-2.29) for embolic events, for women living in the most compared to the least deprived areas. Women living in deprived communities were also more likely to be obese and to smoke, which are both associated with thromboembolism (145) and cardiac events (146), which may explain the increased risk of these conditions.

When the association between the individual domains/subdomains of the IMD was analysed, this analysis found that SMM risk increased proportionally to neighbourhood income, employment and outdoor living environment quintiles, although the magnitude of association with outdoor living environment was small. Other studies have also found an association between neighbourhood income and SMM (23, 58, 79, 85, 88, 89, 92, 94). However, there is limited evidence of the association between neighbourhood employment and SMM (94). Furthermore, the weaker association with outdoor living environment may reflect that environmental conditions have less of an immediate impact on SMM than material resources. Additionally, this analysis identified that there was an association between housing issues, measured using the wider barriers subdomain and SMM. A US study (96) found a 73% (95% CI 15%-59%) increase in the risk of SMM for women living in a municipality with a higher rent to income ratio. However, in this analysis an association between wider barriers and SMM was only seen in the most deprived quintile, where there was a 14% increase in the risk of SMM compared to the least, with the other quintiles showing no association. It could be that housing problems only affect SMM risk at the extreme end of the spectrum. However, the lack

of observed associations in the other quintiles could also be due to power limitations in detecting smaller effects in less deprived groups.

Interestingly, areas with high geographical barriers to services were associated with a lower risk of SMM, with women living closest to services showing a higher risk. This finding may reflect that urban areas with better access to amenities and services also tend to experience higher poverty levels and social problems (147, 148). These factors lead to a higher concentration of high-risk pregnancies in these areas, which in turn increases the risk of SMM. In contrast, although women in rural areas may have less access to healthcare, they may encounter fewer social challenges. This may explain the lower overall risk despite limited resources (149).

Finally, adjusting for individual health factors, such as pre-existing medical and mental health conditions and smoking and/or substance misuse, only had a notable impact on the association between neighbourhood income and employment deprivation and SMM, with a reduction in the strength of the association of 12.5% and 20%, respectively. This suggests that individual health factors may mediate or confound health disparities associated with these socioeconomic domains. Low income and unemployment are both causes and consequences of deprivation, which can exacerbate health risks (150). In contrast, domains which captured more structural or environmental deprivation, such as housing problems, air pollution or geographical barriers to services, appear to influence SMM directly and independently of the pre-existing physical and mental health conditions or individual behaviours captured in this database, suggesting that the association with these domains and SMM may operate through distinct mechanisms.

When sepsis was removed from the composite SMM outcome, there was no longer an association between the indoor living environment, outdoor living environment and geographical barrier to services subdomains, and the association between the wider barriers subdomain decreased. This may be because these aspects of deprivation are strongly associated with sepsis. Alternatively, it could be that sepsis diagnoses and codes appear more frequently in discharge summaries from busy urban hospitals, which have patients who live in areas with poor access to housing and housing quality, high air pollution and are closer to services and amenities, such as London.

4.5.1.3 Influence of Socioeconomic Deprivation and Ethnic Inequality on SMM

11% of SMM was attributable across the whole population to socioeconomic disadvantage using the composite IMD, with income and employment having the highest amount attributable across the population out of the individual domains. Interestingly, the percentage of SMM attributable to income and employment was not notably reduced by adjusting for confounding factors, highlighting the importance of these socioeconomic position factors of SMM at population-level. When combined with ethnic inequality, the proportion of SMM cases attributable to these factors increased to 20% of SMM cases preventable if all women had the same risks as White women living in the least deprived composite IMD quintile. This suggests that addressing both socioeconomic and ethnic disparities is essential to reduce unequal outcomes in maternal health and reduce the overall SMM incidence.

Women of White ethnicity had a dose-response relationship between education, skills and training and SMM with increase in risk as this measure decreased. However, this was not found for women of a minoritised ethnicity in any of the other ethnic groups. This pattern was seen in both the children and young people subdomain, which reflects school attainment and access

to higher education, and the adult skills subdomain, which includes neighbourhood English language proficiency and adult qualifications. One possible explanation is that women from a minoritised ethnic group may face additional barriers, such as discrimination and limited access to culturally appropriate care (44), regardless of their education, skills or training. Furthermore, due to migration patterns, the level of socioeconomic disadvantage may be more likely to be misclassified for minoritised ethnic women than White women. Consequently, the education level of their neighbourhood does not accurately represent their true educational attainment. This is particularly true for the children and young people subdomain because women from a minoritised ethnic group who migrated as adults may not have experienced the same disadvantages or advantages from school education as younger generations who were born in these areas. Finally, this finding may be explained by the relatively small number of women from minoritised ethnic groups living in neighbourhoods with higher educational attainment, which may have resulted in insufficient study power.

4.5.2 Strengths and Limitations

This analysis has highlighted many strengths and limitations of using administrative health data to explore the association between socioeconomic deprivation and SMM and this will be discussed in more detail in **Chapter 7** of this thesis. This analysis is the first to explore how various forms of neighbourhood deprivation are associated with SMM. Disaggregating the IMD into individual domains provides a more detailed understanding of the neighbourhood factors most closely linked to SMM. In contrast to other studies which use broad ethnic groups (17, 44), this analysis also considered ethnicity in ten subgroups. Combining all Asian or all Black women into broader categories risks oversimplifying the socioeconomic, cultural and biological differences within these groups (151). This approach allowed for a greater understanding of the intersection of socioeconomic disadvantage with ethnicity.

However, a significant study limitation is the reliance on neighbourhood-level deprivation scores as a proxy for individual socioeconomic disadvantage. While neighbourhood-level measures are useful for contextual deprivation, they are limited if applied to individual-level analysis. A key issue if used as a proxy for individual socioeconomic position is the risk of misclassification, where women who are not socioeconomically disadvantaged may still live in deprived areas. This misclassification can dilute the effects of deprivation on the outcome, potentially biasing the association towards the null.

Neighbourhood-level measures of deprivation can be particularly challenging when examining the experiences of minoritised ethnic groups. Migrants or individuals from minoritised ethnic groups who do not experience socioeconomic disadvantage in the traditional sense based on income, education or occupation, may still reside in areas of high deprivation due to patterns of migration or settlement (152). Neighbourhood-level deprivation measures may conceal how socioeconomic disadvantage interacts with ethnicity and migration status, and this analysis was further limited as migration status was not available in the data to explore this in more detail.

The analysis further revealed the limitations of using the IMD as a composite score to measure the association between disadvantage and SMM. There was an inverse relationship between the geographical barriers subdomain and SMM risk, which could attenuate the observed effects of the other dimensions of deprivation if a composite score is used. Additionally, the IMD score's design, even when broken down into separate domains and subdomains, makes it difficult to determine causal pathways. For instance, the adult skills subdomain combines measures of English language proficiency and qualifications, which likely increase the risk of SMM through different mechanisms. However, how this subdomain is structured makes it

difficult to determine whether the English language skills or the lack of qualifications drive any observed increased risk and adds challenges to adjusting appropriately for relevant covariates.

Another limitation of this analysis is the significant amount of missing data on gestational age at birth and birthweight, variables which were used to define the cohort of ≥ 20 weeks. However, the sensitivity analysis, which excluded the women with missing data on these variables, did not show a notable impact on the analysis findings. Furthermore, this analysis improved the completeness of the data by using the 'look-back' approach for the variables parity and including OPCS-4 codes for missing data on mode of birth.

4.5.3 Conclusion

The analysis presented in this chapter showed significant disparities in SMM associated with socioeconomic deprivation. The greatest risks of the individual domains/subdomains are associated with neighbourhood income and employment, highlighting that neighbourhood low income and unemployment may be key factors for increased SMM risk (**Thesis Objective 2**). The association between the education domains of deprivation and SMM was modified by ethnicity, where there was different association with SMM for women from minoritised ethnic groups compared to White women (**Thesis Objective 5**). The combined impact of socioeconomic and ethnic disadvantage suggests that targeted interventions addressing both factors are crucial for reducing maternal health disparities (**Thesis Objective 6**).

However, there are some limitations when using the IMD in its current format to measure deprivation. It compiles different domain-specific indicators into a single index, making it difficult to analyse each domain's specific pathways and unique contribution. The pathways between deprivation and SMM remain unclear even when the IMD is separated into domains

and subdomains. In addition, the domains are correlated and may confound and interact with each other, making it difficult to establish the specific impacts on SMM. Therefore, a revised structure for the IMD would be beneficial to address the objectives of this thesis, specifically **Thesis Objective 7** which aims to assess the role of potential mediators, and this will be explored in the following chapter. While the study's large database and population reach provide useful insights, this analysis is limited by only using area-based measures of disadvantage. Further research is needed on both neighbourhood- and individual-level measures of socioeconomic disadvantage to better understand the complex relationship between different levels of disadvantage, ethnicity and SMM and this topic is addressed in **Chapter 6** of this thesis.

Chapter 5: Exploring the Relationship Between Socioeconomic Disadvantage and SMM in England, 2013-2023, Using an Exploratory Factor Analysis (EFA)

5.1 Background

Socioeconomic disadvantage includes multiple interconnected elements, often represented by composite measures like the Index of Multiple Deprivation (IMD). The IMD's broad composite score may capture the influence of cumulative disadvantage (5), but as discussed in the previous chapter, the IMD's composite score in its current structure presents limitations, masking the specific pathways through which different aspects of disadvantage affect health. Furthermore, in the previous chapter and the systematic review, the findings showed that low income, unemployment, low educational attainment, poor outdoor living environment, and poor quality and access to housing were associated with severe maternal morbidity (SMM). This makes it more difficult to know where to target the most effective interventions or to fully understand how the different types of disadvantages, individually or collectively, contribute to SMM. This chapter therefore uses an exploratory factor analysis (EFA) of IMD indicators to address these limitations. This contrasts to the original IMD construction where the domains and their weights were preselected based on the literature. EFA is a statistical method that groups variables with a shared variance to form new latent variable. **Shared variance** refers to how much of one variable's variability overlaps with another's variability. This captures how much of a relationship between two variables is explained by a common influence/latent variable. **Latent variables** are theoretical constructs used to explain relationships between observed data (153) and cannot be measured directly but are inferred indirectly from other observed variables. In this chapter an EFA is conducted to uncover the latent variables of socioeconomic disadvantage by using the IMD indicators. This approach was used to enable a better understanding of the pathways linking socioeconomic disadvantage and SMM.

Experts, including the developers of the IMD, were consulted on the suitability of conducting an EFA on the IMD indices. They agreed that it was an appropriate and valuable method.

5.2 Aim and Objectives

5.2.1 Aim

This analysis aims to identify latent variables, if any, underlying the different indicators/domains that constitute the composite IMD, explore the association between these latent variables and SMM and investigate how this relationship may vary across ethnic groups in England. It also aims to examine the role of modifiable risk factors, such as obesity, pre-existing medical and mental health conditions and engagement with antenatal care that may mediate this relationship and could be targeted for public health interventions.

5.2.2 Objectives

1. To examine the shared variance of individual indicators to uncover distinct latent variables within the IMD that represent unique dimensions of disadvantage in England.

2. To examine the relationship between the IMD's latent variables and SMM in England, to understand further the association between different dimensions of neighbourhood-level disadvantage and an increased risk of SMM (**Thesis Objective 2**).

3. To determine whether the relationship between the IMD latent variables and the risk of SMM differed by ethnic groups, to determine whether specific disadvantage dimensions are more or less associated with the risk of SMM in specific ethnic groups (**Thesis Objective 5**).

4. To calculate the population attributable fractions (PAFs) for SMM across different IMD dimensions, estimating the proportion of SMM cases that could be prevented if all women experienced the same SMM risk as the reference group, defined as women in the highest socioeconomic group (from the latent variables) for the overall analysis or White women in the highest socioeconomic group for the analysis by ethnicity (**Thesis Objective 6**).

5. To conduct causal mediation analysis to evaluate the role of preselected mediators in the relationship between the latent variables and the risk of SMM, in order to quantify the contributions of the direct pathway (the association between the latent variables and SMM that is not mediated) and the indirect pathway (the association between the latent variables and SMM which is mediated) to understand better how these pathways influence the risk of SMM (**Thesis Objective 7**).

5.3 Methods

5.3.1 Population

The birth cohort and study population were identical to those used in **Chapter 4** and included every woman who gave birth in a hospital between 1 January 2013 and 1 March 2023, aged 10-55, with gestational age at childbirth ≥20 weeks in England. Women were excluded if their lower layer super output area (LSOA) was missing. If a woman had two separate pregnancies and births in the study period, one of the births was randomly selected to avoid clustering. Both singleton and multiple births were included.

5.3.2 Exposure

The exposures were latent variables identified from the EFA. All the indicators which comprise the IMD excluding the indictors for the health and disability domain were selected for the EFA. However, some of the domains could not be disaggregated into their individual indicators due to data restrictions. Therefore, the whole domain was included in the analysis as this is the most granular level of publicly available data. The final break down of indicators included income, employment, adult qualifications, English language proficiency, children and young people, homelessness, houses in poor condition, crime, housing affordability, household overcrowding, houses without heating, air quality, geographical barriers to services and road traffic accidents (**Table 5.1**). Two separate EFAs were performed using the 2015 and 2019 IMD indicators. The latent variables from the EFA were ranked and independently divided into population-level quintiles. If a woman had her birth from 1 January 2013 to 1 January 2015, she was assigned the latent variable quintile from the 2015 IMD data and from 1 January 2015 to 31 March 2023, the 2019 IMD data.

Table 5.1. Level of granularity of the indicators included in the EFA. **Bold** font highlights the most granular level of the indicator e.g. Income was included as a whole indicator.

Domain	Indices
Income	Adults and children in income support families Adults and children in income-based Jobseeker's Allowance families Adults and children in income-based Employment and Support Allowance families Adults and children in Pension credit families Adults and children in Working Tax Credit and Child Tax Credit families, below 60% median income and not already counted Asylum seekers in England in receipt of subsistence support, accommodation support, or both Adults and Children in Universal Credit families where no adults in 'Working – no requirements' conditionally regime**
Employment	Claimants of Jobseeker's Allowance, aged 18-59/64 Claimants of Employment and Support Allowance, aged 18-59/64 Claimants of Incapacity Benefit, aged 18-59/64 Claimants of Carer's Allowance, aged 18-59/64 Claimants of Universal Credit in 'Searching for work' and 'No work requirements' conditionality group**
Education Skills and Training	**Children and Young People** Key stage 2 attainment Key stage 4 attainment Secondary school absence Staying on in education post 16 Entry to higher education
	Adults with no or low qualifications, aged 25-59/64 **Adults who cannot speak English or cannot speak English well, aged 25-59/64**
Crime	Recorded crime rates for: violence, burglary, theft and criminal damage
Barriers to Housing and Services	**Geographical Barriers** Road distance to a post office, primary school, general store or supermarket and GP surgery
	Household overcrowding **Homelessness** **Housing affordability**
Living Environment	**Houses without central heating** **Housing in poor condition**
	Air quality **Road traffic accidents**

5.3.3 Outcome

SMM was defined using the same definition in the previous chapter, a modified English Maternal Morbidity Outcome Indicator (EMMOI) (125) (**Appendix Chapter 4 Table 3 (4.3)**).

5.3.4 Covariates

After each latent variable was created, Directed Acyclic Graphs (DAG) (**Appendix Figures 5.1 and 5.2**) were used to conceptually represent which variables were confounders or mediators based on existing literature and clinical knowledge *a priori*. The covariates identified were age, parity, ethnicity, year of childbirth, timing of antenatal booking, obesity, pre-existing medical and mental health conditions and smoking/substance misuse. The maternal age at childbirth was grouped into five-year categories, except for those younger than 20 or older than 40, who were grouped into single categories. Ethnicity was defined using the Office for National Statistics (ONS) categorisation system (127) which was collapsed into ten groups based on the categories used for the MBRRACE-UK perinatal mortality surveillance report (128): White, Black or Black British - African, Black or Black British - Caribbean, Asian or Asian British - Indian, Asian or Asian British - Pakistani, Asian or Asian British - Bangladeshi, Mixed, Other, Other Black and Other Asian. Parity was determined using the algorithm described in **Chapter 4**, and women were categorised as primiparous or multiparous. The year of the birth was included as a categorical variable. The timing of antenatal booking is derived from the gestational age at the time of the first antenatal assessment (antenatal boking), which is recorded in the HES APC additional maternity section. It is calculated using the date of the first antenatal visit, the pregnancy gestational age at booking, and the date of the birth. The National Health Service (NHS) recommends that the first antenatal appointment should occur between eight and 12 weeks of gestation (154). Women who had their antenatal booking on or after 12 weeks were coded as ‘yes’ for late booking, while those who booked before 12 weeks

were coded as ‘no’. Information on the following potential covariates was obtained based on ICD-10 codes: obesity or overweight (yes/no), history of pre-existing medical condition (yes/no), history of pre-existing mental health problems (yes/no), substance misuse and smoking (yes/no). Women were assumed not to have the above confounding factors if they were not coded in any hospital records from the preceding length of time listed in **Appendix Chapter 4 Table 1 (4.1)**. The list of relevant pre-existing medical conditions and mental health problems and the code for all confounding variables is provided in **Appendix Chapter 4 Table 1 (4.1)**.

5.3.5 Statistical Analysis

Statistical analysis was performed using Stata version 18 (StataCorp. 2023. Stata Statistical Software: Release 18. College Station, TX: StataCorp LLC). Statistical significance was assumed to be a two-tailed p value of less than 0.05.

5.3.5.1 Exploratory Factor Analysis (EFA)

The raw data were standardised, so there were no outliers. Women with a missing LSOA were excluded from the data. Polychoric correlations were used because the data were ordinal, violating the assumptions of normality and linearity needed for a factor analysis based on Pearson correlations. Bartlett’s Test of Sphericity and the Kaiser-Meyer-Olkin measure of sampling adequacy were conducted to assess whether the data were suitable for an EFA. A significant result ($p < 0.05$) for Bartlett’s test and a Kaiser-Meyer-Olkin value above 0.6 would indicate sufficient intercorrelations among variables.

The iterated principal factor extraction method was chosen to avoid potential biases when using maximum likelihood estimation when the data has a non-normal distribution (155). Squared multiple correlations were used for the initial communality estimates (156). The least-squares

method was chosen to estimate factor loadings as it is robust against distribution assumptions and remains effective with weak factors (157).

Parallel analysis, minimal average partials, and the scree test were used to determine the number of factors to retain (158). Parallel analysis, which is effective with ordinal data, compares actual data with randomly generated data (159). Minimal average partials ascertain when removing additional factors does not improve the model, with the lowest minimal average partials value specifying the number of factors to retain. The scree test uses a plot to determine the number of factors to retain visually.

The average overall residual misfit of the model was quantified by a root mean squared residual, with lower values indicating better fit (160). Values ≤ 0.08 are preferred, and values ≤ 0.05 indicate a close fit (161). An orthogonal varimax rotation was chosen to simplify factor identification and interpretation (162).

Salience was set at 0.40 to ensure the practical (16% variance) and statistical ($p < 0.01$) significance of pattern loadings (163). Each model was examined for symptoms of over-extraction. These include improper solutions, fewer than three salient loadings, and technical factors. Variables with salient loadings on more than one factor were categorised as complex, meaning they were less interpretable and replicable and were therefore excluded (164).

5.3.5.1.1 Factor Scores

A **factor score** is a numerical value representing an individual observation's position on a latent factor/variable extracted during factor analysis. It quantifies the degree to which an observation aligns with the characteristics of a specific latent factor/variable. Bartlett's method was chosen to estimate factor scores for accuracy and reduced bias when using an orthogonal factor rotation. Spearman's correlation coefficients were calculated between the variables and

the factor scores. Nunnally and Bernstein (165) suggest that good factor scores should have strong correlations with the variables that form each factor but should have limited correlations with factor scores for other factors. Variables were regressed onto their respective factor scores using a linear regression to determine the proportion of variance in the actual latent factors/variables explained by the factor scores. Mulaik (166) advises that factor scores are unreliable unless they explain almost all the variance with an R^2 value greater than 0.95.

5.3.5.1.2 Factor/Latent Variable Labelling

The factors/latent variables were labelled with assistance from the lived experience group according to common themes identified by the factor loadings of the indicators.

5.3.5.2 Descriptive Statistics

The characteristics of the women in the study population are presented as numbers and percentages stratified by each latent variable.

5.3.5.3 Univariable Analysis

Multi-level Poisson regression with a random intercept was used to calculate the risk ratios (RR) (and their 95% confidence intervals (CI)) for each quintile of the latent variables to account for clustering between individuals who shared the same postcode (LSOA) as described in **Chapter 4**. Level 1 was defined as the individual woman and level 2, her LSOA. The baseline group (the reference category) was the quintile with the least disadvantage in either latent variable.

5.3.5.4 Multivariable Analysis

Using a complete case analysis, three multi-level multivariable Poisson regression models were built to estimate the adjusted RR for SMM and their 95% CI in the different quintiles of the latent factors/variables. Model 1 included covariates such as age, year of birth, ethnicity and parity. Likelihood ratio testing for linearity was used to determine whether age should be modelled as continuous or as a categorical variable. Model 2 included additional adjustments for the other latent variable. Model 3 included additional adjustments for the pre-existing medical and mental health conditions and substance misuse and smoking. Model 2 was used as the final model as the covariates in Model 3 could be either confounders or mediators, and therefore there is a potential for over-adjustment. RR and their 95% CI were calculated separately for the major components of the composite SMM outcome using Model 2 in the different quintiles of each latent factor/variable compared to the least.

5.3.5.5 Effect Modification by Ethnicity

Likelihood ratio testing was performed on the final model (Model 2) to determine whether there was an effect modification by ethnicity for each latent factor/variable. All ethnic groups were then compared to a standard reference point (the White women living in the least deprived latent variable quintile) to provide a consistent baseline across all comparisons. Regardless of the evidence of effect modification, the latent variables were presented in this way. Absolute measures were then calculated using average adjusted predictive margins (95% CI), which provide an average probability of SMM for each ethnicity and latent variable quintile.

5.3.5.6 Population Attributable Fractions (PAF)

Population attributable fractions (PAFs) (and their 95% CIs) were calculated using the *punaf* command in Stata in each different factor using Model 2. The data were used for women in

each highest latent variable quintile as the reference group for the overall analysis or those from a White ethnic background in the highest latent variable quintile as the reference group for the analysis by ethnicity, which was then applied to the women in the entire cohort.

5.3.5.7 Causal Mediation Analysis

The role of various mediators on the association between each latent variable and SMM were explored using the *med4way* command in Stata. This decomposes the effects into the total excess relative risk (TERR), pure indirect effect (PIE), controlled direct effect (CDE), the reference interaction and the mediated interaction. The TERR quantifies the overall relationship between the exposure and the outcome irrespective of mediator status. The PIE quantifies the effect of the mediator on the outcome assuming no interaction and the CDE quantifies the effect of the exposure on the outcome that is not mediated when the mediator is fixed at a certain value. Finally, the reference interaction quantifies the effect of any interaction between the exposure and the mediator, and the mediated interaction quantifies the effect of interaction that is only activated when the exposure affects the mediator (**Appendix Table 5.1**). These can then be aggregated to calculate the proportion of the total effect driven by the CDE, the proportion driven by PIE, the total proportion mediated and the proportion explained by an interaction.

A DAG was used to identify potential mediators and any confounding factors based on the literature and clinical knowledge *a priori* (**Appendix Figures 5.3-5.7**). The key mediators chosen for analysis were obesity, mental health problems, pre-existing medical conditions and late antenatal booking (defined as ≥ 12 weeks) and were treated as binary variables. The composite variable of pre-existing medical conditions was modified to remove hypertensive disorders, diabetes and ischaemic heart disease as these conditions are closely related to

obesity. Including these conditions in the pre-existing medical conditions composite violates the **rule of no omitted confounders** in mediation analysis, as obesity is another mediator. Logistic regression and Poisson regression models were used to estimate odds ratios (ORs) and RRs for the mediator model and outcome model, respectively, as the *med4way* command does not support Poisson regression models for the mediator model. However, this is unlikely to bias the results as SMM is relatively rare. The exposure was a binary variable comparing the lowest to the highest quintile of the latent variable.

5.3.5.8 Sensitivity Analyses

Four sensitivity analyses were conducted using Model 2. The first analysis repeated the EFA and excluded geographical barriers to services, as this appeared to have an inverse relationship with disadvantage to the other indices. Secondly, the main analysis was repeated, excluding sepsis from the composite SMM outcome. Thirdly, sepsis was only included in the outcome if the length of hospital stay was three days or more. Finally, ICD-10 codes only were included in the outcome so the results could be compared to the Dutch data (**Chapter 6**), which does not contain OPCS-4 codes. The causal mediation analysis was repeated with the full composite variable of pre-existing medical conditions, including hypertensive disorders, diabetes and ischaemic heart disease to assess the mediation effects of the addition of conditions closely related to obesity on SMM risk.

5.4 Results

5.4.1 Factor Analysis

There were 32,844 LSOAs, a ratio of the observations to variables of 2,346:1, and an adequate sample size (167). The data were appropriate for EFA with most correlation coefficients above 0.3, with the highest being 0.72. Bartlett's Test of Sphericity rejected the null hypothesis of an identity matrix (p-value <0.001 for both 2015 and 2019), which indicated significant correlations among the 14 items. The Kaiser-Meyer-Olkin measure of sampling adequacy was acceptable at 0.83 (2015) and 0.82 (2019) (156).

Results from the scree test and parallel analysis are presented in **Appendix Figures 5.8 and 5.9.** Based on the parallel analysis, minimal average partials and scree test, two latent variables accounted for 79% and 80% of the variance in the 2015 and 2019 data, respectively. 'Crime' and 'housing affordability' cross-loaded onto both latent variables and were subsequently excluded. **Appendix Table 5.2** displays a colour-coded simple structure configuration consistent with the theoretical framework of the scale with 'crime' and 'housing affordability' included. **Table 5.2** displays a colour-coded simple structure configuration of the remaining indicators. 'houses in poor condition' and 'houses without heating' did not achieve salience on either factor. The remaining variables that saliently loaded onto each latent variable yielded an alpha reliability coefficient of 0.85 for Factor 1 and 0.91 for Factor 2 using the 2015 data, and 0.84 and 0.91, respectively, using the 2019 data

Table 5.2. Factor loadings (pattern coefficients). Blue = saliently loaded on to Factor 1. Red = saliently loaded onto Factor 2

	2015			2019		
Indices	Factor 1	Factor 2	Uniqueness	Factor 1	Factor 2	Uniqueness
Houses in poor condition	0.08	0.24	0.94	0.02	0.01	1.00
Household overcrowding	0.36	0.80	0.24	0.36	0.79	0.24
Homelessness	0.00	0.50	0.75	-0.04	0.59	0.65
English language proficiency	0.17	0.75	0.41	0.17	0.77	0.38
Adult qualifications	0.76	-0.31	0.32	0.74	-0.29	0.37
Houses without heating	0.20	0.38	0.81	0.22	0.33	0.84
Road traffic accidents	0.10	0.60	0.63	0.01	0.44	0.81
Air quality	0.08	0.70	0.51	0.02	0.81	0.35
Income	0.91	0.36	0.03	0.93	0.33	0.03
Employment	0.94	0.22	0.08	0.94	0.16	0.08
Children and young people	0.80	0.08	0.35	0.81	0.02	0.35
Geographical barriers	-0.29	-0.60	0.56	-0.30	-0.54	0.61

The Addressing Inequalities in Maternity Services (AIMS) lived experience group labelled the latent variables. The first latent variable (**Factor 1**) consisted of neighbourhood income, employment, adult skills and children and young people, and was labelled Traditional Socioeconomic Status (SES). The second latent variable (**Factor 2**) consisted of neighbourhood homelessness, household overcrowding, air pollution, road traffic accidents, English language proficiency and geographical barriers (inversed so that living closer to services was more, rather than less deprived) and was labelled Urban Deprivation. The root mean squared residual of the two-factor model was 0.053 (2015 and 2019).

5.4.2 Descriptive Statistics

The characteristics of the women in each neighbourhood Traditional SES and Urban Deprivation quintile are shown in **Table 5.3 and Table 5.4**. Women who lived in the most deprived Traditional SES quintiles were more likely to be younger, from minoritised ethnicity

groups, multiparous, live in urban areas, have a history of smoking or substance misuse, be obese and have pre-existing mental health conditions. The North West of England (22.0%), Yorkshire and the Humber (15.7%) and the West Midlands (17.0%) contained the greatest proportion of the most deprived Traditional SES areas. Women residing in the most deprived Traditional SES areas were also more likely to have had an unassisted vertex vaginal birth, an induction of labour, and have registered their pregnancy with the midwife on or after 12 weeks. They were less likely to have an elective caesarean birth and live in the least Urban Deprived areas.

Women who lived in the areas with the highest amount of Urban Deprivation were more likely to have SMM, be older and were considerably more likely to be from minoritised ethnicity groups and have registered their pregnancy with the midwife on or after 12 weeks. They were also more likely to live in areas with a higher percentage of people who were not born in the United Kingdom (UK). 58.3% of the most Urban Deprived areas were in London. Women living in the most Urban Deprived areas were less likely to have a history of smoking or substance misuse, pre-existing medical and mental health problems or obesity. They were also less likely to have had an unassisted vertex vaginal birth, an induction of labour and were more likely to have emergency caesarean or instrumental birth. None were classified as living in rural areas by the ONS definition.

Appendix Table 5.3 indicates that the proportion of composite SMM was higher for sepsis and embolic events among women living in the most deprived Traditional SES quintile than those living in the least. Sepsis also made up a greater proportion of the SMM outcome from women living in the most Urban Deprived areas compared to those in the least Urban Deprived areas (**Appendix Table 5.4).** In contrast, the proportion of SMM cases due to acute renal failure and

management of intra-abdominal or vaginal collection was lower among women living in the most deprived Traditional SES and Urban Deprived areas compared to those living in the least deprived of these areas.

Table 5.3. Characteristics of the study population stratified by neighbourhood Traditional Socioeconomic Status (SES), number and percentage (N(%))

	Traditional SES					
	Most deprived 20%	**More deprived 20-40%**	**Less deprived 40-60%**	**Less deprived 60-80%**	**Least deprived 80-100%**	**Total**
	N(%)	**N(%)**	**N(%)**	**N(%)**	**N(%)**	**N(%)**
Total	**1,029,998 (25.5)**	**943,996 (23.4)**	**853,676 (21.1)**	**737,707 (18.3)**	**474,729 (11.8)**	**4,040,106 (100.0)**
SMM						
No	990,549 (98.3)	926,631 (98.1)	842,363 (98.2)	728,100 (98.3)	481,045 (98.4)	3,968,688 (98.2)
Yes	17,643 (1.7)	17,662 (1.9)	15,587 (1.8)	12,629 (1.7)	7,897 (1.6)	71,418 (1.8)
Age group						
<20	58,612 (5.7)	31,045 (3.3)	18,730 (2.2)	11,245 (1.5)	4,224 (0.9)	123,856 (3.1)
20-25	213,775 (20.8)	145,164 (15.4)	101,836 (11.9)	66,416 (9.0)	26,360 (5.6)	553,551 (13.7)
25-30	316,039 (30.7)	276,292 (29.3)	231,115 (27.1)	177,704 (24.1)	86,171 (18.2)	1,087,321 (26.9)
30-35	271,445 (26.4)	291,228 (30.9)	291,692 (34.2)	271,145 (36.8)	185,599 (39.1)	1,311,109 (32.5)
35-40	135,446 (13.2)	159,098 (16.9)	168,508 (19.7)	169,479 (23.0)	137,180 (28.9)	769,711 (19.1)
>40	34,681 (3.4)	41,169 (4.4)	41,795 (4.9)	41,718 (5.7)	35,195 (7.4)	194,558 (4.8)
Ethnicity						
White	754,748 (76.3)	649,009 (72.3)	609,311 (75.3)	566,312 (81.2)	360,309 (80.7)	2,939,689 (76.6)
Black or Black British - Caribbean	9,756 (1.0)	12,428 (1.4)	8,568 (1.1)	4,548 (0.7)	1,746 (0.4)	37,046 (1.0)
Black or Black British - African	36,073 (3.6)	39,838 (4.4)	24,861 (3.1)	12,642 (1.8)	6,077 (1.4)	119,491 (3.1)
Asian or Asian British - Indian	21,125 (2.1)	32,073 (3.6)	36,419 (4.5)	26,576 (3.8)	19,298 (4.3)	135,491 (3.5)
Asian or Asian British - Pakistani	62,931 (6.4)	40,104 (4.5)	25,523 (3.2)	13,918 (2.0)	7,404 (1.7)	149,880 (3.9)
Asian or Asian British - Bangladeshi	15,366 (1.6)	21,711 (2.4)	12,560 (1.6)	4,888 (0.7)	2,121 (0.5)	56,646 (1.5)
Mixed	19,945 (2.0)	18,807 (2.1)	15,479 (1.9)	12,057 (1.7)	8,054 (1.8)	74,342 (1.9)
Other	41,934 (4.2)	46,425 (5.2)	42,218 (5.2)	33,063 (4.7)	26,975 (6.0)	190,615 (5.0)
Other Asian	18,400 (1.9)	24,981 (2.8)	25,312 (3.1)	18,574 (2.7)	12,231 (2.7)	99,498 (2.6)
Other Black	8,368 (0.8)	12,719 (1.4)	8,697 (1.1)	4,652 (0.7)	2,022 (0.5)	36,458 (0.9)
Parity						
Multiparous	648,808 (63.0)	562,018 (59.5)	487,519 (57.1)	407,483 (55.2)	263,020 (55.4)	2,368,848 (58.6)
Primiparous	381,190 (37.0)	381,978 (40.5)	366,157 (42.9)	330,224 (44.8)	211,709 (44.6)	1,671,258 (41.4)

Table 5.3. (Continued)

	Traditional SES					
	Most deprived 20%	**More deprived 20-40%**	**Less deprived 40-60%**	**Less deprived 60-80%**	**Least deprived 80-100%**	**Total**
	N(%)	**N(%)**	**N(%)**	**N(%)**	**N(%)**	**N(%)**
Urban/Rural						
Urban	981,985 (95.3)	843,485 (89.4)	716,558 (83.9)	581,960 (78.9)	404,000 (85.1)	3,527,988 (87.3)
Rural	48,013 (4.7)	100,511 (10.6)	137,118 (16.1)	155,747 (21.1)	70,729 (14.9)	512,118 (12.7)
Neighbourhood % not born in the United Kingdom (UK)						
Lowest 20%	216,591 (21.0)	139,750 (14.8)	128,497 (15.1)	114,297 (15.5)	34,504 (7.3)	633,639 (15.7)
Lower 20-40%	182,135 (17.7)	143,520 (15.2)	148,273 (17.4)	139,769 (18.9)	59,329 (12.5)	673,026 (16.7)
Middle 40-60%	190,349 (18.5)	152,054 (16.1)	141,978 (16.6)	152,660 (20.7)	108,620 (22.9)	745,661 (18.5)
Higher 60-80%	218,716 (21.2)	183,310 (19.4)	158,513 (18.6)	156,607 (21.2)	150,518 (31.7)	867,664 (21.5)
Highest 80-100%	222,207 (21.6)	325,362 (34.5)	276,415 (32.4)	174,374 (23.6)	121,758 (25.6)	1,120,116 (27.7)
Region						
North East	98,915 (9.8)	31,198 (3.3)	18,953 (2.2)	18,922 (2.6)	9,561 (2.0)	177,549 (4.4)
North West	230,793 (22.9)	112,390 (11.9)	78,008 (9.1)	72,014 (9.7)	38,461 (7.9)	531,666 (13.2)
Yorkshire and Humber	158,648 (15.7)	76,962 (8.2)	61,038 (7.1)	57,225 (7.7)	34,631 (7.1)	388,504 (9.6)
East Midlands	89,453 (8.9)	76,554 (8.1)	64,931 (7.6)	57,385 (7.7)	30,260 (6.2)	318,583 (7.9)
West Midlands	171,214 (17.0)	95,335 (10.1)	75,947 (8.9)	61,358 (8.3)	29,397 (6.0)	433,251 (10.7)
East of England	72,991 (7.2)	114,342 (12.1)	103,287 (12.0)	92,349 (12.5)	59,838 (12.2)	442,807 (11.0)
London	38,465 (3.8)	228,249 (24.2)	229,365 (26.7)	158,196 (21.4)	113,933 (23.3)	768,208 (19.0)
South East	78,092 (7.7)	123,270 (13.1)	138,084 (16.1)	151,347 (20.4)	139,219 (28.5)	630,012 (15.6)
South West	69,621 (6.9)	85,993 (9.1)	88,337 (10.3)	71,933 (9.7)	33,642 (6.9)	349,526 (8.7)
Substance misuse or smoking						
No	682,342 (66.2)	706,442 (74.8)	673,831 (78.9)	603,610 (81.8)	408,890 (86.1)	3,075,115 (76.1)
Yes	347,656 (33.8)	237,554 (25.2)	179,845 (21.1)	134,097 (18.2)	65,839 (13.9)	964,991 (23.9)
Pre-existing medical conditions						
No	773,791 (75.1)	722,468 (76.5)	659,313 (77.2)	570,582 (77.3)	371,307 (78.2)	3,097,461 (76.7)
Yes	256,207 (24.9)	221,528 (23.5)	194,363 (22.8)	167,125 (22.7)	103,422 (21.8)	942,645 (23.3)

Table 5.3. (Continued)

	Traditional SES					
	Most deprived 20%	**More deprived 20-40%**	**Less deprived 40-60%**	**Less deprived 60-80%**	**Least deprived 80-100%**	**Total**
Pre-existing medical conditions (excluding ischaemic heart disease, hypertension and diabetes)						
No	819,645 (79.6)	762,261 (80.8)	691,632 (81.0)	596,492 (80.9)	385,054 (81.1)	3,255,084 (80.6)
Yes	210,353 (20.4)	181,735 (19.3)	162,044 (19.0)	141,215 (19.1)	89,675 (18.9)	785,022 (19.4)
Pre-existing mental health problems						
No	877,746 (85.2)	828,887 (87.8)	757,447 (88.7)	657,369 (89.1)	428,506 (90.3)	3,549,955 (87.9)
Yes	152,252 (14.8)	115,109 (12.2)	96,229 (11.3)	80,338 (10.9)	46,223 (9.7)	490,151 (12.1)
Obesity/ overweight						
No	750,759 (77.0)	730,671 (81.1)	685,633 (83.4)	609,587 (85.3)	413,339 (89.2)	3,189,989 (82.3)
Yes	224,441 (23.0)	170,774 (18.9)	136,082 (16.6)	104,838 (14.7)	50,175 (10.8)	686,310 (17.7)
Mode of birth						
Unassisted vertex vaginal birth	609,443 (59.3)	525,634 (55.8)	459,649 (54.0)	390,187 (53.0)	242,604 (51.2)	2,227,517 (55.3)
Instrumental birth	111,104 (10.8)	123,557 (13.1)	121,798 (14.3)	107,583 (14.6)	72,978 (15.4)	537,020 (13.3)
Breech birth	4,450 (0.4)	4,433 (0.5)	3,643 (0.4)	3,319 (0.5)	2,261 (0.5)	18,106 (0.4)
Elective caesarean birth	125,755 (12.2)	118,673 (12.6)	112,541 (13.2)	104,919 (14.3)	74,079 (15.6)	535,967 (13.3)
Emergency caesarean birth	169,996 (16.5)	163,193 (17.3)	148,348 (17.4)	124,092 (16.9)	77,529 (16.4)	683,158 (16.9)
Other mode of birth	7,602 (0.7)	6,519 (0.7)	5,753 (0.7)	5,647 (0.8)	4,152 (0.9)	29,673 (0.7)

Table 5.3. (Continued)

	Traditional SES					
	Most deprived 20%	**More deprived 20-40%**	**Less deprived 40-60%**	**Less deprived 60-80%**	**Least deprived 80-100%**	**Total**
	N(%)	**N(%)**	**N(%)**	**N(%)**	**N(%)**	**N(%)**
Birth onset method						
Spontaneous: the onset of regular contractions whether or not preceded by spontaneous rupture of the membranes	433,234 (50.6)	412,934 (53.0)	377,445 (53.6)	325,800 (53.7)	208,157 (54.1)	1,757,570 (52.8)
Any caesarean section carried out immediately following the onset of labour, when the decision was made before labour	138,886 (16.2)	125,806 (16.2)	116,323 (16.5)	103,790 (17.1)	70,746 (18.4)	555,551 (16.7)
Surgical induction by amniotomy	50,985 (6.0)	41,790 (5.4)	36,282 (5.2)	32,444 (5.4)	19,813 (5.1)	181,314 (5.4)
Medical induction	160,650 (18.8)	144,634 (18.6)	128,431 (18.2)	105,754 (17.4)	64,016 (16.6)	603,485 (18.1)
Combination of surgical induction and medical induction	71,934 (8.4)	53,790 (6.9)	45,688 (6.5)	38,427 (6.3)	22,212 (5.8)	232,051 (7.0)
Booked antenatal care ≥12 weeks						
No	402,459 (75.2)	377,450 (77.0)	349,185 (78.3)	303,973 (79.6)	187,860 (78.1)	1,620,927 (77.4)
Yes	133,026 (24.8)	112,665 (23.0)	97,005 (21.7)	77,991 (20.4)	52,530 (21.9)	473,217 (22.6)
Index of Multiple Deprivation						
Most deprived 20%	812,874 (78.9)	203,618 (21.6)	30,196 (3.5)	1,663 (0.2)	36 (0.0)	1,048,387 (25.9)
More deprived 20-40%	210,214 (20.4)	452,743 (48.0)	205,049 (24.0)	43,481 (5.9)	4,931 (1.0)	916,418 (22.7)
Less deprived 40-60%	6,910 (0.7)	263,958 (28.0)	331,106 (38.8)	147,250 (20.0)	29,405 (6.2)	778,629 (19.3)
Less deprived 60-80%	0 (0.0)	23,438 (2.5)	256,395 (30.0)	301,043 (40.8)	105,352 (22.2)	686,228 (17.0)
Least deprived 80-100%	0 (0.0)	239 (0.0)	30,930 (3.6)	244,270 (33.1)	335,005 (70.6)	610,444 (15.1)

Table 5.3. (Continued)

	Traditional SES					
	Most deprived 20%	**More deprived 20-40%**	**Less deprived 40-60%**	**Less deprived 60-80%**	**Least deprived 80-100%**	**Total**
	N(%)	**N(%)**	**N(%)**	**N(%)**	**N(%)**	**N(%)**
Urban Deprivation						
Most deprived 20%	203,966 (19.8)	323,657 (34.3)	294,501 (34.5)	201,068 (27.3)	132,139 (27.8)	1,155,331 (28.6)
More deprived 20-40%	371,267 (36.0)	229,797 (24.3)	161,631 (18.9)	112,371 (15.2)	86,664 (18.3)	961,730 (23.8)
Less deprived 40-60%	248,445 (24.1)	175,303 (18.6)	144,004 (16.9)	133,535 (18.1)	99,408 (20.9)	800,695 (19.8)
Less deprived 60-80%	142,572 (13.8)	133,656 (14.2)	139,151 (16.3)	166,777 (22.6)	105,560 (22.2)	687,716 (17.0)
Least deprived 80-100%	63,748 (6.2)	81,583 (8.6)	114,389 (13.4)	123,956 (16.8)	50,958 (10.7)	434,634 (10.8)

Table 5.4. Characteristics of study population stratified by neighbourhood Urban Deprivation, number and percentage (N (%))

	Urban Deprivation					
	Most deprived 20%	**More deprived 20-40%**	**Less deprived 40-60%**	**Less deprived 60-80%**	**Least deprived 80-100%**	**Total**
	N(%)	**N(%)**	**N(%)**	**N(%)**	**N(%)**	**N(%)**
Total	**1,155,331 (28.6)**	**961,730 (23.8)**	**800,695 (19.8)**	**687,716 (17.0)**	**434,634 (10.8)**	**4,040,106 (100.0)**
SMM						
No	1,139,017 (97.8)	953,142 (98.3)	790,918 (98.4)	672,444 (98.5)	413,167 (98.5)	3,968,688 (98.2)
Yes	25,505 (2.2)	16,665 (1.7)	12,559 (1.6)	10,401 (1.5)	6,288 (1.5)	71,418 (1.8)
Age group						
<20	27,628 (2.4)	36,144 (3.8)	28,018 (3.5)	20,213 (2.9)	11,853 (2.7)	123,856 (3.1)
20-25	140,061 (12.1)	150,001 (15.6)	117,745 (14.7)	90,605 (13.2)	55,139 (12.7)	553,551 (13.7)
25-30	288,244 (24.9)	266,281 (27.7)	223,528 (27.9)	187,960 (27.3)	121,308 (27.9)	1,087,321 (26.9)
30-35	380,749 (33.0)	299,239 (31.1)	256,711 (32.1)	229,041 (33.3)	145,369 (33.4)	1,311,109 (32.5)
35-40	250,156 (21.7)	168,648 (17.5)	141,347 (17.7)	128,820 (18.7)	80,740 (18.6)	769,711 (19.1)
>40	68,493 (5.9)	41,417 (4.3)	33,346 (4.2)	31,077 (4.5)	20,225 (4.7)	194,558 (4.8)
Ethnicity						
White	530,146 (49.1)	703,423 (76.7)	685,063 (89.4)	619,646 (93.9)	401,411 (96.2)	2,939,689 (76.6)
Black or Black British - Caribbean	25,685 (2.4)	7,567 (0.8)	2,360 (0.3)	1,000 (0.2)	434 (0.1)	37,046 (1.0)
Black or Black British - African	78,054 (7.2)	26,976 (2.9)	8,971 (1.2)	3,979 (0.6)	1,511 (0.4)	119,491 (3.1)
Asian or Asian British - Indian	76,784 (7.1)	34,560 (3.8)	14,778 (1.9)	7,075 (1.1)	2,294 (0.5)	135,491 (3.5)
Asian or Asian British - Pakistani	92,493 (8.6)	43,126 (4.7)	10,392 (1.4)	3,050 (0.5)	819 (0.2)	149,880 (3.9)
Asian or Asian British - Bangladeshi	43,281 (4.0)	9,469 (1.0)	2,528 (0.3)	1,034 (0.2)	334 (0.1)	56,646 (1.5)
Mixed	33,503 (3.1)	20,382 (2.2)	10,877 (1.4)	6,519 (1.0)	3,061 (0.7)	74,342 (1.9)
Other	113,508 (10.5)	41,843 (4.6)	19,230 (2.5)	11,232 (1.7)	4,802 (1.2)	190,615 (5.0)
Other Asian	60,021 (5.6)	22,542 (2.5)	9,650 (1.3)	5,039 (0.8)	2,246 (0.5)	99,498 (2.6)
Other Black	25,337 (2.3)	6,968 (0.8)	2,455 (0.3)	1,164 (0.2)	534 (0.1)	36,458 (0.9)
Parity						
Multiparous	668,875 (57.9)	573,838 (59.7)	472,284 (59.0)	401,639 (58.4)	252,212 (58.0)	2,368,848 (58.6)
Primiparous	486,456 (42.1)	387,892 (40.3)	328,411 (41.0)	286,077 (41.6)	182,422 (42.0)	1,671,258 (41.4)

Table 5.4. (Continued)

	Urban Deprivation					
	Most deprived 20%	**More deprived 20-40%**	**Less deprived 40-60%**	**Less deprived 60-80%**	**Least deprived 80-100%**	**Total**
	N(%)	**N(%)**	**N(%)**	**N(%)**	**N(%)**	**N(%)**
Urban/ Rural						
Urban	1,155,095 (100.0)	948,148 (98.6)	723,716 (90.4)	483,308 (70.3)	217,721 (50.1)	3,527,988 (87.3)
Rural	236 (0.0)	13,582 (1.4)	76,979 (9.6)	204,408 (29.7)	216,913 (49.9)	512,118 (12.7)
Neighbourhood % not born in the United Kingdom (UK)						
Lowest 20%	55 (0.0)	29,127 (3.0)	146,159 (18.3)	234,864 (34.2)	223,434 (51.4)	633,639 (15.7)
Lower 20-40%	1,016 (0.1)	95,841 (10.0)	213,009 (26.6)	220,827 (32.1)	142,333 (32.7)	673,026 (16.7)
Middle 40-60%	10,834 (0.9)	234,344 (24.4)	260,862 (32.6)	180,748 (26.3)	58,873 (13.5)	745,661 (18.5)
Higher 60-80%	169,305 (14.7)	469,633 (48.8)	170,776 (21.3)	48,836 (7.1)	9,114 (2.1)	867,664 (21.5)
Highest 80-100%	974,121 (84.3)	132,785 (13.8)	9,889 (1.2)	2,441 (0.4)	880 (0.2)	1,120,116 (27.7)
Region						
North East	4,420 (0.4)	22,351 (2.3)	37,679 (4.7)	53,048 (7.8)	60,051 (14.3)	177,549 (4.4)
North West	76,058 (6.5)	163,822 (16.9)	136,425 (17.0)	99,677 (14.6)	55,684 (13.3)	531,666 (13.2)
Yorkshire and Humber	61,094 (5.2)	118,871 (12.3)	97,888 (12.2)	75,572 (11.1)	35,079 (8.4)	388,504 (9.6)
East Midlands	43,547 (3.7)	70,216 (7.2)	71,960 (9.0)	76,798 (11.2)	56,062 (13.4)	318,583 (7.9)
West Midlands	111,768 (9.6)	127,842 (13.2)	91,370 (11.4)	67,738 (9.9)	34,533 (8.2)	433,251 (10.7)
East of England	58,415 (5.0)	132,971 (13.7)	107,289 (13.4)	81,540 (11.9)	62,592 (14.9)	442,807 (11.0)
London	678,387 (58.3)	70,902 (7.3)	15,025 (1.9)	3,686 (0.5)	208 (0.0)	768,208 (19.0)
South East	98,714 (8.5)	198,783 (20.5)	163,625 (20.4)	126,102 (18.5)	42,788 (10.2)	630,012 (15.6)
South West	32,119 (2.8)	64,049 (6.6)	82,216 (10.2)	98,684 (14.5)	72,458 (17.3)	349,526 (8.7)
Substance misuse or smoking						
No	954,45 3 (82.6)	698,655 (72.6)	577,122 (72.1)	514,021 (74.7)	330,864 (76.1)	3,075,115 (76.1)
Yes	200,878 (17.4)	263,075 (27.4)	223,573 (27.9)	173,695 (25.3)	103,770 (23.9)	964,991 (23.9)
Pre-existing medical conditions						
No	916,658 (79.3)	731,110 (76.0)	602,117 (75.2)	518,521 (75.4)	329,055 (75.7)	3,097,461 (76.7)
Yes	238,673 (20.7)	230,620 (24.0)	198,578 (24.8)	169,195 (24.6)	105,579 (24.3)	942,645 (23.3)

Table 5.4. (Continued)

	Urban Deprivation					
	Most deprived 20%	**More deprived 20-40%**	**Less deprived 40-60%**	**Less deprived 60-80%**	**Least deprived 80-100%**	**Total**
	N(%)	**N(%)**	**N(%)**	**N(%)**	**N(%)**	**N(%)**
Pre-existing medical conditions (excluding ischaemic heart disease, hypertension and diabetes)						
No	966,679 (83.7)	768,160 (79.9)	630,232 (78.7)	543,452 (79.0)	346,561 (79.7)	3,255,084 (80.6)
Yes	188,652 (16.3)	193,570 (20.1)	170,463 (21.3)	144,264 (21.0)	88,073 (20.3)	785,022 (19.4)
Pre-existing mental health problems						
No	1,050,538 (90.9)	837,679 (87.1)	690,092 (86.2)	594,271 (86.4)	377,375 (86.8)	3,549,955 (87.9)
Yes	104,793 (9.1)	124,051 (12.9)	110,603 (13.8)	93,445 (13.6)	57,259 (13.2)	490,151 (12.1)
Obesity/ overweight						
No	954,484 (85.9)	745,697 (81.0)	615,430 (80.3)	533,960 (80.8)	340,418 (81.5)	3,189,989 (82.3)
Yes	156,728 (14.1)	174,537 (19.0)	151,137 (19.7)	126,542 (19.2)	77,366 (18.5)	686,310 (17.7)
Mode of birth						
Unassisted vertex vaginal birth	609,333 (52.8)	536,418 (55.9)	450,725 (56.4)	385,839 (56.2)	245,202 (56.5)	2,227,517 (55.3)
Instrumental birth	178,442 (15.5)	121,149 (12.6)	98,856 (12.4)	85,460 (12.5)	53,113 (12.2)	537,020 (13.3)
Breech birth	5,240 (0.5)	4,710 (0.5)	3,728 (0.5)	2,798 (0.4)	1,630 (0.4)	18,106 (0.4)
Elective caesarean birth	141,085 (12.2)	124,087 (12.9)	109,844 (13.7)	97,979 (14.3)	62,972 (14.5)	535,967 (13.3)
Emergency caesarean birth	213,818 (18.5)	167,013 (17.4)	129,157 (16.2)	106,737 (15.6)	66,433 (15.3)	683,158 (16.9)
Other mode of birth	5,212 (0.5)	6,416 (0.7)	6,607 (0.8)	7,176 (1.0)	4,262 (1.0)	29,673 (0.7)

Table 5.4. (Continued)

	Urban Deprivation					
	Most deprived 20%	**More deprived 20-40%**	**Less deprived 40-60%**	**Less deprived 60-80%**	**Least deprived 80-100%**	**Total**
	N(%)	**N(%)**	**N(%)**	**N(%)**	**N(%)**	**N(%)**
Birth onset method						
Spontaneous: the onset of regular contractions whether or not preceded by spontaneous rupture of the membranes	506,823 (56.4)	414,702 (52.0)	348,512 (51.1)	301,424 (51.3)	186,109 (51.0)	1,757,570 (52.8)
Any caesarean section carried out immediately following the onset of labour, when the decision was made before labour	147,798 (16.5)	134,931 (16.9)	113,543 (16.7)	98,003 (16.7)	61,276 (16.8)	555,551 (16.7)
Surgical induction by amniotomy	42,134 (4.7)	42,721 (5.4)	38,234 (5.6)	35,582 (6.1)	22,643 (6.2)	181,314 (5.4)
Medical induction	156,158 (17.4)	144,606 (18.1)	127,273 (18.7)	107,903 (18.4)	67,545 (18.5)	603,485 (18.1)
Combination of surgical induction and medical induction	45,530 (5.1)	60,554 (7.6)	54,066 (7.9)	44,199 (7.5)	27,702 (7.6)	232,051 (7.0)
Booked antenatal care ≥12 weeks						
No	368,385 (67.7)	374,741 (75.7)	355,642 (81.3)	318,943 (84.0)	203,216 (85.6)	1,620,927 (77.4)
Yes	176,081 (32.3)	120,561 (24.3)	81,672 (18.7)	60,758 (16.0)	34,145 (14.4)	473,217 (22.6)
Index of Multiple Deprivation						
Most deprived 20%	410,513 (35.5)	352,851 (36.7)	177,545 (22.2)	81,252 (11.8)	26,226 (6.0)	1,048,387 (25.9)
More deprived 20-40%	367,225 (31.8)	222,022 (23.1)	164,170 (20.5)	105,019 (15.3)	57,982 (13.3)	916,418 (22.7)
Less deprived 40-60%	218,001 (18.9)	165,348 (17.2)	153,479 (19.2)	141,518 (20.6)	100,283 (23.1)	778,629 (19.3)
Less deprived 60-80%	117,682 (10.2)	126,781 (13.2)	151,449 (18.9)	168,576 (24.5)	121,740 (28.0)	686,228 (17.0)
Least deprived 80-100%	41,910 (3.6)	94,728 (9.8)	154,052 (19.2)	191,351 (27.8)	128,403 (29.5)	610,444 (15.1)

Table 5.4. (Continued)

	Urban Deprivation					
	Most deprived 20%	**More deprived 20-40%**	**Less deprived 40-60%**	**Less deprived 60-80%**	**Least deprived 80-100%**	**Total**
	N(%)	**N(%)**	**N(%)**	**N(%)**	**N(%)**	**N(%)**
Traditional SES						
Most deprived 20%	203,966 (17.7)	371,267 (38.6)	248,445 (31.0)	142,572 (20.7)	63,748 (14.7)	1,029,998 (25.5)
More deprived 20-40%	323,657 (28.0)	229,797 (23.9)	175,303 (21.9)	133,656 (19.4)	81,583 (18.8)	943,996 (23.4)
Less deprived 40-60%	294,501 (25.5)	161,631 (16.8)	144,004 (18.0)	139,151 (20.2)	114,389 (26.3)	853,676 (21.1)
Less deprived 60-80%	201,068 (17.4)	112,371 (11.7)	133,535 (16.7)	166,777 (24.3)	123,956 (28.5)	737,707 (18.3)
Least deprived 80-100%	132,139 (11.4)	86,664 (9.0)	99,408 (12.4)	105,560 (15.3)	50,958 (11.7)	474,729 (11.8)

5.4.3 Univariable Analysis

Women living in the most deprived Traditional SES areas had a 8% (95% CI 1.05-1.11) increased risk of SMM compared to women living in the least Traditional SES deprived areas. There was a dose-response relationship between Urban Deprivation and SMM, with women living in the most Urban Deprived neighbourhoods having a 45% (95% CI 1.41-1.50) increased risk of SMM compared to women in the least Urban Deprived neighbourhoods (**Table 5.5**).

5.4.4 Multivariable Analysis

There was a dose-response relationship between Traditional SES and SMM after adjusting for parity, age, year and ethnicity, with women living in the most deprived quintile having a RR of 1.14 (95% CI 1.11-1.18) compared to those living in the least. The RR for Urban Deprivation and SMM was attenuated to 1.21 (95% CI 1.17-1.25) after adjusting for age, parity, year and ethnicity (**Table 5.5**). After mutual adjustment, the RR decreased to 1.20 (95% CI 1.16-1.24) and increased to 1.15 (95% CI 1.11-1.18) for Urban Deprivation and Traditional SES, respectively (**Figure 5.1**). After adjusting for pre-existing medical and mental health problems and smoking and substance misuse, there was a 20% reduction in the strength of the association between women living in the most deprived Traditional SES quintile and SMM and a 5%

increase in the strength of the association between women living in the most Urban Deprived quintile and SMM (**Table 5.5**).

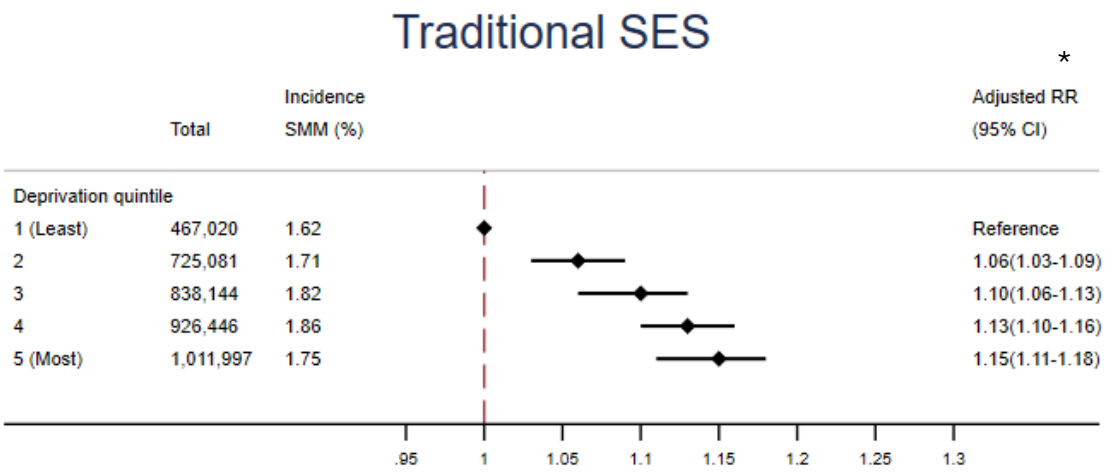
There was an association between Traditional SES and sepsis and 'all other SMM', with the risk plateauing for sepsis in the most deprived quintile and a dose-response relationship between 'all other SMM' and increasing levels of Traditional SES, with an adjusted RR of 1.24 (95% CI 1.22- 1.28) in the most deprived Traditional SES areas compared to the least deprived (**Figure 5.2**). There was a dose-response relationship between increasing Urban Deprivation and risk of sepsis, with an adjusted RR of 1.59 (95% CI 1.50- 1.68) in the most Urban Deprived areas compared to the least. There was an increased risk of acute renal failure only in the most Urban Deprived quintile compared to the least (RR 1.16 95% 1.08-1.25), and there was no evidence of an association between the management of pelvic or intra-abdominal collection or 'all other SMM conditions' (**Figure 5.3**). When the most common of 'all other SMM conditions' was further examined (**Appendix Figure 5.10 and 5.11**), there was an association between Traditional SES and an embolic event, an acute cardiac event and uterine rupture, with RR of 2.19 (95% CI 1.85-2.59), 1.26 (95% CI 1.10-1.44), 1.26 (95% CI 1.10-1.44) for embolic event, cardiac event or uterine rupture, respectively, in the most compared to the least Traditional SES deprived areas. Contrastingly, the risk of embolism and uterine rupture decreased as Urban Deprivation increased.

Table 5.5. Univariable and multivariable analysis to calculate risk ratios between neighbourhood **Traditional SES** and neighbourhood **Urban Deprivation** and SMM in each quintile compared to the least deprived quintile. *Model 1: Adjusted for year, age, parity and ethnicity **Model 2: Model 1 + additionally adjusted for the other factor (neighbourhood Traditional SES or Urban Deprivation) ***Model 3: Model 2 + additionally adjusted for substance misuse/ smoking/ pre-existing medical conditions/ pre-existing mental health conditions.

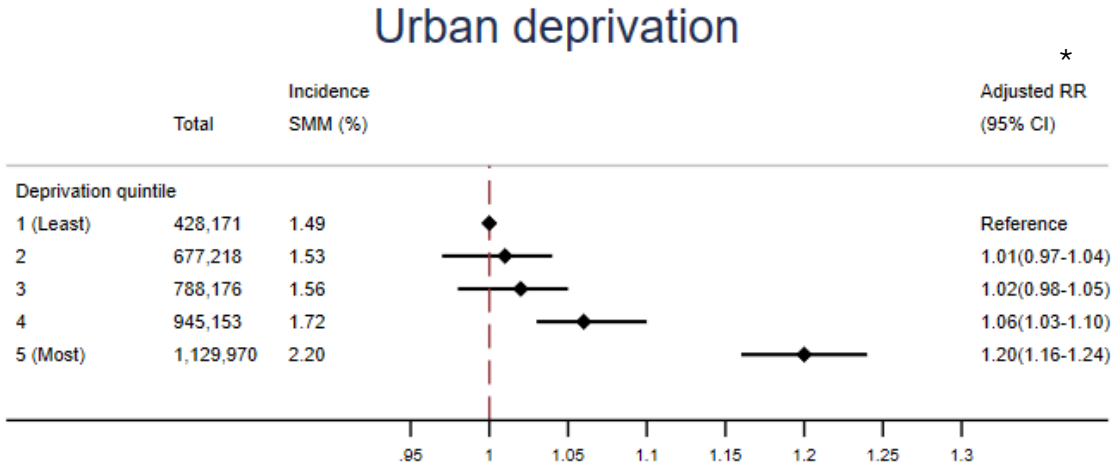
	Unadjusted	**Model 1***	**Model 2 (final model)****	**Model 3*****
Traditional SES	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)
Most deprived 20%	1.08 (1.05-1.11)	1.14 (1.11-1.18)	1.15 (1.11-1.18)	1.12 (1.09-1.16)
More deprived 20-40%	1.14 (1.11-1.18)	1.15 (1.11-1.18)	1.13 (1.10-1.16)	1.11 (1.08-1.15)
Less deprived 40-60%	1.11 (1.08-1.15)	1.11 (1.08-1.14)	1.10 (1.06-1.13)	1.08 (1.05-1.12)
Less deprived 60-80%	1.05 (1.02-1.08)	1.06 (1.03-1.09)	1.06 (1.03-1.09)	1.05 (1.01-1.08)
Least deprived 80-100%	1(ref)	1(ref)	1(ref)	1(ref)
ICC	0.037 (0.034-0.039)	0.028 (0.026-0.031)	0.027 (0.024-0.029)	0.027 (0.024-0.029)
Urban Deprivation				
Most deprived 20%	1.45 (1.41-1.50)	1.21 (1.17-1.25)	1.20 (1.16-1.24)	1.21 (1.17-1.25)
More deprived 20-40%	1.14 (1.11-1.18)	1.08 (1.04-1.11)	1.06 (1.03-1.10)	1.06 (1.03-1.10)
Less deprived 40-60%	1.04 (1.01-1.08)	1.02 (0.99-1.06)	1.02 (0.98-1.05)	1.02 (0.98-1.05)
Less deprived 60-80%	1.02 (0.98-1.05)	1.00 (0.97-1.04)	1.01 (0.97-1.04)	1.01 (0.98-1.04)
Least deprived 80-100%	1(ref)	1(ref)	1(ref)	1(ref)
ICC	0.030 (0.027-0.032)	0.027 (0.024-0.029)	0.027 (0.024-0.029)	0.027 (0.024-0.029)

Abbreviations: CI, confidence interval; ICC, Intra-class Correlation Coefficient

Figure 5.1. The adjusted risk ratio (and their 95% confidence intervals) of SMM in each quintile of Traditional SES and Urban Deprivation compared to the least deprived quintile.

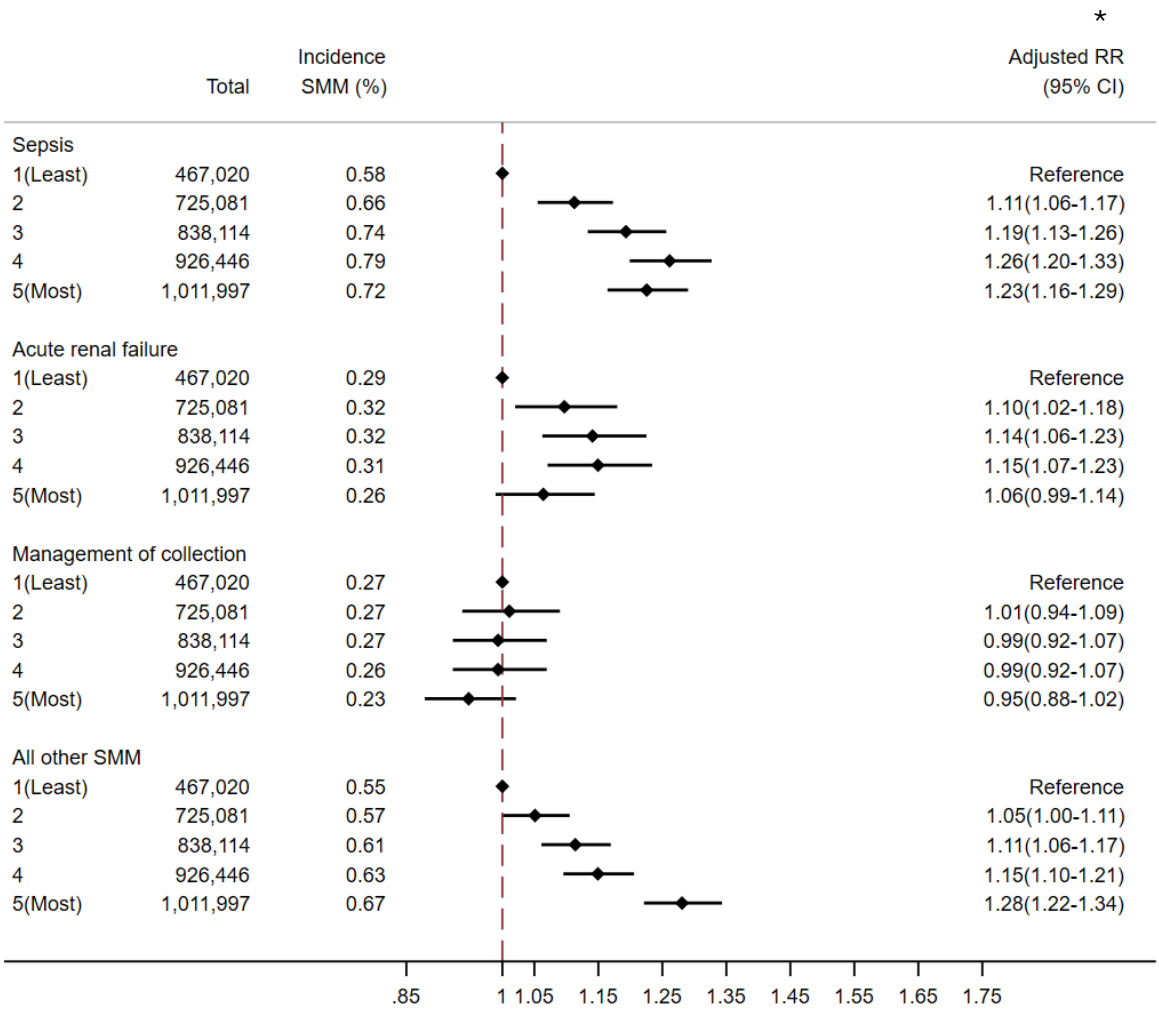


** Adjusted for age, year, parity, ethnicity and Urban Deprivation*



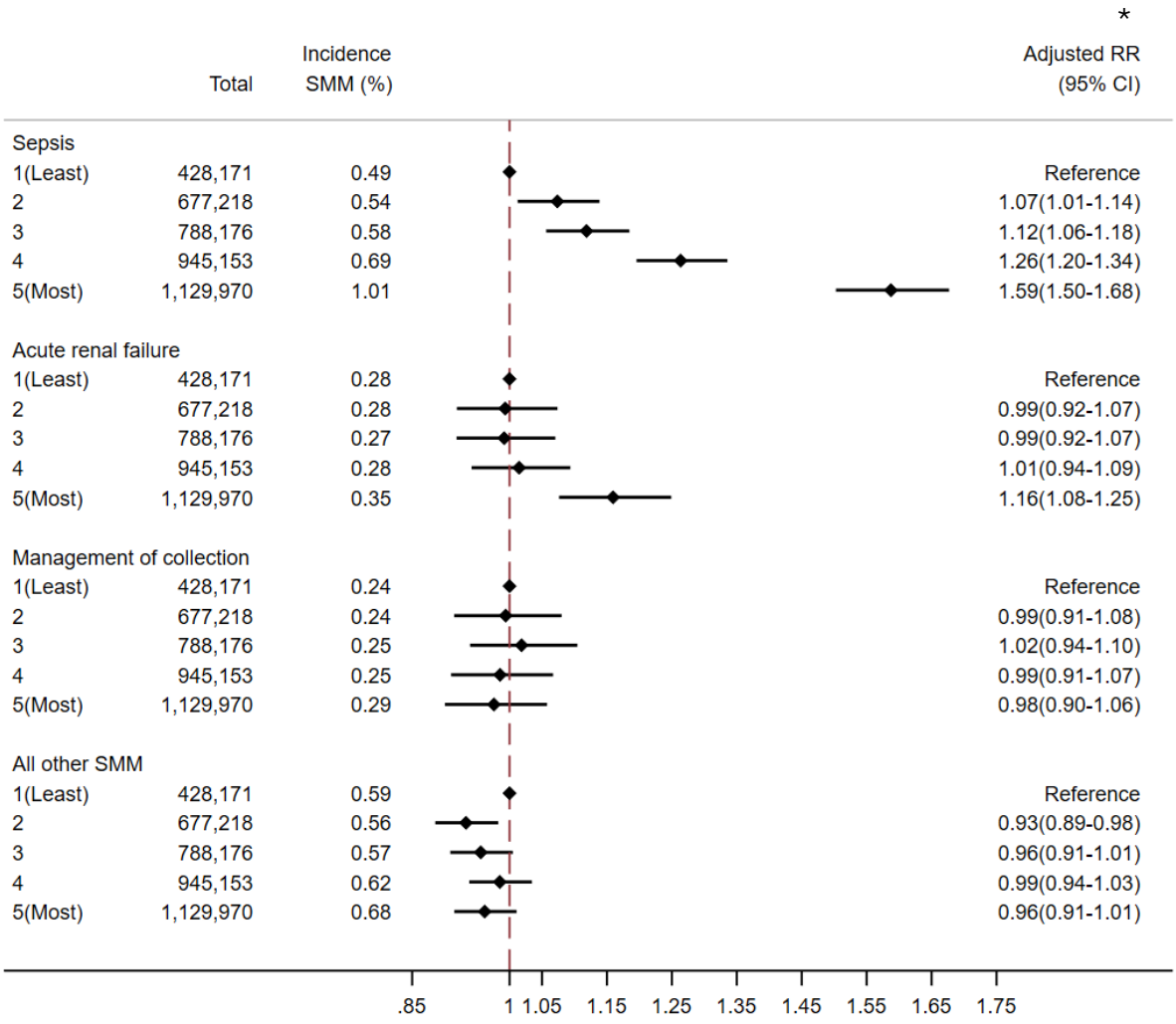
** Adjusted for age, year, parity, ethnicity and Traditional SES*

Figure 5.2. Adjusted risk ratios (and their 95% confidence intervals) of sepsis, acute renal failure, management of collection and 'all other SMM conditions' in the Traditional SES quintiles compared to the least deprived quintile.



* *Adjusted for age, year, parity, ethnicity and Urban Deprivation*

Figure 5.3. Adjusted risk ratios (and their 95% confidence intervals) of sepsis, acute renal failure, management of collection and 'all other SMM conditions' in the Urban Deprivation quintiles compared to the least deprived quintile.



* *Adjusted for age, year, parity, ethnicity and Traditional SES*

5.4.5 Effect Modification by Ethnicity

There was evidence for an effect modification between the Traditional SES (p=0.01) and ethnicity but not Urban Deprivation (p=0.28) and ethnicity with SMM. The evidence for effect modification may not have been statistically significant due to small sample size in certain categories, especially for the more socioeconomically advantaged minoritised ethnicities. **Figures 5.4 and 5.5** show the average adjusted predictive margin (and their 95% CI) for each

ethnic group stratified by neighbourhood Traditional SES and Urban Deprivation, compared to White women in the highest quintile of each exposure. The corresponding RRs (and their 95% CI) and the number of women and proportion of SMM in each quintile stratified by ethnicity are shown in **Appendix Tables 5.5 and 5.6**. There was a dose-response relationship between both increasing neighbourhood Traditional SES and Urban Deprivation and SMM risk for White women, with an average adjusted predictive margin of SMM of 1.65% (95% CI 1.52-1.69) and 1.77% (95% CI 1.73-1.81) for women living in the most deprived Traditional SES neighbourhoods and Urban Deprived neighbourhoods, respectively. There was no evidence for a dose-response relationship between Urban Deprivation or neighbourhood Traditional SES in any other ethnic group. However, the average probability of SMM was higher for all the minoritised ethnic groups regardless of the neighbourhood that they lived in, than for White women living in any quintile of disadvantage. The highest average probability of SMM across all quintiles of both Urban Deprivation and Traditional SES disadvantage was for Black or Black British African or Caribbean women and Asian or Asian British Bangladeshi women, with an average adjusted predictive margin of SMM of 3.14% (95% CI 2.94-3.34) and 2.74% (95% CI 2.39-3.09) for African and Caribbean women living in the most deprived Traditional SES areas, and 3.16% (95% CI 3.03-3.30) and 3.25% (95% CI 3.06-3.44) for African and Bangladeshi women living in the most Urban Deprived areas respectively. However, as there are small numbers of women from minoritised ethnic groups especially living in the least Urban Deprived areas, there remains uncertainty in these results.

Figure 5.4. The average adjusted predictive margins (%) and their 95% confidence intervals of SMM for women living each quintile of neighbourhood Traditional SES stratified by ethnicity

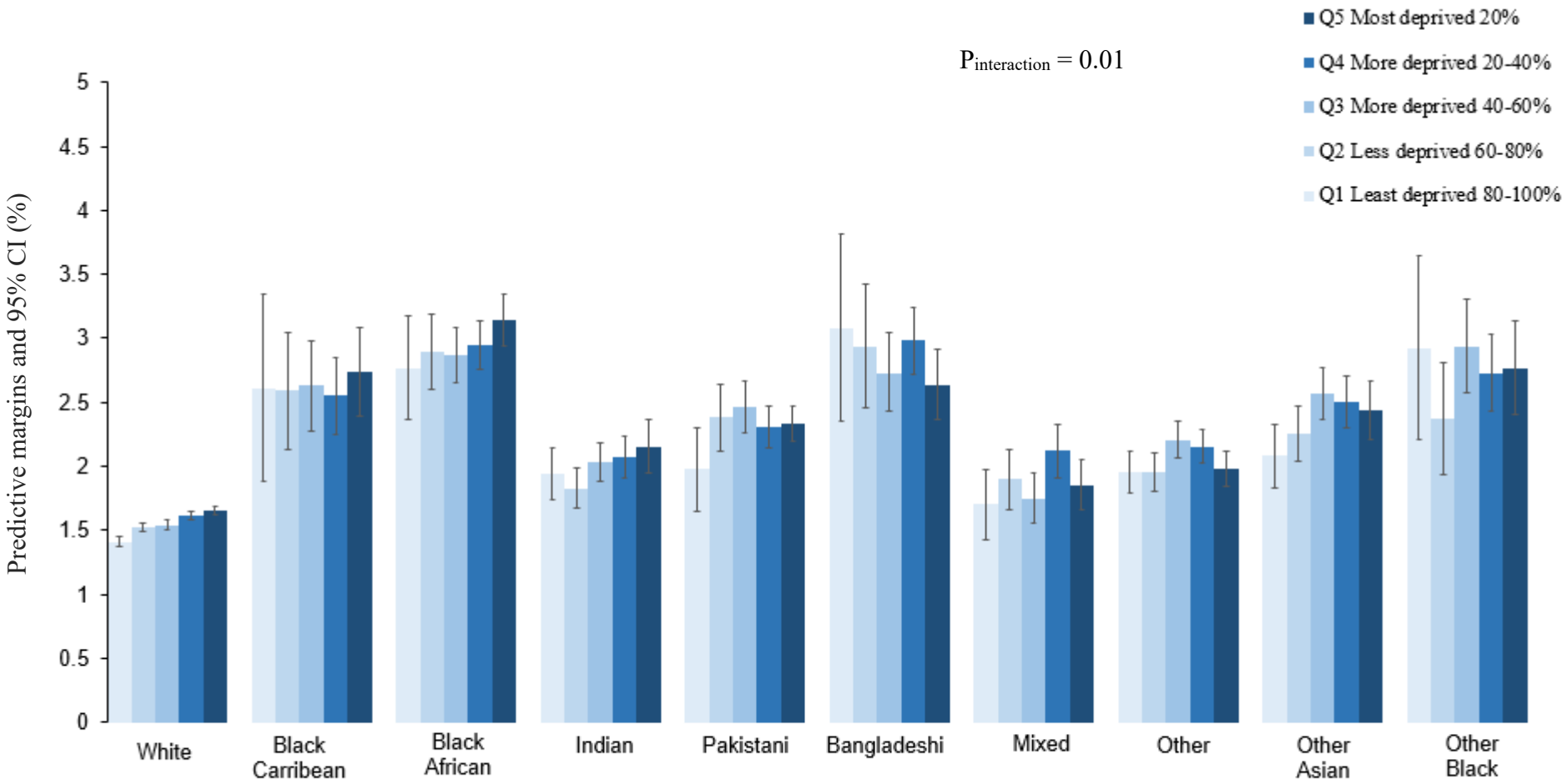
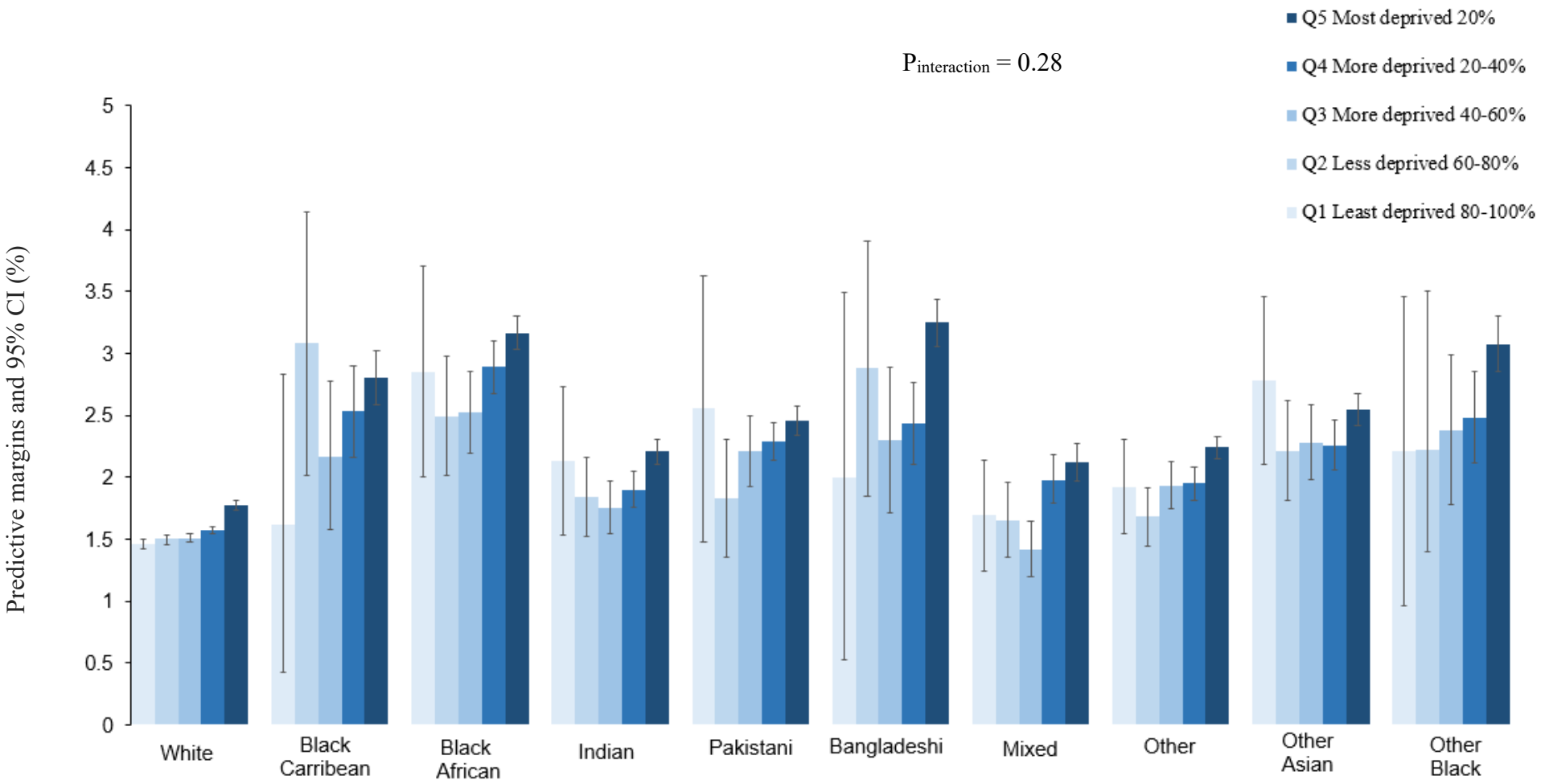


Figure 5.5. The average adjusted predictive margins (%) and their 95% confidence intervals of SMM for women living in each quintile of Urban Deprivation stratified by ethnicity



5.4.6 Population Attributable Fractions

The PAFs indicated that almost 8% (95% CI 5.8%-10.0%) and 15% (12.9%-17.1%) of SMM could be attributed to neighbourhood Traditional SES and Urban Deprivation, respectively. In the adjusted model, these fractions were increased to 8.8% (95% CI 6.6%-10.9%) for Traditional SES and reduced to 7.6% (95% CI 5.1%-9.9%) for Urban Deprivation.

The PAF indicated that 15.8% (95% CI 13.5%-18.0%) of SMM could be attributed to both Traditional SES and ethnic inequality and 16% (13.8%-18.2%) to both Urban Deprivation and ethnic inequality, which increased to 17.7% (95% CI 15.4%-19.9%) and 15.9% (95% CI 13.7%-18.1%), respectively, in the adjusted models (**Table 5.6**).

Table 5.6. Univariable and multivariable population attributable fractions (PAF) of **Traditional SES** and **Urban Deprivation** using the least deprived 20% of women across all ethnicities and the least deprived 20% of White women as the baseline group. The multivariable analysis uses Model 2.

	Traditional SES	**Urban Deprivation**
	PAF % (95% CI)	PAF % (95% CI)
Univariable analysis using the least deprived 20% of all women as the baseline group	8.0 (5.8-10.0)	15.0 (12.9-17.1)
Univariable analysis using the least deprived 20% of White women as the baseline group	15.8 (13.5-18.0)	16.0 (13.8-18.2)
Multivariable analysis using the least deprived 20% of all women as the baseline group	8.8 (6.6-10.9)	7.6 (5.1-9.9)
Multivariable analysis using the least deprived 20% of White women as the baseline group	17.7 (15.4-19.9)	15.9 (13.7-18.1)

5.4.7 Causal Mediation Analysis

5.4.7.1 Traditional SES

The relationship between Traditional SES and SMM was partially mediated by obesity, medical conditions, mental health and delayed antenatal booking (**Table 5.7**). However, obesity mediated the largest proportion of the Traditional SES effect (19.8% (95% CI 15.7% - 23.9%)), followed by pre-existing medical conditions (8.0% (95% CI 6.0%-9.0%)), mental health (2.6% (95% CI 2.0%-3.2%)) and delayed antenatal booking (1.7% (95% CI 1%-2.4%)). Large

interactions existed for medical conditions and delayed antenatal booking and Traditional SES, contributing 13.0% (95% CI 6.0%-21.0%)) and 11.1% (95% CI 1.0%-21.1%)) to the total effects, respectively.

In examining the relationship between Traditional SES and SMM, mediated by pre-existing medical conditions (including the conditions closely related to obesity) (**Table 5.8**), 13.5% (95% CI 11.2%-15.8%) of the total effect was mediated through pre-existing medical conditions, and 24.7% (95% CI 15.4%-34.0%) of the effect was due to the interaction between Traditional SES and pre-existing medical conditions. Eliminating pre-existing medical conditions could reduce 33.3% of SMM risk for women living in the most deprived Traditional SES areas. The results of the CDE for M=1, representing a hypothetical scenario where the mediator is present for all women, are shown in **Appendix Tables 5.7 and 5.8.**

5.4.7.2 Urban Deprivation

The relationship between Urban Deprivation and SMM focused on a single mediator: delayed antenatal booking (**Table 5.9**). The interactive effects between delayed antenatal booking and Urban Deprivation were minimal and there was no evidence of any mediation by antenatal booking, suggesting that other factors likely play a greater role in the relationship between Urban Deprivation and SMM. The results for M=1, representing a hypothetical scenario where the mediator is present for all women, are shown in **Appendix Table 5.9**.

5.4.8 Sensitivity Analyses

When the domain, geographical barriers to services, was removed from the EFA, there was no change in the estimates in any of the models. When sepsis was removed from the composite SMM outcome, there was no material differences in the association between Traditional SES

and SMM. However, there was no longer evidence for an association between Urban Deprivation and SMM (**Appendix Table 5.10**). Furthermore, after removing sepsis, there was no evidence for effect modification by ethnicity with either measure (Traditional SES p=0.16, Urban Deprivation p=0.51). However, this could be due to a reduction in study power. When the results were stratified to compare each ethnic group across different disadvantage quintiles to White women living in the least deprived quintile for each measure, the pattern remained consistent with the main analysis for Traditional SES, showing a dose-response relationship between increasing Traditional SES disadvantage and SMM risk for White women, but not for women from minoritised ethnic groups (**Appendix Table 5.11**). The incidence of SMM without sepsis in each disadvantage quintile stratified by ethnic group is shown in **Appendix Table 5.12**. When sepsis was included only if the length of hospital stay was 3 days or more, there were no material changes in the results from the main analysis (**Appendix Table 5.10 and Table 5.13**). When ICD-10 codes only were included in the SMM outcome (**Appendix Table 5.10**) the risk of SMM in the most Traditional SES deprived and Urban Deprived quintiles increased to 1.18 (95% CI 1.14-1.22) and 1.27 (95% CI 1.23-1.32) compared to the least deprived quintiles, respectively.

Table 5.7. Four-way decomposition of the association between **Traditional SES** and SMM. CDE is for the mediator=0, and the reference interaction is for the mediator=1. Mediators are obesity, pre-existing medical conditions (excluding conditions closely related to obesity: diabetes, ischaemic heart disease and hypertension), mental health problems and antenatal booking ≥ 12 weeks.

	Obesity	**Pre-existing medical conditions**	**Mental health conditions**	**Antenatal booking ≥ 12 weeks**
Outcome model	**Risk Ratios (95% CI)**	**Risk Ratios (95% CI)**	**Risk Ratios (95% CI)**	**Risk Ratios (95% CI)**
SMM				
Traditional SES	1.16 (1.12-1.20)	1.17 (1.14-1.21)	1.19 (1.16-1.23)	1.16 (1.10-1.21)
Mediator	1.37 (1.29-1.46)	1.34 (1.27-1.41)	1.23 (1.15-1.31)	1.10 (1.02-1.19)
Mediator X Traditional SES	0.99 (0.92-1.06)	1.06 (0.99-1.13)	1.04 (0.96-1.12)	1.08 (0.99-1.19)
Mediator model	**Odds Ratios (95% CI)**	**Odds Ratios (95% CI)**	**Odds Ratios (95% CI)**	**Odds Ratios (95% CI)**
Mediator				
Traditional SES	2.59 (2.56-2.61)	1.27 (1.26-1.28)	1.31 (1.30-1.33)	1.11 (1.10-1.13)
Four-way decomposition	**Coefficients (95% CI)**	**Coefficients (95% CI)**	**Coefficients (95% CI)**	**Coefficients (95% CI)**
Total Excess Relative Risk	0.19 (0.16-0.23)	0.20 (0.17-0.24)	0.20 (0.17-0.24)	0.18 (0.13-0.23)
Controlled Direct Effect	0.15 (0.12-0.19)	0.16 (0.13-0.20)	0.19 (0.15-0.23)	0.16 (0.10-0.21)
Reference Interaction	0.00 (0.00-0.01)	0.02 (0.01-0.03)	0.01 (0.00-0.01)	0.02 (0.00-0.03)
Mediated Interaction	0.00 (-0.01-0.01)	0.00 (0.00-0.01)	0.00 (0.00-0.00)	0.00 (0.00-0.00)
Pure Indirect Effect	0.04 (0.03-0.04)	0.01 (0.01-0.01)	0.00 (0.00-0.00)	0.00 (0.00-0.00)
Total Excess Relative Risk	0.19 (0.16-0.23)	1.20 (1.17-1.24)	0.20 (0.17-0.24)	0.18 (0.13-0.23)
Proportions four-way decomposition	**Proportion (%) (95% CI)**	**Proportion (%) (95% CI)**	**Proportion (%) (95% CI)**	**Proportion (%) (95% CI)**
Controlled Direct Effect	78.9 (72.5-85.3)	81.0 (74.0-88.0)	94.6 (91.5-97.7)	88.2 (78.5-97.8)
Reference Interaction	1.4 (-2.2-4.9)	11.0 (5.0-17.0)	2.8 (0.1-5.5)	10.1 (0.9-19.3)
Mediated Interaction	1.8 (-2.9-6.5)	2.0 (1.0-4.0)	0.8 (0.0-1.6)	1.0 (0.1-1.8)
Pure Indirect Effect	18.0 (13.1-22.9)	5.0 (4.0-7.0)	1.8 (1.1-2.4)	0.8 (0.1-1.4)
Overall Proportion Mediated	19.8 (15.7-23.9)	8.0 (6.0-9.0)	2.6 (2.0-3.2)	1.7 (1.0-2.4)
Overall Proportion Attributable to Interaction	3.1 (-5.1-11.4)	13.0 (6.0-21.0)	3.6 (0.1-7.1)	11.1 (1.0-21.1)
Overall Proportion Eliminated	21.1 (14.7-27.5)	19.0 (12.0-26.0)	5.4 (2.3-8.5)	11.8 (2.2-21.5)

Table 5.8. Four-way decomposition of the association between **Traditional SES** and SMM. CDE is for the mediator=0, and the reference interaction is for the mediator=1. The mediator is pre-existing medical conditions, including conditions closely related to obesity: diabetes, ischaemic heart disease and hypertension.

	Pre-existing medical conditions (including conditions related to obesity)
Outcome model	**Risk Ratios (95% CI)**
SMM	
Traditional SES	1.14 (1.10-1.18)
Mediator	1.42 (1.35-1.49)
Mediator X Traditional SES	1.11 (1.04-1.18)
Mediator model	**Odds Ratios (95% CI)**
Mediator	
Traditional SES	1.32 (1.30-1.33)
Four-way decomposition	**Coefficients (95% CI)**
Total excess relative risk	0.20 (0.16-0.23)
Excess relative risk due to controlled direct effect	0.13 (0.10-0.17)
Excess relative risk due to reference interaction	0.04 (0.03-0.05)
Excess relative risk due to mediated interaction	0.01 (0.01-0.01)
Excess relative risk due to pure indirect effect	0.02 (0.01-0.02)
Total effect risk ratio	1.20 (1.16-1.23)
Proportions Four-way Decomposition	**Proportion (%) (95% CI)**
Proportion controlled direct effect	66.7 (57.7-75.6)
Proportion reference interaction	19.8 (12.4-27.3)
Proportion mediated interaction	4.9 (3.0-6.7)
Proportion pure indirect effect	8.6 (6.7-10.6)
Overall proportion mediated	13.5 (11.2-15.8)
Overall proportion attributable to interaction	24.7 (15.4-34.0)
Overall Proportion Eliminated	33.3 (24.4-42.3)

Table 5.9. Four-way decomposition of the association between **Urban Deprivation** and SMM. CDE is for the mediator=0, and the reference interaction is for the mediator=1. The mediator is antenatal booking ≥ 12 weeks. RR (95% CI): Risk ratios and their 95% confidence intervals. OR (95% CI): Odds ratios and their 95% confidence intervals.

	Antenatal booking ≥ 12weeks
Outcome model	**Risk Ratios (95% CI)**
SMM	
Urban deprivation	1.27 (1.16-1.38)
Mediator	1.21 (1.04-1.42)
Mediator X Urban Deprivation	0.84 (0.71-0.99)
Mediator model	**Odds Ratios (95% CI)**
Mediator	
Urban deprivation	2.55 (2.48-2.61)
Four-way decomposition	**Coefficients (95% CI)**
Total excess relative risk	0.23 (0.13-0.33)
Excess relative risk due to controlled direct effect	0.26 (0.15-0.36)
Excess relative risk due to reference interaction	-0.03 (-0.07-0.00)
Excess relative risk due to mediated interaction	-0.03 (-0.07-1.00)
Excess relative risk due to pure indirect effect	0.04 (0.00-0.07)
Total effect risk ratio	1.23 (1.13-1.33)
Proportions Four-way Decomposition	**Proportion (%) (95% CI)**
Proportion controlled direct effect	112.8 (92.5-133.1)
Proportion reference interaction	*14.5 (-31.7-2.8)
Proportion mediated interaction	*14.5 (-31.6-2.8)
Proportion pure indirect effect	16.1 (-0.1-32.3)
Overall proportion mediated	1.7 (-4.7-8.0)
Overall proportion attributable to interaction	*28.9 (-63.2-5.5)

**negative number*

5.5 Discussion

5.5.1 Main Findings

An EFA of the components of the IMD across English LSOAs revealed two latent variables with distinct sociodemographic, pregnancy and birth characteristics that demonstrate two dimensions of disadvantage. Urban Deprivation appeared to exhibit a threshold effect, whereas Traditional SES had a gradient effect on the risk of SMM. There were differences between the two deprivation dimensions on which SMM conditions were the drivers of the association, with sepsis playing a key role in the association between Urban Deprivation and SMM. In contrast, a range of other SMM conditions, particularly embolism, appeared to be a key driver of the association between Traditional SES and SMM. Additionally, the Traditional SES disadvantage dimension exhibited less pronounced dose-response relationships in women from minoritised ethnic groups than for White women. On a population level, the proportion of SMM attributable to both measures of socioeconomic disadvantage were similar, emphasising that interventions are needed to address both aspects of disadvantage to reduce SMM. Finally, 21% of the association between Traditional SES and SMM could be reduced if obesity was eliminated, and 33% if pre-existing medical conditions (including conditions closely related to obesity) were eliminated, highlighting a key focus for a public health intervention.

5.5.1.1 Sociodemographic Characteristics of the Latent Variables

Traditional SES included income, employment and education indicators. These markers of socioeconomic position are closely related and are foundational markers of disadvantage. For example, an individual with lower educational attainment may have lower employment opportunities and, therefore, a lower income. The areas with a high proportion of individuals with these markers were more likely to be situated in the North of England and the Midlands, with the greatest proportion of the most deprived Traditional SES areas being in the North West

of England, Yorkshire and the Humber, and the West Midlands. Women living in the most deprived compared to the least deprived Traditional SES areas were younger (5.07% were under 20 years vs 0.9%), were more likely to be multiparous (63.3% vs 55.4%) were more likely to be smokers or have a history of substance misuse (33.8% vs 13.9%), be obese (23.0% vs 10.8%) and have a history of pre-existing mental health conditions (14.8% vs 9.7%).

The Urban Deprivation factor included neighbourhood poor housing conditions, homelessness, road traffic accidents, air pollution and lower English language proficiency, which are often associated with urban living. Over half of the most deprived of these areas were in London. The geographical barriers subdomain showed an inverse relationship with other disadvantage indicators in this latent variable. This suggests that access to services, which is likely a proxy for rurality, may be a distinct form of disadvantage compared to the other indicators and that urban areas closer to services are more closely correlated with other aspects of disadvantage, such as housing quality and air pollution. Women living in the most Urban Deprived areas were much more likely than women living in the least Urban Deprived areas to be from minoritised ethnic groups (50.9% vs 3.8%) and live in areas with a high proportion of residents who were not born in the UK (84.3% vs 0.2%). This suggests that this disadvantage dimension is more likely to represent the challenges experienced by migrant and minoritised ethnic populations, such as racism, language barriers and the stress of acculturation (168).

Interestingly, women living in areas with a high amount of Urban Deprivation had lower rates of smoking or substance misuse (17.4% vs 23.9%), obesity (14.1% vs 18.5%) and pre-existing medical (20.7% vs 24.3%) and mental health conditions (9.1% vs 13.2%) compared to women living in areas with a low amount of Urban Deprivation. The lower prevalence of certain comorbidities, particularly mental health problems and substance misuse in women from minoritised ethnic groups, has also been seen in other studies which use the HES APC database

(169). This could be explained by limitations with the data for migrant women who would not have any hospital admissions recorded if they occurred outside of the NHS. Alternatively, differences in healthcare access between ethnic communities may explain these findings (45, 170, 171). However, protective cultural factors within specific ethnic communities may also be an explanation. For instance, strong community networks may promote lower rates of smoking and substance misuse and other healthier behaviours among these groups (172).

5.5.1.2 Association Between Traditional SES, Urban Deprivation, and SMM

There was a notable difference in the strength and pattern of the association between Traditional SES and Urban Deprivation and SMM. There was a dose-response relationship between Traditional SES and SMM. The dose-response to compositional disadvantage has also been found in the Marmot review of overall life expectancy and disability-free life years in England (173), where there was a gradient effect on health outcomes of neighbourhood income. Consequently, deprivation and health are not only relevant for the most and least deprived areas, but every small increase in income is likely to improve an individual's health. Additionally, Marmot notes that all individuals except those in the highest socioeconomic strata experience some level of health inequality. Marmot, therefore, argues that to tackle the social gradient of health at a population level, proportionate universalism should be applied, where actions should be universal in nature but tailored in scale and intensity to match the degree of disadvantage.

Out of the key individual SMM conditions, there was only a dose-response relationship between increasing levels of Traditional SES and 'all other SMM' conditions, which was particularly driven by cardiac and embolic events, where the adjusted RR for each in the most deprived Traditional SES quintile was 1.26 (95% 1.10-1.44) and 2.19 (95% CI 1.85-2.59) respectively, compared to the least deprived quintile. Cardiac events are associated with

hypertension, obesity, diabetes and smoking (174), all of which have also been shown to be associated with low income and low educational attainment (40, 175-178). Furthermore, many studies have described an association between socioeconomic disadvantage and thromboembolism among the general population (179, 180). Specifically, a study from South Korea (181) analysing insurance data revealed that pregnant women receiving government assistance faced a threefold increase in thromboembolism risk compared to those who did not. In this analysis, among the lowest Traditional SES quintile, the prevalence of risk factors for cardiac disease or thromboembolism, such as obesity and smoking, were higher, potentially explaining this increased risk finding. Women were also at a greater risk of uterine rupture in the most Traditional SES deprived areas (adjusted RR 1.26 (95% CI 1.11-1.44)). Women residing in the most traditionally deprived areas may be more likely to experience grand multiparity (182) and in this analysis they were more likely to have a labour induction than those in less deprived areas. Both grand multiparity and labour induction have been found to increase the risk of uterine rupture (183) which may account for this finding.

After adjusting for pre-existing medical conditions, mental health problems, and smoking/ substance misuse measured at the individual level, the association between Traditional SES and the composite SMM outcome was reduced by 20%, highlighting their role in this relationship. Furthermore, obesity was identified as a key mediator in the association between Traditional SES and SMM, accounting for 20% of the effects. In the literature, lower income and education status is strongly associated with higher obesity rates (184, 185), which in turn elevate the risk of adverse maternal outcomes, including SMM (186, 187). Pre-existing medical conditions also play a significant role in the relationship between Traditional SES and SMM, with 8% of the association mediated and 13% due to an interaction between medical conditions and Traditional SES. Including diabetes, hypertension and ischemic heart disease in the composite variable increased the proportion mediated to 14%, and there was also a significant

interaction between this variable and living in the most deprived Traditional SES areas. Notably, women living in the most deprived Traditional SES areas could experience a decrease of over one-third in SMM if pre-existing medical conditions, including those linked to obesity, could be eliminated. Contrastingly, mental health conditions and the timing of antenatal booking with a midwife had minimal mediation effects on this association. However, the timing of antenatal care may be a poor proxy for access to and engagement with care during pregnancy, since some women might delay their initial contact yet still receive adequate care afterwards. Thus, it is likely that this result does not accurately reflect the true impact of care engagement on SMM risk for deprived women. Furthermore, there was a large amount of missing data on antenatal booking timing, and therefore, the power to detect a significant effect was limited, and these findings should be interpreted cautiously. Moreover, the modified EMMOI focuses mainly on physical over mental health morbidity (188), which may explain the small role of a previous mental health history as a mediator in the association.

Urban Deprivation appeared only to affect women living in extremes of disadvantage, or 'a threshold effect'. This may indicate a specific lack of resources in these areas. From the key individual SMM conditions, there was a strong association between Urban Deprivation and sepsis, with women living in the most Urban Deprived areas having an adjusted RR of 1.59 (95% CI 1.50-1.68) compared to women living in the least deprived areas. Moreover, there was no longer any association between Urban Deprivation and SMM after removing sepsis from the composite outcome. From this analysis, it is unclear what could be driving this increased risk. One explanation could be that women in these areas appeared to be more likely to undergo instrumental or emergency caesarean births, which both increase the risk of infection. Living in areas with high air pollution, poor housing quality and overcrowding may also increase infection risk (189-191). Additionally, the increased difficulties in the access and quality care for migrant populations may increase the severity of any infection and influence the mode of

birth (192-194). However, this analysis found no mediating effects of antenatal booking timing in this association. Finally, the strong association between Urban Deprivation and sepsis may reflect differences in sepsis diagnosis criteria and the details of discharge summaries in large urban teaching hospitals, such as in London, Manchester or Birmingham, compared to those outside big cities. However, it is not possible to use these data to ascertain which of these explanations is the most likely.

After adjusting for pre-existing medical conditions, mental health problems and lifestyle factors measured at the individual level, the association between Urban Deprivation and the composite SMM outcome increased by 5%. One possible explanation for this small increase in effect size is the potential for differential coding of these covariates among migrant women, as discussed above. This could suggest that the likelihood of having a previous medical/mental health condition or substance misuse/smoking identified in the data may be correlated with length of time a woman has resided in the UK, with women without a previous health history more likely to be new migrants. Newly arrived migrants, in turn, may face language barriers and challenges in navigating the healthcare system (195), and therefore have an increased risk of SMM.

5.5.1.3 Influence of Traditional SES, Urban Deprivation and Ethnic Inequality on SMM

Although the strongest association between disadvantage and SMM occurs in the most Urban Deprived areas, on a population level, Traditional SES and Urban Deprivation had similar associations with the risk of SMM. After including the associations attributable to ethnicity, if all women had the same risk as the White women living in the least deprived Traditional SES areas, 18% of SMM cases could have been prevented, and 16% of SMM could have been prevented if all women had the same risk as White women living in the least Urban Deprived

areas. Targeted public health interventions to reduce SMM disparities should address both Traditional SES-related and Urban Deprivation factors alongside ethnic inequities.

This analysis also indicates that the association between Traditional SES and SMM risk varies across ethnic groups. Among White women, there was a clear dose-response relationship with an increased SMM risk as Traditional SES increased. However, this was not seen in other ethnic groups. Many hypotheses have been put forward to explain this pattern of effect modification by ethnicity concerning socioeconomic position on health outcomes. Firstly, it has been argued that minoritised ethnicities may experience a unique disadvantage, such as racism, discrimination and limited access to culturally appropriate care within the healthcare system, regardless of their socioeconomic position (196). Secondly, the 'diminishing returns hypothesis' describes how minoritised ethnic women may not experience the same returns as White women for higher socioeconomic positions (5). Finally, the distinction between relative and absolute disadvantage may explain this observation. Research shows that the gradient in socioeconomic position among minoritised ethnic women is less pronounced compared to that of White women. Moreover, it has been suggested that relative disadvantage impacts health outcomes more than absolute disadvantage. In societies with smaller income disparities, mortality rates tend to be lower, even when taking into account average incomes, absolute poverty, and various other socioeconomic factors (197). Although minoritised ethnic women often face greater absolute disadvantage, they may also perceive more nuanced socioeconomic differences compared to other women within their minoritised ethnic group. Therefore, these women may not experience the impact of relative socioeconomic disadvantage as severely.

The strength of the association between Urban Deprivation and SMM also appears to vary by ethnicity, although this was not statistically significant. For White women, there is an increasing risk of SMM as Urban Deprivation increases, and this is particularly pronounced in

the most Urban Deprived quintile. However, there was no dose-response relationship seen in any of the other ethnic groups. Minoritised ethnic group women living in the most deprived areas may experience the highest levels of poverty, whilst women who live in more affluent but less diverse areas may experience social isolation and marginalisation (198). However, these findings should be interpreted cautiously due to the small sample sizes of minoritised ethnic groups living in both the least deprived Traditional SES and Urban Deprived areas, with particularly low numbers in the least Urban Deprived areas.

5.5.2 Strengths and Limitations

The main strength of this analysis was using EFA to decompose the different dimensions of the IMD. This allowed the identification of specific aspects of disadvantage, such as Traditional SES and Urban Deprivation, and allowed for analysis of how each aspect was associated with SMM. These findings may guide the targeted allocation of resources and were a good foundation for the subsequent causal mediation analysis. Causal mediation analysis was used to identify key mediators, including obesity and pre-existing medical conditions. This directly affects policy and practice, helping to prioritise interventions that could reduce the incidence of SMM and close the disparities gap.

However, the analysis also has several limitations including the limitations with the HES APC data specified in **Chapter 4**. Additionally, factor analysis is population specific so that variables loaded onto each factor may differ between populations. Moreover, the factor analysis excluded ‘crime’ and ‘housing affordability’ because they cross-loaded onto multiple factors. Consequently, the final model did not capture all relevant dimensions of disadvantage and may have omitted some key drivers of SMM. A further limitation was that derived factor scores are not uniquely defined and may vary depending on the computation method, a condition known

as ‘indeterminacy.’ This could impact the reliability of rankings based on these scores and introduce uncertainty into the results (199). Finally, there were substantial amounts of missing data for antenatal care booking dates, which could also lead to reduced power to study the mediator’s effects.

5.5.3 Conclusion

This analysis differentiated between two latent variables that reflect two dimensions of the IMD, Traditional SES and Urban Deprivation, providing a clearer understanding of the complex interconnectedness of the IMD indices, how their combinations affect SMM and elucidating the role of key mediators (**Thesis Objective 7**). The Traditional SES domain highlighted that income, employment and education are closely aligned and pre-existing medical conditions and obesity are key mediators in the association between Traditional SES and SMM. In contrast, the Urban Deprivation dimension highlighted aspects associated with urban environments, such as language barriers, housing instability and environmental hazards, are also closely associated. Both dimensions exhibited varying prevalence of the most deprived areas across different regions, distinct sociodemographic characteristics and differing strengths of associations with key SMM conditions, although both were associated with SMM overall (**Thesis Objective 2**). Urban Deprivation was characterised by a high proportion of women from minoritised ethnic groups who may face additional health risks driven by systemic inequalities and structural racism. Both latent variables appeared to have varying strengths of association with SMM across different ethnic groups (**Thesis Objective 5**). However, this analysis was limited by using neighbourhood-level disadvantage measures, from the IMD, which may mask individual-level pathways between disadvantage and SMM and underestimate the association. This highlights the need for further research comparing neighbourhood- and individual-level disadvantage measures within the same cohort, to help

explore in more detail the limitations of using neighbourhood-level disadvantage measures in SMM research, and this will be conducted in the following chapter (**Chapter 6**).

Chapter 6: The Association Between Individual and Neighbourhood-level Measures of Socioeconomic Disadvantage and SMM, in the Netherlands, 2012-2021

6.1 Background

This study analysed a nationwide administrative dataset from the Netherlands. Firstly, this dataset was used to assess whether the findings from England could be replicated in a second high-income country, including quantifying the role of mediators in the association between socioeconomic disadvantage and severe maternal morbidity (SMM). In addition, this dataset contains both individual- and neighbourhood-level measures of socioeconomic disadvantage. Therefore, the association between each level of measure and SMM and the impact of misclassification bias when neighbourhood-level measures are used as proxies for individual socioeconomic position could be investigated. This will help clarify the potential underestimation of the relationship between disadvantage and SMM in the English data (**Chapters 4 and 5**), should neighbourhood-level measures be used as proxies for individual-level measures, as well as explore the role of neighbourhood-level disadvantage as a standalone measure. Finally, the Dutch database has additional information, such as individual-level migration status, that may help unpick the intersection between individual- and neighbourhood-level disadvantage, ethnicity and migration status, an aspect which was a limitation of the English analysis (**Chapters 4 and 5**).

6.1.1 The Dutch Healthcare System

The Netherlands is a high-income country that has universal health coverage, similar to the United Kingdom (UK). However, the two countries differ in how their healthcare systems are funded. The Netherlands health system is based on mandatory government regulated insurance whereas the UK's National Health Service (NHS) is publicly funded, free for individuals at the

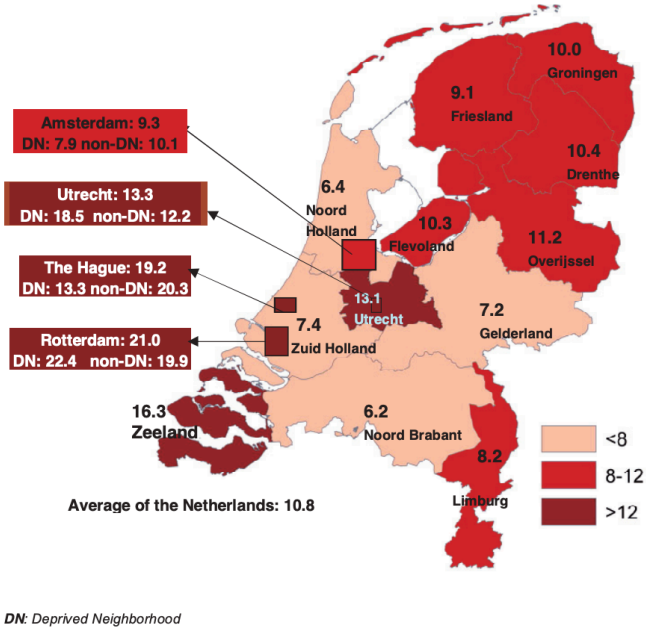
point of care. However, all Dutch residents, including immigrants, must obtain basic health insurance, which guarantees access to essential medical services, including comprehensive maternity care, and they cannot be refused insurance based on pre-existing conditions (200). Government subsidies are also available for lower-income residents, making healthcare access equitable and available to all. The basic insurance covers midwife-led care for low-risk pregnancies and hospital maternity care (201). Furthermore, in contrast to the UK, the Dutch maternity system has a high prevalence of home births. Approximately 13% of births in the Netherlands occur at home, compared to 2% in the UK.

6.1.2 Maternal Mortality in the Netherlands

The maternal mortality ratio (MMR) in the Netherlands for 2006–2018 was 6.2 per 100,000 live births (21). Direct causes of death were the most common during the time of pregnancy and up to 42 days postpartum. This contrasts with the UK, where indirect causes have been more prevalent than direct causes since 2003 (17). However, unlike the UK, in the Netherlands, the data for the maternal mortality reviews are not linked using national death registries and birth records for any deaths of women of reproductive age, so indirect cases may be missed. The leading cause of death was cardiac disease (14.9%), followed by hypertensive disorders (14.2%) and thrombosis (13.5%). Up to one year postpartum, the most common cause of death was cardiac disease (18.7%), followed by suicide (11.1%). Women from a minoritised ethnic group have an increased MMR compared with Caucasian women (MMR 6.5 vs. 5.0, RR 1.3). Compared with Dutch and Western women, women from minoritised ethnic groups had twice the likelihood of pre-existing medical conditions and obesity and 25 times the rate of teenage pregnancy. The MMR was particularly high among women from Surinam/Dutch Antilles, at 14.7 per 100,000 live births. Parity, both nulliparity and multiparity, was a risk factor for maternal mortality. Furthermore, modifiable care factors were identified in 47.5% of all deaths.

Substantial variations in maternal mortality by region and neighbourhood deprivation have also been shown (18). Across the 12 provinces, MMR ranges from 6.2 in Noord-Brabant to 16.3 in Zeeland. In urban areas, Rotterdam reports the highest MMR (21.0 per 100,000), while Amsterdam has an MMR of 9.3 (**Figure 6.1**).

Figure 6.1. Maternal mortality (per 100,000 live births) in the Netherlands by provinces and the four largest cities 1993-2008 (permission from author de Graaf) (18)



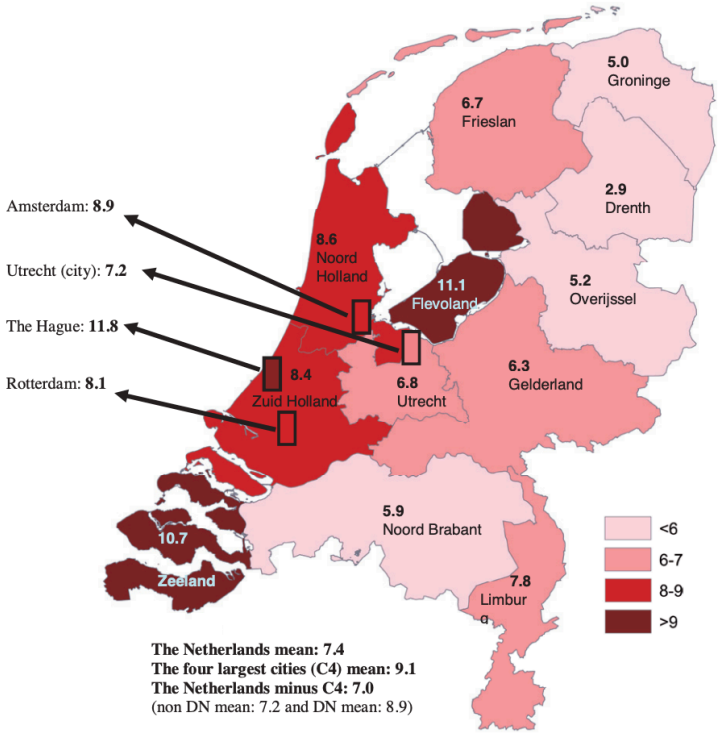
DN: Deprived Neighborhood

6.1.3 Severe Maternal Morbidity in the Netherlands

Similar to other high-income countries, the rate of SMM is over 100 times higher than maternal mortality in the Netherlands with 7.4 cases of SMM per 1,000 births (202) (defining SMM as a composite of uterine rupture, eclampsia, major obstetric haemorrhage, miscellaneous cases and cases necessitating intensive care admission), and therefore SMM studies have greater power to study trends and provide more robust results than maternal mortality studies (22). Disparities have been reported at the regional level (202) (**Figure 6.2**), with the highest SMM

rates observed in Flevoland with an incidence of 11.1 per 1,000 live births. A higher prevalence of SMM is also reported in the four largest cities (C4), which combined show an SMM rate of 9.1 per 1,000 live births, compared to 7.0 in other areas of the country. Furthermore, SMM rates are disproportionately higher among specific demographic groups, particularly for women from minoritised ethnicities, who experience a 52% increased risk of SMM compared to Caucasian women after excluding the C4 regions. A separate prospective nationwide cohort study also found that there were disparities in SMM based on migration status, with Sub-Saharan African women having the highest risk, with three and a half times the risk of SMM than Caucasian women (108). Despite these demographic and regional variations, no significant differences in SMM rates were found between disadvantaged and non-disadvantaged neighbourhoods at the ecological level, either in the four largest cities or the rest of the country (202).

Figure 6.2. SMM Ratio (per 1,000 live births) in the Netherlands by provinces and the four largest cities 1993-2008 (permission from author de Graaf) (202)



6.1.4 Knowledge Gaps

In the Netherlands, while associations have been found between region, ethnicity, migration status and SMM (108, 202), as well as between region, ethnicity, neighbourhood deprivation and maternal mortality (18, 21), there is limited evidence examining the relationship between individual socioeconomic factors and both maternal mortality and SMM. As a result, it is unclear what may be driving these differences, making it difficult to produce targeted evidenced based interventions to reduce the disparities described above. Furthermore, as shown in **Chapter 3**, across all high-income countries there is a paucity of evidence exploring the differences in the effect of living in a disadvantaged neighbourhood compared to being individually socioeconomically disadvantaged, and how these two factors intersect with each other, as well as with ethnicity and migration status, concerning SMM. It is therefore unclear whether studies in other high-income countries that use neighbourhood-level measures of disadvantaged summarised in **Chapter 3**, alongside the findings in England from **Chapters 4 and 5** of this thesis, are underestimating the true association between socioeconomic disadvantage and SMM. It is therefore unclear whether resources should be aimed at disadvantaged areas or disadvantaged people.

6.2 Aim and Objectives

6.2.1 Aim

This analysis therefore aims to explore the association between neighbourhood-level socioeconomic disadvantage and SMM at the time of birth in the Netherlands. It also aims to examine the relationship between individual- and neighbourhood-level measures of socioeconomic disadvantage and the differences in their associations with the risk of SMM, to quantify the extent of misclassification bias of using a neighbourhood measure. Finally, the analysis aims to explore how the relationship between different measures of socioeconomic

disadvantage at different levels varies across different ethnic and migrant groups and the role of potential mediators in any association.

6.2.2 Objectives

1. To examine the trend in the incidence rate of SMM in the Netherlands from 2013 to 2021 and to investigate which specific SMM conditions or procedures contribute to changes in the risk of SMM during this period, if applicable.

2. To explore the associations between neighbourhood-level measures of socioeconomic disadvantage, both the composite (SES-WOA) and disaggregated measures, and the risk of SMM in the Netherlands, in order to examine the contribution of specific aspects of neighbourhood-level socioeconomic disadvantage, such as income, education and employment, to any increased risk of SMM (**Thesis Objective 3**).

3. To investigate the correlations between different individual- and neighbourhood-level measures of socioeconomic disadvantage, to assess how the different measures relate to each other and the extent to which neighbourhood-level measures may serve as proxies for individual-level measures (**Thesis Objective 4**).

4. To explore how different measures of socioeconomic disadvantage, at both the individual- and neighbourhood-level, are associated with the risk of SMM, and to compare the strength of the associations, to assess whether any individual- or neighbourhood-level measures are more strongly related to SMM (**Thesis Objective 4**).

5. To explore how the association between the different measures of socioeconomic disadvantage and the risk of SMM may vary across various ethnic and migrant groups (**Thesis Objective 5**).

6. To calculate the population attributable fractions (PAFs) for SMM to quantify the contribution of socioeconomic, ethnic and migration-related disparities to the overall risk of SMM (**Thesis Objective 6**). PAFs will estimate the proportion of SMM cases that could be prevented if all women had the same risk as the reference group.

7. To perform causal mediation analysis to evaluate the role of preselected mediators in the relationship between the different measures of disadvantage and the risk of SMM, to quantify the contributions of the direct pathway (the effect of disadvantage on SMM risk that is not mediated) and the indirect pathway (the effect of disadvantage on SMM risk through the mediators), to understand better how these pathways influence the risk of SMM (**Thesis Objective 7**).

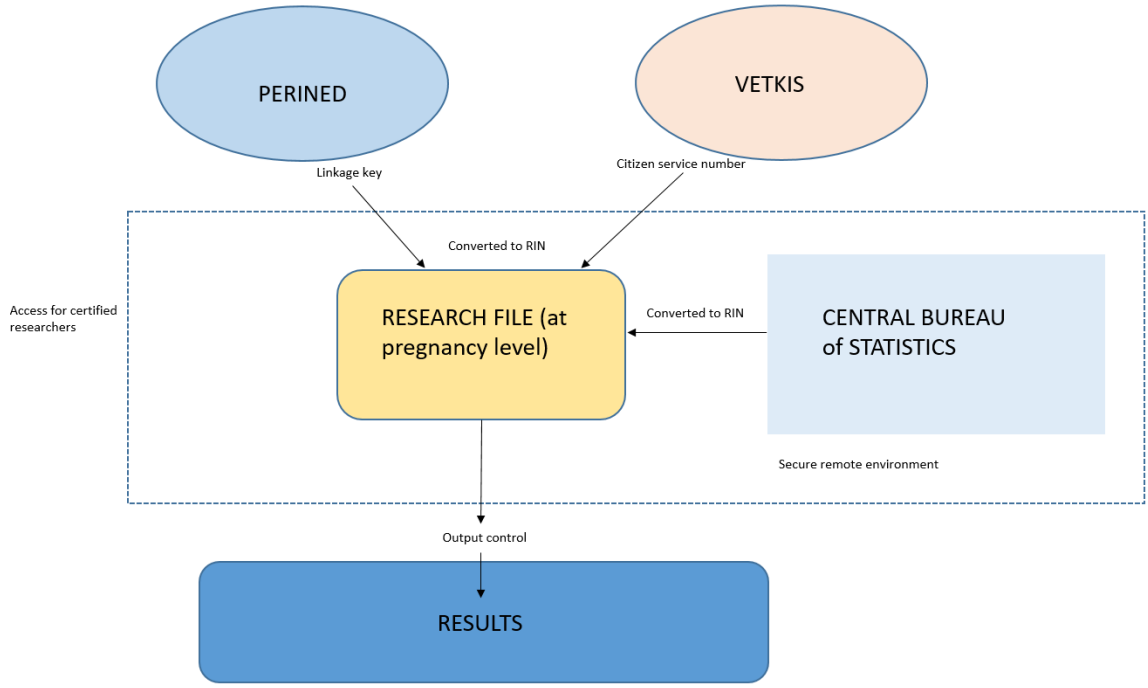
6.3 Methods

6.3.1 Database

The data sources used for this analysis are Perined, the national Dutch Hospital Discharge (DHD) register and the System of Social Statistical Datasets (SSD) linked at the individual level within the nationwide Data-Infrastructure for Parents and Children (DIAPER) (203) (**Figure 6.3**). Perined is the national pregnancy and birth registry, comprising routine care data on >96% of pregnancies in The Netherlands from 2000 onwards, provided by midwifery, general practice, obstetric and pediatric practices (204). The DHD register contains the principal diagnosis at discharge in the International Classification of Diseases, ninth and 10th revisions (ICD-9 and ICD-10). From 2000 until 2012, the hospital discharge data were

registered in the National Medical Registry (LMR), covering approximately 97% of admissions until 2006. After 2006, the coverage decreased to 81% in 2012 (205). From 2013 onwards, the hospital discharge data were collected in another registry (LBZ), with no missing hospital admissions data (206). The SSD covers aggregated yearly demographic data at the individual level (e.g. education level, migration background, household income) of the complete Dutch population (207). Perined, DHD and SSD data were pseudonymised and accessible only in a secure remote access environment in Statistics Netherlands.

Figure 6.3. The Data-InfrAstructure for ParEnts and children (DIAPER)



6.3.2 Population

The study population consisted of women who had given birth in hospital or at home between 1 January 2013 and 31 December 2021, aged 10-55, and with a gestational age at childbirth ≥20 weeks in the Netherlands. Women were excluded if they had missing information on the socioeconomic status scores for districts and neighbourhoods (SES-WOA). If a woman had two separate pregnancies and births during the study period, one of the births was randomly selected to avoid within-individual clustering.

6.3.3 Exposures

Eight different exposures were used to describe socioeconomic disadvantage: five neighbourhood- and three individual-level measures. The neighbourhood-level measures included SES-WOA (composite), SES-WOA Welfare, SES-WOA Employment, SES-WOA Education, and liveability (LBM 3.0). The individual-level measures included household disposable income, individual educational attainment, and individual employment status.

6.3.3.1 Socioeconomic Status Scores for Districts and Neighbourhoods (SES-WOA)

The SES-WOA is a neighbourhood-level socioeconomic score that provides information on an area's average household welfare, education level, and labour participation. The SES-WOA score is calculated using a multiple correspondence analysis (MCA). The coefficients are then added to make both composite scores and sub-scores per household on welfare-education level, and recent labour participation (208). The average score per region (municipality/district/neighbourhood) is calculated based on the scores per household. The smallest sized area, a ‘buurt’ which translates in English to neighbourhood, was chosen for this study to be the most comparable to the English data (HES APC), and a smaller area unit is also more likely to accurately describe the socioeconomic circumstances of an individual compared

to measures taken over a larger area. In this study, the composite SES-WOA variable was divided into quintiles at a population level based on the final score, with the first quintile being the least disadvantaged and the fifth the most.

6.3.3.1.1 Sub Scores of the SES-WOA

6.3.3.1.1.1 SES-WOA Welfare

To calculate the score, households are divided into deciles based on their financial disadvantage (income and wealth) compared to all households in the Netherlands. Households in the first decile group belong to the 10% of households with the lowest financial wealth. For a small population of the households (<1%), no data on income are known; these households were excluded from the research population. The average score of all the houses in each neighbourhood is used to calculate the overall neighbourhood score. For this study, the neighbourhood score was then grouped into quintiles.

6.3.3.1.1.2 SES-WOA Education

The education domain is based on the Labour Force Survey that covers 12 million people living in the Netherlands the coverage of which decreases with age. The educational level of a household is determined by the highest educational level completed by the primary breadwinner and any partner. Because the educational level file does not contain the educational level of all Dutch people, missing values are imputed using multinomial logistic regression (208). The educational level of a household is given an average score across the neighbourhood. For this analysis, the scores were then grouped into quintiles.

6.3.3.1.1.3 SES-WOA Employment

Recent labour participation is calculated per household using the Regional Employment Survey, which covers the whole population and measures the maximum extent to which the primary breadwinner and any partner have worked in the last four years. The household's employment status was averaged across a neighbourhood, and the scores were then grouped into quintiles for this analysis.

6.3.3.2 Liveability Meter 3.0 (LBM 3.0)

The LBM 3.0 (209) was developed by the Dutch Ministry of the Interior and Kingdom Relations and is an instrument that, using five dimensions, estimates quality of life at a scale of 100 × 100 meter grids, which participants' home addresses are matched to. Liveability is 'the extent to which the environment fits the requirements and wishes placed on it by humans'. The measure comprised a judgement model, which is how pleasant residents find living in their neighbourhood, and a behavioural model of the housing market, which was merged to arrive at the final score. Both models were based on the correlation between environmental characteristics and criteria specific to each model used to test how people appreciate different aspects of the living environment. The five dimensions include housing stock, facilities, social cohesion, physical environment, nuisance and insecurity, and they are based on many characteristics of the living environment (45 characteristics from 94 indices). To give meaning to the scores, they are converted into classes. These scores are divided into nine classes ('very poor' to 'excellent'). For determining the LBM 3.0 class, the distribution of judgments on liveability is classed according to Woon Onderzoek Nederland 2018 (210), which is a comprehensive survey that aims to gather data about housing conditions, preferences, and experiences of Dutch residents. Using the WoON 2018 classes helps with clear interpretation that aligns with the experiences of residents and policymakers. For this analysis, to provide enough individuals in each category, the classes were collapsed into five groups: very poor and

relatively poor, poor and weak, sufficient and reasonably sufficient, good and very good, and excellent.

6.3.3.3 Individual Educational Attainment

The highest level of education at individual-level was provided by Statistics Netherlands, which uses the International Standard Classification of Education. The analysis used three categories: lower, medium, and high education levels. The lower education level includes all years of primary education plus the first three years of senior general secondary education (HAVO) and pre-university secondary education (VWO) and the various pathways of prevocational secondary education (VMBO), including lower secondary vocational training and assistant's training (MBO-1). The medium education level includes upper secondary education (HAVO/VWO), basic vocational training (MBO-2), vocational training (MBO-3), and middle management and specialist education (MBO-4). Higher education refers to associate degree programmes-higher education (HBO/WO), Bachelor programmes-4-year education at universities of applied sciences (HBO), master's degree programmes at universities of applied sciences and research universities (HBO-WO) and doctoral degree programmes at research universities (WO).

6.3.3.4 Household Disposable Income

Household income was provided by Statistics Netherlands and is standardised with the distribution running from -6 to 100,000 euros. This analysis divided household disposable income into five groups based on the national standardised distribution of <20,000 euros, 20-39,999 euros, 40-59,999 euros, 60-79,999 euros and 80-100,999 euros. The standardised distribution allows income groups to be defined based on a national benchmark, making income comparisons across households fairer and more interpretable.

6.3.3.5 Individual Employment

Individual-level employment variable was derived from Statistics Netherlands' Labour Force Survey, which is cross-checked using administrative data and contains information on whether the woman was employed full-time or part-time (yes/no). For this analysis, this variable was categorised into employed and unemployed.

6.3.4 Outcome

SMM was defined using the updated English Maternal Morbidity Indicator (EMMOI) (125) and modified again to be applicable in the Dutch data. However, the DIAPER database does not contain OPCS-4 procedure codes; therefore, the definition was limited to diagnoses of ICD-10 codes only. Incidence rates of each SMM condition were compared to the incidence rates in population-based studies from other high-income (OECD) countries. If a condition had an incidence rate notably higher than other population-based studies, each code for this condition was examined to ascertain which code was responsible for the increased rate. If a code was recorded significantly more frequently than expected, it was dropped from the indicator.

6.3.5 Comparison

For each neighbourhood-level measure, the reference group was the least disadvantaged group with the highest SES-WOA or LBM 3.0 scores. For the individual-level measures, the reference group was women with a household disposable income of 80-100,000 euros, women with the highest educational level, and employed women.

6.3.6 Covariates

The covariates in the multivariable models were chosen to mirror those in the models in the HES APC data. Covariates included age, parity, ethnicity, migration status, year, obesity, pre-

existing medical conditions, pre-existing mental health issues and smoking and/or substance misuse. The maternal age at childbirth was grouped into five-year categories, except for those younger than 20 or older than 40, who were grouped into single categories. Maternal ethnicity was defined using Perined, which is reported by the woman's care provider (204), collapsed into five categories: Caucasian, Mediterranean (North African and Turkish), Other Black, Other Asian (including Hindustani) and Other including Mixed (also including Latin American). Parity was categorised into nulliparous (yes/no). Migration status was defined using Statistics Netherlands from the Personal Records Database based on the country of birth. This analysis categorised migration as Dutch native (Yes/No). The year of the birth was included as a categorical variable. Information on the following potential confounding factors was obtained based on ICD-10 codes (2013 onwards) and ICD-9 codes (2000-2013): obesity or overweight (yes/no), history of pre-existing medical condition (yes/no), history of pre-existing mental health problems (yes/no) and substance misuse and/or smoking (yes/no). Women were assumed not to have the above confounding factors if they were not coded in any hospital records from the preceding length of time listed in **Appendix Table 6.1** to before the birth. The list of relevant pre-existing medical and mental conditions and the code for all confounding variables is provided in **Appendix Table 6.1**. Only one covariate, neighbourhood-level Dutch language proficiency, included in the multivariable analyses of the HES APC data was not available in DIAPER. This covariate was included in the analyses to examine the association between income, employment and children's educational attainment, and SMM.

6.3.7 Statistical Analysis

Statistical analysis was performed using Stata version 16 (StataCorp. 2019. Stata Statistical Software: Release 16. College Station, TX: StataCorp LLC). Statistical significance was assumed to be a two-tailed p value of less than 0.05.

6.3.7.1 Descriptive Statistics

The data were checked for implausible values, and these were recoded as missing. The characteristics of the women in the study population are presented as numbers and percentages stratified by the composite neighbourhood-level measure, SES-WOA. The total incidence rate (and 95% confidence intervals (CI)) of SMM per 1000 maternities in total and by SES-WOA quintiles was calculated using a Poisson distribution with the number of maternities (women with either live or stillbirths) as the denominator over years. Cochran-Armitage's test for trend was used to determine if there were significant changes in the rate of SMM between years. The individual condition's contribution to the composite SMM indicator rate was calculated stratifying by year and SES-WOA quintile.

6.3.7.2 Comparing the Measures of Disadvantage

Spearman's correlation coefficient for all continuous measures of socioeconomic disadvantage that used ranked scores was used to compare how the different measures of disadvantage correlate to each other. A biserial correlation was calculated if the measures were binary (individual employment status). The individual-level measures were grouped by the corresponding neighbourhood measure to describe the proportion of women from each group of individual measure who lived in the corresponding neighbourhood to that measure. For example, the proportion of those with a high, medium or low educational attainment level who lived in the highest, middle and lowest quintiles of neighbourhood educational attainment. The individual-level measures were grouped by each other individual measure. For example, household disposable income was cross tabulated by individual educational attainment to describe the proportion of women with different incomes who had a low, medium or high education level.

6.3.7.3 Multilevel Modelling

For the neighbourhood-level exposures in the univariable and multivariable analyses, multi-level Poisson regression models with a random intercept were used to calculate the risk ratios (RR) (and 95% CI) to account for clustering between individuals who shared the same postcode (PC4). Level 1 was the individual woman and Level 2 was her postcode. Maximum likelihood estimation (MLE) was used to estimate the parameters of the multi-level model. A fixed effects null model was compared to one that included both fixed and random effects using a likelihood ratio test. A caterpillar plot was used to visualise the estimated random effects (and 95% CI). The intraclass coefficient (ICC) was used to quantify the proportion of the total variance that is due to differences between individuals (Level 1) compared to differences between groups (Level 2).

6.3.7.4 Univariable Analysis

The baseline group (the reference category) had the highest socioeconomic advantage. Multi-level Poisson regression models were used for the four neighbourhood-level measures of socioeconomic disadvantage, and fixed effects Poisson regression models were used for the three individual-level measures of socioeconomic disadvantage, to estimate the RRs of SMM and their 95% CI for each level of exposure.

6.3.7.5 Multivariable Analysis

Confounding factors were chosen to mirror the analysis in the HES APC. Multi-level (neighbourhood-level measures) and fixed effects (individual-level measures) multivariable Poisson regression was used to estimate the RRs of SMM and their 95% CIs in the different levels of exposure using a complete case analysis. **Table 6.1** describes the covariates adjusted for in each exposure in each model. For the composite SES-WOA, RRs and their 95% CI (using

Model 1) were calculated separately for the major components of the composite SMM outcomes in the most disadvantaged SES-WOA quintile compared to the least.

Table 6.1. Covariates included in each model as confounding factors in the association between different measures of socioeconomic disadvantage and SMM

	Model 1	**Model 2**	**Model 3**	**Model 4**
SES-WOA	age, parity, ethnicity, migration status	Model 1+ pre-existing medical and mental health conditions, substance misuse	Model 1 + neighbourhood liveability	Model 1 + individual educational attainment, household disposable income, individual employment
SES-WOA Education	age, parity, ethnicity, migration status	Model 1+ pre-existing medical and mental health conditions, substance misuse	Model 1 + individual educational attainment	Model 1 + individual educational attainment, household disposable income, individual employment
SES-WOA Welfare	age, parity, ethnicity, migration status	Model 1+ pre-existing medical and mental health conditions, substance misuse	Model 1 + household disposable income	Model 1 + individual educational attainment, household disposable income, individual employment
SES-WOA Employment	age, parity, ethnicity, migration status	Model 1+ pre-existing medical and mental health conditions, substance misuse	Model 1 + individual employment status	Model 1 + individual educational attainment, household disposable income, individual employment
Neighbourhood Liveability	age, parity, ethnicity, migration status	Model 1+ pre-existing medical and mental health conditions, substance misuse	Model 1 + SES-WOA	Model 1 + individual educational attainment, household disposable income, individual employment
Household Disposable Income	age, parity, ethnicity, migration status	Model 1+ pre-existing medical and mental health conditions, substance misuse	Model 1 + SES-WOA Welfare	NA
Individual Educational Attainment	age, parity, ethnicity, migration status	Model 1+ pre-existing medical and mental health conditions, substance misuse	Model 1 + SES-WOA Education	NA
Individual Employment Status	age, parity, ethnicity, migration status	Model 1+ pre-existing medical and mental health conditions, substance misuse	Model 1 + SES-WOA Employment	NA

6.3.7.6 Effect Modification

Likelihood ratio testing was used to examine if ethnicity and neighbourhood-level disadvantage modified the association between different measures of socioeconomic disadvantage and SMM. It was planned *a priori* that effect modification would be tested between each measure of disadvantage and ethnicity to assess whether the association between deprivation and SMM is stronger or weaker across different ethnic groups. Additionally, evidence for effect modification between each neighbourhood-level measure and its corresponding individual-level measure were examined to determine whether the combined association between individual-level socioeconomic disadvantage and residing in a more disadvantaged neighbourhood with SMM is greater or weaker than the association between each level of disadvantage independently. For example, an effect modification was tested between SES-WOA Welfare and household disposable income.

If there was evidence of effect modification between ethnicity and a measure of disadvantage, all ethnic groups were compared to a standard reference point (the least disadvantaged Caucasian women category) to provide a consistent baseline across all comparisons. This was to give a clear, standardised assessment of how different ethnic groups fare relative to a commonly understood standard, offering a benchmark relevant to understanding broader patterns of advantage or disadvantage. Absolute measures were then calculated using average adjusted predictive margins for each ethnicity category and socioeconomic disadvantage.

6.3.7.7 Population Attributable Fractions (PAFs)

Univariable and multivariable (using Model 1) population attributable fractions (PAFs) (and their 95% CI) were calculated using the *punaf* command in Stata for each measure of disadvantage. The data for the reference rate were women in each highest socioeconomic

disadvantage group, those from a Caucasian ethnic background in the highest socioeconomic group, and finally, those from a Caucasian ethnic group who were Dutch natives in the highest socioeconomic group. The reference rate was then applied to the women in the entire cohort.

6.3.7.8 Causal Mediation Analysis

The roles of various mediators on the association between the different measures of socioeconomic disadvantage and SMM were explored using the *paramed* command in Stata. This decomposes the total effects (TE) of socioeconomic disadvantage on SMM into:

- Controlled Direct Effects (CDE) or the effect of socioeconomic disadvantage on SMM if the mediator is set at a predefined level
- Natural direct effects (NDE), or the effect of the exposure on the outcome that does not involve the mediator, holding the mediator at a constant level that it would have been without the exposure
- Natural indirect effects (NIE) or the effect of the exposure on the outcome that operates through the mediator

The proportion mediated was subsequently calculated. The mediators were selected to mirror the causal mediation analysis in the English data and were treated as binary variables. The mediators included pre-existing medical and mental health conditions. However, obesity and the timing of antenatal booking were not included as mediators, as obesity had a low prevalence rate and is likely misclassified as it is considerably lower than has been reported in the literature (211). There was no variable for timing of antenatal booking in the Dutch data. The confounding variables were ethnicity, age, parity, year of birth and migration status. The composite variable of pre-existing medical conditions was modified to remove hypertensive

disorders, diabetes and ischaemic heart disease, as these conditions are closely related to obesity, which could be another mediator. Logistic regression and Poisson regression models were used to estimate odds ratios (ORs) and RRs for the mediator model and outcome model, respectively, as the paramed command does not support Poisson regression models for the mediator model. However, this is unlikely to bias the results as SMM is relatively rare. The exposure was a binary variable comparing the lowest to the highest measure of disadvantage.

6.3.7.9 Sensitivity Analyses

A sensitivity analysis was conducted where acute pancreatitis was excluded from the outcome, as the rate of this condition was larger than expected compared to other population-based studies (212), and therefore it may be misclassifed. A second sensitivity analysis included making a new variable of ethnicity, which was further stratified by migration status using the categories Caucasian and Dutch native, Caucasian and non-Dutch native, missing ethnicity and Dutch native, missing ethnicity and non-Dutch native, minoritised ethnicity and Dutch native and minoritised ethnicity and non-Dutch native. Model 1 was tested for evidence of effect modification between the measures of socioeconomic disadvantage and this new variable using a likelihood ratio test. If there was evidence of effect modification ($p_{interaction}$ <0.05) each ethnic group was then compared to a standard reference point (least disadvantaged Caucasian-Dutch natives in the highest category of socioeconomic advantage). Testing for evidence for effect modification by ethnicity, and ethnicity and migration status was repeated using fixed effects models for neighbourhood-level measures. Individual measures were cross-tabulated with their corresponding neighbourhood-level measures and stratified by ethnicity and migration status to quantify the extent of misclassification bias. A further sensitivity analysis involved re-categorising the neighbourhood-level variables to be the same size (% of the population) as their corresponding individual-level measure. For example, if 14% of the population was

classified as having individually low educational attainment, the lowest neighbourhood educational category also included 14% of the cohort. The mediation analysis was repeated with the full composite variable of pre-existing medical conditions, including hypertensive disorders, diabetes and ischaemic heart disease. Finally, a sensitivity analysis was conducted, which repeated the multivariable analysis using Model 1 but excluded sepsis from the composite outcome to match the analysis conducted in **Chapters 4 and 5**.

6.3.7.10 Missing Data

The outcome was classified using diagnosis codes; no quantifiable missing information existed. The characteristics of the women with and without missing 'buurt' data and those with and without missing data on the other exposures, individual educational attainment, household disposable income and liveability, were compared to assess the likelihood of bias of excluding these women from the analysis. A complete case analysis was chosen for the neighbourhood-level exposures. For the individual-level exposures, the missing data appeared missing at random (MAR), and the 'missingness' pattern was at least partially dependent on known variables. Sensitivity analysis included imputing the values for maternal characteristics if they were missing in the individual exposures in the multivariable analysis, using fully conditional specification multiple imputations by chained equations (MICE) to generate 50 datasets. As less than 5% of the data on the other covariates was missing, these values were not imputed.

6.4 Results

6.4.1 Descriptive Statistics

6.4.1.1 Study Population

The cohort comprised 832,866 women who gave birth from 1 January 2013 to 31 December 2021. The identification of the study population is shown in **Figure 6.4**. The overall incidence of SMM was 16.1 per 1000 maternities (95% CI 15.8-16.4). The characteristics of the study population, including maternal age at birth, ethnicity, migration status, parity, mode and place of birth, mode of onset of birth, pre-existing medical and mental health problems, smoking/substance misuse and obesity are shown in **Table 6.2**. Women who lived in the most disadvantaged areas were more likely to be younger, from minoritised ethnicity groups, to be obese and to have a history of smoking/substance misuse. They were also less likely to give birth at home and to be a Dutch native compared to those living in the least disadvantaged areas.

Figure 6.4. Flow chart showing the identification of the cohort

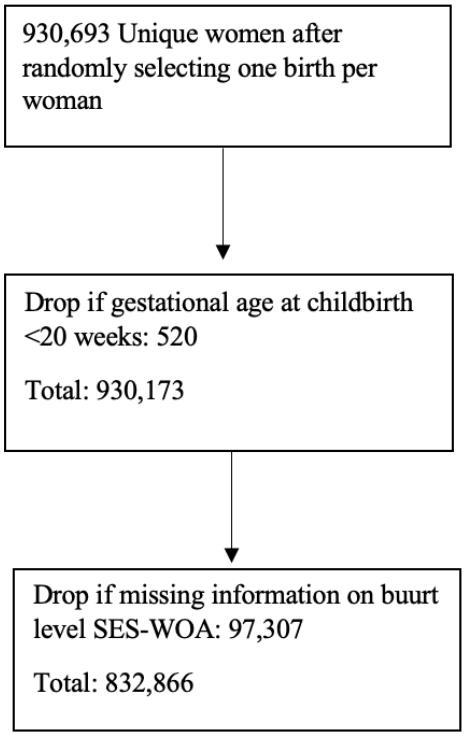


Table 6.2. Characteristics of the study population stratified by SES-WOA, number and percent (N (%))

	Most disadvantaged 20%	More disadvantaged 20%-40%	Less disadvantaged 40%-60%	Less disadvantaged 60%-80%	Least disadvantaged 80%-100%	Total
	N(%)	N(%)	N(%)	N(%)	N(%)	N(%)
Total	**245,783 (29.5)**	**191,521 (23.0)**	**158,269 (19.0)**	**134,403 (16.1)**	**102,890 (12.4)**	**832,866 (100.0)**
SMM						
No	241,231 (98.2)	188,554 (98.4)	155,827 (98.5)	132,401 (98.5)	101,440 (98.6)	819,453 (98.4)
Yes	4,552 (1.9)	2,967 (1.6)	2,442 (1.5)	2,002 (1.5)	1,450 (1.4)	13,413 (1.6)
Age group						
<20	3,982 (1.6)	1,755 (0.9)	1,049 (0.7)	724 (0.5)	333 (0.3)	7,843 (0.9)
20-25	31,066 (12.6)	17,166 (9.0)	11,137 (7.0)	7,150 (5.3)	3,599 (3.5)	70,118 (8.4)
25-30	77,825 (31.7)	60,478 (31.6)	47,919 (30.3)	37,738 (28.1)	24,612 (23.9)	248,572 (29.9)
30-35	81,913 (33.3)	72,504 (37.9)	63,203 (39.9)	56,595 (42.1)	45,253 (44.0)	319,468 (38.4)
35-40	41,040 (16.7)	32,981 (17.2)	29,016 (18.3)	26,938 (20.0)	24,445 (23.8)	154,420 (18.5)
>40	9,934 (4.0)	6,616 (3.5)	5,932 (3.8)	5,243 (3.9)	4,641 (4.5)	32,366 (3.9)
Parity						
Primiparous	122,848 (50.0)	98,377 (51.4)	77,741 (49.1)	65,603 (48.8)	47,489 (46.2)	412,058 (49.5)
Multiparous	122,935 (50.0)	93,144 (48.6)	80,528 (50.9)	68,800 (51.2)	55,401 (53.8)	420,808 (50.5)
Ethnicity						
Caucasian	157,668 (65.8)	157,983 (84.6)	137,056 (88.9)	116,946 (89.1)	89,631 (89.2)	659,284 (81.2)
Mediterranean (North African + Turkish)	7,846 (3.3)	2,071 (1.1)	1,026 (0.7)	939 (0.7)	639 (0.6)	12,521 (1.5)
Other African	11,897 (5.0)	3,376 (1.8)	1,673 (1.1)	1,139 (0.9)	692 (0.7)	18,777 (2.3)
Other Asian	16,658 (7.0)	7,846 (4.2)	5,349 (3.5)	4,771 (3.6)	4,025 (4.0)	38,649 (4.8)
Other including Mixed	45,401 (19.0)	15,366 (8.2)	9,159 (5.9)	7,454 (5.7)	5,493 (5.5)	82,873 (10.2)

Table 6.2. (Continued)

	Most disadvantaged 20%	More disadvantaged 20%-40%	Less disadvantaged 40%-60%	Less disadvantaged 60%-80%	Least disadvantaged 80%-100%	Total
	N(%)	N(%)	N(%)	N(%)	N(%)	N(%)
Migration background						
Dutch native	124,212 (50.5)	139,803 (73.0)	124,926 (78.9)	106,999 (79.6)	81,271 (79.0)	577,211 (69.3)
Moroccan	18,633 (7.6)	5,076 (2.7)	2,563 (1.6)	2,139 (1.6)	1,575 (1.5)	29,986 (3.6)
Other non-Western	33,436 (13.6)	14,904 (7.8)	9,812 (6.2)	7,458 (5.6)	5,771 (5.6)	71,381 (8.6)
Other Western	33,308 (13.6)	22,209 (11.6)	15,801 (10.0)	12,903 (9.6)	10,208 (9.9)	94,429 (11.3)
Surinamese	9,954 (4.1)	3,094 (1.6)	2,040 (1.3)	1,963 (1.5)	1,615 (1.6)	18,666 (2.2)
Turkish	19,029 (7.7)	4,542 (2.4)	2,102 (1.3)	2,114 (1.6)	1,757 (1.7)	29,544 (3.6)
Netherlands Antilles	7,211 (2.9)	1,893 (1.0)	1,025 (0.7)	827 (0.6)	693 (0.7)	11,649 (1.4)
Year						
2013	29,582 (12.0)	23,289 (12.2)	20,018 (12.7)	16,491 (12.3)	12,615 (12.3)	101,995 (12.2)
2014	29,176 (11.9)	22,162 (11.6)	18,463 (11.7)	15,305 (11.4)	11,581 (11.3)	96,687 (11.6)
2015	26,928 (11.0)	20,025 (10.5)	16,393 (10.4)	13,578 (10.1)	10,101 (9.8)	87,025 (10.5)
2016	26,766 (10.9)	19,959 (10.4)	15,829 (10.0)	13,348 (9.9)	10,001 (9.7)	85,903 (10.3)
2017	25,498 (10.4)	19,385 (10.1)	15,886 (10.0)	13,298 (9.9)	10,297 (10.0)	84,364 (10.1)
2018	25,073 (10.2)	19,314 (10.1)	15,799 (10.0)	13,423 (10.0)	10,449 (10.2)	84,058 (10.1)
2019	26,962 (11.0)	20,912 (10.9)	17,377 (11.0)	15,098 (11.2)	11,177 (10.9)	91,526 (11.0)
2020	28,000 (11.4)	22,910 (12.0)	18,953 (12.0)	16,628 (12.4)	13,101 (12.7)	99,592 (12.0)
2021	27,798 (11.3)	23,565 (12.3)	19,551 (12.4)	17,234 (12.8)	13,568 (13.2)	101,716 (12.2)
Substance misuse or smoking						
No	238,830 (97.2)	186,468 (97.4)	154,438 (97.6)	131,405 (97.8)	100,747 (97.9)	811,888 (97.5)
Yes	6,953 (2.8)	5,053 (2.6)	3,831 (2.4)	2,998 (2.2)	2,143 (2.1)	20,978 (2.5)
Obesity						
No	237,074 (96.5)	185,061 (96.6)	153,269 (96.8)	130,397 (97.0)	100,028 (97.2)	805,829 (96.8)
Yes	8,709 (3.5)	6,460 (3.4)	5,000 (3.2)	4,006 (3.0)	2,862 (2.8)	27,037 (3.3)

Table 6.2. (Continued)

	Most disadvantaged 20%	More disadvantaged 20%-40%	Less disadvantaged 40%-60%	Less disadvantaged 60%-80%	Least disadvantaged 80%-100%	Total
	N(%)	N(%)	N(%)	N(%)	N(%)	N(%)
Pre-existing mental health problem						
No	217,903 (88.7)	169,090 (88.3)	140,502 (88.8)	119,961 (89.3)	91,896 (89.3)	739,352 (88.8)
Yes	27,880 (11.3)	22,431 (11.7)	17,767 (11.2)	14,442 (10.8)	10,994 (10.7)	93,514 (11.2)
Pre-existing medical conditions						
No	176,002 (71.6)	135,426 (70.7)	112,949 (71.4)	96,239 (71.6)	73,569 (71.5)	594,185 (71.3)
Yes	69,781 (28.4)	56,095 (29.3)	45,320 (28.6)	38,164 (28.4)	29,321 (28.5)	238,681 (28.7)
Pre-existing medical conditions (excluding ischemic heart disease, diabetes and hypertension)						
No	178,755 (72.3)	137,433 (71.76)	114,641 (72.4)	97,682 (72.7)	74,632 (72.5)	603,143 (72.4)
Yes	67,028 (27.3)	54,088 (28.2)	43,628 (27.6)	36,721 (27.3)	28,258 (27.5)	229,723 (27.6)
Migration status and ethnicity						
Caucasian and Dutch native	118,849 (48.4)	134,521 (70.2)	120,403 (76.1)	103,280 (76.8)	78,621 (76.4)	555,674 (66.7)
Caucasian and non-Dutch native	38,819 (15.8)	23,462 (12.2)	16,653 (10.5)	13,666 (10.2)	11,010 (10.7)	103,610 (12.4)
Minoritised ethnicity and Dutch native	2,369 (1.0)	1,991 (1.0)	1,637 (1.0)	1,507 (1.1)	975 (1.0)	8,479 (1.0)
Other including mixed and non-Dutch native	48,864 (19.9)	15,741 (8.2)	9,230 (5.8)	7,539 (5.6)	5,797 (5.6)	87,171 (10.5)
Mediterranean and non-Dutch native	7,806 (3.2)	2,051 (1.1)	1,011 (0.6)	927 (0.7)	632 (0.6)	12,427 (1.5)
Other African and non-Dutch native	11,655 (4.7)	3,284 (1.7)	1,625 (1.0)	1,103 (0.8)	667 (0.7)	18,334 (2.2)
Other Asian and non-Dutch native	11,108 (4.5)	5,592 (2.9)	3,704 (2.3)	3,227 (2.4)	2,778 (2.7)	26,409 (3.2)
Missing ethnicity and Dutch native	2,994 (1.2)	3,291 (1.7)	2,886 (1.8)	2,212 (1.7)	1,675 (1.6)	13,058 (1.6)
Missing ethnicity and non-Dutch native	3,319 (1.4)	1,588 (0.8)	1,120 (0.7)	942 (0.7)	735 (0.7)	7,704 (0.9)

Table 6.2. (Continued)

	Most disadvantaged 20%	More disadvantaged 20%-40%	Less disadvantaged 40%-60%	Less disadvantaged 60%-80%	Least disadvantaged 80%-100%	Total
	N(%)	N(%)	N(%)	N(%)	N(%)	N(%)
Birth onset method						
Induction	61,873 (26.2)	46,807 (25.2)	37,621 (24.5)	30,789 (23.6)	22,601 (22.6)	199,691 (24.8)
Elective Caesarean Birth	20,121 (8.5)	15,095 (8.1)	12,847 (8.4)	10,614 (8.1)	8,400 (8.4)	67,077 (8.3)
Spontaneous Birth	154,092 (65.3)	123,600 (66.6)	103,117 (67.1)	89,048 (68.3)	68,995 (69.0)	538,852 (66.9)
Place of birth						
At home	20,408 (8.4)	24,259 (12.7)	22,868 (14.5)	19,695 (14.7)	15,406 (15.0)	102,636 (12.4)
Birth centre	8,351 (3.4)	4,533 (2.3)	3,253 (2.1)	3,309 (2.5)	2,309 (2.3)	21,755 (2.6)
Hospital (1st line)*	24,008 (9.8)	18,686 (9.81)	15,671 (9.96)	13,846 (10.36)	11,885 (11.61)	84,096 (10.2)
Hospital (2nd line)**	191,240 (78.4)	142,901 (75.1)	115,586 (73.4)	96,842 (72.4)	72,795 (71.1)	619,364 (74.8)
En route	26 (0.0)	15 (0.0)	17 (0.0)	8 (0.0)	7 (0.0)	73 (0.0)
Mode of birth						
Unassisted vaginal birth	168,322 (71.9)	133,006 (72.6)	110,767 (73.1)	94,303 (73.4)	73,154 (74.1)	579,552 (72.8)
Assisted vaginal birth	20,426 (8.7)	16,617 (9.1)	13,438 (8.9)	11,509 (9.0)	8,469 (8.6)	70,459 (8.9)
Elective caesarean birth	21,378 (9.1)	16,047 (8.8)	13,601 (9.0)	11,262 (8.8)	8,883 (9.0)	71,171 (8.9)
Emergency caesarean birth	23,983 (10.2)	17,567 (9.6)	13,673 (9.0)	11,277 (8.8)	8,120 (8.2)	74,620 (9.4)
Termination of pregnancy	56 (0.0)	56 (0.0)	47 (0.0)	53 (0.0)	44 (0.0)	256 (0.0)

*1st line = midwifery and GP led care, 2nd line= obstetrician led care

6.4.1.2 SMM Outcome

Appendix Table 6.2 shows how each condition of the composite SMM outcome compares to population-based studies or the English data. The ICD-10 codes K35 – K37 were dropped from the indicator as the rate of appendicitis was 0.7%, 13 times higher than reported in studies across similar high-income countries (213). Therefore, these codes were thought to be misclassified in the Dutch data.

The total incidence rate (and 95% CI) and the incidence rate stratified by SES-WOA quintile of SMM per year are shown in **Figures 6.5 and 6.6**. There was an increase in the incidence rate from 2013 to 2014 of 13.9 per 1000 maternities to 16.7 per 1000 maternities ($p_{trend}<0.001$); the rate then remained consistent from 2015 to 2019. Then it decreased ($p_{trend}<0.001$) in 2020 to 14.7 per 1000 maternities and 15.2 per 1000 maternities in 2021.

The conditions that made up the highest proportion of the indicator were sepsis (40.6%), embolic events (9.2%), uterine rupture (7.9%), acute pancreatitis (7.8%) and eclampsia (5.7%) (**Figure 6.7).** The number and proportion of SMM events that make up the final indicator, stratified by year, are shown in **Appendix Table 6.3**. Despite the apparent fluctuations in overall SMM incidence over the years, the proportion of each SMM condition contributing to the overall outcome remained stable. **Appendix Table 6.4** indicates the number and proportion of the total SMM outcome of each condition stratified by SES-WOA. No proportion of a condition to the total SMM outcome significantly increased or decreased over the SES-WOA quintiles.

Figure 6.5. The incidence rate (N per 1000 births) and their 95% confidence intervals per year of SMM

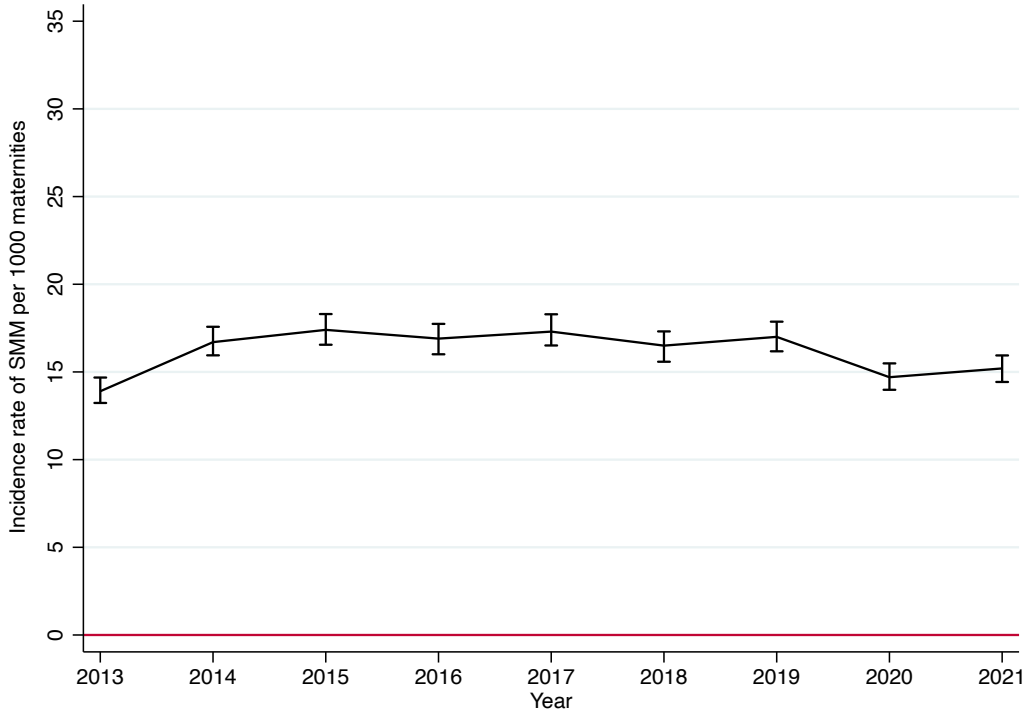


Figure 6.6. The incidence rate per year (N per 1000 births) of SMM per year stratified by SES-WOA

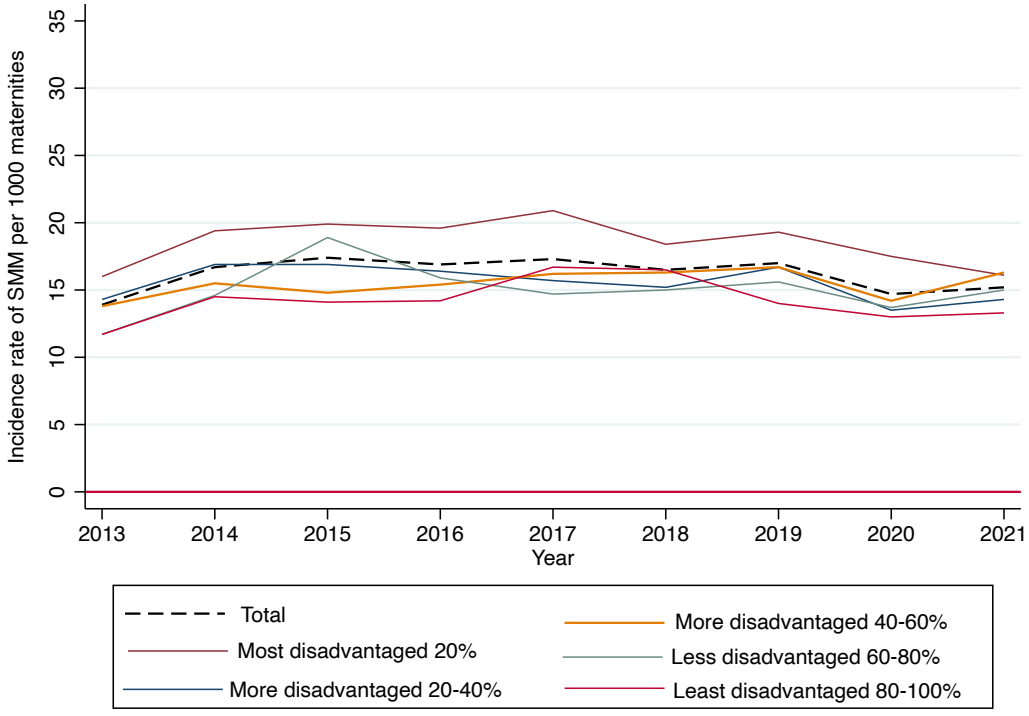
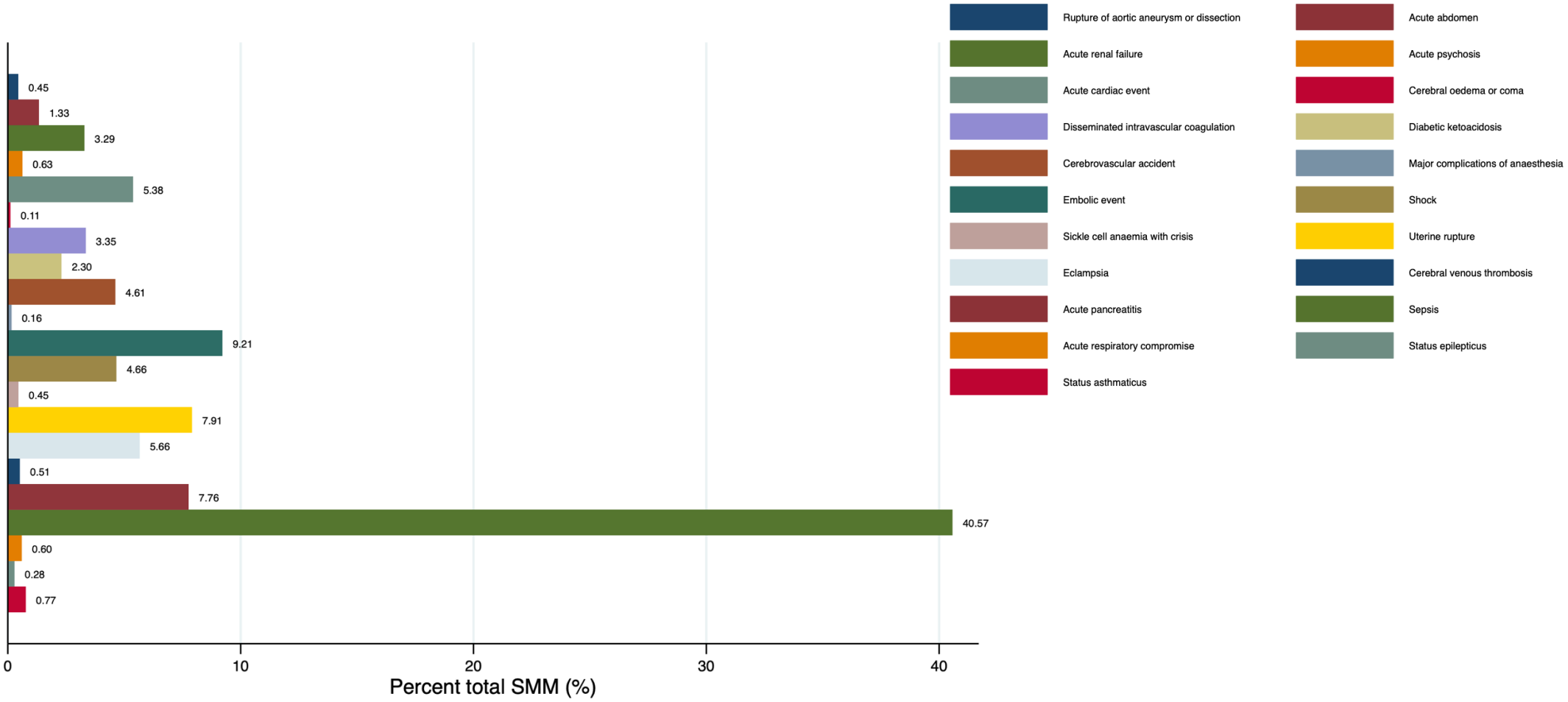


Figure 6.7. The proportion (%) of each SMM diagnoses (ICD-10) of the final composite outcome



6.4.2 The Different Measures of Disadvantage

There were more births in the more disadvantaged neighbourhoods across all measures, except for neighbourhood liveability, where more births occurred in medium liveability neighbourhoods. Women with a household disposable income of €80,000 to €100,000 comprised 45% of all births, and those who gave birth were also more likely to be employed and possess medium to high levels of educational attainment (**Table 6.3**).

Across all the different socioeconomic disadvantage measures, many women with the highest individual-level socioeconomic advantage lived in the most advantaged neighbourhoods. The highest neighbourhood education quintile comprised 54% of women with the highest level of educational attainment, compared to 5% in the lowest; the highest neighbourhood employment quintile included 85% of employed women versus 15% who were unemployed; and the highest neighbourhood income quintile consisted of 46% of women with a household disposable income of €80,000 to €100,000, compared to 5% of women with a household disposable income of less than €20,000. However, the correlation between each individual measure and its corresponding neighbourhood-level measure remained weak (**Table 6.4**). The highest correlation between an individual- and a corresponding neighbourhood-level measure was between individual educational attainment and SES-WOA Education (Spearman's Rho=0.34). Similarly, the individual-level measures of disadvantage had a weak to moderate correlation with other individual-level measures, with the greatest correlation being between household disposable income and individual educational attainment (Spearman's Rho=0.52). Individual employment status exhibited the weakest correlation with another individual measure of socioeconomic disadvantage, with 12% of unemployed individuals having a household disposable income of €80,000 to €100,000 euros and 24% achieving high educational attainment. This contrasts with only 6% of women with low educational attainment having a

household disposable income of €80,000 to €100,000 euros (**Appendix Table 6.5**). The neighbourhood-level measures strongly correlated with each other with the strongest correlation between SES-WOA Employment and SES-WOA Welfare (Spearman's Rho=0.91). There was a moderate correlation between the composite SES-WOA and neighbourhood liveability (Spearman's Rho= 0.52). The individual-level measures' cross-tabulation with other measures is shown in **Appendix Table 6.5**.

Table 6.3. The cross-tabulation of each individual measure of socioeconomic disadvantage with the corresponding neighbourhood measure N (%)

Individual measure	**Neighbourhood measure**					
	Lowest SES-WOA Education 20%	**Lower SES-WOA Education 20-40%**	**Lower SES-WOA Education 40-60%**	**High SES-WOA Education 60-80%**	**Highest SES-WOA Education 80-100%**	**Total**
Individual Educational Attainment						
Low	44,127 (19.9)	22,201 (12.2)	12,990 (9.2)	9,159 (7.2)	7,368 (4.6)	96,845 (11.6)
Medium	84,559 (38.2)	67,311 (37.1)	47,989 (34.0)	38,247 (30.0)	32,146 (20.0)	270,252 (32.4)
High	41,786 (18.9)	52,715 (29.0)	50,373 (35.6)	53,210 (41.8)	86,990 (54.1)	284,074 (34.1)
Missing	51,160 (23.1)	39,421 (21.7)	30,135 (21.3)	26,769 (21.0)	34,210 (21.3)	181,695 (21.8)
Total	221,632 (26.6)	181,648 (21.8)	141,487 (17.0)	127,385 (15.3)	160,714 (19.3)	832,866 (100.0)
	Lowest SES-WOA Employment 20%	**Lower SES-WOA Employment 20-40%**	**Lower SES-WOA Employment 40-60%**	**Higher SES-WOA Employment 60-80%**	**Highest SES-WOA Employment 80-100%**	
Individual Employment						
Unemployed	86,189 (35.5)	43,262 (23.8)	30,235 (19.2)	21,985 (17.5)	19,028 (15.2)	200,699 (24.0)
Employed	156,759 (64.5)	138,409 (76.2)	127,082 (80.8)	103,530 (82.5)	106,387 (84.8)	632,167 (76.0)
Total	242,948 (29.1)	181,671 (21.8)	157,317 (18.9)	125,515 (15.1)	125,415 (15.1)	832,866 (100.0)
	Lowest SES-WOA Welfare 20%	**Lower SES-WOA Welfare 20-40%**	**Lower SES-WOA Welfare 40-60%**	**Higher SES-WOA Welfare 60-80%**	**Highest SES-WOA Welfare 80-100%**	
Household Disposable Income (euros)						
<20,000	62,087 (24.2)	23,928 (12.3)	13,821 (8.1)	8,111 (5.7)	3,143 (4.5)	111,090 (11.9)
20-39,999	39,562 (15.4)	22,661 (11.6)	15,198 (9.0)	9,483 (6.7)	3,422 (4.9)	90,326 (9.7)
40-59,999	40,923 (16.0)	35,222 (18.1)	28,746 (16.9)	20,381 (14.3)	7,736 (11.1)	133,008 (14.2)
60-79,999	42,414 (16.6)	46,132 (23.7)	44,500 (26.2)	37,097 (26.1)	16,040 (23.0)	186,183 (19.9)
80-100,00	41,258 (16.1)	45,480 (23.3)	49,407 (29.1)	52,121 (36.6)	32,075 (45.9)	220,341 (23.6)
Missing	29,863 (11.7)	21,475 (11.0)	18,088 (10.7)	15,096 (10.6)	7,396 (10.6)	92,918 (9.9)
Total	256,107 (30.1)	194,898 (23.3)	169,760 (20.5)	142,289 (17.1)	69,812 (8.4)	832,866 (100.0)

Table 6.3. (Continued)

Neighbourhood measure	Neighbourhood measure					
	Lowest SES-WOA Composite 20%	Lower SES-WOA Composite 20-40%	Lower SES-WOA Composite 40-60%	Higher SES-WOA Composite 60-80%	Highest SES-WOA Composite 80-100%	Total
Liveability						
Lowest	56,463 (22.3)	6,019 (3.1)	2,102 (1.3)	1,298 (1.0)	694 (0.7)	66,576 (8.0)
Lower	43,330 (17.6)	15,384 (8.0)	5,145 (3.3)	4,089 (3.0)	1,889 (1.8)	69,837 (8.5)
Middle	85,007 (34.6)	79,411 (41.5)	51,420 (32.5)	37,715 (28.1)	27,601 (26.8)	281,54 (33.7)
Higher	26,570 (10.8)	51,412 (26.8)	54,326 (34.6)	46,832 (34.8)	35,424 (34.4)	215,068 (25.8)
Highest	7,665 (3.1)	16,993 (8.8)	54,830 (16.5)	29,136 (21.7)	25,910 (25.2)	105,749 (12.7)
Missing	26,748 (10.9)	22,362 (11.7)	26,105 (11.8)	15,333 (11.4)	11,372 (11.1)	94,483 (11.5)
Total	245,783 (29.5)	191,521 (23.0)	158,269 (19.0)	134,403 (16.1)	102,890 (12.4)	832,866 (100.0)

Table 6.4. Spearman's and biserial correlation coefficients between the different measures of disadvantage. Red=strong correlation, Orange = moderate correlation, Green = weak correlation

	SES-WOA Employment	SES-WOA Welfare	SES-WOA Education	Liveability	Household Disposable Income	Individual Educational Attainment	Employment	SES-WOA Composite
SES-WOA Employment	1							
SES-WOA Welfare	0.91	1.000						
SES-WOA Education	0.65	0.73	1.000					
Liveability	0.44	0.53	0.50	1.00				
Household Disposable Income	0.28	0.33	0.37	0.25	1.00			
Individual Educational Attainment	0.18	0.23	0.34	0.22	0.52	1.00		
Individual Employment	0.18	0.17	0.16	0.13	0.38	0.29	1.00	
SES-WOA Composite	0.93	0.98	0.83	0.52	0.35	0.26	0.18	1.00

6.4.3 Multi-level Modelling

There were 8,975 different neighbourhoods modelled with a range of observations per neighbourhood of between 1 and 2,311, with an average of 104.8. Multi-level modelling was chosen to model all the neighbourhood disadvantage measures as in the null model, the multi-level model had a better fit than the fixed effect model (LRT test: X^2=126 p<0.001). 1.6% (95% CI 1.3%-2.1%) of the variance came from the differences between neighbourhoods (Level 2) compared to the remaining 98.4% (95% CI 97.9%-98.7%), which was from the variance between individuals within neighbourhoods (Level 1). The caterpillar plot is shown in the **Appendix Figure 6.1**.

6.4.4 Univariable and Multivariable Analysis

Tables 6.5-6.12 show the results of the univariable and multivariable analysis. In the univariable analysis, there was a dose-response relationship between household disposable income, neighbourhood liveability, individual educational attainment and SES-WOA Education, and SMM. The largest effect size was seen in women with the lowest individual educational attainment level who had an increased risk of SMM of 1.50 (95% CI 1.33-1.59) compared to women with the highest individual educational attainment level, followed by women who lived in households with a disposable income of less than €20,000, who had an increased risk of SMM of 1.40 (95% CI 1.33-1.48) compared to women who lived in households with a disposable income of €80,000 to €100,000. Unemployed women also had a 1.32 (95% CI 1.28-1.37) increased risk of SMM compared to employed women.

Figure 6.8 shows the multivariable analysis for Model 1 for each measure of disadvantage, adjusting for age, parity, ethnicity, year and migration status. There was a dose-response relationship between increasing neighbourhood SES-WOA Education disadvantage, lower

household disposable income and lower individual educational attainment, and SMM, with the strongest association seen between women with low compared to high individual educational attainment and SMM (adjusted RR 1.41 (95% CI 1.33-1.55)). After adjusting for pre-existing medical and mental health conditions and smoking and/or substance misuse the magnitude of association between the most and least disadvantaged neighbourhoods across the neighbourhood-level measures was 13-31% lower, with women living in the most disadvantaged composite SES-WOA neighbourhoods having the smallest attenuation in the RR and women living in the least 'liveable' neighbourhoods having the greatest. There was a 19%, 12% and 29% reduction in the RRs after adjusting for pre-existing medical and mental health conditions and smoking and/or substance misuse for the association between having a household disposable income of less than €20,000, being unemployed and having the lowest educational attainment level, and SMM, compared to the most advantaged of each of these measures, respectively.

Although the RR attenuated after additionally adjusting for individual-level disadvantage measures (Model 3), an association remained between the neighbourhood-level measures and SMM. The largest change in the strength of an association was seen in the association between SES-WOA Education and SMM, with the adjusted RR reducing from 1.21 (95% CI 1.14-1.28) to 1.12 (95% CI 1.05-1.19) between the highest and lowest SES-WOA Education quintile (43% decrease), after adjusting for individual educational attainment (**Table 6.6**). There were only minor reductions in the measure of association in the individual-level measures of disadvantage after adjusting for neighbourhood-level measures (**Tables 6.10-6.12**). There were no notable changes in the association between SES-WOA and SMM after adjusting for neighbourhood liveability. However, there was a 48% reduction in the RR after adjusting for the individual-

level measures of educational attainment, employment status and household disposable income (**Table 6.5**).

Table 6.5. Univariable and multivariable analysis showing risk ratios (and their 95% confidence intervals) between **SES-WOA** and SMM compared to the least SES-WOA disadvantaged quintile. *Model 1: Adjusted for year, age, parity, migration status and ethnicity **Model 2: Model 1 + additionally adjusted for pre-existing medical conditions, smoking/substance misuse, and pre-existing mental health conditions ***Model 3: Model 1 + additionally adjusted for neighbourhood livability. ****Model 4: Model 1 + additionally adjusted for individual-level measures of socioeconomic position (household income, educational attainment and employment status)

SES-WOA	**Univariable**	**Model 1***	**Model 2****	**Model 3*****	**Model 4*****
	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)
Most disadvantaged 20%	1.31 (1.23-1.40)	1.23 (1.15-1.31)	1.20 (1.11-1.28)	1.23 (1.15-1.33)	1.12 (1.04-1.20)
More disadvantaged 20-40%	1.12 (1.05-1.19)	1.11 (1.04-1.19)	1.09 (1.02-1.17)	1.11 (1.03-1.19)	1.04 (0.97-1.12)
Less disadvantaged 40-60%	1.11 (1.03-1.19)	1.11 (1.03-1.19)	1.10 (1.03-1.18)	1.13 (1.05-1.21)	1.07 (0.99-1.15)
Less disadvantaged 60-80%	1.06 (0.99-1.14)	1.08 (1.00-1.16)	1.07 (1.00-1.15)	1.08 (1.00-1.16)	1.05 (0.98-1.14)
Least disadvantaged 80-100%	1(ref)	1(ref)	1(ref)	1(ref)	1(ref)
ICC	0.014 (0.011-0.018)	0.015 (0.010-0.018)	0.015 (0.011- 0.019)	0.013 (0.010-0.018)	0.015 (0.011-0.020)

Abbreviations: CI, confidence interval; ICC, Intra-class Correlation Coefficient

Table 6.6. Univariable and multivariable analysis showing risk ratios (and their 95% confidence intervals) between **SES-WOA Education** and SMM compared to the least SES-WOA Education disadvantaged quintile. *Model 1: Adjusted for year, age, parity, migration status and ethnicity **Model 2: Model 1 + additionally adjusted for pre-existing medical conditions, smoking/substance misuse, and pre-existing mental health conditions ***Model 3: Model 1 + additionally adjusted for individual educational attainment. ****Model 4: Model 1 + additionally adjusted for individual-level measures of socioeconomic position (household income, educational attainment and employment status)

SES-WOA Education	**Univariable**	**Model 1***	**Model 2****	**Model 3*****	**Model 4********
	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)
Most disadvantaged 20%	1.27 (1.20-1.34)	1.21 (1.14-1.28)	1.16 (1.09-1.23)	1.12 (1.05-1.19)	1.09 (1.01-1.16)
More disadvantaged 20-40%	1.14 (1.08-1.21)	1.13 (1.07-1.20)	1.10 (1.03-1.16)	1.08 (1.01-1.15)	1.06 (1.00-1.14)
Less disadvantaged 40-60%	1.12 (1.05-1.19)	1.12 (1.05-1.19)	1.09 (1.02-1.16)	1.08 (1.01-1.16)	1.07 (1.00-1.15)
Less disadvantaged 60-80%	1.03 (1.00-1.01)	1.03 (0.97-1.10)	1.01 (0.95-1.08)	1.00 (0.93-1.01)	1.00 (0.93-1.07)
Least disadvantaged 80-100%	1(ref)	1(ref)	1(ref)	1(ref)	1(ref)
ICC	0.015 (0.012-0.020)	0.014 (0.010-0.018)	0.015 (0.011-0.019)	0.015 (0.011- 0.020)	0.015 (0.011-0.020)

Abbreviations: CI, confidence interval; ICC, Intra-class Correlation Coefficient

Table 6.7. Univariable and multivariable analysis showing risk ratios (and their 95% confidence intervals) between **SES-WOA Employment** and SMM compared to the least SES-WOA Employment disadvantaged quintile. *Model 1: Adjusted for year, age, parity, migration status and ethnicity **Model 2: Model 1 + additionally adjusted for pre-existing medical conditions, *smoking/*substance misuse, and pre-existing mental health conditions ***Model 3: Model 1 + additionally adjusted for individual employment status. ****Model 4: Model 1 + additionally adjusted for *individual-level measures of socioeconomic position* (household income, educational attainment and employment status)

SES-WOA Employment	**Univariable**	**Model 1***	**Model 2****	**Model 3*****	**Model 4********
	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)
Most disadvantaged 20%	1.26 (1.19-1.33)	1.17 (1.10-1.24)	1.13 (1.06-1.20)	1.14 (1.07-1.21)	1.08 (1.01-1.15)
More disadvantaged 20-40%	1.07 (1.01-1.14)	1.06 (0.99-1.13)	1.05 (0.98-1.11)	1.05 (0.98-1.12)	1.01 (0.94-1.08)
Less disadvantaged 40-60%	1.06 (1.00-1.13)	1.06 (1.00-1.13)	1.06 (1.00-1.13)	1.06 (1.00-1.13)	1.01 (0.95-1.09)
Less disadvantaged 60-80%	1.01 (0.94-1.08)	1.01 (0.95-1.09)	1.01 (0.94-1.08)	1.01 (0.94-1.08)	1.01 (0.93-1.08)
Least disadvantaged 80-100%	1(ref)	1(ref)	1(ref)	1(ref)	1(ref)
ICC	0.014 (0.011-0.018)	0.014 (0.010-0.018)	0.014 (0.010- 0.018)	0.015 (0.011-0.019)	0.014 (0.011-0.020)

Abbreviations: CI, confidence interval; ICC, Intra-class Correlation Coefficient

Table 6.8. Univariable and multivariable analysis showing risk ratios (and their 95% confidence intervals) between **SES-WOA Welfare** and SMM compared to the least SES-WOA Welfare disadvantaged quintile. *Model 1: Adjusted for year, age, parity, migration status and ethnicity **Model 2: Model 1 + additionally adjusted for pre-existing medical conditions, smoking/substance misuse, and pre-existing mental health conditions ***Model 3: Model 1 + additionally adjusted for household disposable income. ****Model 4: Model 1 + additionally adjusted for individual-level measures of socioeconomic position (household income, educational attainment and employment status)

SES-WOA Welfare	**Univariable**	**Model 1***	**Model 2****	**Model 3*****	**Model 4********
	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)
Most disadvantaged 20%	1.32 (1.23-1.42)	1.24 (1.15-1.34)	1.17 (1.08-1.27)	1.21 (1.11-1.29)	1.14 (1.05-1.24)
More disadvantaged 20-40%	1.13 (1.05-1.22)	1.12 (1.03-1.21)	1.08 (0.99-1.17)	1.10 (1.01-1.81)	1.07 (0.98-1.17)
Less disadvantaged 40-60%	1.14 (1.05-1.23)	1.14 (1.05-1.23)	1.12 (1.04-1.22)	1.13 (1.04-1.22)	1.13 (1.03-1.22)
Less disadvantaged 60-80%	1.07 (0.99-1.15)	1.07 (0.99-1.16)	1.05 (0.97-1.15)	1.06 (0.98-1.15)	1.07 (0.97-1.16)
Least disadvantaged 80-100%	1(ref)	1(ref)	1(ref)	1(ref)	1(ref)
ICC	0.014 (0.011-0.019)	0.014 (0.010-0.018)	0.013 (0.010-0.017)	0.015 (0.011-0.019)	0.015 (0.011-0.020)

Abbreviations: CI, confidence interval; ICC, Intra-class Correlation Coefficient

Table 6.9. Univariable and multivariable analysis showing risk ratios (and their 95% confidence intervals) between neighbourhood **liveability** and SMM compared to the least neighbourhood liveability category. *Model 1: Adjusted for year, age, parity, migration status and ethnicity **Model 2: Model 1 + additionally adjusted for pre-existing medical conditions, smoking/substance misuse and pre-existing mental health conditions ***Model 3: Model 1 + additionally adjusted for SES-WOA. ****Model 4: Model 1 + additionally adjusted for individual-level measures of socioeconomic position (household income, educational attainment and employment status)

Liveability	**Univariable**	**Model 1***	**Model 2****	**Model 3*****	**Model 4********
	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)
Lowest	1.26 (1.16-1.36)	1.13 (1.04-1.23)	1.09 (1.00-1.19)	1.00 (0.91-1.10)	1.04 (0.95-1.14)
Lower	1.20 (1.11-1.29)	1.13 (1.04-1.23)	1.09 (1.01-1.18)	1.02 (0.94-1.11)	1.05 (0.97-1.15)
Middle	1.06 (1.00-1.12)	1.04 (0.98-1.10)	1.01 (0.95-1.08)	0.98 (0.92-1.04)	1.01 (0.94-1.07)
Higher	1.02 (0.96-1.08)	1.01 (0.95-1.08)	1.00 (0.94-1.06)	0.98 (0.92-1.05)	1.00 (0.93-1.07)
Highest	1(ref)	1(ref)	1(ref)	1(ref)	1(ref)
ICC	0.016 (0.012-0.021)	0.015 (0.011-0.020)	0.016 (0.012-0.021)	0.016 (0.012-0.020)	0.016 (0.012-0.020)

Abbreviations: CI, confidence interval; ICC, Intra-class Correlation Coefficient

Table 6.10. Univariable and multivariable analysis showing risk ratios (and their 95% confidence intervals) between **household disposable income** and SMM compared to the highest household disposable income quintile. *Model 1: Adjusted for year, age, parity, migration status and ethnicity **Model 2: Model 1 + additionally adjusted for pre-existing medical conditions, smoking/substance misuse and pre-existing mental health conditions ***Model 3: Model 1 + additionally adjusted for SES-WOA Welfare (multi-level model).

Household Disposable Income (euros)	**Univariable**	**Model 1***	**Model 2****	**Model 3*****
	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)
<20,000	1.40 (1.33-1.48)	1.33 (1.24-1.41)	1.27 (1.19-1.35)	1.29 (1.21-1.37)
20-39,999	1.31 (1.24-1.39)	1.30 (1.22-1.38)	1.23 (1.15-1.30)	1.26 (1.18-1.35)
40-59,999	1.17 (1.11-1.23)	1.19 (1.12-1.26)	1.15 (1.08-1.21)	1.17 (1.10-1.24)
60-79,999	1.05 (1.00-1.11)	1.07 (1.02-1.13)	1.05 (1.00-1.11)	1.06 (1.01-1.12)
80-100,000	1(ref)	1(ref)	1(ref)	1(ref)
ICC				0.015 (0.011-0.019)

Abbreviations: CI, confidence interval; ICC, Intra-class Correlation Coefficient

Table 6.11. Univariable and multivariable analysis showing risk ratios (and their 95% confidence intervals) between **unemployment** and SMM compared to employed women. *Model 1: Adjusted for year, age, parity, migration status and ethnicity **Model 2: Model 1 + additionally adjusted for pre-existing medical conditions, smoking/substance misuse and pre-existing mental health conditions ***Model 3: Model 1 + additionally adjusted for SES-WOA Employment (multi-level model)

Employment Status	**Univariable**	**Model 1***	**Model 2****	**Model 3*****
	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)
Unemployed	1.32 (1.28-1.37)	1.25 (1.20-1.30)	1.22 (1.17-1.27)	1.23 (1.18-1.28)
Employed	1(ref)	1(ref)	1(ref)	1(ref)
ICC				0.015 (0.011-0.019)

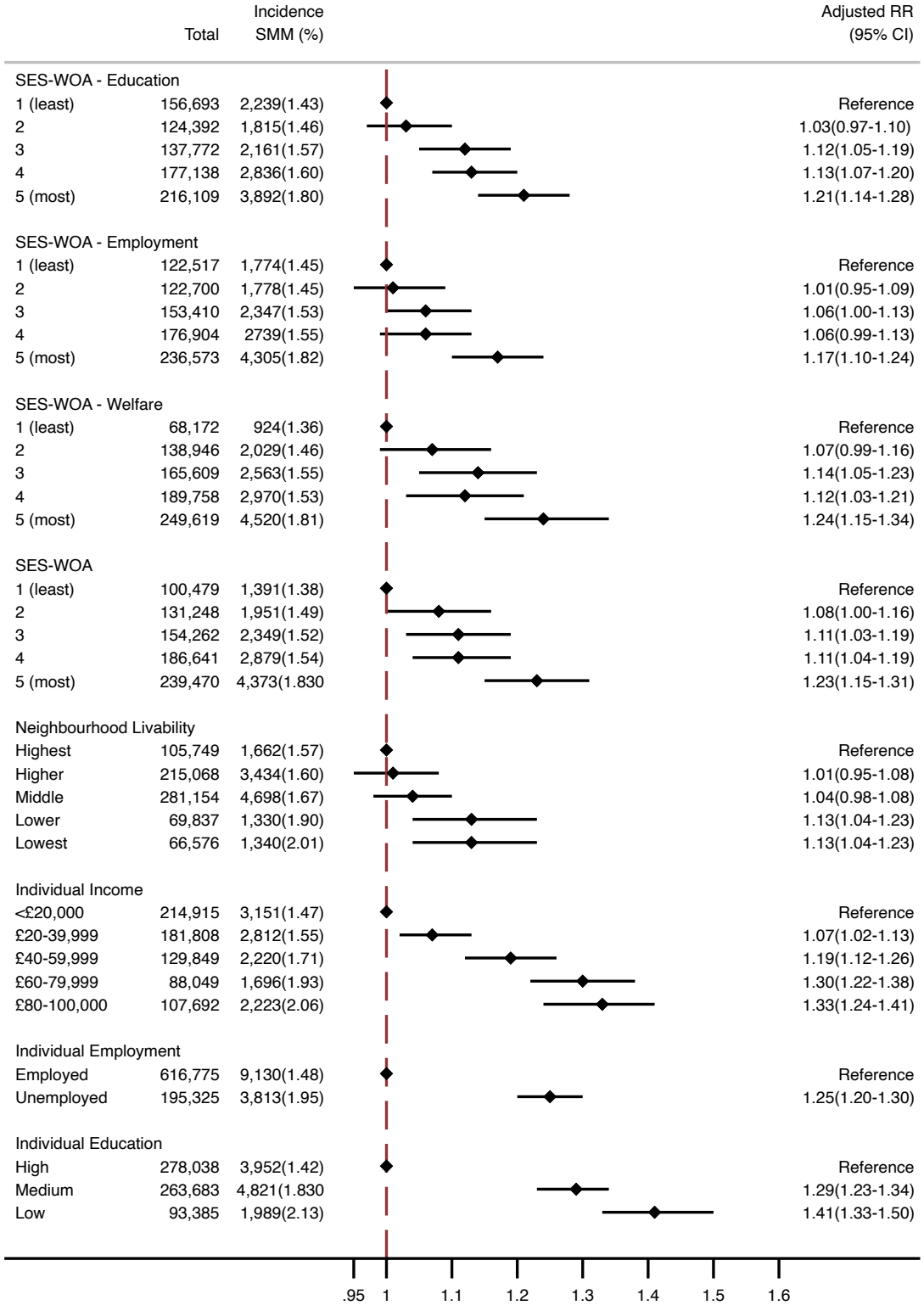
Abbreviations: CI, confidence interval; ICC, Intra-class Correlation Coefficient

Table 6.12. Univariable and multivariable analysis showing risk ratios (and their 95% confidence intervals) between **individual educational attainment** and SMM compared to women with the highest educational attainment. *Model 1: Adjusted for year, age, parity, migration status and ethnicity **Model 2: Model 1 + additionally adjusted for pre-existing medical conditions, smoking/substance misuse and pre-existing mental health conditions ***Model 3: Model 1 + additionally adjusted for SES-WOA Education (multi-level model)

Individual Educational Attainment	**Univariable**	**Model 1***	**Model 2****	**Model 3*****
	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)
Low	1.50 (1.43-1.59)	1.41 (1.33-1.50)	1.29 (1.22-1.37)	1.38 (1.30-1.46)
Medium	1.29 (1.24-1.35)	1.29 (1.23-1.34)	1.20 (1.15-1.25)	1.26 (1.20-1.32)
High	1(ref)	1(ref)	1(ref)	1(ref)
ICC				0.015 (0.011- 0.020)

Abbreviations: CI, confidence interval; ICC, Intra-class Correlation Coefficient

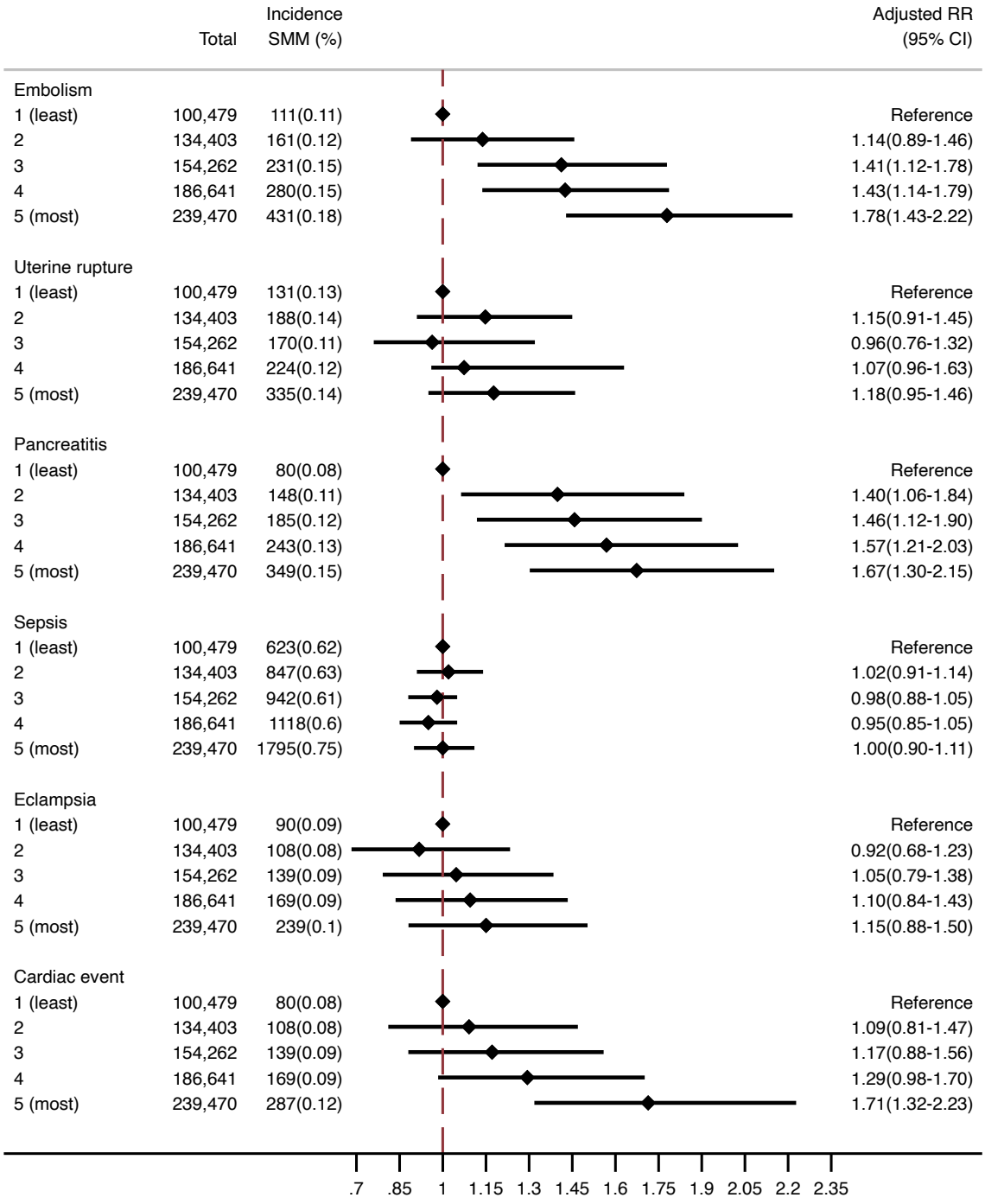
Figure 6.8. The risk ratios (and their 95% confidence intervals) of SMM in each category of the disadvantaged measures compared to the least disadvantage category. Least= least disadvantaged 80-100%, most = most disadvantaged 20%



Adjusted for age, ethnicity, parity and migration status

Figure 6.9 shows the association between the composite SES-WOA and the individual conditions comprising the highest proportion of SMM (>5%). There was a dose-response relationship between the increasingly disadvantaged SES-WOA quintile and acute cardiac events, embolic events and pancreatitis, with adjusted RRs of 1.71 (95% CI 1.32 -2.23), 1.78 (95% CI 1.43-2.22) and 1.67 (95% CI 1.30-2.15) in the most compared to the least disadvantaged quintile respectively. There was no evidence for an association between increasingly disadvantaged SES-WOA quintile and sepsis, uterine rupture, or eclampsia, compared to the least disadvantaged SES-WOA quintile.

Figure 6.9. The risk ratios (and their 95% confidence intervals) of each condition comprising the high proportion of SMM in each SES-WOA quintile compared to the least disadvantaged SES-WOA quintile (Model 1). Least= least disadvantaged 80-100%, most = most disadvantaged 20%



Adjusted for age, ethnicity, parity and migration status

6.4.5 Effect Modification

There was no evidence of effect modification between the neighbourhood-level measures and their corresponding individual-level measures (LRT test: p=0.57, p=0.83 and p=0.20 for income, employment and education, respectively). There was evidence for effect modification between ethnicity and household disposable income (p=0.03), individual employment (p=0.02) and SES-WOA Education (p=0.045) and the risk of SMM. The number of women, the incidence (%) of SMM and the adjusted RRs (and their 95% CI) in each of these measures compared to the least disadvantaged group stratified by ethnicity are shown in **Appendix Tables 6.6-6.8.** The adjusted average predictive margins (and 95% CIs) of each disadvantage group stratified by ethnicity using Caucasian women with the least disadvantage, as the reference group are shown in **Figures 6.10-6.12**. Being unemployed increased the risk of SMM across all ethnic groups, but it was particularly pronounced for unemployed Mediterranean (Turkish and North African) women, who had an estimated 3.0% (95% CI 2.5%-3.5%) probability of SMM compared to employed Mediterranean women, whose probability of SMM was 2.2% (95% CI 1.9%-2.6%). A dose-response relationship was demonstrated for Caucasian women with decreasing household disposable income associated with increasing probability of SMM. A dose-response relationship was not seen for minoritised ethnic women, although for Mediterranean, Other African and Other Asian women, having a household disposable income of less than €40,000 was associated with a higher probability of SMM, compared with those with a household disposable income of between €60,000 and €100,000. Contrastingly, in the association between SES-WOA Education and SMM, there was a small dose-response for Caucasian women with an increasing risk of SMM as the average neighbourhood education decreased, but this was not seen in any of the minoritised ethnic groups.

Figure 6.10. The average adjusted predictive margins (%) (and their 95% confidence intervals) of SMM for unemployed and employed women stratified by ethnicity

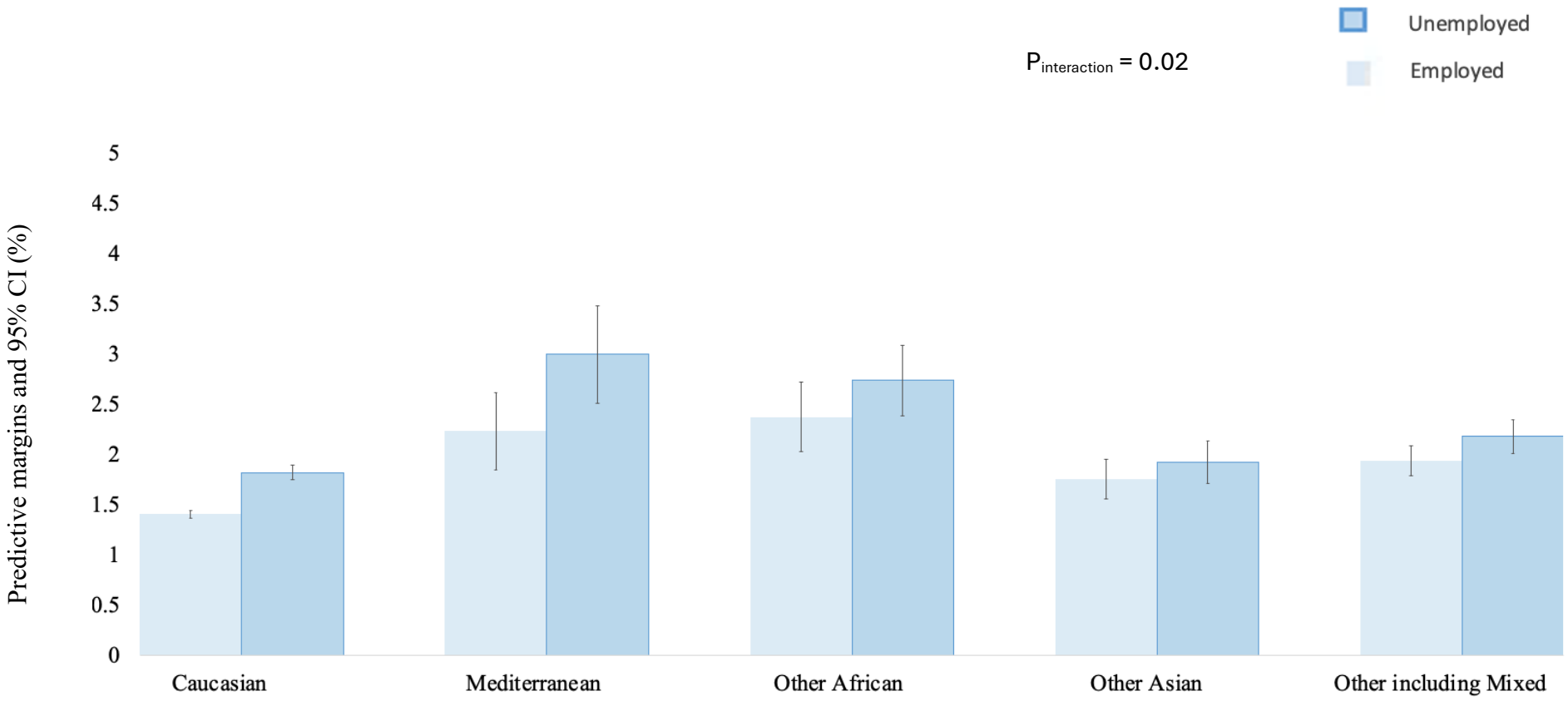


Figure 6.11. The average adjusted predictive margins (%) (and their 95% confidence intervals) of SMM in each household disposable income quintile stratified by ethnicity

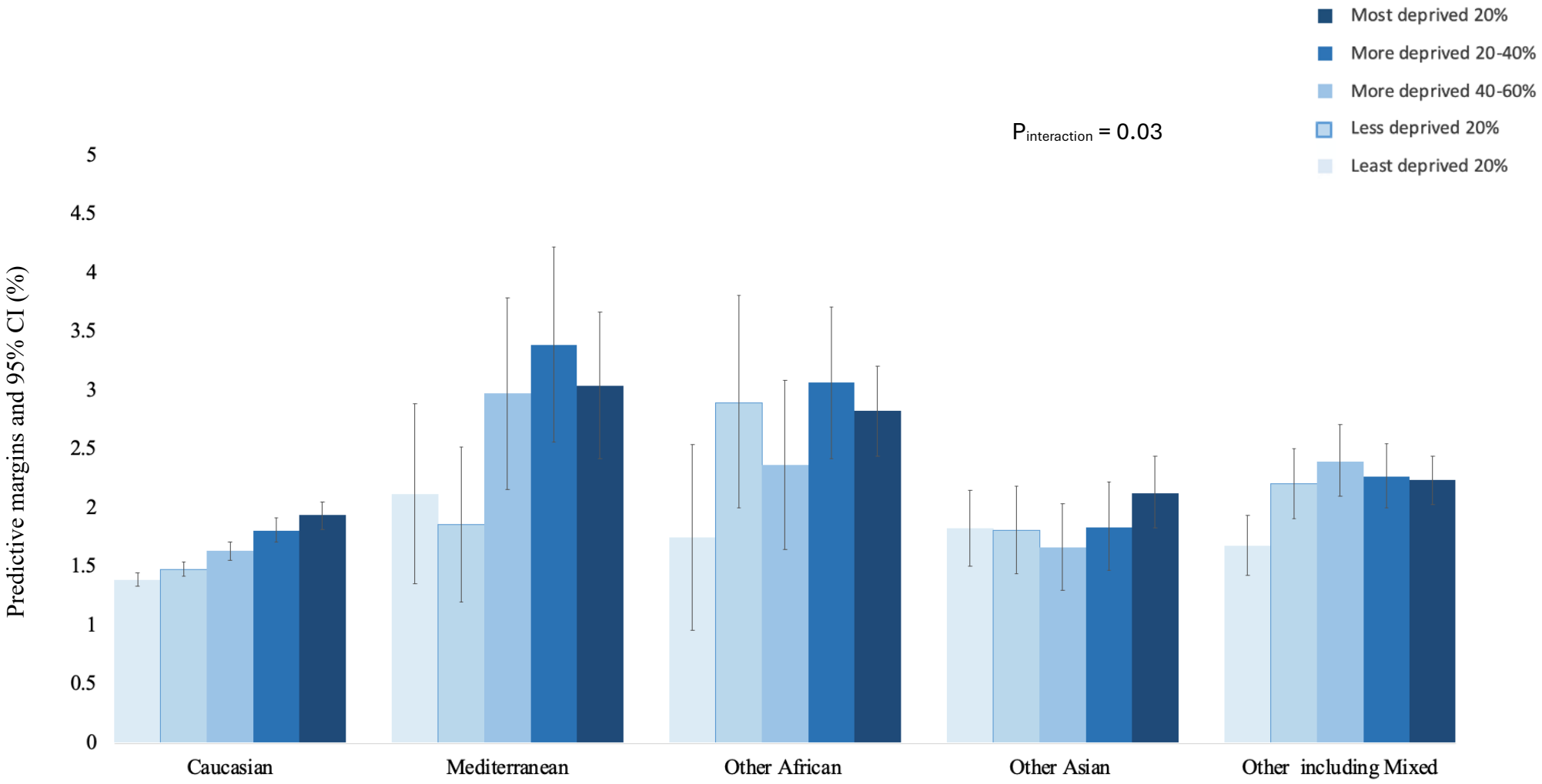
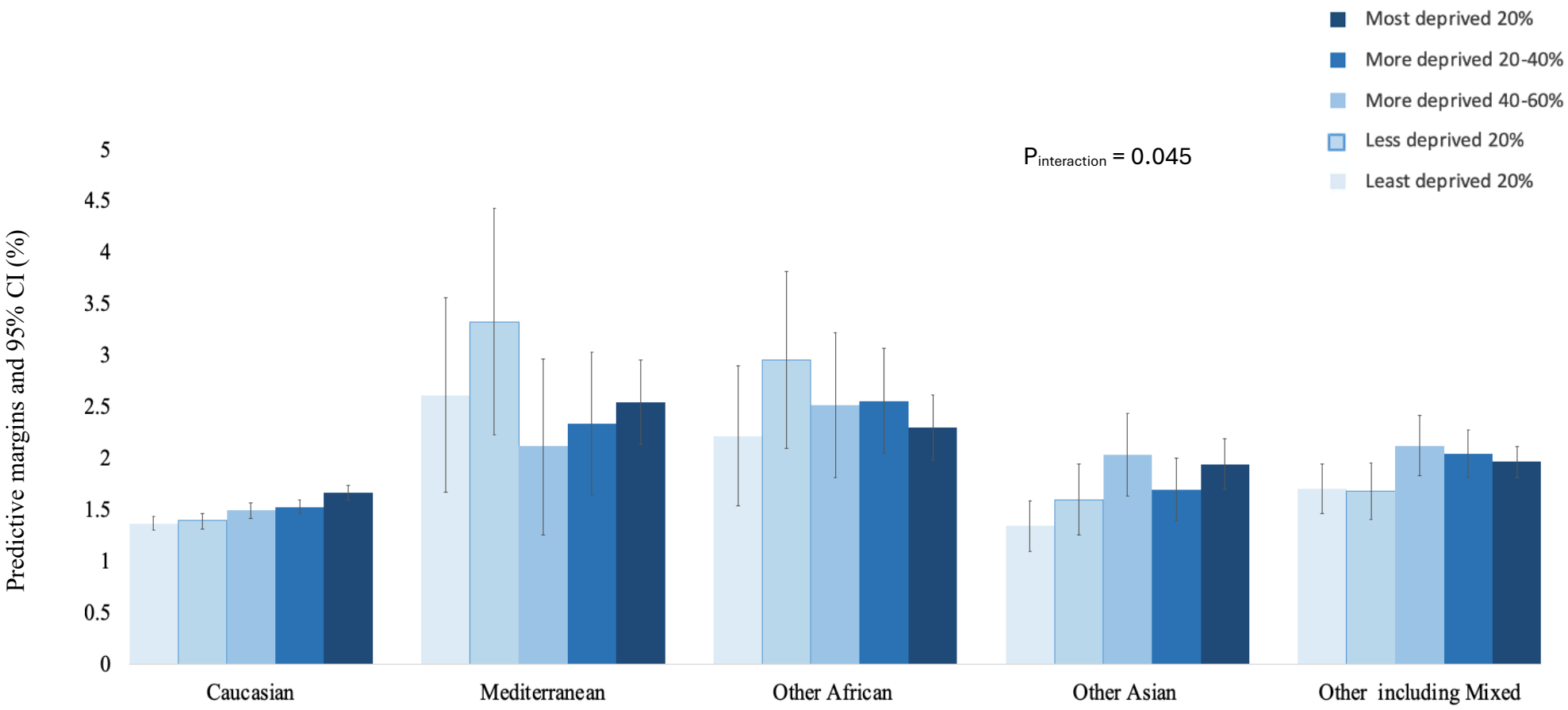


Figure 6.12. The average adjusted predictive margins (%) (and their 95% confidence intervals) of SMM in each SES-WOA Education quintile stratified by ethnicity



6.4.6 Population Attributable Fractions (PAFs)

Across the different measures of disadvantage, individual educational attainment had the highest adjusted PAFs with 15.3% (95% CI 13.0%-17.5%) of SMM attributable to educational attainment measured on an individual level. The largest adjusted PAF in the neighbourhood-level measures was for the SES-WOA Welfare, where 12.2% (95% CI 6.3%-17.6%) of SMM was attributable to neighbourhood income.

Individual educational attainment again had the highest PAFs where socioeconomic and ethnic inequalities were combined, with 19.4% (95% CI 17.1%-21.7%) of SMM attributable to educational attainment measured at the individual level and ethnic inequalities. SES-WOA Welfare and ethnic inequalities had the highest adjusted PAF in the neighbourhood-level measures with 17.2% (95% CI 11.4%-22.6%) of SMM being attributable to neighbourhood income and ethnic inequalities. Finally, when Caucasian-Dutch native women in the highest socioeconomic groups were used as the reference population, individual educational attainment continued to be the highest adjusted PAF, with 21.3% (95% CI 18.8%-23.7%) of SMM attributable to individual educational attainment, ethnic and migration related inequalities (**Table 6.13**).

Table 6.13. Univariable and multivariable population attributable fractions (PAFs) of the different measures of socioeconomic disadvantage using the least disadvantaged groups of women across all ethnicities, the least disadvantaged groups of Caucasian women and the least disadvantaged groups of Caucasian Dutch native women as the reference group. The multivariable analysis adjusted for year, parity and age (and migration status and ethnicity when comparing to the least disadvantaged women across all ethnicities and migration status)

Category	Unadjusted % (95% CI)	Adjusted % (95% CI)
Compared to the least disadvantaged women (all ethnicities)		
Reference group		
Highest educational attainment	16.3 (14.2-18.3)	15.3 (13.0-17.5)
Employed	7.2 (6.2-8.2)	5.6 (4.5-6.7)
Highest disposable income	12.4 (9.7-14.9)	12.0 (9.1-14.8)
Highest liveability neighbourhood	6.4 (1.8-10.8)	5.7 (0.5-10.5)
Live in the highest SES-WOA Employment neighbourhoods	9.4 (5.3-13.3)	6.8 (2.4-11.0)
Live in the highest SES-WOA Education neighbourhoods	11.2 (7.5-14.7)	9.9 (6.1-13.5)
Live in the highest SES-WOA Welfare neighbourhoods	12.4 (8.8-19.6)	12.2 (6.3-17.6)
Live in highest SES-WOA neighbourhoods	13.0 (8.4-17.3)	11.1 (6.3-15.6)
Compared to the least disadvantaged Caucasian women		
Reference group		
Caucasian and have the highest educational attainment	18.6 (16.4-20.8)	19.4 (17.1-21.7)
Caucasian and employed	10.7 (9.4-12.0)	11.8 (10.3-13.2)
Caucasian and the highest household disposable income quintile	14.0 (11.2-16.8)	16.8 (13.9-19.7)
Caucasian and live in the highest liveability neighbourhoods	8.4 (3.6-13.1)	9.2 (4.2-13.9)
Caucasian and live in in highest SES-WOA Employment neighbourhoods	12.3 (7.9-16.6)	12.7 (8.3-17.0)
Caucasian and live in highest SES-WOA Education neighbourhoods	13.6 (9.7-17.4)	14.7 (10.8-18.5)
Caucasian and live in highest SES-WOA Welfare neighbourhoods	16.4 (10.6-21.8)	17.2 (11.4-22.6)
Caucasian and live in highest SES-WOA neighbourhoods	16.1 (11.2-20.7)	16.7 (11.9-21.3)
Compared to the least disadvantaged Caucasian Dutch native women		
Reference group		
Caucasian Dutch native and have the highest educational attainment	13.9 (9.9-17.7)	21.3 (18.8-23.7)
Caucasian Dutch native and employed	11.5 (7.0-15.8)	10.9 (9.3-12.4)
Caucasian Dutch native and the highest household disposable income quintile	15.6 (10.8-20.3)	16.8 (13.6-19.8)
Caucasian Dutch native and live in the highest liveability neighbourhoods	10.1 (4.9-15.0)	9.6 (4.4-14.5)
Caucasian Dutch native and live in the highest SES-WOA Employment neighbourhoods	11.5 (6.8-16.0)	11.1 (6.6-15.4)
Caucasian Dutch native and live in the highest SES-WOA Education neighbourhoods	15.8 (11.5-19.8)	15.7 (11.6-19.6)
Caucasian Dutch native and live in the highest SES-WOA Welfare neighbourhoods	14.8 (8.6-20.6)	14.2 (8.1-19.9)
Caucasian Dutch native and live in the highest SES-WOA neighbourhood	16.0 (10.9-21.7)	15.4 (10.2-20.3)

Abbreviations: CI, confidence interval

6.4.7 Causal Mediation Analysis

When examining mental health problems as a mediator in the association between the different measures of disadvantage and SMM, the NDE explained most of the effect, highlighting that much of the risk of each disadvantage measure is independent of mental health problems. There was only evidence of mental health problems mediating the effects of neighbourhood liveability and individual educational attainment, and SMM, with 10% and 7% of the total effects mediated, respectively (**Table 6.14**).

Contrastingly, the mediation effects of pre-existing medical conditions (excluding conditions which are closely related to obesity) were more significant and were seen across all measures of disadvantage, with the greatest proportion mediated between neighbourhood liveability and SMM (26%), although the total effects were small (TE: 1.17 (95% CI 1.07-1.27)) and individual educational attainment and SMM where 22% of the total effects (1.51 (95% CI 1.42-1.60) were mediated by pre-existing medical conditions (**Table 6.15**).

Table 6.14. Causal mediation analysis of the association between the different measures of socioeconomic disadvantage and SMM mediated by mental health problems.

Category	Household Disposable Income	Educational Attainment	Employment	SES-WOA	SES-WOA Employment	SES-WOA Welfare	SES-WOA Education	Liveability
Outcome Model								
	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)
Measure of disadvantage	1.34 (1.25-1.44)	1.38 (1.29-1.48)	1.20 (1.15-1.26)	1.27 (1.18-1.36)	1.20 (1.12-1.28)	1.28 (1.18-1.39)	1.20 (1.13-1.27)	1.12 (1.02,1.23)
Mental health problem	1.37 (1.23-1.52)	1.34 (1.22-1.48)	1.33 (1.25-1.41)	1.59 (1.38-1.84)	1.55 (1.36-1.75)	1.59 (1.34-1.89)	1.33 (1.18-1.51)	1.53 (1.33-1.76)
Interaction*	1.12 (0.97-1.30)	1.16 (1.01-1.33)	1.23 (1.11-1.35)	0.91 (0.78-1.07)	0.91 (0.78-1.07)	0.92 (0.76-1.11)	1.14 (0.98-1.32)	1.06 (0.87-1.29)
Mediator Model								
	Odds Ratio (95% CI)	Odds Ratio (95% CI)	Odds Ratio (95% CI)	Odds Ratio (95% CI)	Odds Ratio (95% CI)	Odds Ratio (95% CI)	Odds Ratio (95% CI)	Odds Ratio (95% CI)
Mental Health problem	1.65 (1.61-1.70)	1.89 (1.84-1.94)	1.34 (1.32-1.37)	1.22 (1.18-1.25)	1.07 (1.04-1.10)	1.19 (1.6-1.23)	1.28 (1.25-1.31)	1.33 (1.28-1.38)
Mediation								
	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)
Controlled direct effects	1.34 (1.25-1.44)	1.38 (1.29-1.48)	1.20 (1.15-1.26)	1.27 (1.18-1.36)	1.11 (1.03-1.19)	1.28 (1.18-1.39)	1.20 (1.13-1.27)	1.12 (1.02-1.23)
Natural direct effects	1.36 (1.27-1.45)	1.40 (1.32-1.49)	1.23 (1.18-1.29)	1.25 (1.17-1.33)	1.10 (1.02-1.17)	1.36 (1.27-1.45)	1.22 (1.15,1.28)	1.13 (1.04-1.23)
Natural indirect effects	1.02 (1.01-1.02)	1.03 (1.02-1.04)	1.02 (1.01-1.02)	1.01 (1.01-1.01)	1.00 (1.00-1.00)	1.02 (1.01-1.03)	1.01 (1.01-1.01)	1.01 (1.01-1.02)
Total effects	1.39 (1.30-1.49)	1.45 (1.36-1.54)	1.25 (1.20-1.31)	1.26 (1.18-1.34)	1.10 (1.03-1.17)	1.28 (1.19-1.38)	1.23 (1.16-1.30)	1.15 (1.05-1.25)
Proportion mediated (%)	6.0 (-1.0-13.0)	7.0 (1.0-13.0)	6.0 (-2.0-10.0)	3.0 (-3.0-9.0)	3.0 (-3.0-9.0)	2.0 (-5.0-9.0)	5.0 (-1.0-11.0).	10.0 (1.0-19.0)

***Interaction between measure of disadvantage and pre-existing mental health conditions*
****Abbreviations: CI, confidence interval*

Table 6.15. Causal mediation analysis of the association between the different measures of socioeconomic disadvantage and SMM mediated by pre-existing medical conditions (excluding ischemic heart disease, hypertension and diabetes).

Category	Household Disposable Income	Educational Attainment	Employment	SES-WOA	SES-WOA Employment	SES-WOA Welfare	SES-WOA Education	Liveability
Outcome Model								
	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)
Measure of disadvantage	1.25 (1.16-1.36)	1.25 (1.15-1.36)	1.15 (1.09-1.21)	1.23 (1.13-1.33)	1.16 (1.08-1.25)	1.26 (1.14-1.38)	1.14 (1.07-1.22)	1.10 (0.99-1.22)
Pre-existing medical condition	1.73 (1.60-1.86)	1.76 (1.65-1.88)	1.79 (1.71-1.86)	1.92 (1.72-2.13)	1.88 (1.71-2.07)	1.93 (1.70-2.21)	1.68 (1.54-1.83)	2.00 (1.80-2.21)
Interaction*	1.21 (1.08-1.35)	1.25 (1.12-1.39)	1.22 (1.13-1.32)	1.02 (0.90-1.15)	1.04 (0.93-1.17)	1.00 (0.86-1.15)	1.16 (1.04-1.29)	1.05 (0.91-1.22)
Mediator Model								
	Odds Ratio (95% CI)	Odds Ratio (95% CI)	Odds Ratio (95% CI)	Odds Ratio (95% CI)	Odds Ratio (95% CI)	Odds Ratio (95% CI)	Odds Ratio (95% CI)	Odds Ratio (95% CI)
Pre-existing medical condition	1.51 (1.48-1.54)	1.80 (1.77-1.83)	1.20 (1.18-1.21)	1.21 (1.19-1.23)	1.14 (1.12-1.16)	1.20 (1.17-1.22)	1.30 (1.28-1.32)	1.29 (1.26-1.33)
Mediation								
	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)
Controlled direct effects	1.25 (1.16-1.36)	1.25 (1.15-1.36)	1.16 (1.08-1.25)	1.23 (1.13-1.33)	1.16 (1.08-1.25)	1.26 (1.14-1.28)	1.14 (1.07-1.22)	1.10 (0.99-1.22)
Natural direct effects	1.35 (1.26-1.44)	1.36 (1.27-1.44)	1.18 (1.11-1.25)	1.24 (1.16-1.32)	1.18 (1.11-1.25)	1.25 (1.16-1.35)	1.20 (1.14-1.27)	1.12 (1.03-1.22)
Natural indirect effects	1.07 (1.06-1.08)	1.11 (1.10-1.13)	1.02 (1.02-1.02)	1.03 (1.02-1.03)	1.02 (1.02-1.02)	1.03 (1.02-1.03)	1.04 (1.03-1.04)	1.04 (1.03-1.05)
Total effects	1.44 (1.35-1.54)	1.51 (1.42-1.60)	1.20 (1.13-1.27)	1.27 (1.19-1.36)	1.20 (1.13-1.27)	1.29 (1.19-1.39)	1.25 (1.18-1.32)	1.17 (1.07-1.27)
Proportion mediated (%)	16.0 (9.0-23.0)	22.0 (16.0-28.0)	11.0 (7.0-15.0)	10.0 (4.0-17.0)	10.0 (4.0-16.0)	9.0 (2.0-17.0)	16.0 (0.10-0.21)	26.0 (17.0-36.0)

**Interaction between measure of disadvantage and pre-existing medical conditions*
Abbreviations: CI, confidence interval

6.4.8 Sensitivity Analyses

There were no notable differences when acute pancreatitis was excluded from the outcome (**Appendix Table 6.9**).

Effect modification by ethnicity and migration status was found between individual educational attainment ($p<0.001$), individual employment ($p<0.001$) and household disposable income ($p<0.001$). **Figures 6.13-6.15** show the average adjusted predictive margins (and 95% CIs) of each disadvantage category stratified by ethnicity and migration status using the Dutch native Caucasian, least disadvantaged woman as the reference group. The corresponding RRs (and their 95% CI), the incidence of SMM (%) and the total number of women in each ethnic and migrant group are shown in **Appendix Tables 6.10-6.12.** There appeared to be an association between increasing disadvantage across all the disadvantage measures for Caucasian and minoritised ethnic Dutch native women, which was not seen for Caucasian and minoritised ethnic non-Dutch native women. There was no change in the evidence for effect modification by ethnicity, or ethnicity and migration status, when fixed effects models were used for neighbourhood-level measures.

Migrants (including both Caucasian and minoritised ethnic migrants) were more likely to have a lower socioeconomic position than Dutch native women, including Dutch native women from a minoritised ethnic group. When individual-level measures were cross tabulated with their corresponding neighbourhood measure, and stratified by ethnicity and migration status, women from minoritised ethnic groups and migrant women were more likely to have their individual socioeconomic position misclassified than Netherlands born women if they lived in the least disadvantaged areas (**Appendix Tables 6.13-6.18**).

Table 6.16 shows the proportion of the total effect of the different measures of disadvantage mediated by pre-existing medical conditions, including those closely related to obesity (ischaemic heart disease, hypertension and diabetes). The proportion mediated was more significant, with 29% and 25% of the association between neighbourhood liveability and individual educational attainment being mediated by pre-existing medical conditions, respectively. Pre-existing medical and mental health conditions were lower in migrant women than in Dutch women for both Caucasian and minoritised ethnic women (**Appendix Table 6.19**).

When the neighbourhood-level measures were recategorised to match their corresponding individual-level measure proportionally, the individual-level measures continued to have the strongest association with SMM compared to the neighbourhood-level measures with adjusted RRs of 1.25 (95% CI 1.17-1.33), 1.14 (95% CI 1.09-1.19) and 1.22 (95% 1.15-1.28) in the most disadvantaged compared to the least disadvantaged of SESWOA Welfare, SES-WOA Employment and SES-WOA Education, respectively (**Appendix Tables 6.20-6.22**).

Excluding sepsis from the composite outcome resulted in a stronger association among all aspects of disadvantage. Individual education remained the most significant factor, as women with low educational attainment displayed a 97% (95% CI 1.81-2.10) higher risk of SMM than those with high educational attainment (**Appendix Table 6.23).**

Figure 6.13. The average adjusted predictive margins (%) (and their 95% confidence intervals) of SMM for unemployed and employed women stratified by ethnicity and migration status

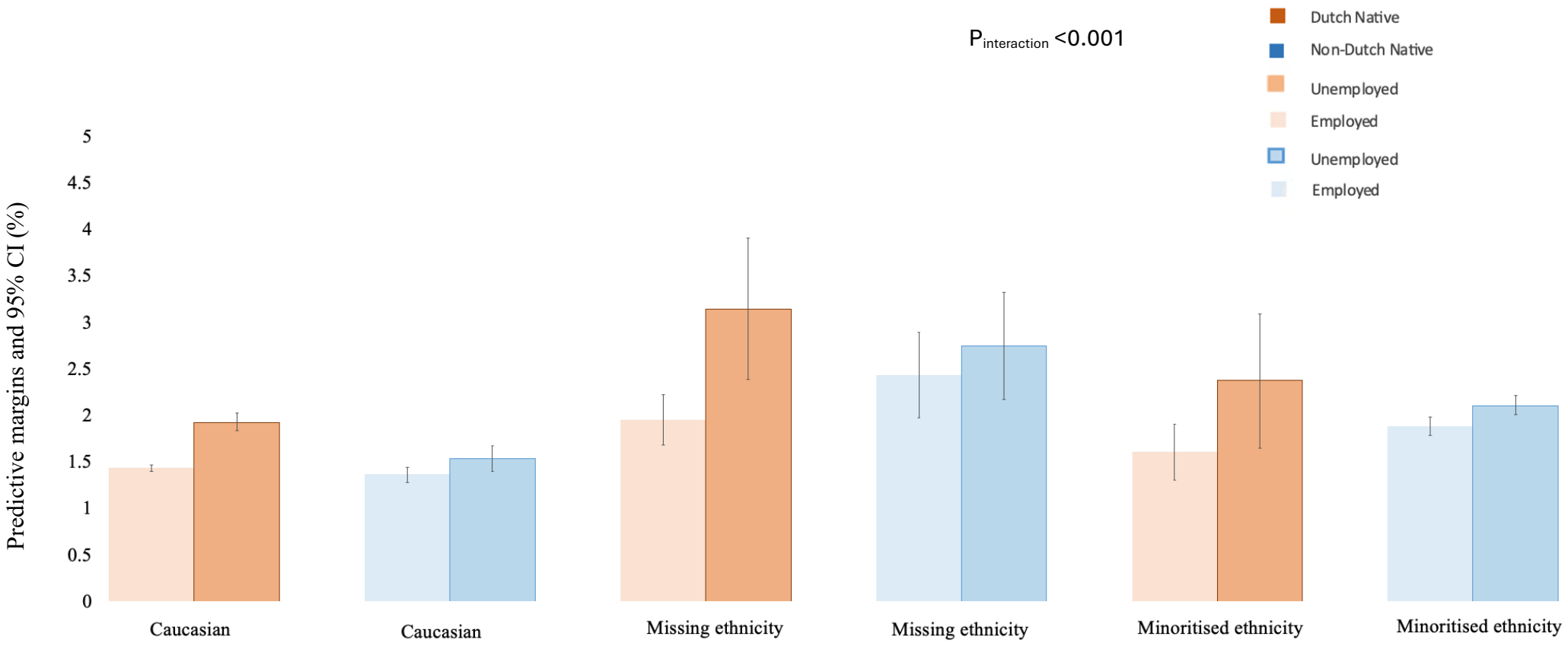


Figure 6.14. The average adjusted predictive margins (%) (and their 95% confidence intervals) of SMM in each household disposable income quintile stratified by ethnicity and migration status

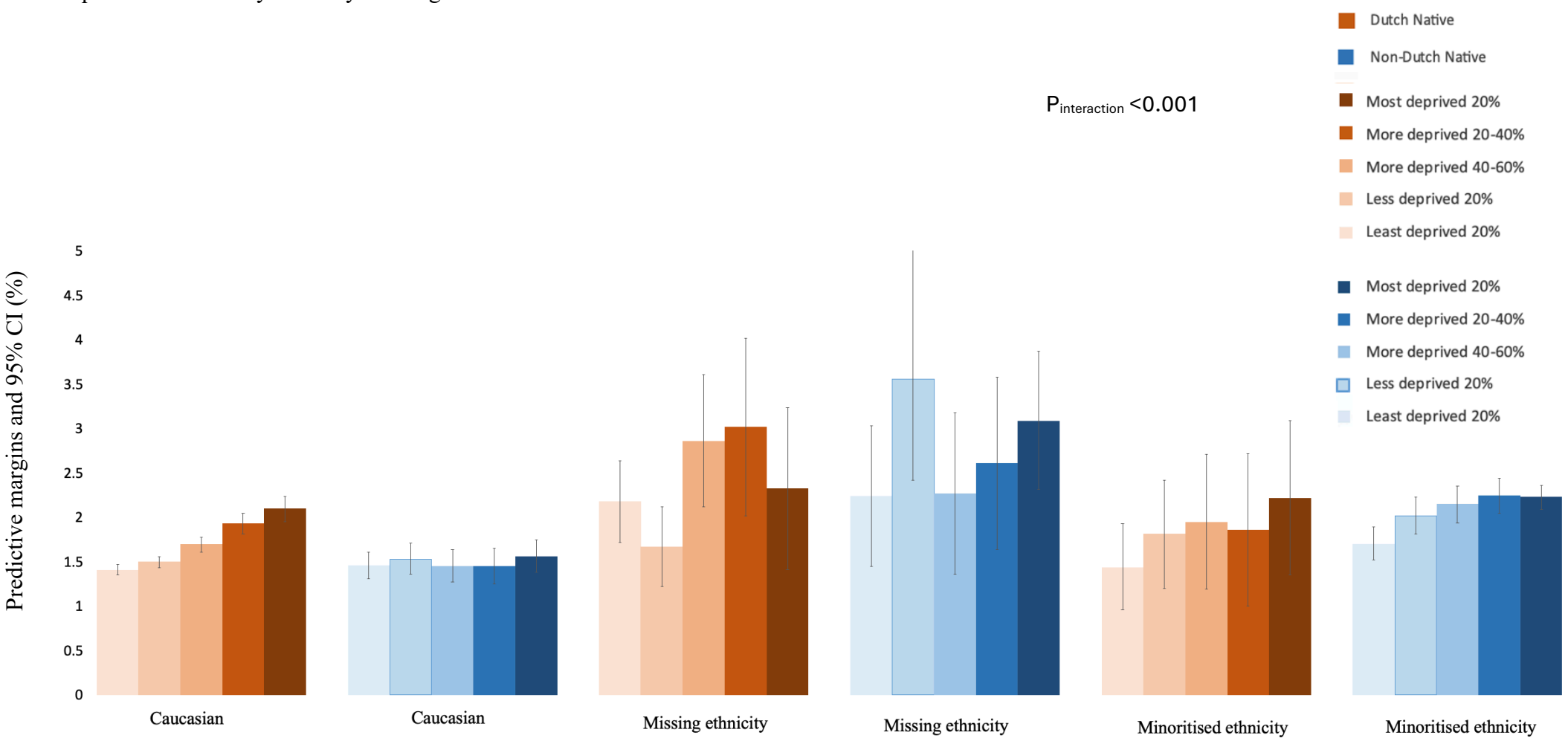


Figure 6.15. The average adjusted predictive margins (%) (and their 95% confidence intervals) of SMM at each level of educational attainment stratified by ethnicity and migration status

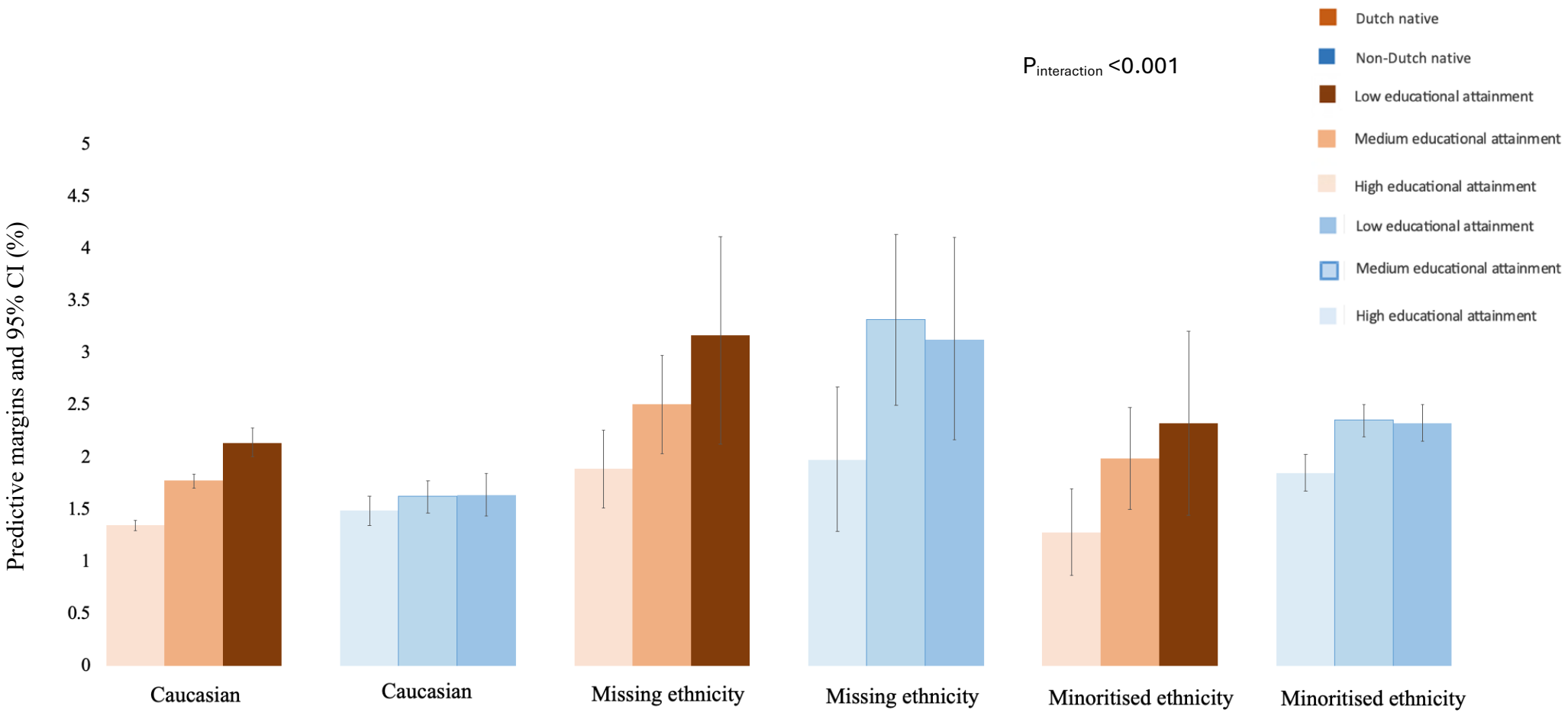


Table 6.16. Causal mediation analysis of the association between the different measures of socioeconomic disadvantage and SMM mediated by pre-existing medical conditions (including ischaemic heart disease, hypertension and diabetes)

Category	Household Disposable Income	Individual Educational Attainment	Employment Status	SES-WOA	SES-WOA Employment	SES-WOA Welfare	SES-WOA Education	Liveability
Outcome Model								
	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)
Measure of disadvantage*	1.22 (1.12–1.32)	1.20 (1.10–1.30)	1.14 (1.08–1.2)	1.20 (1.10–1.30)	1.14 (1.06–1.23)	1.23 (1.11–1.35)	1.11 (1.04–1.19)	1.07 (0.96–1.19)
Pre-existing medical conditions	1.79 (1.66–1.92)	1.81 (1.69–1.93)	1.87 (1.79–1.95)	1.96 (1.76–2.18)	1.95 (1.78–2.15)	1.97 (1.73–2.25)	1.74 (1.59–1.89)	2.03 (1.84–2.25)
Interaction**	1.27 (1.13–1.41)	1.32 (1.19–1.48)	1.23 (1.14–1.33)	1.06 (0.94–1.20)	1.07 (0.96–1.19)	1.05 (0.91–1.21)	1.21 (1.09–1.35)	1.09 (0.94–1.27)
Mediator Model								
	Odds Ratio (95% CI)	Odds Ratio (95% CI)	Odds Ratio (95% CI)	Odds Ratio (95% CI)	Odds Ratio (95% CI)	Odds Ratio (95% CI)	Odds Ratio (95% CI)	Odds Ratio (95% CI)
Pre-existing medical conditions	1.53 (1.50–1.56)	1.82 (1.78–1.85)	1.20 (1.19–1.22)	1.22 (1.20–1.24)	1.14 (1.12–1.16)	1.20 (1.18–1.23)	1.32 (1.30–1.34)	1.30 (1.26–1.33)
Mediation								
	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)
Controlled direct effects	1.22 (1.12–1.32)	1.20 (1.1–1.30)	1.14 (1.08–1.2)	1.20 (1.10–1.3)	1.14 (1.06–1.23)	1.23 (1.11–1.35)	1.11 (1.04–1.19)	1.07 (0.96–1.19)
Natural direct effects	1.33 (1.25–1.43)	1.34 (1.25–1.42)	1.24 (1.19–1.29)	1.23 (1.16–1.31)	1.17 (1.11–1.24)	1.25 (1.16–1.34)	1.19 (1.13–1.26)	1.11 (1.02–1.21)
Natural indirect effects	1.08 (1.07–1.09)	1.13 (1.11–1.15)	1.04 (1.03–1.04)	1.03 (1.03–1.04)	1.02 (1.02–1.03)	1.03 (1.03–1.03)	1.05 (1.04–1.05)	1.05 (1.04–1.06)
Total effects	1.44 (1.35–1.54)	1.51 (1.42–1.6)	1.29 (1.24–1.34)	1.27 (1.19–1.35)	1.20 (1.13–1.27)	1.29 (1.19–1.38)	1.25 (1.18–1.32)	1.17 (1.07–1.27)
Proportion mediated (%)	19.0 (12.0-26.0)	25.0 (19.0–32.0)	13.0 (9.0–17.0)	12.0 (6.0–18.0)	11.0 (5.0–17.0)	11.0 (4.0–18.0)	19.0 (14.0–25.0)	29.0 (20.0–38.0)

**Interaction between measure of disadvantage and pre-existing medical conditions*
***Abbreviations: CI, confidence interval*

6.4.9 Missing Data

Appendix Table 6.24 shows the characteristics of the women who had missing data on SES-WOA and were therefore excluded from the cohort. Women who were more likely to have missing information on SES-WOA were non-Dutch native compared to Dutch native (RR 2.09 (95% CI 2.06-2.11)), from a minoritised ethnic group compared to Caucasian women (RR 2.10 (95% CI 2.07-2.13)), and over the age of 35 compared to aged 10-35 (RR 1.38 (95% CI 1.36-1.40)). Women who were less likely to have missing information on SES-WOA were multiparous women compared to primiparous women (RR 0.88 (95% CI 0.87-0.89)) and were women who had SMM compared to those with no SMM (RR 0.87 (95% CI 0.82-0.91)). This suggests that the data were missing at random (MAR).

Appendix Table 6.25 shows the characteristics of the women who had missing data on household disposable income, individual educational attainment and neighbourhood liveability. There were no material differences between the characteristics of the women who had missing data on neighbourhood liveability or household disposable income compared to those who did not, although women with missing data on household disposable income were less likely to have SMM recorded (RR 0.59 (95% CI 0.55-0.63)). However, the women who had missing data on individual educational level were more likely to be older (p_{trend} $p<0.001$), be from a minoritised ethnicity group (RR 1.72 (95% CI 1.71- 1.74)), have not been born in the Netherlands (RR 2.09 (95% CI 2.07-2.11)) and were also less likely to have had SMM recorded (RR 0.77 (95% CI 0.74-0.81)). The results of the multiple imputation of individual educational level and household disposable income were not materially different from the complete case analysis (**Appendix Tables 6.26 and 6.27**).

The amount of missing data on the covariates included in the multi-level models was low (<2.5%) (**Appendix Table 6.28**). The multi-level model had no missing data on postcode (Level 2).

6.5 Discussion

6.5.1 Main Findings

This nationwide study that used three linked databases (Perined, DHD and SSD) and included 832,866 maternities from 2013-2021 showed an overall incidence of SMM to be 16 per 1000 maternities in the Netherlands. The individual-level measures of socioeconomic disadvantage had the strongest association with SMM, with women with low educational attainment compared to high educational attainment, having the highest risk of SMM. Additionally, the intersection of disadvantage, ethnicity, and migration had a varying impact on SMM, contingent on the particular measure of disadvantage. Notably, Netherlands-born women appeared to have a clearer dose-response relationship, with increased risk for SMM with increasing individual-level disadvantage, than migrant women, regardless of their ethnicity. However, women from minoritised ethnic groups had a greater overall probability of SMM compared to Caucasian women. Pre-existing medical conditions were found to mediate the association between all the measures of disadvantage and SMM, with the greatest proportion mediated if conditions associated with obesity, such as hypertension, diabetes and ischemic heart disease were included in the composite of pre-existing medical conditions.

6.5.1.1 Pattern in SMM

The incidence of SMM remained relatively stable over time, then decreased in 2020 and 2021, which aligns with the date of the Covid-19 pandemic. This decrease was also found in the English data. As discussed in **Chapter 4**, this may be explained by healthcare access

disruptions or clinical management alterations during this period, or a change in recording practices and underreporting. Furthermore, the incidence of SMM was notably lower in 2013, which may be driven by the change in the registry of hospital data (from LMR to LBZ) between 2012 and 2013. Similar to the findings from the English data analysis, sepsis comprised the greatest proportion (40%) of SMM, with an incidence of 65 in 10,000 maternities. Embolic events, acute cardiac events, uterine rupture, eclampsia and acute pancreatitis also contributed to a significant proportion of the SMM outcome. The incidence of these conditions was similar to their incidence in England (the exception was acute pancreatitis, which had a higher incidence in the Netherlands, though this may be attributable to misclassification). However, these conditions comprised a greater proportion of the SMM outcome in the Netherlands than in England, as DIAPER did not include SMM procedures (OPCS-4 codes).

6.5.1.2 Risk of SMM by the Different Measures of Socioeconomic Disadvantage

Women living in the most disadvantaged neighbourhoods in the Netherlands, measured using the composite SES-WOA, had a 23% increased risk of SMM compared to those living in the least. The SMM risk gap between the most and least disadvantaged women appeared relatively stable over the study period. The key conditions driving this increased risk included embolism, cardiac events and acute pancreatitis, conditions associated with smoking and obesity (214-216). Although the database appears to inadequately capture data on smoking and obesity, it still suggests a higher prevalence of these risk factors in the most disadvantaged neighbourhoods.

Socioeconomic disadvantage was associated with SMM across all the measures. However, individual-level measures appeared to have a stronger association with SMM than neighbourhood-level measures. This was especially evident when the size of the groups of the neighbourhood-level measures was reclassified from quintiles to match the size of the

denominator of the individual-level measure classifications. This difference in strength of association may be explained by the misclassification of socioeconomic position, demonstrated in the cross-tabulation of the individual- and neighbourhood-level measures, highlighting that many women living in the most disadvantaged areas are not individually disadvantaged. Although weakly to moderately correlated, a woman's level of neighbourhood disadvantage was relatively poor in predicting her individual socioeconomic position across all measures. Other research, such as a study with 3.5 million participants in the US (217), also identified weak correlations between individual education, employment and income with their respective neighbourhood-level measures. Notably, in the US study the weakest correlation was observed for employment, while the strongest was identified for income. Furthermore, this US study found that neighbourhood-level socioeconomic position measures underestimated the individual socioeconomic position-related mortality due to misclassification between individual- and neighbourhood-level measures.

At a population level, the proportion of SMM attributable to individual- and neighbourhood-level socioeconomic disadvantage was similar. However, as the strength of the association between neighbourhood-level disadvantage and SMM appears weaker than between individual-level disadvantage, this finding is likely driven by the fact that a larger cohort of women were exposed to neighbourhood-level disadvantage than individual-level disadvantage. While disadvantaged neighbourhoods experienced more births overall, a larger proportion of these births were among women with higher household disposable incomes and higher educational attainment, rather than those with lower incomes and education levels. This reflects women of childbearing age in the current economic climate, who likely have had access to higher education and high salaries yet cannot afford to live in certain neighbourhoods due to housing costs (218).

Interestingly, although attenuated after adjusting for individual socioeconomic position measures, neighbourhood-level measures remained associated with SMM. This has also been found in studies examining other health outcomes, such as a study in the US that found that neighbourhood deprivation was associated with heart disease even after adjusting for individual socioeconomic disadvantage (219). This may suggest that neighbourhood-level disadvantage impacts SMM above and beyond compositional socioeconomic factors. Alternatively, unmeasured confounding beyond individual employment status, educational attainment and household disposable income may be responsible for this association.

Contrastingly, neighbourhood-level socioeconomic measures had little impact on the association between individual socioeconomic position and SMM. This finding was also found in a US study (220) of 184,194 individuals where rate ratios between the association of individual educational attainment and all-cause mortality, all-vascular disease mortality and all-cancer mortality were unchanged after adjusting for a composite of census-tract level socioeconomic disadvantage. Furthermore, this study also found that census-tract level socioeconomic disadvantage was a less important predictor of mortality than individual education for all these outcomes. Additionally, similar to the analysis described in this chapter, after adjustment for individual education, neighbourhood-level socioeconomic disadvantage remained associated with all-cause and all-vascular disease associated mortality, all the effect sizes were notably reduced.

Across all the measures of socioeconomic position, women with the lowest individual educational attainment were at the greatest risk of SMM, with a 41% (95% CI 33%-50%) increased risk for women with the lowest compared to the highest education levels in the Netherlands. Educational attainment likely affects health outcomes through different

mechanisms. Women with lower educational attainment may have less health literacy, limiting their understanding of medical advice and warning signs for pregnancy complications, and they may struggle to navigate complex healthcare systems (221). Education can also be a marker for childhood social environment (222). Moreover, women with lower educational attainment are more likely to participate in risky health behaviours such as smoking, substance misuse and having an unhealthy diet (223, 224) leading to poorer health. In this analysis, adjusting for these factors gave the largest reduction in the association between education and SMM compared to the other measures of disadvantage, highlighting their key role in this relationship. Furthermore, this analysis revealed that pre-existing medical conditions mediated 22% of the association between individual education and SMM, and this increased to 25% when conditions closely related to obesity were included in the composite outcome. This was the second largest proportion mediated by pre-existing medical conditions out of the different disadvantage measures, with the largest being neighbourhood liveability (26%) where the overall effect of liveability on SMM risk was small. Mental health conditions were also shown to mediate the association between low education and SMM, however the proportion mediated was small (7%). Women with lower education may have fewer employment opportunities and low-paying jobs where they have limited control over their working schedules, raising the risk of various medical conditions due to stress and chronic physiological wearing (225). Job opportunities may also restrict access to antenatal care if, for example, the woman is in a zero-hour contract (226). Finally, as shown in analysis, having lower levels of education is correlated with lower income levels (1) and, therefore, fewer resources, which are independently associated with poor pre-conception health (227, 228).

6.5.1.3 Effect Modification by Ethnicity and Migration Status

Ethnicity significantly modified the impact of various socioeconomic disadvantage measures. The relationship between disadvantage and SMM varied by ethnicity based on the

socioeconomic indicator used. Being unemployed had a particularly pronounced association with SMM for Turkish and North African women, whereas household disposable income and neighbourhood education was less associated with SMM in minoritised ethnic group women compared to Caucasian women. Unemployed Turkish and North African women may be poorly integrated and have lower Dutch language skills than their employed counterparts, accounting for the compounded effects of employment status and ethnicity for these women. Contrastingly, women from minoritised ethnic groups with high household disposable income may experience other disadvantages within the healthcare setting because of additional factors associated with ethnicity discussed in **Chapters 4 and 5** (196).

In addition, the association between socioeconomic disadvantage and SMM appeared to be weaker in minoritised ethnic groups than in White women across different levels of neighbourhood education levels, a finding replicated in the English data. One possible reason is that, according to the Dutch data, minoritised ethnic women are more frequently misclassified as having a high socioeconomic position compared to White women when high neighbourhood education serves as a proxy for individual socioeconomic position. For example, 28% of 'Other African' women living in the most advantaged neighbourhood education areas, had individual low educational attainment compared to only 5% of Caucasian women. Although it was not possible to explore the misclassification level in the English data, analogous patterns might be present.

In the Dutch data, migration status further modified the association between the individual disadvantage measures and SMM, where the association between disadvantage and SMM was weaker for migrant groups for both Caucasian and minoritised ethnic women. The weaker impact of socioeconomic position for migrants has also been found in other studies on perinatal outcomes (229-231). For example, a Canadian study indicated that only after residing in

Canada for 15 years or more did migrants experience a comparable risk of preterm birth due to neighbourhood deprivation as native Canadians (232). Social and health-related challenges unique to migrants may contribute to this, such as navigating a new healthcare system and facing communication difficulties (233), which heighten SMM risk for these women across the socioeconomic spectrum. Alternatively, moving to the Netherlands may alter the relative socioeconomic position of an individual. For example, a woman might have moved from earning a relatively high income in a low- or middle-income country to a lower relative income. However, the influence of this shift in relative disadvantage due to migrating to the Netherlands may not yet have affected health outcomes (234). Contrastingly, second-generation migrants are more likely to have 'assimilated' into the stratification system of the receiving society (234). Additionally, for migrants, higher education and employment may not carry the same implications for socioeconomic position as they do for Dutch women, given that the Netherlands generally offers more accessible opportunities for higher education and may have different cultural values regarding women in the workforce (235). For example, in the Dutch context, completing high-school education may not be as strong an indicator of high socioeconomic position as it is for certain migrant groups, where it may be less common. Moreover, for some migrant women, unemployment may not necessarily signal low socioeconomic position, as it could be more culturally accepted or prevalent within their communities.

Notably, the proportion of SMM attributed to socioeconomic position, ethnicity and migration status was smaller than that attributed to socioeconomic position and ethnicity alone across some of the socioeconomic position measures (SES-WOA, SES-WOA Employment, SES-WOA Welfare and individual employment status). This is likely driven by Caucasian migrants exhibiting a lower overall probability of SMM, regardless of socioeconomic position,

compared to Caucasian Dutch women, thereby demonstrating a 'healthy migrant' effect (236). This phenomenon describes how migrants often constitute a selection of strong and healthy individuals who can handle the physiological, social and mental hardships of uprooting, travel and resettlement. A Swedish study confirmed this finding, showing that Western migrants had better health outcomes than Swedish citizens. However, non-Western migrants faced overall greater health risks, which was also found in this analysis (236).

6.5.2 Strengths and Limitations

The strengths and limitations of using a large-population-based administrative database are discussed in **Chapter 7**. This analysis used three linked databases, including Statistics Netherlands, which contains detailed information on a wide range of socioeconomic characteristics at the area and individual levels. It provides deeper insights into the potential misclassification bias associated with using individual- versus neighbourhood-level socioeconomic position measures, which could benefit research studying the effects of socioeconomic disadvantage beyond maternity. The DIAPER database also contained detailed information on ethnicity and migration status, which allowed for an exploration of the intersection of these factors and the different measures of disadvantage. This offers new insights into how ethnicity, migration status and disadvantage interact in their association with SMM, which aids in informing public health strategies for diverse populations. Finally, the longitudinal nature of this database facilitated the identification of key mediators, such as pre-existing medical and mental health conditions, which enables a comparison of mediation effects across different measures of disadvantage. This provides insights into how to effectively prioritise interventions aimed at reducing SMM.

However, this analysis also has limitations. The database did not include OPCS-4 procedure codes; therefore, there is a higher likelihood of false negatives of SMM, and a direct comparison of SMM prevalence with England was not possible. Furthermore, because of data protection laws, the maternal morbidity indicator, which was not constructed for this database, could not be validated in the Dutch data. Additionally, certain ICD-10 codes, such as those for appendicitis, appeared unreliable and, therefore, had to be excluded from the indicator, limiting the scope of SMM captured. Covariates such as obesity, smoking and substance misuse were also probably misclassified, since there was a lower prevalence of these conditions than in other studies. Consequently, the role of obesity in mediating the relationship between disadvantage and SMM could not be investigated, which could have provided valuable insights. Finally, there was a large amount of missing data on individual-level measures of socioeconomic disadvantage. However, multiple imputation of the missing data demonstrated that excluding these women from the analysis did not significantly bias the results.

6.5.3 Conclusion

The analysis undertaken in this chapter demonstrated that similar to the English analysis, neighbourhood-level disadvantage is associated with SMM, with neighbourhood income having the strongest association out of the singular neighbourhood-level measures (**Thesis Objective 3**). In addition, this analysis has highlighted that using individual- and neighbourhood-level measures had different implications for SMM, with individual-level measures of socioeconomic position having a moderately stronger association with SMM than neighbourhood-level measures (**Thesis Objective 4**). However, individual-level measures did not fully account for the association between neighbourhood-level socioeconomic disadvantage and SMM, suggesting that living in a disadvantaged neighbourhood may increase SMM above and beyond the risk of being individually disadvantaged. Interestingly, the

modifying effects of ethnicity varied across the different measures of socioeconomic disadvantage (**Thesis Objective 5**). The association between some of the disadvantage measures and SMM were less pronounced for migrant women, particularly for the individual disadvantage measures. Similar to the English data, pre-existing medical conditions played a key role in mediating the association between socioeconomic disadvantage and SMM (**Thesis Objective 7**). However, the extent to which pre-existing medical and mental health conditions' mediation effects differed among the measures of disadvantage indicates that while there is some overlap, each measure possesses its own distinct pathways.

Chapter 7: Discussion

7.1 Main Findings

7.1.1 Summary of Thesis

The aim of this thesis is to investigate the association between socioeconomic disadvantage and SMM in high-income countries, focusing on England and the Netherlands. It specifically aims to examine the role of different aspects of socioeconomic disadvantage, including the differences in the strength of the association with severe maternal morbidity (SMM) if disadvantage was measure at the neighbourhood or individual level, and how the association between each measure and SMM may vary across different ethnic groups. Additionally, the thesis aims to identify the role of modifiable risk factors that could inform targeted public health interventions to reduce any increased risk of SMM.

The systematic review included 52 studies across high-income countries and found a relatively consistent association between disadvantage and SMM and maternal mortality across population-based studies, regardless of the measure of disadvantage used or whether this measure was at the individual or neighbourhood level (**Thesis Objective 1**). However, no previous study compared individual- with neighbourhood-level measures within the same cohort. Furthermore, no study performed mediation analysis, and therefore the role of factors which may be amenable to interventions remained unknown. Therefore, the data analysis chapters of the thesis aims to address these gaps in the existing literature.

In the data analysis, an association between neighbourhood-level socioeconomic disadvantage and SMM was identified in England and the Netherlands (**Thesis Objectives 2 and 3**), with the proportion of SMM attributable to disadvantage at the neighbourhood-level varying

depending on the measures used, with neighbourhood income being the most significant factor across both countries. However, the highest risk was observed for the individual-level measures of disadvantage in the Netherlands (**Thesis Objective 4**), particularly for women with low educational attainment. 15% of SMM cases could potentially be avoided if all women experienced the same risk of SMM as those with high educational attainment. When considering both socioeconomic disadvantage and ethnicity together, the proportion of SMM attributable to these combined factors increased substantially, ranging from a quarter to nearly double the increase, depending on the measure of socioeconomic disadvantage. This highlights the need to address both socioeconomic and ethnic disparities to reduce inequalities in maternal health outcomes and lower the overall incidence of SMM (**Thesis Objective 6**).

The analysis also revealed effect modification by ethnicity in both countries (**Thesis Objective 5**). Specifically, when socioeconomic disadvantage was measured using neighbourhood education levels, minoritised ethnic women in both countries were less affected by living in neighbourhoods with an average lower education than White women. However, this result should be interpreted with caution due to limited study power as there were only small number of women from minoritised ethnic groups living in the neighbourhoods with high educational attainment. In the Netherlands, socioeconomic disadvantage measured at the individual level also showed effect modification by ethnicity. However, the difference in the strength of the association between disadvantage and SMM between Caucasian and minoritised ethnic women varied depending on which measure was used, with a stronger association between unemployment and SMM, and a weaker association between household disposable income and SMM, in women from minoritised ethnic groups compared to Caucasian women. Furthermore, the association between individual socioeconomic disadvantage and SMM appeared weaker for migrant women across the individual socioeconomic position measures. However, being

from a minoritised ethnicity, irrespective of migration status, emerged as a significant risk factor for SMM, independent of socioeconomic position or how it is measured.

Finally, obesity and pre-existing medical conditions were found to play an important role in mediating the relationship between socioeconomic disadvantage and SMM (**Thesis Objective 7**). Policies aimed at reducing obesity among women of childbearing age and improving prenatal care for women with pre-existing medical conditions may be crucial in addressing the disparities identified in this research, particularly for women with lower socioeconomic positions.

7.1.2 Neighbourhood-level Measures: Composite Variables versus Disaggregated Variables verses Latent Variables from the EFA

This thesis found that women living in the most deprived areas of England faced a 21% (95% confidence interval (CI) 17%-24%) higher risk of SMM compared to those in the least deprived areas, based on the composite Index of Multiple Deprivation (IMD) measure. In the systematic review, composite neighbourhood deprivation was the third most used measure of socioeconomic disadvantage in SMM studies and the most frequently used measure in mortality studies. The association between neighbourhood deprivation and SMM observed in the English data aligns with findings from other high-income countries, including Canada (60), the United States (US) (95, 100) and Australia (55, 56). The pooled unadjusted odds ratio for SMM across these countries was 1.45 (95% CI 1.13–1.84), with adjusted risk ratios (RRs) ranging from 1.09 (95% CI 1.06–1.12) in the US (95) to 2.00 (95% CI 1.29–3.10) in Australia (56).

However, this thesis has highlighted key limitations in using a composite measure of socioeconomic disadvantage. While such measures effectively capture the cumulative impact

of multiple disadvantages, they obscure the distinct pathways through which different aspects of disadvantage contribute to SMM risk. The analysis revealed that the strength of association between socioeconomic factors and SMM varied, with neighbourhood income consistently emerging as having the strongest association with SMM out of the disaggregated neighbourhood measure in both England and the Netherlands. In the systematic review, neighbourhood income was one of the most frequently used indicators of socioeconomic disadvantage in SMM studies highlighting its availability in administrative databases, and all but one study reported a significant association with SMM, suggesting that it may be the most informative of the separate neighbourhood-level measures.

Other disaggregated neighbourhood-level measures showed weaker and more variable associations. In both countries, neighbourhood education had less pronounced associations with SMM, while in England, living environment and wider barriers (reflecting housing-related issues) were also associated but followed inconsistent patterns. Interestingly, geographical barriers to services in England demonstrated an inverse relationship with SMM, which further exposes the limitations of the composite IMD in its current structure, as the inclusion of this domain may dilute the overall association between deprivation and SMM, potentially underestimating the impact of other deprivation domains. Neighbourhood education levels in both England and the Netherlands showed effect modification by ethnicity, suggesting that measuring education at the neighbourhood-level may not be a reliable indicator of disadvantage in diverse populations.

When an exploratory factor analysis (EFA) was performed using all the indices of the IMD, two distinct latent variables representing different deprivation concepts were identified. The first, Traditional Socioeconomic Status (SES), captured compositional disadvantages such as low neighbourhood income, education and employment. The second, Urban Deprivation,

reflected environmental and social factors associated with urban living, including air pollution, road traffic accidents, housing conditions and English language proficiency. These disadvantage concepts varied in their sociodemographic characteristics, association with SMM and the key SMM conditions driving any relationship. Disaggregating the IMD in this manner is therefore important for elucidating the mechanisms underlying SMM risk and informing targeted interventions.

7.1.3 Neighbourhood-level Variables in England versus the Netherlands

The Traditional SES measure was similar to the Dutch SES-WOA measure which also captures neighbourhood income, employment and education, which allowed for a comparison between the two countries. A dose-response relationship was observed between increasing Traditional SES disadvantage and SMM, in England, which showed a 15% (95% CI 11%-18%) higher risk of SMM in the most Traditionally SES-disadvantaged neighbourhoods compared to the least disadvantaged neighbourhoods, which increased to an 18% (95% CI 14%-22%) higher risk if ICD-10 codes only were included in the SMM outcome. The SES-WOA in Netherlands showed a 23% (95% CI 15%-31%) rise in SMM risk in the most disadvantaged neighbourhoods compared to the least. However, the dose-response relationship across the gradient of socioeconomic disadvantage in the Netherlands was less pronounced.

The variations in the pattern of the association may be explained by unmeasured differences in sociodemographic characteristics between the two countries which could not be accounted for in the models, potentially leading to unmeasured confounding, as well as differences in the databases used. The Hospital Episode Statistics Admitted Patient Care (HES APC) database is directly used for payment of individual hospitals, where hospitals send HES APC data to assess costs and determine payments according to the type and complexity of treatments delivered (113). In contrast, Perined and the Dutch Hospital Discharge (DHD) used for the Data-

InfrAstructure for ParEnts and children (DIAPER) are not submitted directly for payment, and their primary purpose is for policy making, research and quality improvement (203).

Additionally, the variations between the two countries may reflect genuine differences in how socioeconomic disadvantage impacts preconception health, pregnancy and childbirth, shaped by broader public health interventions and maternal care practices. Notably, the Netherlands has a significantly higher proportion of home births (12% vs. 2% in England), and women who were living in the least disadvantaged areas were more likely to give birth at home than those living in the least. Moreover, in the most disadvantaged areas, Dutch women were less likely to have an unassisted vaginal birth, whereas in England, women from the most disadvantaged areas were more likely to have an unassisted vaginal birth. In England there was a stronger socioeconomic gradient in elective caesarean birth rates, with women in the least deprived areas having a higher prevalence than those in the most deprived, a pattern not observed in the Netherlands.

Finally, the differences in the strength and pattern of the association may be explained by the differences in the measures of disadvantage between the two countries. While there are clear similarities between the English Traditional SES measure and the SES-WOA used in the Netherlands, both evaluating income, education and employment disparities, there are also distinctions in their compositions. The English Traditional SES measure assesses relative deprivation by calculating scores based on the proportion of the most deprived individuals in an area, such as those receiving income support or unemployment benefits, whereas the SES-WOA score compiles neighbourhood averages.

Notable differences were also observed in the key SMM conditions driving the associations. Specifically, living in the most disadvantaged Traditional SES neighbourhoods in England was associated with sepsis, whereas no such association was found in the most disadvantaged SES-

WOA neighbourhoods in the Netherlands. However, embolic and acute cardiac events had a dose-response relationship with the composite of neighbourhood income, education and employment in both countries, with an increasing risk of both conditions as disadvantage increased. Notably, in England, the risk of having an embolic event had a 220% increased risk in the most disadvantaged Traditionally SES quintile compared to the least disadvantaged quintile. Obesity is a risk factor for thromboembolism, cardiac infarction, cardiac failure and cardiomyopathy (237-239), supporting the hypothesis that obesity is a key mediator in the association between socioeconomic disadvantage and SMM and highlighting an important area for policy intervention.

7.1.4 Individual versus Neighbourhood-level Measures

In the Dutch data, individual-level measures had a stronger association with SMM than the neighbourhood-level measures, with individual educational attainment having the strongest association, with an increased risk of SMM of 41% (95% CI 1.33-1.50) for women with low educational attainment compared to women with high educational attainment. Individual educational attainment was one of the most commonly used measures of socioeconomic disadvantage in SMM studies in the systematic review. The studies were all from the US and also found an association between individual educational attainment and SMM (28, 81, 84, 86, 90, 91, 96), where the pooled unadjusted odds ratio was 1.29 (95% CI 1.22-1.37) and the adjusted odds ratios ranged from 1.20 (95% CI 1.10-1.40) (81) to 1.28 (95% CI 1.25-1.32) (90). Various mechanisms may explain how education impacts health status. For example, people with higher education may have developed better information processing and critical thinking skills, skills in navigating bureaucracies and institutions and abilities required to interact effectively with healthcare providers. Individuals with higher education may also be

more likely to be socialised to health-promoting behaviour and lifestyles and have better work, economic conditions and psychological resources (5).

Many women are misclassified if neighbourhood-level measures are taken as proxies for individual-level socioeconomic positions, as demonstrated in the cross-tabulation of individual- and neighbourhood-level measures. This reduces the strength of the association between socioeconomic position and SMM towards the null. Although there were no notable differences between the results using individual- and neighbourhood-level measures when comparing various pooled studies, no studies included in the systematic review compared individual- and neighbourhood-level measures in the same study. Therefore, differences in study design and populations may account for a more similar strength in the association between the two levels of measure across different studies. The difference in effect size between the neighbourhood-level and individual-level socioeconomic measures in the Netherlands has important implications for interpreting the association between the composite IMD, the separate domains/subdomains of the IMD and the variables from the EFA and SMM, where the association between socioeconomic disadvantage is likely underestimated if these variables are taken as proxies for individual socioeconomic disadvantage. However, no studies have examined the association between individual-level measures of socioeconomic disadvantage and SMM in England at a population level, and these are not currently collected in large administrative databases.

The association between neighbourhood disadvantage measured by the SES-WOA and SMM, although weak, remained after adjusting for individual-level socioeconomic measures such as individual income, employment and education. This may suggest that neighbourhood-level effects impact SMM above and beyond compositional socioeconomic factors. Research has

evaluated whether spatial context matters for health beyond an individual's compositional circumstances, and findings are generally consistent in demonstrating that contextual effects matter independently of compositional ones (7). Diez-roux (7) argues that purely individual-based explanations of ill-health causes are insufficient and fail to capture important disease determinants such as social cohesion, support networks and psychosocial stress associated with living in deprived neighbourhoods. This might explain the similarities in the strength of the association between individual- and neighbourhood-level measures in the systematic review. Neighbourhood disadvantage not only acts as a proxy for individual-level disadvantage but also assesses its own phenomenon of the effects of neighbourhoods on health. However, this remaining association may also be driven by unmeasured confounding from missing individual-level factors.

7.1.5 Key Mediators

In England, one-fifth of the association between living in a Traditional SES disadvantaged area and SMM was mediated by obesity. Research in various high-income countries also shows that obesity primarily impacts pregnant women from lower socioeconomic positions (240), those with lower education (241) and specific ethnic groups (242). Women from lower socioeconomic positions may lack the material resources, time and knowledge to exercise and prepare nutritious food (243). There may also be norms and behaviours linked to overweight and obesity, which may vary between different social groups (185). Furthermore, studies have shown that neighbourhood also plays a role, with more fast-food outlets per capita and fewer healthy food stores per capita in poorer areas than in more affluent neighbourhoods (244). Deprived neighbourhoods may be characterised by built environments that provide fewer opportunities for physical activity. Obesity is linked with an increased risk of pre-existing medical problems, including heart disease (239) and pregnancy complications such as

gestational hypertension and diabetes (245). Also, it increases the risk of induction of labour or an emergency caesarean birth, which are directly associated with the risk of SMM (246). In the Netherlands, obesity was poorly recorded in the database, and therefore, the mediation effects could not be studied. However, when conditions closely related to obesity were included in the pre-existing medical conditions composite, the role of this composite in the association between disadvantage and SMM notably increased, suggesting that obesity-related conditions have a key mediation role in the Netherlands. These findings suggest that interventions which target obesity at a population level, particularly in deprived areas and for women of childbearing age, may effectively reduce the disparities in SMM.

If pre-existing medical conditions were eliminated, the association with Traditional SES within England could be reduced by one-fifth (if conditions closely related to obesity were excluded) and by over one-third (if conditions closely related to obesity were included). Pre-existing medical conditions also mediated the association among various socioeconomic disadvantages in the Netherlands, with 22%, 16% and 11% of the association between individual educational attainment, household disposable income and employment status and SMM being mediated by pre-existing medical conditions (excluding obesity-related conditions), respectively. Lower education, income and employment opportunities may increase the risk of pre-existing medical conditions due to poor housing, living in an area with high air pollution, being unable to afford healthy food, or having jobs with poor environmental conditions or shift work (2). In turn, pre-existing medical conditions may limit employment opportunities, creating a vicious cycle. Furthermore, living in poverty causes chronic stress, which contributes to physical deterioration and a rise in medical issues (247). An English study identified this pathway through biomarkers, using allostatic load biomarkers to measure how stress leads to the 'chronic weathering' of physiological function. The findings revealed that allostatic load

mediated the association between neighbourhood deprivation and physical health outcomes (247).

7.2 Strengths and Limitations

This thesis has many strengths. It has achieved the overall aim of exploring how different aspects of socioeconomic disadvantage, measured at both the individual and neighbourhood level are associated with SMM across high-income countries, with a focus on England and the Netherlands. It also achieved its aim of exploring how the association between disadvantage and SMM varies across different ethnic and migrant groups, as well as the role of key mediators in the relationship between socioeconomic disadvantage and SMM. The lived experience group guided the thesis objectives, approved the acceptability of the methods and put context into the findings, which was vital to accelerate the understanding of the results.

This thesis comprised two large, population-based studies, which included nearly all women giving birth in England and the Netherlands. The studies were nationally representative, had a low risk of selection bias and were largely generalisable to their populations. Using a composite outcome to measure SMM allowed for a more accurate capture of a broad range of outcomes, reducing the risk of false negatives. If a woman experiences a severe health event at the time of birth, and one aspect of that event was not coded, the event may still have been captured by another code in the composite outcome. Additionally, the composite measure provided more statistical power to analyse trends in specific subgroups. Furthermore, the data covered twenty years in both countries and could therefore control for sociodemographic, health and behavioural characteristics over time. A methodological strength is multi-level modelling, which accounted for clustering within neighbourhoods and adjusted for individuals living in

the same neighbourhoods who may share unobserved characteristics. Using two high-income countries validates the findings, and the results may apply to other high-income countries.

However, there are also limitations. Firstly, disadvantage was only assessed at the time of childbirth, and therefore the effects of moving between areas and how this may interact with confounding factors remains unclear. There is, therefore, a limited understanding of the effect of the length of time spent living in a disadvantaged area, social mobility or where socioeconomic disadvantage imposes the greatest risk in the life course.

As the outcome has not been validated using clinical notes in either country, the variation in the quality of administrative data for studying SMM between hospitals and regions is unknown and there may be reporting bias between hospitals. It is unclear in this study, whether in England, the increase in the rate of SMM or the differences in the sepsis incidence between different hospitals are true findings or attributable to variations in data quality over time and between areas.

In addition, whilst using a composite measure of SMM as the outcome was necessary to ensure sufficient statistical power to detect trends within the data, it also introduces challenges in interpreting the relationship between socioeconomic disadvantage and SMM. The composite outcome groups together various conditions contributing to SMM, but these conditions may have varying relationships with disadvantages and distinct causal pathways. For example, different measures of socioeconomic disadvantage or their mediators may increase the risk of some conditions but decrease the risk of others.

The analyses faced additional challenges disentangling the complex relationship between relationship covariates like pre-existing physical and mental health conditions and SMM. These factors may confound and mediate the relationship between socioeconomic disadvantage and SMM. For example, women experiencing significant socioeconomic disadvantage may be

more likely to have chronic health conditions, which in turn could increase their risk of SMM. However, despite the longitudinal dataset, it was impossible to determine the timing of conditions precisely. For instance, if asthma is coded for during a hospital admission, this does not necessarily reflect the timing of this condition. Therefore, reverse causation cannot be ruled out.

When using administrative data, there is a risk of false negatives for both the outcome and covariates, especially as the codes for the covariates such as pre-existing medical and mental health conditions were selected from pre-existing studies (130, 169), which included ICD-10 codes only and not OPCS-4 codes. The inclusion of OPCS-4 codes could help reduce the risk of false negatives, as a related procedure might be recorded even if the condition itself is not. Additionally, since the diagnosis of pre-existing medical and mental health conditions, as well as obesity, was determined solely from secondary care data, they are likely only to capture the most severe cases. Many women are often managed for chronic conditions within the community and may never have these conditions diagnosed in a hospital admission. Therefore, the actual proportion of the effect mediated or confounded by such conditions is likely to be underestimated. The risk of false negatives of the covariates may also differentially affect individuals who recently migrated into each country and are new to services. There were lower rates of such conditions in women living in England's most deprived urban areas, with a higher proportion of minoritised ethnic women and migrants. In the Dutch data, there was also a lower proportion of pre-existing medical and mental health conditions for minoritised ethnic and migrant women than for Dutch Caucasians. In both countries, this may be explained by disparities in healthcare access (248), underdiagnoses (249), or care outside of each country before pregnancy for ethnic and migrant populations. However, given the data's limitations, it is impossible to determine whether this finding is valid, or which of the above hypotheses are

responsible. As a result, the role of the pre-selected mediators may be disproportionately underestimated in ethnic or migrant populations.

Further limitations to using administrative data in examining key mediators were that not all mediating factors can be captured in data, key variables were missing, or other variables were used as proxies. In the HES APC database, the timing of pregnancy booking with the midwife was considered a proxy for her engagement with care. However, this does not necessarily indicate her ongoing engagement or the quality of the care throughout the pregnancy which limited the exploration of the role of care factors. It was also not possible to explore the barriers that might explain potential differences in engagement with care, leaving potential areas for intervention unidentified. In the DIAPER database, there was a lack of data on care engagement, and obesity was insufficiently recorded, preventing the assessment of either potential mediating role. One major challenge highlighted by the lived experience group was the belief that they were treated differently by healthcare staff due to discrimination and bias, factors that are difficult to capture through data.

Finally, the SMM outcome in this thesis was based on the original English Maternal Morbidity Outcome Indicator (EMMOI), which has been criticised for overlooking maternal mental health issues by including only one mental health condition, psychosis. For example, while suicide is a leading cause of maternal death in the United Kingdom (UK), conditions such as depression are not classified as SMM indicators under the EMMOI (188).Therefore, although mental health problems played a minor role in mediating the relationship between socioeconomic disadvantage and SMM in both England and the Netherlands as reported in this thesis, they may still significantly influence severe maternal outcomes. However, the potential mediating role of mental health were not captured by the SMM definition used in this study.

7.3 Research and Policy Implications

7.3.1 Implications for Future Research

1. Improve Maternity Data Collection and Quality in England and the Netherlands

Improving the quality of maternity data in England and the Netherlands is essential to effectively study SMM trends and risk factors using routinely collected healthcare data. DIAPER had low prevalence of confounding factors such as obesity and substance misuse and/or smoking, suggesting that these are likely misclassified as well as potential false positives of certain SMM conditions (e.g. acute pancreatitis and appendicitis). The HES APC dataset had a significant amount of missing or poor-quality data in important variables for maternity research. This may have resulted in unmeasured confounding or an underestimation of the incidence of key mediators. For example, parity, gestational age at birth, mode of birth, method of birth onset, birthplace, timing of pregnancy booking with the midwife and status of the person conducting the birth are included in the maternity section of HES APC, but collection is non-mandatory, leading to missing or unreliable data. To strengthen maternity research using such data, these variables should be made mandatory and should have quality checks. Linking HES data with other databases such as the Maternity Services Dataset (MSDS) or Clinical Practice Research Datalink (CPRD) could enhance data quality, capture missing variables and provide additional information such as the number of maternity appointments to provide more information on care factors. CPRD, which includes primary care data, could also provide additional information on less severe pre-existing medical and mental health conditions and obesity, improving the validity of these variables.

2. Further Investigation of the Increase in SMM in England

This thesis found that the incidence of SMM significantly increased from 2013-2019 in England. However, whether this increase is due to changes in the maternity population, shifts

in obstetric practices, or variations in coding methods remains uncertain. Consequently, further research is needed to identify which of the above explanations may account for this upward trend. This could be investigated further using a decomposition analysis approach, which can study the change in SMM over time, accounting for changing pregnancy and birth characteristics.

Additionally, the study highlighted considerable variation in sepsis rates among English hospitals. More investigation is needed to determine whether differences exist in diagnostic criteria and coding practices across hospitals. Comparing the quality of hospital discharge summaries, speaking to clinical coders or performing a prospective cohort study of sepsis incidence across different hospitals may provide more information. If future research shows that specific hospitals report genuinely higher rates of sepsis, further investigation will be necessary to explore the reasons behind this.

3. Perform an Exploratory Factor Analysis (EFA) on the Composite SMM Outcome

This thesis found that certain conditions within the composite outcome of SMM are more strongly associated with socioeconomic disadvantage than others. Conducting an EFA on all components of the modified EMMOI may highlight the relationships between groups of SMM conditions and different aspects of disadvantage. For example, some groups of conditions may be more strongly associated with caesarean birth, such as surgical injury or sepsis. Contrastingly, others may be more closely correlated with other care factors. Therefore, grouping different conditions together may help determine more precise causal relationships and better identify where interventions can be targeted.

4. Improve Measures of Socioeconomic Position for Research and Policy in England

In population-based studies in England, there is a pressing need for individual-level measures of socioeconomic position. The research conducted in the Netherlands reveals the limitations of relying solely on neighbourhood-level socioeconomic position measures, which appear to underestimate the association between socioeconomic disadvantage and SMM. Furthermore, it has been observed that women from minoritised ethnic groups living in the least disadvantaged neighbourhoods are more likely to have their individual socioeconomic position misclassified when neighbourhood-level measures are used. In the absence of individual socioeconomic position measures where true associations may be obscured, conducting causal mediation analyses and creating targeted interventions for specific populations becomes more challenging. In addition, focusing on women with an individually low socioeconomic position rather than on all women living in the most disadvantaged neighbourhoods may be a more cost-effective strategy. For example, in the Netherlands, the population attributable fractions (PAFs) were often similar between the neighbourhood-level and individual-level socioeconomic position measures. However, a larger number of women were exposed to neighbourhood-level disadvantage, with over one-fifth of births occurring in the most disadvantaged neighbourhoods in both countries. Therefore, many more women in the most disadvantaged areas would need an intervention or a change in their social circumstances, compared to if interventions were targeted at individually deprived women in order to reduce the same proportion of SMM. Finally, regarding social acceptability, members of the lived experience group showed readiness to share personal socioeconomic position information. However, they highlighted the need for sensitivity in obtaining this information, suggesting methods such as a questionnaire in the waiting room instead of direct inquiries from healthcare staff.

This study emphasises that educational attainment may be the most effective measure to assess among individual socioeconomic position indicators. Low educational attainment levels showed the strongest association with SMM and were also closely correlated to household disposable income, which also had a strong association with SMM. In contrast, unemployment demonstrated the weakest association with SMM and had poor correlations with other socioeconomic position indicators. A key benefit of using education as a socioeconomic position measure for adults is the reduced likelihood of reverse causation, often a concern with other standard socioeconomic position measures, since education is typically completed before adverse health effects manifest. Furthermore, participants in the lived experience group reported that they were more comfortable sharing their educational attainment rather than income. In this thesis, modifiable factors such as pre-existing medical conditions, mental health problems and obesity significantly influence the relationship between educational attainment and SMM. Therefore, identifying women with lower educational attainment as being at higher risk for SMM may serve as a particularly actionable socioeconomic position indicator for policy interventions.

Finally, if individual socioeconomic position measures are not available in the administrative databases, the new variables created from the EFA of the IMD might serve as a superior alternative to the composite measure. They may provide clearer insights and a more detailed understanding of neighbourhood-level socioeconomic disadvantage in England compared to what is often used in many population-based studies.

5. Explore Differences in Birth Characteristics and Care Factors

This thesis highlights differences in birth factors, such as caesarean birth rate and rate of labour induction, across the gradient of socioeconomic disadvantage in England and the Netherlands.

However, it is uncertain whether these differences arise from differences in demographics, the clinical needs and higher-risk profiles of women from lower socioeconomic positions, biases of healthcare providers, variations in birth preferences, or inequities in mothers' ability to advocate for themselves. Further investigation is needed to account for confounding variables and to examine these patterns in more detail. The study could not adequately assess care factors such as engagement or quality of care, which may play an important role in these outcomes. In an analysis of a national English maternity survey, Lindquist et al. (75) found that, with decreasing socioeconomic position, women were more likely to report that they were not treated respectfully or spoken to in a way they could understand by doctors and midwives. Women from the lived experience group expressed feelings of being overlooked or judged by healthcare professionals due to their social circumstances, impacting their decisions during labour and birth as well as their overall pregnancy health. However, available data did not allow for a thorough exploration of this issue. To overcome this limitation, qualitative research is essential to better understand women's experiences and viewpoints.

6. Explore the Intersection of Socioeconomic Disadvantage, Ethnicity and Migration Status

In both the Netherlands and England, minoritised ethnicities and migrants were overrepresented in the most disadvantaged neighbourhoods. Different intersectional positions (such as between ethnicity and socioeconomic position) are associated with differential access to power, prestige, resources and social identities (250). The impact of health across multi-dimensional intersectional positions should be considered to understand the social determinants of health inequalities. This thesis found that while certain minoritised ethnic groups in England and the Netherlands are at a greater risk of SMM, the association between socioeconomic position and SMM appeared less pronounced among these women. However, in the English data, it was not known whether these women were migrants or UK-born. Interestingly,

socioeconomic position also appeared to have less impact on SMM for migrants than for Netherlands-born women in the Dutch data. Additional research is necessary to explore the interaction between ethnicity, migration and socioeconomic position, especially concerning migration timing and duration of residence in the host country, and how this may impact the association between socioeconomic position and risk of SMM.

In addition, qualitative studies investigating the protective and detrimental factors influencing SMM among minoritised ethnic and migrant women facing socioeconomic disadvantages could provide insights for developing targeted interventions for other high-risk populations. These findings could help guide the design of tailored healthcare policies that address the specific needs of minoritised ethnic and migrant groups, considering both socioeconomic and cultural factors.

The observed lower rates of certain individual risk factors, such as pre-existing medical or mental health conditions, among migrants (in the Netherlands) or in areas with higher proportions of migrants (in England), warrant further examination. Whether these patterns reflect true differences or potential misclassification, possibly due to previous care outside the respective countries, remains unclear. To address this, future studies which include surveys that collect comprehensive health histories from migrants, rather than relying only on routinely collected healthcare data, may have more accurate assessments of the health risks faced by migrant populations and capture the extent of any potential misclassification.

7. Explore Geographical Variations in Neighbourhood-level Disadvantage and SMM Risk

This study has highlighted the significant regional disparities in the two key dimensions of disadvantage across England. This has emphasised the need to investigate further how these factors intersect in association with SMM risk. There is a notable gap in research that

specifically examines the intersectionality of socioeconomic disadvantage and regional factors concerning SMM risk in England. Different regions may have distinct combinations of risk factors related to SMM, driven by variations in socioeconomic conditions, healthcare access, cultural factors and environmental elements. Therefore, these regional differences could necessitate tailored, localised interventions to mitigate SMM rates effectively.

Further research is essential to explore these variations in greater depth. Geographic Information System (GIS) software may enable the identification of specific geographic areas with the highest concentration of SMM associated with distinct socioeconomic disadvantage domains. Such spatial analysis could provide valuable insights into the geographic distribution of risk and help identify areas where interventions could have the greatest impact. Additionally, this could inform more equitable allocation of healthcare resources and guide policymakers in targeting interventions where they are most needed to aim to achieve proportionate universalism.

7.3.2 Policy Implications

This thesis demonstrates that socioeconomic disadvantage, regardless of how it is measured, is a significant risk factor for SMM in the Netherlands and England, where there are adequate resources and opportunities to ameliorate the social gradient of health. The main determinants of health lie outside the healthcare system such as income, housing, education and behaviour (173). While these broader social structures are key drivers of health outcomes, this thesis does not propose direct alterations to these fundamental social determinants. Instead, it focuses on more immediate, modifiable factors within the maternity care system that can be addressed to improve outcomes for socially disadvantaged women. Recognising the complexity of health inequities, the recommendations aim to target achievable interventions within maternity care,

acknowledging that addressing the root causes of socioeconomic disadvantage requires long-term policy changes and societal shifts. However, by focusing on maternity-specific factors, the thesis seeks to offer practical solutions that could have a tangible impact on reducing disparities in maternal health outcomes for those at the greatest risk.

1. Addressing Obesity in Maternity

Obesity, and medical conditions closely related to obesity, were found to be key mediators in the association between socioeconomic disadvantage and SMM. There is a rising prevalence of obesity among pregnant women. For instance, in England 45.7% of pregnant women are classified as overweight or obese (251). Obesity disproportionately affects women with lower socioeconomic position, as evidenced in this study. However, interventions to reduce pre-conception and pregnancy obesity remain under-researched, with few high-quality, large-scale randomised trials (252). Moreover, obesity interventions are likely to be cost-effective for the National Health Service (NHS), as maternal obesity increases pregnancy and birth costs by 39% compared to women with a healthy weight (253). Therefore, enhancing the guidance on pre-pregnancy weight loss and improving the success rates of weight loss (252) interventions may be a key area to reduce the disparities gap found in this thesis.

2. Improving Care for Pre-Existing Medical Conditions

Pre-existing medical conditions were also found to mediate the association between socioeconomic disadvantage and SMM. Pre-existing medical conditions are becoming increasingly important as women are choosing to get pregnant at a later age (254). Since 2021, maternal medicine networks in the UK have provided pre-pregnancy, antenatal and postnatal care for women with significant medical conditions, whether pre-existing or arising during pregnancy or postpartum (255). These networks aim to reduce outcome disparities and address

geographical variations in care. To maximise their impact, maternal medicine networks should integrate strategies addressing socioeconomic disadvantage, ensuring that interventions effectively reduce SMM risk among the most vulnerable populations. Although the Netherlands does not have the same structured maternal medicine networks, centres which provide specialist maternal medicine care should similarly prioritise reaching socioeconomically disadvantaged women.

Public health interventions to improve pre-conception health in the population may reduce the incidence and severity of pre-existing medical conditions for women with lower socioeconomic positions, reducing the disparities highlighted in this study. Preconception care provides a valuable opportunity to identify, screen, manage and prevent health risk factors, including long-term physical and mental health conditions, alcohol use, smoking, lack of physical activity, poor diet, insufficient social support and low immunisation rates (256). Preconception care interventions should prioritise reaching higher-risk women, such as those living in deprived areas and with lower levels of education and income (257). Additionally, these interventions should be co-designed by researchers, policymakers and the women themselves. Women who have experienced socioeconomic disadvantage possess valuable insights into the most effective ways to engage with their peers and identifying the most impactful interventions across diverse communities.

3. Improving the Prevention of Venous Thromboembolism (VTE) for Socioeconomically Disadvantaged Women

VTE is the most prevalent embolic condition in pregnancy (258), and represents a significant proportion of the embolism outcomes in this study. Thrombosis is not only a major cause of maternal mortality in England and the Netherlands; this research also indicates its disproportionate impact on women from lower socioeconomic backgrounds. Public health

interventions can help prevent VTE by addressing risk factors such as smoking and obesity before conception and during pregnancy, as well as increasing public and provider awareness (259). Additionally, pharmacological measures can effectively prevent VTE through appropriate thromboprophylaxis for women at high risk. The 2018 (260) and 2024 (17) confidential enquiries into maternal deaths in England made several recommendations regarding the prophylaxis and treatment of venous thromboembolism. These include simplifying VTE risk assessment tools, reweighing women during pregnancy and post-partum, recalculating their VTE risk accordingly and assessing adherence to thromboprophylaxis (260). Although not specifically aimed at women from lower socioeconomic backgrounds, prioritising these recommendations may help reduce the risk for these women and help close the disparities gap.

7.4 Conclusion

This thesis has successfully achieved its primary aim of exploring the significant socioeconomic disparities in SMM across high-income countries, with a particular focus on England and the Netherlands. Maternal health outcomes offer insight into wider health disparities and systemic healthcare issues. Pregnancy represents a unique window of opportunity to address these disparities, potentially influencing health outcomes across the life course.

A key finding of this thesis is that neighbourhood-level measures may underestimate the extent of socioeconomic disparities in England, highlighting the need for more precise indicators of socioeconomic position. Addressing conditions such as obesity and pre-existing medical issues prior to conception could serve as a practical and impactful strategy to mitigate health inequities. By prioritising preconception health interventions, policymakers and healthcare

professionals can take meaningful steps toward reducing these disparities and enhancing maternal health outcomes.

However, further research is needed to explore and address factors raised by the lived experience group, such as how individuals facing socioeconomic disadvantage might experience discrimination from care providers, an issue that could not be examined using the available data. Additionally, more investigation is required to identify which interventions are most effective in reducing the impact of the mediators of the disparities highlighted in this thesis.

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Appendices

Appendix Chapter 3

Appendix Table 3.1. Definition of socioeconomic position by Shavers (5)

Measures	
Compositional	Measures of socioeconomic circumstances of individuals. Examples include occupation (including employment status), income, education
Contextual	Contextual approaches typically involve ecologic area measures and examine the social and economic conditions that affect all individuals who share a particular social environment. Examples or commonly used area measures are neighbourhoods or geographical areas such as countries or states. Examples of measures are average house value, median monthly rental value of housing, percentage of single-parent families, percentage of unemployed persons, per capita income
Composite	Composite socioeconomic disadvantage measures are constructed by combining information about several socioeconomic disadvantage measures. Examples include measures combining income, employment, education, communications, transportation, home ownership.

Appendix Table 3.2. Example search strategy for Medline

1	((maternal or pregnan*) adj4 (mortality or death?)).ti,ab,kf.	30,354
2	((maternal or pregnan*) adj4 morbid$).ti,ab,kf.	14,541
3	pregnancy complications/ or exp hypertension, pregnancy-induced/ or maternal death/ or obstetric labor complications/ or exp abruptio placentae/ or exp dystocia/ or fetal membranes, premature rupture/ or chorioamnionitis/ or placenta accreta/ or placenta previa/ or postpartum hemorrhage/ or uterine inversion/ or uterine rupture/ or vasa previa/ or exp placenta diseases/ or exp pregnancy complications, cardiovascular/ or exp pregnancy complications, infectious/ or exp pregnancy, ectopic/ or puerperal disorders/ or puerperal infection/	260,222
4	exp Maternal Mortality/	11,306
5	traumatic delivery.mp.	137
6	'maternal complications'.mp.	2,955
7	Pregnancy Complications, Hematologic/	10,139
8	obstetric surgical procedures/ or hysterotomy/ or cesarean section/	52,774
9	exp pregnancy/ or postpartum period/ or peripartum period/	1,007,014
10	Near miss, healthcare/ or 'near miss'.mp.	2,057
11	'intensive care'.mp.	224,981
12	exp Hemorrhage/ or exp blood transfusion/ or exp multiple organ failure/ or hysterectomy/	475,632

13	((cardiomyopathies/ or shock/ or heart arrest/ or arrhythmias, cardiac/ or cardiopulmonary resuscitation/ or exp acidosis/ or cyanosis/ or exp intubation/ or Respiration, Artificial/ or Hypoxia, Brain/ or oliguria/ or exp acute kidney injury/ or exp renal dialysis/ or pulmonary edema/ or exp Embolism/) and Thrombosis/) or exp blood coagulation/ or thrombocytopenia/ or fatty liver/ or cholecystitis, acute/ or cholestasis, intrahepatic/ or liver failure/ or coma/ or seizures/ or exp stroke/ or paralysis/ or abdomen, acute/ or Psychotic Disorders/ or infarction/ or brain edema/ or acute chest syndrome/ or anemia, sickle cell/ or status asthmaticus/ or status epilepticus/ or sepsis/ or sinus thrombosis, intracranial/ or haematoma/ or cystostomy/ or surgical wound dehiscence/	594,343
14	10 or 11 or 12 or 13	1,224,870
15	9 and 14	60,874
16	1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 15	346,300
17	Geographic differences.mp.	1,692
18	rural population/ or suburban population/ or urban population/	113,760
19	sociological factors/ or adverse childhood experiences/ or community resources/ or cultural characteristics/ or cultural deprivation/ or cultural diversity/ or psychosocial deprivation/ or 'ethnic and racial minorities'/ or exp marital status/ or family separation/ or illegitimacy/ or single-parent family/ or hierarchy, social/ or minority groups/ or social capital/ or social change/ or urbanization/ or social conditions/ or exp home environment/ or exp social environment/ or social isolation/ or social marginalization/ or social norms/ or social vulnerability/ or socialization/ or sociodemographic factors/ or exp socioeconomic factors/ or exp education/	1,482,224
20	sociology/ or exp social structure/ or exp social problems/ or exp social welfare/ or exp sociology, medical/ or exp social work/	420,085
21	enviroment.mp.	161
22	(neighbourhood deprivation or index of multiple deprivation or 'deprivation index' or 'deprivation indices' or 'deprivation indexes').mp.	2,945
23	Environmental Pollution/	20,847
24	Health Services Accessibility/ or health equity/	88,265
25	language barriers.mp.	2,307
26	homelessness.mp. or Homeless Persons/ or alcoholics/ or drug users/ or 'emigrants and immigrants'/ or undocumented immigrants/ or 'health disparity, minority and vulnerable populations'/ or vulnerable populations/ or homeless persons/ or prisoners/ or refugees/ or working poor/	74,167
27	complex social factors.mp.	29
28	Communication Barriers/	7,230

29	Health Inequities/	315
30	Psychosocial Deprivation/	2,053
31	social determinants of health/	6,281
32	Residence Characteristics/	38,036
33	(inequality or inequit*).mp.	44,375
34	Healthcare Disparities/ or Health Status Disparities/	38,348
35	((health or healthcare or care) adj1 (barrier* or disparit* or inequalit*)).tw,kw.	26,093
36	(sociodemographic* or socio demographic*).tw,kw.	109,503
37	((education* adj3 status) or (maternal adj3 education*)).tw,kw.	31,835
38	((financ* adj2 difficult*) or (financ* adj2 problem*) or (income* adj2 difference*) or indigent).tw,kw.	7,272
39	(jobless or (job* adj3 insecurit*) or (low adj3 income*) or marginaliz* or (occupational adj3 status)).tw,kw.	88,464
40	(social adj3 (disparit* or disadvantage* or environment or exclu* or gradient or position)).tw,kw.	20,704
41	(socioeconomic* or socio economic* or SES).tw,kw.	176,707
42	((standard adj3 living) or underprivilege* or under privilege* or unemployed or unemployment*).tw,kw.	26,523
43	(segregat* or crime* or (hous* adj2 insecur*) or (food adj2 insecur*) or (childhood adj2 advers*)).tw,kw.	121,840
44	or/17-43	2,320,032
45	afghanistan/ or exp africa/ or albania/ or andorra/ or antarctic regions/ or argentina/ or exp asia, central/ or exp asia, northern/ or exp asia, southeastern/ or exp atlantic islands/ or bahrain/ or bangladesh/ or bhutan/ or bolivia/ or borneo/ or 'bosnia and herzegovina'/ or brazil/ or bulgaria/ or exp central america/ or exp china/ or colombia/ or 'commonwealth of independent states'/ or croatia/ or 'democratic people's republic of korea'/ or ecuador/ or gibraltar/ or guyana/ or exp india/ or indonesia/ or iran/ or iraq/ or jordan/ or kosovo/ or kuwait/ or lebanon/ or liechtenstein/ or macau/ or 'macedonia (republic)'/ or exp melanesia/ or moldova/ or monaco/ or mongolia/ or montenegro/ or nepal/ or netherlands antilles/ or new guinea/ or oman/ or pakistan/ or paraguay/ or peru/ or philippines/ or qatar/ or 'republic of belarus'/ or romania/ or exp russia/ or saudi arabia/ or serbia/ or sri lanka/ or suriname/ or syria/ or taiwan/ or exp transcaucasia/ or ukraine/ or uruguay/ or united arab emirates/ or exp ussr/ or venezuela/ or yemen/	1,334,162
46	'organisation for economic co-operation and development'/	532

47	australasia/ or exp australia/ or austria/ or exp baltic states/ or belgium/ or exp canada/ or chile/ or czech republic/ or europe/ or exp france/ or exp germany/ or greece/ or hungary/ or ireland/ or israel/ or exp italy/ or exp japan/ or korea/ or luxembourg/ or mexico/ or netherlands/ or new zealand/ or north america/ or poland/ or portugal/ or exp 'republic of korea'/ or exp 'scandinavian and nordic countries'/ or slovakia/ or slovenia/ or spain/ or switzerland/ or turkey/ or exp united kingdom/ or exp united states/	3,464,088
48	european union/	17,606
49	developed countries/	21,328
50	46 or 47 or 48 or 49	3,479,989
51	45 not 50	1,242,445
52	Epidemiologic Studies/	9,307
53	exp case control studies/	1,409,601
54	exp cohort studies/	2,472,799
55	Case control.tw.	152,184
56	(cohort adj (study or studies)).tw.	308,902
57	Cohort analy$.tw.	11,542
58	(Follow up adj (study or studies)).tw.	55,842
59	(longitudinal or retrospective or prospective).tw.	1,650,631
60	cross sectional.tw.	502,143
61	Cross-sectional studies/	463,985
62	52 or 53 or 54 or 55 or 56 or 57 or 58 or 59 or 60 or 61	3,861,713
63	16 and 44 and 62	11,500
64	63 not 51	6,537

Appendix Table 3.3. Data extracted from included studies

Category	**Variables to be extracted**
Basic descriptive information	Study setting and location
	Publication reference
	Study year(s)
	Year of publication
Research question(s)	Primary objectives
	Secondary objectives
Participant characteristics	Study population demographics
	Baseline characteristics
Study type and design	Data source
	Sample size
	Details of exposure and control condition (measurement of socioeconomic status used and the comparator)
	Outcome definition (severe maternal morbidity (SMM)/maternal mortality)
	Confounders adjusted for
	Information for assessment of risk of bias
Outcomes	Primary and secondary outcome measures
	Effect estimate and prevalence of SMM/maternal mortality

Appendix Table 3.4. Modified Newcastle-Ottawa scale risk of bias tool for cohort studies (and National Maternal Mortality Surveillance Programmes)

SELETION

1) Selection - Representative of the exposed cohort

a) Truly representative of the average pregnant women in the community LOW
b) Somewhat representative of the average pregnant in the community LOW
c) Selected group of users eg. nurses, volunteers, from one hospital only and this not defined in the research question HIGH
d) No description of the derivation of the cohort UNKNOWN

2) Selection of the non-exposed Cohort

a) Drawn from the same community as the exposed cohort LOW
b) Drawn from a different source HIGH
c) No description of the derivation of the non-exposed cohort UNKNOWN

3) Ascertainment of exposure

a) Secure record (eg. post code) LOW
b) Structured interview LOW
c) Written self-report, pregnancy booking self-report SOME CONCERNS
d) No description/ unclear UNKNOWN

COMPARABILITY

a) Study controls for age and ethnicity (+/-parity). LOW
b) Other controlled factors LOW
c) Does not control for age and ethnicity HIGH
d) Over adjustment for factors on the causal pathway HIGH

OUTCOME

1) Assessment

a) Independent or blind assessment stated in the paper, or confirmation of the outcome by reference to secure records (x-rays, medical records, etc.). LOW
b) Record linkage (e.g. identified through ICD codes on database records). SOME CONCERNS
c) Self-report (i.e. no reference to original medical records or x-rays to confirm the outcome) HIGH
d) No description. UNKNOWN

2) Was follow-up long enough for outcomes to occur

a) Yes – Time-period stated in aims/ objectives and correct LOW
b) No – Just at time of birth but this not mentioned in aims and objectives of paper SOME CONCERNS
c) No – Time-period not adequate for what is stated in aims and objectives HIGH
d) Unclear - UNKNOWN

3) Adequacy of follow up of cohorts/ missing data

a) Complete follow up - all subjects accounted for and no missing data LOW
b) Missing data unlikely to introduce bias - small number lost - > 90% follow up or no missing data, or description provided of those lost and no evidence of bias (sensitivity analysis/ multiple imputation shows results not materially different) LOW
c) Follow up rate < 90% and no description of those lost or evidence of bias in multiple imputation HIGH

Appendix Table 3.5. Modified Newcastle-Ottawa scale risk of bias tool for case-control studies

SELECTION

1) Is the case definition adequate

a) Requires some independent validation (e.g. >1 person/record/time/process to extract information, or reference to primary record source such as x-rays or medical/hospital records) LOW
b) Record linkage (e.g. ICD codes in database) or self-report with no reference to primary record SOME CONCERNS
c) No description UNKNOWN
d) No HIGH

2) Representativeness of the cases

a) All eligible cases with outcome of interest over a defined period of time, all cases in a defined catchment area, all cases in a defined hospital or clinic, group of hospitals, health maintenance organisation (if stated in the research question), or an appropriate sample of those cases (e.g. random sample). LOW
b) Potential for selection bias. Not satisfying requirements in part a. HIGH
c) or not stated UNKNOWN

3)Selection of controls

This item assesses whether the control series used in the study is derived from the same population as the cases and essentially would have been cases had the outcome been present.
a) Community or hospital controls (i.e. same community as cases and would be cases if had outcome). LOW
b) From different population HIGH
c) No description UNKNOWN

COMPARABILITY

a) Study controls for age and ethnicity(+/-parity). LOW
b) Other controlled factors LOW
c) Does not control for age and ethnicity HIGH
d) Over adjustment for factors on the causal pathway HIGH

EXPOSURE

1) Ascertainment of exposure

a) Secure record (eg post code) LOW
b) Structured interview where blind to case/control status LOW
c) Interview not blinded to case/control status HIGH
d) Written self-report, pregnancy booking information only SOME CONCERNS
e) No description UNKNOWN

2)Method of ascertainment of exposure

Same method of ascertainment for cases and controls
a) Yes LOW
b) No HIGH

3)Nonresponse rate

a) Same rate for both groups LOW
b) Non respondents described – yes and evidence of limited bias SOME CONCERNS, yes and evidence of bias HIGH
c) Rate different and no designation or not recorded UNKNOWN

Missing data

a) Complete follow up - all subjects accounted for and no missing data LOW
b) Missing data unlikely to introduce bias - small number lost - > 90% follow up or no missing data, or description provided of those lost and no evidence of bias (sensitivity analysis/ MI shows results not materially different) LOW
c) Follow up rate < 10% and no description of those lost or evidence of bias in MI HIGH

Appendix Table 3.6. Modified Newcastle-Ottawa scale risk of bias tool for cross-sectional studies

SELECTION

1) Representativeness

a) Truly representative of the average pregnant women in the community LOW
b) Somewhat representative of the average pregnant in the community LOW
c) Selected group of users eg. nurses, volunteers, from one hospital but not stated in the research question HIGH
d) No description of the derivation of the cohort UNKNOWN

2) Sample size

a) Justified and satisfactory or very large sample size (eg. nationwide cohort) LOW
b) Not justified UNKNOWN
c) No information provided UNKNOWN
d) Sample size does not meet pre specified power calculations HIGH

3) Non-respondents

a) Proportion of women included is >90% initial sample LOW
b) Unsatisfactory recruitment rate, no summary data on non-respondents HIGH
c) No information provided UNKNOWN

EXPOSURE

Ascertainment of the exposure

a) Secure record (eg. post code) LOW
b) Structured interview LOW
c) Written self-report SOME CONCERNS
d) No description UNKNOWN

COMPARABILTY

a) Study controls for age and ethnicity(+/-parity). LOW
b) Other controlled factors LOW
c) Does not control for age and ethnicity. HIGH
d) Over adjustment for factors on the causal pathway. HIGH

OUTCOME

Assessment

a) Independent or blind assessment stated in the paper, or confirmation of the outcome by reference to secure records (x-rays, medical records, etc.). LOW
b) Record linkage (e.g. identified through ICD codes on database records). SOME CONCERNS
c) Self-report (e.g. no reference to original medical records or x-rays to confirm the outcome) HIGH
d) No description. UNKNOW

Appendix Table 3.7. Characteristics of included studies. (Studies in italics had overlapping cohorts with other studies in the systematic review and had the smaller sample sizes and therefore not included in the meta-analysis). NMMSP: National Maternal Mortality Surveillance Programs.

Country	Author, year	Study design	Data source	Time period	Population
Australia	Adane 2020	Cohort	Midwives Notification System (MNS), Hospital Morbidity Data Collection (HMDC) and birth and death registers	2002-2015	All women who gave birth >20 weeks in Western Australia
	AIHW 2020	NMMSP	NMMDC (National Maternal Mortality Data Collection NMMDC)	2015-2017	All women in Australia who had a live birth >20weeks/ 400g
	Lindquist 2015 (a)	Case control	The Australasian Maternal Outcomes Surveillance System (AMOSS)	N/A	All pregnant women across Australia (if hospital >50 births)
	Lindquist 2015 (b)	Case control	Victorian Perinatal Data Collection (VPDC)	2006-2008	All maternities, Victoria
Canada	Aoyama 2019	Cohort	Discharge Abstract Database (DAD)	2004-2015	Women giving birth in hospital across all of Canada, excluding Quebec
	Ray 2018	Cohort	DAD	2002-2017	All hospital deliveries Ontario
	Snelgrove 2021	Cohort	DAD linked to MOMBABY dataset, registered persons database and OHIP claims database, immigration, Refugees and Citizenship Canada (IRCC) Permanent Resident Database	2002-2018	Primiparous women ages 10-55 giving birth in hospital, Ontario
France	Azria 2016	Cohort	Questionnaires for social information from women and healthcare professionals filled in questionnaire for pregnancy and birth information	2010-2011	All pregnant women >than 18 years old after 22 weeks in four hospitals in Paris
	Sante Publique 2021	NMMSP	National Confidential Enquiry into Maternal deaths (ENCMM)	2013-2015	All maternities, France
	Saucedo 2012	Case control	ENCMM (cases) French National Perinatal Survey (controls)	2001-2006	Cases and controls: Birth after 22 weeks/ 500g
Germany	David 2019	Cohort	Standardised interviews linked with perinatal data	2011-2012	Three maternity hospitals, Berlin

Country	Author, year	Study design	Data source	Time period	Population
Ireland	Lutomski 2012	Cohort	Economic and Social Research Institute-Hospital In-Patient Enquiry (HIPE) database	2005-2009	All hospital births Ireland
Italy	Donati 2018	Cohort	Regional and national death registers and hospital discharge databases	2006-2012	All maternities from 10 regions in Italy
Mexico	Romero-Gutierrez 2007	Case control	Questionnaire	1992-2004	Women who delivered in the Hospital of Obstetrics and Gynaecology at the Mexican Institute of social security, Leon
New Zealand	PMMRC 2022	NMMSP	Maternal mortality review working group (MMRWG)/Perinatal and Maternal Review Committee (PMMRC)	2006-2020	All maternities, New Zealand
South Korea	Jeong 2020	Cohort	Korean National Health Insurance Service (NHIS) and Korean National Statistical Office	2003-2018	All hospital births, South Korea
	Nam 2022	Cohort	National Health Insurance (NHI) database	2003-2018	Women giving birth in South Korea with national health insurance
The Netherlands	De Graaf 2012	Cohort	Dutch MM Committee (MMC) and Statistics Netherlands	1993-2008	All maternities, The Netherlands
United Kingdom	Lewis 2004	NMMSP	Confidential Enquiry into Maternal and Child Health (CEMACH)	2000-2002	All maternities, United Kingdom
	Lewis 2007	NMMSP	CEMACH	2003-2005	All maternities, United Kingdom
	Lewis 2011	NMMSP	Centre for maternal and child health enquiries (CMACE)	2006-2008	All maternities, United Kingdom
	Knight 2009	*Case control*	*United Kingdom Obstetric Surveillance System (UKOSS)*	*2005-2006*	*All pregnant women giving birth in consultant led units, United Kingdom*
	Knight 2020	Cohort (based on data from three NMMSP)	Mothers and Babies. Reducing risk through audit and National Maternal Mortality Surveillance Programs across the UK (MBRRACE-UK)	2009-2017	All maternities, United Kingdom
	Lindquist 2013	Case control	UKOSS	2005-2010	All pregnant women giving birth in consultant led units, United Kingdom
	Knight 2022	NMMSP	MBRRACE-UK	2018-2020	All maternities, United Kingdom

Country	Author, year	Study design	Data source	Time period	Population
	Nair 2016	Case control	CMACE and UKOSS	2009-2013 (cases) 2010-2012 (controls)	Cases: All maternities, United Kingdom Controls: Women without SMM delivering in consultant led unit
United States	Campbell 2013	Cohort	Linking birth certificate data from the New York City Department of Health and Mental Hygiene to hospital discharge data from the New York State-wide Planning and Research Cooperative System	1995-2003	Women giving birth in hospital, New York City
	Creanga 2014	Cohort	Healthcare Cost and Utilization Project State In-patient Database (SID)	2008-2010	Women giving birth in hospital in selected hospitals in: Arizona, California, Florida, Michigan, New Jersey, New York, North Carolina
	Frederiksen 2017	Cohort	Linked Iowa birth certificate and hospital discharge data	2009-2014	Women giving birth in hospital, Iowa
	Freese 2020	Cohort	Administrative database	2003-2012	Women with singleton births in Magee-Women's Hospital, Pittsburgh, Pennsylvania
	Friedman 2016	*Cohort*	*National Inpatient Sample (NIS) from the Healthcare Cost and Utilization Project (HCUP)*	*1998-2019*	*Stratified sample (20%) of women giving birth in hospital (97%) across the United States*
	Frolich 2014	Case control	Medical records	1990-2010	All maternities, University of Alabama at Birmingham (UAB) Hospital
	Goffman 2007	Case control	Quality improvement records, ICU admission records and medical record database	1995-2001	Women giving birth at Weiler Hospital of the Albert Einstein College of Medicine/Montefiore Medical Centre
	Gray 2012	Casecontrol	Comprehensive Hospital Abstratc Reporting System (CHARS) linked to birth cirtificate	1987-2008	Women giving birth Washington State
	Guglielminotti 2021	*Cohort*	*SID*	*2006-2016*	*Women giving birth in hospital New York State*
	Howland 2019	Cohort	New York City birth certificates matched with hospital discharge records	2008-2012	Women having a live birth, New York City
	Huang 2023	Cohort	NIS from the HCUP	2016-2018	Stratified sample (20%) of women giving birth in hospital (97%) across the United States

Country	Author, year	Study design	Data source	Time period	Population
	Janevic 2020	Cross sectional	SID linked with birth records linked with ACS data	2012-2014	Women giving birth in hospital, New York State
	Kozhimannil 2019	*Cohort*	*NIS from the HCUP*	*2007-2015*	*Stratified sample (20%) of women giving birth in hospital (97%) across the United States*
	Leonard 2022	*Cohort*	*California Maternal Quality Care Collaberative Data Centre (CMQCC) linked to Birth Cirtficates*	*2011-2017*	*All women having a live birth in Califorrnia*
	Leonard 2019	Cohort	CMQCC linked to Birth Cirtficates	2007-2014	All women having a live birth in Califorrnia
	Luke 2020	Cohort	NIS from the HCUP	2012-2017	Stratified sample (20%) of women giving birth in hospital (97%) across the United States
	Matas 2021	Cohort	Nationwide Readmissions Database	2016-2017	Women giving birth in selected hospitals across the United States
	Meeker 2021	Cohort	EPIC electronic medical record (EMR) system	2010-2017	Women giving birth in hospital in the University of Pennsylvania Health System
	Muchomba 2021	Cross sectional	New Jersey live birth files linked to maternal hospital discharge records and US Census municipal expenditures data	2008-2018	Women giving birth in hospital in New Jersey
	Muchomba 2022	Cross sectional	Birth records linked to maternal hospital discharge records and municipal-level housing and demographic data from the state of New Jersey and the US Census Bureau (for housing data)	2008-2018	Women giving birth in hospital in New Jersey
	Oot 2021	Cohort	Illinois Health and Hospital Association Comparative Health Care and Hospital Data Reporting Services (COMPdata)	2016-2018	Women giving birth in hospital across 127 hospitals, Illinois
	Petersen 2019	Cohort	PMSS (numerator) and National centre for health statistics (denominator)	2011-2015	Pregnant women in 13 states USA

Country	Author, year	Study design	Data source	Time period	Population
	Reid 2018	Cohort	Maryland Health Services Cost Review Commission (HSCRC) linked to Centres for Medicare and Medicaid Services (CMS) Hospital Compare databases linked to American Community Survey	2010-2015	Women giving birth in hospital, Maryland
	Snowden 2021	Cohort	California Office of State-wide Health Planning and Development linked birth cohort files	2007-2012	Women giving birth in hospital, California
	Staniczenko 2022	Cross sectional	NIS from the HCUP	2008-2018	Stratified sample (20%) of women giving birth in hospital (97%) across the United States
	Tipre 2022	Cohort	Electronic health records	2010-2020	All live births from University of Alabama at Birmingham

Appendix Table 3.8. Studies which reported on the association between neighbourhood deprivation and risk of SMM

Author, year, country	Exposure category	Exposure	Comparison	Confounding factors	Effect measure	Category	Unadjusted (95% CI)	Multivariable analysis (95% CI)	Prevalence
Adane 2020, Australia	Neighbourhood deprivation	Socio-Economic Indexes for Areas (SEIFA) quintile from postcode	Least deprived quintile	Age, ethnicity, area of residence, parity, smoking, pre-existing conditions, pregnancy complications, multiple birth, year of birth	risk ratio	1(least) 2 3 4 5 missing	1.00(1.00-1.00) 1.12(1.04-1.21) 1.40(1.13-1.31) 1.21(1.31-1.50) 1.63(1.53-1.75) 1.45(1.27-1.66)	1.00 (1.00-1.00) 1.09 (1.01-1.17) 1.13(1.05-1.22) 1.25(1.16-1.34) 1.29(1.20-1.39) 1.34(1.15-1.56)	Caucasian 8283 events** (2.02%) Aboriginal 18411 events** (4.49%)
Lindquist 2015, Australia	Neighbourhood deprivation	Socio-Economic Indexes for Areas (SEIFA) quintile from postcode	Highest deprivation quintile	Maternal age, country of birth, body mass index (BMI), Aboriginal or Torres Strait Islander status, remoteness of residence, parity, smoking, previous medical and pregnancy complications, multiple pregnancy, previous caesarean delivery and number of, and insurance status	OR	1 (least) 2 3 4 5	1.00(1.00-1.00) 1.17(0.88-1.56) 1.54(1.07-2.20) 1.69(1.05-2.28) 1.80(1.23-2.63)	1.00(1.00-1.00) 1.28(0.94-1.75) 1.79(1.26-2.54) 1.56(1.02-2.38) 2.00(1.29-3.10)	623 cases

Author, year, country	Exposure category	Exposure	Comparison	Confounding factors	Effect measure	Category	Unadjusted (95% CI)	Multivariable analysis (95% CI)	Prevalence
Lindquist 2015, Australia	Neighbourhood deprivation	Socio-Economic Indexes for Areas (SEIFA) quintile from postcode	Highest deprivation quintile	Maternal age, country of birth, ATSI status, parity, multiple pregnancy, coexisting medical condition, past caesarean section and past spontaneous abortion	OR	1 (least) 2 3 4 5 missing	1.00(1.00-1.00) 1.20(1.00-1.44) 0.94(0.76-1.15) 1.47(1.22-1.77) 1.13(0.93-1.36) 1.73(1.21-2.46)	1.00(1.00-1.00) 1.23(1.03-1.49) 0.98(0.79-1.21) 1.55(1.28-1.87) 1.21(1.00- 1.47) 1.74(1.21-2.50)	1119 cases (0.53%)
Snelgrove 2021, Canada	Neighbourhood deprivation	Neighbourhood material deprivation quintile from the Ontario marginalization index (ON-MARG) from postcode	Least deprived quintile	Age, rural setting, number of years since immigration, mode of delivery, multiple pregnancy	risk ratio – 'unadjusted' is adjusted for pregnancy year	1 (least) 2 3 4 5	1.00(1.00-1.00) 0.95(0.91-0.99) 1.00(0.96-1.05) 1.02(0.98-1.07) 1.11(1.06-1.16)	1.00(1.00-1.00) 0.97(0.92-1.01) 1.03(0.98-1.07) 1.06(1.01-1.11) 1.16(1.11-1.21)	SMM rate 18/1000 18800 events (1.80%)
Muchomba 2021, United States	Neighbourhood deprivation	Municipality level deprivation - Messer et al	No deprivation	Year of delivery, race, ethnicity, parity, age. municipality factors: spending per capita, population size	odds ratio (unadjusted still adjusted for municipality factors)	Not deprived Deprived	1.00(1.00-1.00) 1.20(1.16-1.23)	1.00 (1.00-1.00) 1.09(1.06-1.12)	SMM rate 199/10000 19928 events** (1.99%)

Author, year, country	Exposure category	Exposure	Comparison	Confounding factors	Effect measure	Category	Unadjusted (95% CI)	Multivariable analysis (95% CI)	Prevalence
Tipre 2022, Unites States	Neighbourhood deprivation	Area deprivation index (ADI)	Least deprived quintile	Age, race, insurance status, residence in medically underserved area/population and residence urban/rural	odds ratio	1 (least) 2 3 4 5	1.00(1.00-1.00) 1.28(1.11-1.48) 1.43(1.24-1.67) 1..58(1.37-1.82) 1.84(1.60-2.12)	1.00 (1.00-1.00) 1.18(0.95-1.47) 1.47(1.18-1.84) 1.55(1.18-2.04) 1.78(1.22-2.59)	3230 events (9.8%) – 26 were maternal deaths

**Worked out from rate and N study population

Appendix Table 3.9. Studies which reported on the association between neighbourhood educational level and risk of SMM

Author, year, country	Exposure category	Exposure	Comparison	Confounding factors	Effect measure	Category	Univariable analysis (CI)	Multivariable analysis (95% CI)	Prevalence
Meeker 2021, United States	Neighbourhood education	% of women aged 15–50 y in each Census tract who graduated high school	Per 1 unit change in neighbourhood covariate	None	% change in SMM per 1 unit change in neighbourhood covariate	% of women in each census tract aged 15-50 who graduated high school	0.29(0.10-0.47)		11726 events (2.73%)
Reid 2018, United States	Neighbourhood education	%women no high school diploma	Lowest %women no high school diploma	%medium income, %poverty, %female headed household %women uninsured, race, age, marital status, health insurance, residence region, comorbidities, other medical risk factor, health behaviour, substance misuse, hospital level measures	risk ratio	<1.9% 1.9-3.8% 3.9-6.1% 6.2-10.1% 10.2-100%		1.00(1.00-1.00) 0.96(0.81-1.15) 1.01(0.85-1.20) 1.25(1.05-1.49) 1.38(1.16-1.65)	SMM rate 197/10000 7171 events (1.97%)

Appendix Table 3.10. Studies which reported on the association between neighbourhood employment and risk of SMM

Author, year, country	Exposure category	Exposure	Comparison	Confounding factors	Effect measure	Category	Unadjusted (95% CI)	Multivariable analysis (95% CI)	Prevalence
Meeker 2021, United States	Neighbourhood employment	% of women aged 16-50 in the census tract who are in the labour force			% change in SMM per 1 unit change in neighbourhood covariate	1 unit change	-0.05(-0.24-0.14) P=0.618		11726 events (2.73%)

Appendix Table 3.11. Studies which reported on the association between neighbourhood poverty and risk of SMM

Author, year, country	Exposure category	Exposure	Comparison	Confounding factors	Effect measure	Category	Unadjusted (95% CI)	Multivariable analysis (95% CI)	Prevalence
Howland 2019, United States	Neighbourhood poverty	Percent of residents living below the federal poverty level, and empirically categorised as low (<15%), medium (15-29%) and high (30-44%)	Poverty low (<15%)	Maternal race/ethnicity, maternal age (years), maternal birthplace, year of delivery, delivery insurance, maternal education, pre-pregnancy BMI, chronic conditions, smoking during pregnancy, prenatal care entry, parity, single or multiple birth and data clustering within facilities	odds ratio	low medium high	1.00(1.00-1.00) 1.07(1.02-1.13) 1.11(1.05.1.18)	1.00(1.00-1.00) 1.01(0.96-1.07) 1.04(0.97-1.07)	SMM rate 229.6/10000 13505 events (2.30%)
Meeker 2021, United States	Neighbourhood poverty	% of women in census tract aged 15-50 below the 100% poverty level			% change in SMM per 1 unit change in neighbourhood covariate	% of women below the poverty level	0.11(-0.03-0.25)		11726 events (2.73%)

Author, year, country	Exposure category	Exposure	Comparison	Confounding factors	Effect measure	Category	Unadjusted (95% CI)	Multivariable analysis (95% CI)	Prevalence
Oot 2021, United States	Neighbourhood poverty	ZCTA percentage of poverty households	Least percentage of poverty	Age, race, insurance status, pre-existing conditions, substance misuse, psychiatric conditions, morbid obesity, pregnancy related conditions, delivery year, hospital delivery volume, region, other hospital characteristics	rate ratio	<5% 5-9.99% 10-19.99% >20% Out of state		1.00(1.00-1.00) 0.97(0.85-1.09) 1.13(0.97-1.30) 1.20(1.00-1.43) 1.47(1.05-2.07)	11800 events** (2.80%)
Reid 2018, United States	Neighbourhood poverty	ZCTA percentage of poverty households	% Neighbourhood poverty <2.9	%Medium income, %no high school diploma, %female headed household %women uninsured, race, age, marital status, health insurance, residence region, comorbidities, other medical risk factor, health behaviour, substance misuse, hospital level measures	risk ratio	<2.9% 3.0-5.5% 5.6-9.1% 9.2-14.4% 14.4-100.0%	1.00(1.00-1.00) 1.11(0.95-1.31) 1.19(1.02-1.39) 1.38(1.18-1.61) 1.60(1.36-1.87)		SMM rate 197/10000 7171 events (1.97%)

**Worked out from rate and N study population

Appendix Table 3.12. Studies which reported on the association between neighbourhood income and risk of SMM

Author, year, country	Exposure category	Exposure	Comparison	Confounding factors	Effect measure	Category	Unadjusted (95% CI)	Multivariable analysis (95% CI)	Prevalence
Aoyama 2019, Canada	Neighbourhood income	Neighbourhood median household income quintile from zip code	Highest income quintile	Patient-level covariates included age, parity, urban or rural residence location, hospital transfer. Hospital-level covariates included province or territory, urban or rural hospital location, and hospital pregnancy volume	risk ratio (unadjusted - worked out with raw data), odds ratio (adjusted)	5 (highest) 4 3 2 1	1.00(1.00-1.00) 0.98(0.95-1.02) 1.02(0.99-1.05) 1.06(1.03-1.09) 1.16(1.13-1.19)	1 .00(1.00-1.00) 1.02(0.98-1.05) 1.05(1.01-1.08) 1.11(1.07-1.15) 1.19(1.14-1.22)	SMM rate 17.7/ 1000 54219 events (1.77%)
Creanga 2014, United States	Neighbourhood income	Neighbourhood median household income quartile from zip code	Lowest income quartile	Race, insurance, age, chronic medical conditions	risk ratio	1 (poorest) 2 3 4		1.00(1.00-1.00) 0.90(0.90-0.90) 0.80(0.80-0.90) 0.80(0.80-0.80)	SMM rate 150.7/10000 52389 events** (1.51%)
Friedman 2016, United States	Neighbourhood income	Neighbourhood median household income quartile from zip code	Lowest income quartile	Age, race, year of discharge, payer status, hospital characteristics (bed size, location, region, teaching status, owner), and comorbid risk	risk ratio	1 (poorest) 2 3 4 unknown		1.00(1.00-1.00) 1.02(1.01-1.03) 1.00(0.99-1.01) 0.96(0.95-0.97) 1.02(0.99-1.05)	284883 events (0.57%)

Author, year, country	Exposure category	Exposure	Comparison	Confounding factors	Effect measure	Category	Unadjusted (95% CI)	Multivariable analysis (95% CI)	Prevalence
Janevic 2020, United States	Neighbourhood income	The Index of Concentration at the Extremes (ICE) - Economic spatial polarisation from zip code, ICE = population costs of the number of households in the bottom and top quintiles of annual US household income.	Highest ICE	Race/ethnicity, age, nativity, previous live births, education, insurance status, BMI, multiple pregnancy, co-existing medical problems, placentation disorders, anaemia, asthma, prior caesarean delivery, and hospital of delivery.	RD	5(highest) 4 3 2 1	0.00(0.00-0.00) 0.50(0.20-0.80) 0.70(0.30-1.20) 1.00(0.60-1.50) 1.40(0.80-2.00)	0.00(0.00-0.00) 0.30(0.10-0.50) 0.30(0.10-0.50) 0.40(0.20-0.60) 0.40(0.20-0.60)	8239 events (2.6%)
Kozhimannil 2019, United states	Neighbourhood income	Neighbourhood median household income quartile from zip code	Top three quartiles of income	Year, age, insurance, race/ethnicity, census region hospital, caesarean delivery, substance misuse, pre-existing medical conditions	Neighbourhood income - Neighbourhood median household income quartile from zipcode	Top three quartiles Bottom quartile	1.00(1.00-1.00) 1.11(1.08-1.14)	1.00(1.00-1.00) 1.11(1.08-1.14)	140/10000 events rural 135/10000 events urban

Author, year, country	Exposure category	Exposure	Comparison	Confounding factors	Effect measure	Category	Unadjusted (95% CI)	Multivariable analysis (95% CI)	Prevalence
22021, United States	Neighbourhood income	Neighbourhood median household income quartile from zipcode	2nd, 3rd and 4th highest income quartiles	None	risk ratio Absolute standardized mean difference (%)	high low 4.4 P<0.001	1.00(1.00-1.00) 1.33(1.31-1.36)		SMM rate 13.4/1000 993864 events (1.34%)
Luke 2020, United States	Neighbourhood income	Neighbourhood median household income quartile from zipcode	Top three highest quartiles	Locality and clinical risk adjustment (age and comorbidities), social risk factors (race, insurance status), hospital characteristics	odds ratio	Top three quartiles (highest) Bottom quartile	1.00 (1.00-1.00) 1.32(1.29-1.35)	1.00(1.00-1.00) 1.09(1.06-1.11)	Lowest quartile 96174 events** (2.14%) Top three quartiles 73703 events ** (1.64%)
Matas 2021, United States	Neighbourhood income	Neighbourhood median household income quartile from zip code	Highest income quartile	None	risk ratio	4(highest) 3 2 1	1.00(1.00-1.00) 1.05(1.03-1.07) 1.12(1.10-1.14) 1.44(1.41-1.47)		101757 events (1.60%)
Meeker 2021, United States	Neighbourhood income	Percent of women aged 15-50 years in each census tract that received public assistance	Per 1 unit change in neighbourhood income		% change in SMM per 1 unit change in neighbourhood covariate	1 unit change	0.40(0.01-0.79) P=0.043		11726 events (2.73%)

Author, year, country	Exposure category	Exposure	Comparison	Confounding factors	Effect measure	Category	Unadjusted (95% CI)	Multivariable analysis (95% CI)	Prevalence
Reid 2018, United States	Neighbourhood income	Neighbourhood median household income quartile from zipcode		%No high school diploma, %poverty, %female headed household %women uninsured, race, age, marital status, health insurance, residence region, comorbidities, other medical risk factor, health behaviour, substance misuse, hospital level measures	risk ratio	99,376-123,855 81,875-99,375 66,938-81,874 20,828-66,937 <20,828	1.00(1.00-1.00) 1.15(1.01-1.31) 1.16(1.02-1.31) 1.48(1.30-1.68) 1.67(1.46-1.91)	1.00(1.00-1.00) 1.05(0.94-1.17) 1.05(0.94-1.17) 1.10(0.98-1.23) 1.06(0.93-1.22)	SMM rate 197/10000 7171 events (1.97%)

**Worked out from rate and N study population

Appendix Table 3.13. Studies which reported on the association between neighbourhood housing and risk of SMM

Author, year, country	Exposure category	Exposure	Comparison	Confounding factors	Effect measure	Category	Unadjusted (95% CI)	Multivariable analysis (95% CI)	Prevalence
Muchomba 2022, United States	Neighbourhood housing	Municipal-level rental costs relative to income (housing cost burden), 1% increase in the percentage of residents spending >30% of income on rent, 50% = severe housing cost burden, medium rent to income ratio	Per 1% increase	Individual-level factors (educational attainment, age, race and ethnicity, parity, and year of birth, municipal-level factors (median rent, percentage of residents with income lower than the poverty level, and population size)	odds ratio	percentage with housing cost burden severe housing cost burden median rent to income ratio		1.27(1.01-1.60) 1.38(1.04-1.82) 1.73(1.15-2.59)	SMM rate 199/10000 19928 events** (1.99%)
Meeker 2021, United States	Neighbourhood housing	Neighbourhood housing violations and percent of occupied housing units in each census tract that are owner occupied	Per 1 unit change in neighbourhood covariate		% change in SMM per 1 unit change in neighbourhood covariate	housing violations (log transformed) %number of owner occupied housing %number of renter occupied housing	3.90(1.40-6.21) -0.05(-0.09-1.90) 0.05(-0.09-0.19)		11726 events (2.73%)

**Worked out from rate and N study population

Appendix Table 3.14. Studies which reported on the association between neighbourhood crime and risk of SMM

Author, year, country	Exposure category	Exposure	Comparison	Confounding factors	Effect measure	Category	Unadjusted (95% CI)	Multivariable analysis (95% CI)	Prevalence
Meeker 2021, United states	Neighbourhood crime	Number of neighbourhood crimes (total, violent and non-violent)	per 1 unit change in neighbourhood covariate	None	% change in SMM per 1 unit change in neighbourhood covariate	number of none-violent crime (log transformed) number of violent crimes (log transformed)	2.00(-1.80-5.90) 4.90(2.02-7.83)	3.0 (-0.15-6.8)	11726 events (2.73%)

Appendix Table 3.15. Studies which reported on the association between individual educational level and risk of SMM

Author, year, country	Exposure category	Exposure	Comparison	Confounding factors	Effect measure	Category	Unadjusted (95% CI)	Multivariable analysis (95% CI)	Prevalence
David 2019, Germany	Education	Education level	Upper secondary school and higher		odds ratio	high medium low	1.00(1.00-1.00) 0.94(0.62-1.44) 0.99(0.61-1.59)		140 cases*
Frederiksen 2017, United States	Education	Education level	>high school	First trimester prenatal care, previous delivery, gestational hypertension, pre-pregnancy hypertension, payer, marital status, rural/urban, ethnicity, age	odds ratio	>high school <=high school	1.00(1.00-1.00) 1.38(1.26-1.60)	1.00(1.00-1.00) 1.12(1.00-1.25)	SMM rate 105/10000 2066** events (1.05%)
Freese 2020, United States	Education	Education level	No college degree		risk ratio	college degree no college degree		1.00(1.00-1.00) 1.20(1.10-1.40)	1739 events (2.0%)
Goffman 2007, United States	Education	Education level	Some college (unadjusted), college graduate (adjusted)	Race, maternal age, past medical history, previous caesarean, obesity, gravity, Medicaid status, marital status	odds ratio	college graduate some college high school graduate <high school graduate	0.40(0.20-0.90) 1.00(1.00-1.00) 0.80(0.40-1.60) 0.40(0.10-1.10)	1.00(1.00-1.00) 0.60(0.20-1.60) 0.50(0.20-1.20) 0.40(0.10-1.60)	77 cases

Author, year, country	Exposure category	Exposure	Comparison	Confounding factors	Effect measure	Category	Unadjusted (95% CI)	Multivariable analysis (95% CI)	Prevalence
Gray 2012, United states	Education	Education level	>high school	unadjusted	odds ratio	>high school <=high school	1.00(1.00-1.00) 1.29(1.22-1.37)		9485 cases 41112 controls
Howland 2019, United States	Education	Education level	College graduate	Maternal race/ethnicity, maternal age, maternal birthplace, year of delivery, delivery insurance, neighbourhood poverty, pre-pregnancy BMI, chronic conditions, smoking during pregnancy, prenatal care entry, parity, single or multiple birth and data clustering within facilities	odds ratio	college graduate high school < high school	1.00(1.00-1.00) 1.15(1.09-1.21) 1.25(1.18-1.33)	1.00(1.00-1.00) 1.12(1.06-1.19) 1.27(1.19-1.36)	SMM rate 229.6/10000 13505 events (2.30%)
Leonard 2021, United States	Education	Educational level	College graduate or higher	Leonard comorbidity index (includes age and BMI)	odds ratio	< high school High school Some college College graduate	1.28 (1.25–1.31) 1.16 (1.14–1.19) 1.06 (1.04–1.09) 1.00(1.00-1.00)	1.28 (1.25–1.32) 1.15 (1.12–1.18) 1.01 (0.98–1.03) 1.00(1.00-1.00)	53296 events (1.61%)

Author, year, country	Exposure category	Exposure	Comparison	Confounding factors	Effect measure	Category	Unadjusted (95% CI)	Multivariable analysis (95% CI)	Prevalence
Leonard 2019, United States	Education	Education level	Some college and college	unadjusted	odds ratio	Less than or equal to high school Greater than high school	1.15(1.13-1.17) 1.00(1.00-1.00)		47,973 events (1.35%)
Muchomba 2021, United States	Education	Education level	< high school	Year of delivery, ethnicity, parity, age, municipally level deprivation, spending per capita, population size	odds ratio	<high school high school some college >= college		1.00(1.00-1.00) 0.92(0.87-0.96) 0.82(0.78-0.87) 0.75(0.71-0.80)	SMM rate 199/10000 19928 events** (1.99%)
Snowden 2021, United States	Education	Education level	College graduate		odds ratio	college graduate some college <=high school missing	1.00(1.00-1.00) 1.07(1.04-1.10) 1.21(1.18-1.24) 1.30(1.23-1.37)		39647 events (1.30%)

**Worked out from rate and N study population

Appendix Table 3.16. Studies which reported on the association between individual occupation and risk of SMM

Author, year, country	Exposure category	Exposure	Comparison	Confounding factors	Effect measure	Category	Unadjusted (95% CI)	Multivariable analysis (95% CI)	Prevalence
Knight 2009, United Kingdom	Occupation	Woman's occupation, if unemployed then partners occupation, NS-SEC	Managerial/ professional	Ethnicity, age, smoking, BMI, parity	odds ratio	managerial/ professional	1.00(1.00-1.00)	1.00(1.00-1.00)	686 cases*
						other	1.10(0.88-1.37)	1.32(1.02-1.69)	
Lindquist 2013, United Kingdom	Occupation	Woman's occupation, NS-SEC	Managerial/ professional	Ethnicity, maternal age, smoking, pre-existing medical conditions and, BMI, parity, multiple pregnancy and past pregnancy complications	odds ratio	managerial/ professional	1.00 (1.00-1.00)	1.00(1.00-1.00)	1144 cases*
						intermediate	0.98(0.80-1.21)	1.17(0.94-1.45)	
						routine/ manual	0.89(0.73-1.09)	1.16(0.93-1.45)	
						unemployed	0.89(0.70-1.14)	1.22(0.92-1.61)	
						missing	1.24(0.98-1.56)	1.51(1.18-1.94)	

*Both studies included despite overlapping cohort and the same outcome/ exposure as the exposure is grouped differently

Appendix Table 3.17. Studies which reported on the association between individual/household income and risk of SMM

Author, year, country	Exposure category	Exposure	Comparison	Confounding factors	Effect measure	Category	Unadjusted (95% CI)	Multivariable analysis (95% CI)	Prevalence
Lutomski 2012, Ireland	Income at individual level (Medical card status used as proxy)	Medical card status (card which provides low-income individuals with selected free health care services and is a proxy for socioeconomic deprivation)	Women without a medical card	None	risk ratio	No Yes Unknown	1.00(1.00-1.00) 1.07(1.00-1.16) 1.63(1.35-1.97)		SSM rate 13/10000 4438 events (13.00%) 4 maternal deaths
Nam 2022, South Korea	Household income	Household income level in quartiles	Highest income quartile	Maternal age, household income level, type of health insurance, residential area, mode of delivery, preterm birth, parity, multiple birth, prenatal care, maternal comorbidities, type of hospital, region of hospital, and year	risk ratio	**CDC** 4 (highest) 3 2 1 **ACOG** 4 (highest) 3 2 1 **ZWART** 4 (highest) 3 2 1 **EURO-peristat** 4 (highest) 3 2 1		1.00(1.00-1.00) 1.07(1.06-1.09) 1.14(1.12-1.16) 1.17(1.15-1.19) 1.00 (1.00-1.00) 1.06(1.05-1.08) 1.12(1.10-1.13) 1.14(1.13-1.16) 1.00 (1.00-1.00) 1.11(1.07-1.16) 1.24(1.18-1.29) 1.30(1.24-1.36) 1.00(1.00-1.00) 1.04(1.02-1.06) 1.09(1.07-1.12) 1.13(1.10-1.15)	151533 events (2.36%) 200090 events (3.12%) 20084 events (0.3%) 87452 events (1.36%)

Appendix Table 3.18. Studies which reported on the association between individual housing insecurity and risk of SMM

Author, year, country	Exposure category	Exposure	Comparison	Confounding factors	Effect measure	Category	Unadjusted (95% CI)	Multivariable analysis (95% CI)	Prevalence
Huang 2023, United States	Individual housing insecurity	Housing insecurity ICD10 z59 'Problems related to housing and economic circumstances'	Women with no housing insecurity	Leonard obstetric comorbidities (includes age>35), insurance, median income based on zip code, and rurality	odds ratio	stable housing unstable housing	1.00(1.00-1.00) 2.17(1.75-2.68)	1.00(1.00-1.00) 1.17(0.94-1.47)	Housing secure 12419** (2.3%) Housing insecure 25918** (4.8%)
Staniczenko 2022, United States	Individual housing insecurity	Housing insecurity ICD 9 code v60.89 'Housing/econ services NEC'	Women with no housing insecurity	None	risk ratio	stable housing unstable housing	1.00(1.00-1.00) 2.73(2.50-2.97)		n/a

Worked out from rate and N study population * Both studies included despite overlapping cohort as Staniczenko et al has a larger cohort size but only conducted univariable analysis

Appendix Table 3.19. Studies which reported on the association between individual social vulnerability and risk of SMM

Author, year, country	Exposure category	Exposure	Comparison	Confounding factors	Effect measure	Category	Unadjusted (95% CI)	Prevalence
Azria 2016, France	Individual housing insecurity	Individual social vulnerability	No social vulnerability	NA	risk ratio	Social vulnerability No social vulnerability	1.30(1.01-1.69) 1.00(1.00-1.00)	NA

Appendix Table 3.20. Studies which reported on the association between neighbourhood deprivation and risk of maternal mortality

Author, year, country	Exposure category	Exposure	Comparison	Confounding factors	Effect measure	Category	Unadjusted (and their 95% confidence intervals)	Confidence intervals
AIHW 2020, Australia	Neighbourhood deprivation	Socio-Economic Indexes for Areas (SEIFA) quintile from postcode	Least deprived quintile	None	odds ratio	1 (least) 2 3 4 5	1.00(1.00-1.00) 1.17(0.42-3.23) 1.61(0.62-4.20) 1.96(0.77-0.97) 2.06(0.83-5.15)	MMR 6.4/100000 59 deaths
PMMRC 2022, New Zealand	Neighbourhood deprivation	NZDep 2006 Index of Deprivation quintile from postcode	Least deprived quintile	None	risk ratio	1 (least) 2 3 4 5	1.00 (1.00-1.00) 0.99 (0.45–2.16) 1.50 (0.75–3.01) 2.05 (1.08–3.91) 2.18 (1.16–4.08)	MMR 7.75/100000 135 deaths
DeGraaf 2012, The Netherlands	Neighbourhood deprivation	Deprived neighbourhood - 40 neighbourhoods labelled as deprived by Dutch government based on high rates of unemployment, crime, insecurity, and poor housing	Being from a non-deprived neighbourhood	None	risk ratio	Not deprived Deprived	1.00 (1.00-1.00) 1.41(0.97-2.06)	MMR 10.8/100000 336** deaths
Lewis 2007, United Kingdom	Neighbourhood deprivation	Index of multiple deprivation (IMD)	Least deprived quintile	None	risk ratio	1 (least) 2 3 4 5	1.00 (1.00-1.00) 1.50 (0.90-2.70) 2.40 (1.40-4.10) 3.80 (2.30-6.10) 5.10 (3.20-8.10)	MMR 14/100000 295 deaths

Author, year, country	Exposure category	Exposure	Comparison	Confounding factors	Effect measure	Category	Unadjusted (and their 95% confidence intervals)	Confidence intervals
Lewis 2011, United Kingdom	Neighbourhood deprivation	Index of multiple deprivation (IMD)	Least deprived quintile	None	risk ratio	1 (least) 2 3 4 5	1.00 (1.00-1.00) 0.87(0.51-1.48) 1.18(0.73-1.91) 1.14(0.71-1.82) 1.69(1.11-2.57)	MMR 11.39/100000 261 deaths
Knight 2020 (2009-2011), United Kingdom	Neighbourhood deprivation	Index of multiple deprivation (IMD)	Least deprived quintile	None	odds ratio	1 (least) 2 3 4 5	1.00 (1.00-1.00) 1.24 (0.69-2.26) 1.25 (0.71-2.24) 1.65 (0.99-2.84) 1.69 (1.03-2.87)	MMR 10.63/1000000 253 deaths
Knight 2020 (2012 -2014), United Kingdom	Neighbourhood deprivation	Index of multiple deprivation (IMD)	Least deprived quintile	None	odds ratio	1 (least) 2 3 4 5	1.00 (1.00-1.00) 0.99 (0.48-2.05) 1.00 (0.50-2.01) 1.56 (0.86-2.93) 1.62 (0.92-2.99)	MMR 8.5/1000000 241 deaths
Knight 2020 (2015-2017), United Kingdom	Neighbourhood deprivation	Index of multiple deprivation (IMD)	Least deprived quintile	None	odds ratio	1 (least) 2 3 4 5	1.00 (1.00-1.00) 1.00 (0.46-2.22) 1.39 (0.70-2.90) 2.03 (1.09-4.01) 2.23 (1.23-4.33)	MMR 9.2/1000000 240 deaths
Knight 2022, United Kingdom	Neighbourhood deprivation	Index of multiple deprivation (IMD)	Least deprived quintile	None	risk ratio	1 (least) 2 3 4 5	1.00 (1.00-1.00) 0.98 (0.49-1.96) 1.06 (0.55-2.07) 1.38 (0.77-2.58) 2.52 (1.50-4.47)	MMR 10.9/100000 229 deaths

**Worked out from MMR and N study participants

Appendix Table 3.21. Studies which reported on the association between neighbourhood income and risk of maternal mortality

Author, year, country	Exposure category	Exposure	Comparison	Confounding factors	Effect measure	Category	Unadjusted (95% CI)	Multivariable analysis (95% CI)	Prevalence
Aoyama 2019, Canada	Neighbourhood income	Neighbourhood median household income quintile, based on zip code	Highest income quintile	Patient-level covariates included age, parity, urban or rural residence location, hospital transfer. Hospital-level covariates included province or territory, urban or rural hospital location, and hospital pregnancy volume.	odds ratio	5(richest) 4 3 2 1		1.00(1.00-1.00) 3.00(1.42-6.36) 3.94(1.90-8.08) 3.39(1.63-7.03) 4.14(2.03-8.05)	MMR 6.2/100000 192 deaths
Frolich 2014, United States	Neighbourhood income	Neighbourhood median household income quartile, based on zip code	Cases: maternal deaths, controls were live births	Matched 2:1 on maternal age and week of delivery	Median neighbourhood income x$1000 (SD)	Cases Controls	35.7(17.8-102.8) 36.3(18.1-93.0) P=0.18		77 cases
Ray, 2018 Canada	Neighbourhood income	Neighbourhood median household income from zip code	Highest income quintile	None	risk ratio	Low-income quintile 1 and 2 High income quintile 3 and 4	1.63(1.21-2.18) 1.00(1.00-1.00)		MMR 9.3/100000 181 deaths

Appendix Table 3.22 Studies which reported on the association between individual employment and risk of maternal mortality

Author, year, country	Exposure category	Exposure	Comparison	Confounding factors	Effect measure	Category	Unadjusted (95%CI)	Multivariable analysis (95% CI)	Prevalence
Saucedo 2012, France	Employment	Employment status of woman	Employed	None	odds ratio	employed unemployed	1.00(1.00-1.00) 0.95(0.74-1.22)		286 cases
Romero-Gutierrez 2007, Mexico	Employment	Employed outside of the home (woman)	Employed	None	odds ratio	employed unemployed	1.00(1.00-1.00) 0.25(0.09-0.55)		110 cases
Lewis 2007, United Kingdom	Employment	Employment status from woman's partner	Employed	None	risk ratio	employed unemployed/ unclassified/ unknown	1.00 (1.00-1.00) 7.40(5.60-9.90)		MMR 14/100000 295 deaths
Lewis 2011, United Kingdom	Employment	Employment status from woman's partner	Employed	None	risk ratio	employed unemployed/ unclassified/ unknown	1.00 (1.00-1.00) 5.74(3.88-8.49)		MMR 11.39/100000 261 deaths
Nair 2016, United Kingdom	Employment	Employment status of the women or their partners (where information about employment status of the women was not available)	Employed	Ethnicity, substance misuse, smoking, age, BMI, multiple pregnancy, gestational diabetes, anaemia, inadequate use of antennal care, previous pregnancy problem, pre-existing medical	odds ratio	employed unemployed missing	1.00 (1.00-1.00) 2.81(1.98-3.98) 1.39(1.05-1.83)	1.00(1.00-1.00) 1.81(0.76-2.47) 0.63(0.44-1.51)	383 cases

Author, year, country	Exposure category	Exposure	Comparison	Confounding factors	Effect measure	Category	Unadjusted (95%CI)	Multivariable analysis (95% CI)	Prevalence
Campbell 2013, United States	Employment	Employment status of woman	Unemployed	None	risk ratio	employed unemployed	1.00(1.00-1.00) 1.30(0.89-1.90)		MMR 12.12/100000 132 deaths
Jeong 2020, South Korea	Employment	Employment status of woman	Unemployed	Age, insurance type, residential area, working status, mode of delivery, preterm birth, prenatal care, multiple birth, maternal comorbidities, type of hospital	risk ratio	employed unemployed	1.00(1.00-1.00) 1.46(1.18-1.79)	1.00(1.00-1.00) 1.39(1.11-1.75)	MMR 10.59/100000 353 deaths

Appendix Table 3.23. Studies which reported on the association between individual housing and risk of maternal mortality

Author, year, country	Exposure category	Exposure	Comparison	Confounding factors	Effect measure	Category	Unadjusted (95% CI)	Multivariable analysis (95% CI)	Prevalence
Huang 2023, United States	Individual housing	Housing insecurity ICD10 z59 'Problems related to housing and economic circumstances'	Women with no housing insecurity	Leonard obstetric comorbidities (includes age>35), insurance, median income based on zip code, and rurality	odds ratio	no housing insecurity housing insecurity	1.00 (1.00-1.00) 2.17(1.75-2.68)	1.00 (1.00-1.00) 1.17(0.94-1.47)	MMR 26.3/1000000 21241 deaths

Appendix Table 3.24. Studies which reported on the association between individual occupation and risk of maternal mortality

Author, year, country	Exposure category	Exposure	Comparison	Confounding factors	Effect measure	Category	Unadjusted (95% CI)	Prevalence
Lewis 2011, United Kingdom	Occupation	NS-SEC from woman's partner/ husband	Professional or managerial occupation	None	risk ratio	Professional/ managerial Intermediate Routine and manual	1.00(1.00-1.00) 2.09(1.28-3.41) 2.30(1.49-3.53)	MMR 11.39/100000 261 deaths
Lewis 2007, United Kingdom	Occupation	NS-SEC from woman's partner/ husband	Professional or managerial occupation	None	risk ratio	Professional/ managerial Intermediate Routine and manual	1.00(1.00-1.00) 1.00(0.70-1.60) 1.10(0.80-1.60)	MMR 14/100000 295 deaths
Lewis 2004, United Kingdom	Occupation	NS-SEC from woman's partner/ husband	Professional or managerial occupation	None	risk ratio	Professional/ managerial Intermediate Routine and manual Not classified	1.00(1.00-1.00) 2.02(1.20-3.40) 1.71(1.08-1.97) 18.70(12.00-29.11)	MMR 12/100000 242 deaths**

**risk ratio worked out from MMR

Appendix Table 3.25. Studies which reported on the association between individual educational attainment and risk of maternal mortality

Author, year, country	Exposure category	Exposure	Comparison	Confounding factors	Effect measure	Category	Unadjusted (95% CI)	Prevalence
Donati 2018, Italy	Education	Education	high education >= 8 years	None	risk ratio	high education low education	1.00 (1.00-1.00) 3.06(2.09-4.46)	9.18/100000 277 deaths
Campbell 2013, United States	Education	Education	>high school	None	risk ratio	>high school <= high school	1.00(1.00-1.00) 1.22(0.84-1.77)	12.12/100000 132 deaths
Petersen 2019, United States	Education	Education	<high school	None	odds ratio	<high school high school graduate some college college graduate	1.00(1.00-1.00) 1.57(1.41-1.76) 2.58(2.32-2.86) 2.11(1.87-2.38)	17.2/100000 6765 deaths

Appendix Table 3.26. Justification for risk of bias assessment for cohort studies and National Maternal Morality Surveillance Programs

Author, year, country	SELECTION Representative	Selection of the non-exposed cohort	Ascertainment of exposure	COMPARABILITY	OUTCOME	Was follow up long enough for outcomes to occur	Adequacy of follow up of cohorts/ missing data
AIHW 2020 Australia	LOW Nationwide	LOW	LOW Postcode	HIGH Univariable analysis only	LOW Confidential enquiry	LOW 42 days all of pregnancy and post-partum	LOW 3-6% missing data on postcode
Adane 2020 Canada	LOW All births in western Australia with hospital data- 98.7% births	LOW	LOW Postcode	HIGH Univariable analysis or in multivariable analysis adjusted for factors on the causal pathway	SOME CONCERNS ICD-10 codes	LOW Delivery hospitalisations but stated in the methods	LOW 5% missing data on SES status
Aoyama 2019 Canada	LOW All pregnant women admitted to Canadian acute care hospitals (aside from Quebec)	LOW	LOW Postcode	HIGH Over adjustment for factors on causal pathway or univariable analysis only.	SOME CONCERNS ICD-10 codes	LOW Pregnancy and 42 days postpartum	LOW 13.9% missing on income quintile but MI performed
Snelgrove 2021 Canada	LOW All primiparous women in Ontario and stated on aims and objectives of paper	LOW	LOW Postcode	HIGH Model 1 univariable only, Model 2 adjusted just for age, model 3 over adjusted as it included mode of delivery	SOME CONCERNS ICD-10 codes	LOW Pregnancy and 42 days postpartum	LOW 1.6% missing data
Ray 2018 Canada	LOW All pregnant women in Ontario	LOW	LOW Zip code	HIGH Univariable only	LOW Death registry vital statistics	LOW From index delivery to 42 days post-partum but stated in methods	LOW 0.5% missing

Author, year, country	SELECTION Representative	Selection of the non-exposed cohort	Ascertainment of exposure	COMPARABILITY	OUTCOME	Was follow up long enough for outcomes to occur	Adequacy of follow up of cohorts/ missing data
Jeong 2020 South Korea	LOW Nationwide although only primiparous women	LOW	LOW Insurance database	HIGH Over adjustment for factors on causal pathway. Did not adjust for ethnicity but in South Korea this may not be a major confounder	SOME CONCERNS Record linkage	LOW Pregnancy and up to 6 weeks post-partum	LOW No missing data
Nam 2022 South Korea	LOW Nationwide although only women with national health insurance which was most women	LOW	LOW From insurance data	HIGH Over adjusted for factors on the causal pathway	SOME CONCERNS ICD-10 data linkage	LOW From pregnancy to 30 days post-partum	LOW Missing data minimal - 0.4% on prenatal care. no other missing data reported
DeGraaf 2012 The Netherlands	LOW National confidential enquiry	LOW	LOW Postcode	HIGH Univariable analysis only	LOW Maternal mortality committee	LOW 42 days post-partum as set out by aims and objectives	UNKNOWN Amount of missing postcode information is stated as non-applicable. Unclear whether this is none or not available.
Lewis 2004 United Kingdom	LOW Nationwide	LOW	UNKNOWN Partner occupation and employment. Unclear how they were ascertained	HIGH Univariable analysis only	LOW Confidential enquiry	LOW 42 days all of pregnancy and post-partum	UNKNOWN – 1 category for missing and unemployed

Author, year, country	SELECTION Representative	Selection of the non-exposed cohort	Ascertainment of exposure	COMPARABILITY	OUTCOME	Was follow up long enough for outcomes to occur	Adequacy of follow up of cohorts/ missing data
Lewis 2007 United Kingdom	LOW Nationwide	LOW	UNKNOWN Partner occupation and employment. Unclear how they were ascertained	HIGH Univariable analysis only	LOW Confidential enquiry	LOW 42 days all of pregnancy and post-partum	UNKNOWN – 1 category for missing and unemployed
Lewis 2011 United Kingdom	LOW Nationwide	LOW	UNKNOWN Partner occupation and employment. Unclear how they were ascertained	HIGH Univariable analysis only	LOW Confidential enquiry	LOW 42 days all of pregnancy and post-partum	UNKNOWN – 1 combined category for missing data and unemployed therefor total amount of missing data unknown
Knight 2020 United Kingdom	LOW National confidential enquiry	LOW	LOW Postcode	HIGH Univariable analysis only	LOW Confirmation of outcome	LOW pregnancy and 42 days postpartum	UNKNOWN Unclear how much missing data on IMD quintile
Knight 2022 United Kingdom	LOW Nationwide	LOW	LOW Postcode	HIGH Univariable analysis only	LOW Confidential enquiry	LOW 42 days all of pregnancy and post-partum	UNKNOWN Missing data on postcode not recorded
Campbell 2013 United states	LOW Urban but diverse community	LOW	UNKNOWN From hospital discharge database but unclear how information for this gathered - most likely self-reported at booking	HIGH Univariable analysis only	SOME CONCERNS Record linkage	LOW Delivery hospitalisations but stated in the methods	UNKNOWN Amount of missing data not reported

Author, year, country	SELECTION Representative	Selection of the non-exposed cohort	Ascertainment of exposure	COMPARABILITY	OUTCOME	Was follow up long enough for outcomes to occur	Adequacy of follow up of cohorts/ missing data
Creanga 2014 United states	LOW Representative of 7 states	LOW	LOW Postcode	HIGH Controlled for age and ethnicity but also chronic medical conditions which could be on the causal pathway	SOME CONCERNS Record linkage	LOW At time of birth but stated in aims and objectives of paper	LOW 4% missing on postcode
Frederiksen 2017 United states	LOW Although 8% of the population unable to link to birth certificate, so not included	LOW	UNKNOWN From discharge database but unclear how the information for this gathered	HIGH Controlled for age and ethnicity but adjusted for factors on the causal pathway	SOME CONCERNS Record linkage	LOW SMM at delivery hospitalisations – but stated clearly in the methods	LOW 2.7% missing data on income
Freese 2020 United states	HIGH Single hospital	LOW	SOME CONCERNS Self-reported	HIGH Adjusted for age and ethnicity but over adjusted for factors on the causal pathway	SOME CONCERNS Record linkage	UNKNOWN Does not state whether at the time of birth or antenatal/ postnatal	LOW 1% missing data on ethnicity and education

Author, year, country	SELECTION Representative	Selection of the non-exposed cohort	Ascertainment of exposure	COMPARABILITY	OUTCOME	Was follow up long enough for outcomes to occur	Adequacy of follow up of cohorts/ missing data
Huang 2023 United states	LOW 20% stratified sample of all discharges from the United States. Hospitals without zip codes excluded but in sensitivity analysis the results did not materially change when zip codes were included	LOW	LOW ICD-10 code	HIGH Univariable analysis or multivariable analysis controlled for factors on the causal pathway	SOME CONCERNS Record linkage	LOW At delivery hospitalisation but stated in the title	UNKNOWN Amount of missing data unknown
Kozhimannil 2019, United states	LOW Stratified sample of US births	LOW	LOW Zip code	HIGH Controlled for age and ethnicity but also other factors on the causal pathway	SOME CONCERNS ICD codes	LOW At delivery hospitalisation but stated in methods	LOW <1.8% missing data
Leonard 2019, United states	LOW All live births California	LOW	SOME CONCERNS Self-reported educational status	HIGH Univariable analysis only	SOME CONCERNS ICD codes	LOW At delivery hospitalisation but stated in methods	UNKNOWN Amount of missing information on educational attainment not reported
Leonard 2021, United states	LOW All live births California	LOW	SOME CONCERNS Self-reported educational status	HIGH Univariable or adjusted for obstetric medical conditions which could be on the causal pathway	SOME CONCERNS ICD codes	LOW At delivery hospitalisation but stated in methods	LOW Missing data <5%

Author, year, country	SELECTION Representative	Selection of the non-exposed cohort	Ascertainment of exposure	COMPARABILITY	OUTCOME	Was follow up long enough for outcomes to occur	Adequacy of follow up of cohorts/ missing data
Luke 2020 United states	LOW Stratified sample of all women who gave birth in the USA (20%)	LOW	LOW Zip code	HIGH Controlled for age and ethnicity but also other factors on the causal pathway	SOME CONCERNS Record linkage	LOW Just at delivery hospitalisation but stated in aims and objectives	UNKNOWN Amount of missing data not recorded
Matas 2021 United states	LOW All delivery hospitalisations nationwide	LOW	LOW Postcode	HIGH Univariable analysis only	SOME CONCERNS ICD-10 codes	LOW At delivery as stated in table	LOW Missing data <5%
Meeker 2021 United states	LOW Representative of urban women	LOW	LOW Census information	HIGH Univariable analysis or in the multivariable analysis adjusted for factors on the causal pathway	SOME CONCERNS ICD-10 codes	LOW At delivery but stated in methods	UNKNOWN Does not report the amount of missing data, assumed most women had census tract information, so most likely low
Oot 2021 United states	LOW 127 Hospitals in Illinois	LOW	LOW Postcode	HIGH Over adjustment for factors on causal pathway	SOME CONCERNS ICD-10 codes	LOW Delivery hospitalisations but stated in the methods	UNKNOWN Amount of missing data not reported - unlikely to be none as routinely collected data
Petersen 2019 United states	LOW Most deaths from 13 states in the USA	LOW	UNKNOWN How educational status obtained - through Pregnancy mortality surveillance system (PMSS)	HIGH Univariable analysis only	LOW PMSS	LOW 1 year	HIGH 14% missing on educational status
Reid 2018 United states	LOW State-wide population-based study	LOW	LOW Zip code	HIGH Univariable analysis or over adjustment in multivariable analysis	SOME CONCERNS ICD codes	LOW Delivery hospitalisations but stated in the methods	LOW <1% on exposure, 2% on race ethnicity. Unlikely to introduce bias

Author, year, country	SELECTION Representative	Selection of the non-exposed cohort	Ascertainment of exposure	COMPARABILITY	OUTCOME	Was follow up long enough for outcomes to occur	Adequacy of follow up of cohorts/ missing data
Snowden 2021 United states	LOW All live/still hospital births from California that had linked discharge records	LOW	UNKNOWN Unclear how information on education was collected	HIGH Univariable analysis only	SOME CONCERNS ICD codes	LOW Delivery hospitalisations but stated in the methods	LOW 3.3% missing data on education. Low percentage so unlikely to introduce bias
Tipre 2022, United states	HIGH One hospital	LOW	LOW Residential census block location	HIGH Univariable analysis or over adjustment in multivariable analysis	SOME CONCERNS ICD codes	LOW At delivery hospitalisation but stated in methods	LOW No missing data on Area Deprivation Index

Appendix Table 3.27. Justification for risk of bias assessment for case-control studies

Author, year, country	SELECTION - Case definition	Representativeness of the cases	Selection of controls	COMBARBILITY	EXPOSURE - Ascertainment of exposure	Method of ascertainment of exposure	Nonresponse rate	MISSING DATA
Lindquist 2015 (a) Australia	LOW Validated cases	LOW Nationwide	LOW Women who delivered just before SMM event in same hospital	HIGH Controlled for age and aboriginal status; however, only univariable analysis or over adjustment for factors on the causal pathway in the multivariable analysis (smoking, BMI)	LOW Postcode	LOW	UNKNOWN Not relevant	LOW <1% missing data on exposure
Lindquist 2015 (b) Australia	SOME CONCERNS Record linkage	LOW All of Victoria	LOW From same cohort as cases	HIGH Either unadjusted analysis or adjusted for factors on the causal pathway.	LOW Postcode	LOW	LOW Routinely collected data	LOW Missing data 3% on exposure and less on confounding factors. Such a small amount unlikely to introduce bias
Saucedo 2012 France	LOW Confidential enquiry	HIGH Only 75% of maternal deaths included	LOW Same population as deaths - from a nationwide survey	HIGH Only univariable analysis	HIGH Not blinded to case/ control status and self-reported from questionnaire	HIGH confidential inquiry and questionnaire from controls different	UNKNOWN Not documented for controls -75% of cases responded	HIGH 13% missing on cases on work status compared to 4% controls. Could have introduced bias

Author, year, country	SELECTION - Case definition	Representativeness of the cases	Selection of controls	COMBARBILITY	EXPOSURE - Ascertainment of exposure	Method of ascertainment of exposure	Nonresponse rate	MISSING DATA
Romero-Gutierrez 2007 Mexico	LOW Independently validated	HIGH Cases from only one hospital and not defined in the research question	LOW Hospital controls from the same day case gives birth	HIGH Only univariable analysis	HIGH From interview with woman/ husband of dead woman. Interviewers not blinded to case/ control status	HIGH woman compared to woman's husband	UNKNOWN Not described	UNKNOWN Not described
Knight 2009 United Kingdom	LOW Independently validated	LOW Nationwide	LOW Two women from same hospital delivering immediately before	HIGH Adjusted for age and ethnicity but also smoking and BMI which are on the causal pathway	UNKNOWN Form filled by staff who are not blinded to case/control status. However, most likely recorded from booking records before outcome - self reported	LOW	LOW No nonresponse	UNKNOWN Has missing data but amount and effect on bias unknown
Lindquist 2013 United Kingdom	LOW Validated	LOW Nationwide	LOW Two women delivering in the same hospital just before SMM case	HIGH Univariable analysis or over adjustment for factors on the causal pathway	UNKNOWN Occupation from UKOSS forms - unclear if from booking records taken prior to case/control status	LOW	LOW No nonresponse	HIGH Large amounts of missing data which could introduce bias

Author, year, country	SELECTION - Case definition	Representativeness of the cases	Selection of controls	COMBARBILITY	EXPOSURE - Ascertainment of exposure	Method of ascertainment of exposure	Nonresponse rate	MISSING DATA
Nair 2016 United Kingdom	LOW Confidential enquiry	LOW Nationwide	LOW Hospital controls from the same day case gave birth	HIGH Either univariable analysis or adjusted for all factors which are on the causal pathway	UNKNOWN Unclear how employment status ascertained. Most likely gathered from booking information which is self-reported. Also unblinded at time of attainment but may have been recorded before	HIGH MBRRACE-UK and UKOSS have different methods for collecting information on exposure	LOW No nonresponse	HIGH Large amounts of missing data on employment status 22.5%
Frolich 2014 United states	LOW Two persons validated records	HIGH Only one hospital but defined in the research question	LOW Delivered in the same hospital on the same day	HIGH Matched for age, not ethnicity	LOW Postcode	LOW	LOW No nonresponse	LOW No missing data reported
Goffman 2007 United states	LOW Medical records used to validate cases	HIGH Cases from one hospital and for 20% of cases there were no records, so excluded	LOW Hospital controls from the same day case gave birth	HIGH Univariable analysis or adjusted for factors on the causal pathway	UNKNOWN From medical records but unclear how educational attainment was recorded from there	LOW	LOW As ascertained from records rather than interviews - no nonresponse rate	LOW All the included women had complete data
Gray 2012 United States	SOME CONCERNS Record linkage	HIGH All cases from Washington State	LOW From the same cohort of births in Washington matched on year of delivery	HIGH Univariable analysis	UNKNOWN From birth certificate but unclear how educational attainment was recorded from there	LOW	LOW As ascertained from records rather than interviews - no nonresponse rate	HIGH >20% missing data on educational attainment (worked out from raw data)

Appendix Table 3.28. Justification for risk of bias assessment for cross-sectional studies

Author, year, country	SELECTION - Representativeness	Sample size	Non-respondents	Ascertainment of the exposure	Comparability	Outcome - assessment
Janevic 2020 United states	LOW representative of women who lived in New York City	LOW Large sample size	LOW Only 1091 women excluded as no zip code information	LOW Postcode	HIGH Univariable analysis or controlled for age and ethnicity but also factors on the causal pathway	SOME CONCERNS ICD 9 codes
Muchomba 2021 United States	LOW All New Jersey births	LOW > 1 million births	LOW Routinely collected data	UNKNOWN Education in routinely collected data but unclear how initially collected	LOW Controlled for age, ethnicity and parity	SOME CONCERNS ICD-10 codes
Muchomba 2022 United states	LOW All New Jersey births	LOW Large sample size	LOW <1% missing data	LOW Postcode	HIGH Controlled for age and ethnicity but also individual educational attainment which could be on the causal pathway	SOME CONCERNS Record linkage
Staniczenko 2022 United states	LOW NIS - Stratified sample of 20% of births in the USA	LOW 7 million births	LOW Routinely collected data	HIGH ICD-10 codes for billing – potential for misclassification as not mandated	HIGH Univariable analysis only	SOME CONCERNS ICD-10 codes

Appendix Chapter 4

Appendix Table 4.1. ICD-10 codes for covariates

Pre-existing Medical Condition (125)	ICD-10 Code (169)	Timing
Diabetes	G590 G632 H280 H360 M142 N083 O240 O241 O243 H350 H352 E103 E113 E123 E133 E143 E10-E14	Any code from 2003 up to the birth
Heart disease - ischaemic	I252 I20 I21 I22 I23 I24 I25 I270 I272	Any code from 2003 to before the birth episode
Heart disease – heart failure and cardiomyopathy	I43 I50 I130 I110 I132	Any code from 2003 up to the birth
Heart disease- congenital	Q20-Q26	Any code from 2003 up to the birth
Heart disease – valve	I34 I35 I05-I08	Any code from 2003 up to the birth
Hypertension	I10-I13 I15	Any code from 2003 up to the birth
Thyroid disease	E035 E038 E039 E050 E051 E052 E055 E058 E059 E062 E063 E065 E069 H062	Any code from 2003 up to the birth
Obstructive lung disorders – cystic fibrosis	E84	Any code from 2003 up to the birth
Restrictive lung disorders	J60 J61 J62 J63 J64 J65 J66 J67 J84 J841 J701 J703 J704 G532 M633 D86	Any code from 2003 up to the birth
Polyarthropothies	I730 J990 M350 M05 M06 M34 L93 M32	Any code from 2003 up to the birth
Obstructive lung disorders	J45 J46	Any code from 2003 to before the birth episode
Inflammatory bowel disease	K51 K50	Any code from 2003 up to the birth
Coeliac	K900	Any code from 2003 up to the birth
Infective hepatitis	B150 B160 B190 B18	Any code from 2003 up to the birth
Alcohol related liver disease	K701 K702 K703 K704 K70	Any code from 2003 up to the birth
Cirrhosis and liver failure	K717 K740 K741 K742 K744 K745 K746 K72	Any code from 2003 up to the birth
Other liver disease	K743 K754 K711 K762 K763	Any code from 2003 up to the birth
Cerebrovascular disease	I61 I64 I60 I65 I66 I691 I630 I631 I632 I633 I634 I635 I638 I639 I693 G463 G464 G465 G466 G467 G468 I694 I690 G450 G451 G452 G453 G454 G458 G459 G460 G461 G462	Any code from 2003 up to the birth
Epilepsy	G40 G41	Any code from aged 11+ to before the birth episode
Chronic kidney disease	N185 T824 Y602 Y612 Y841 Z491 Z492 Z992 N165 T861 Z940 N183 N184 N187 N188 N189 N186	Any code from 2003 up to the birth
Psoriasis and eczema	l20 l40 M090	Any code from aged 11+ up to the birth
HIV	F024 B20 B21 B22 B23 B24 R75 Z21	Any code from 2003 up to the birth

Pre-existing Medical Condition (125)	ICD-10 Code (169)	Timing
Cancer	C880 C882 C221 C751 C752 C753 C754 C755 C220 C222 C223 C224 C227 C229 C260C261 C268 C269 C300 C301 C380 C381 C382 C383 C384 C388 C390 C398 C399 C750 C758 C759 C883 C884 C887 C889 C797 C795 C784 C785 C793 C794 C787 C780 C781 C783 C788 C790 C791 C792 C796 C798 C799 C786 C782 C81 C91-C95 C82-C85 C86 C90 C40 C41 C70 – C72 C51-C53 C31-C34 C43-C49 C64-C67 C97 C00-C21 C23-C25 C37 C57 C58 C60 C63 C68 C69 C74 C76 C80 C96 C56 C73 C54 C55 C77 C50 D05	Any code from 2003 up to the birth
Transplant	Z94	Any code from 2003 up to the birth
Fibroids	D25	Any code from 2003 up to the birth
Endometriosis	N80	Any code from 5 years prior to pregnancy up to the birth
Inflammatory bowel syndrome	K58	Any code from 5 years prior to pregnancy up to the birth
Post viral and related fatigue	G933	Any code from 5 years prior to pregnancy up to the birth
Fibromyalgia	M797	Any code from 5 years prior to pregnancy up to the birth
Thrombophilia and thromboembolic disease	D68, I74-I76, I26, I80-I82	Any code from 2003 up to the birth
Substance misuse (130)	**ICD-10 code - coded from 5 years prior to index pregnancy up to the birth**	
Mental and behavioural disorders due to psychoactive substance use	F11-F17, F19 (not F171)	
Finding of drugs not normally found in blood	R781-R785	
Poisoning by drugs, medicaments and biological substances	T36-T50 (not T506)	
Poisoning, undetermined intent	Y10-Y14	
Drug rehabilitation	Z503	
Drug abuse counselling and surveillance	Z715	
Drug use	Z722	
Personal history of psychoactive substance abuse	Z864	
Mental and behavioural disorders due to use of volatile solvents	F18	
Accidental poisoning by and exposure to noxious substances	X40–X44, X46-X49	
Poisoning by chemical or noxious substance, undetermined intent	Y16-Y19	
Substance misuse (130)	**ICD-10 code - coded from 5 years prior to index pregnancy up to the birth**	
Special epileptic syndromes - (related to alcohol, drugs, etc)	G405	

Blood-alcohol and blood-drug test	Z040
Alcohol-induced pseudo-Cushing's syndrome	244
Mental and behavioural disorders due to use of alcohol	F10
Degeneration of nervous system due to alcohol	G312
Alcoholic polyneuropathy	G621
Alcoholic myopathy	G721
Alcoholic cardiomyopathy	I426
Alcoholic gastritis	K292
Alcoholic liver disease	K70
Alcohol-induced acute pancreatitis	K852
Alcohol-induced chronic pancreatitis	K860
Finding of alcohol in blood	R780
Poisoning: antidotes and chelating agents, not elsewhere classified	T506
Toxic effect of alcohol	T51
Accidental poisoning by exposure to alcohol	X45
Poisoning by exposure to alcohol, undetermined intent	Y15
Evidence of alcohol involvement determined by blood alcohol level	Y90
Evidence of alcohol involvement determined by level of intoxication	Y91
Alcohol rehabilitation	Z502
Alcohol abuse counselling and surveillance	Z714
Alcohol use	Z721
Mental Health conditions/ behavioural disorders (130)	**ICD-10 code - coded from 5 years prior to index pregnancy up to the birth**
Organic, including symptomatic, mental disorders	F00-F09
Schizophrenia, schizotypal and delusional disorders	F20-F29
Mood (affective) disorders	F30-F39
Neurotic, stress-related and somatoform disorders	F40-F48
Behavioural syndromes associated with physiological disturbances and physical factors	F50-F59
Disorders of adult personality and behaviour	F60-F69
Mental retardation	F70-F79
Disorders of psychological development	F80-F89
Behavioural and emotional disorders with onset usually occurring in childhood and adolescence	F90-F98
Unspecified mental disorder	F99
Sedatives, hypnotics and antianxiety drugs	Y47
Psychotropic drugs, not elsewhere classified	Y49
Mental Health conditions/ behavioural disorders (130)	**ICD-10 code - coded from 5 years prior to index pregnancy up to the birth**
Personal history of other mental and behavioural disorders	Z865

Previous pregnancy (126, 261)	ICD-10: O342 O757 Z354 Z876 Z875	Coded for from 2003 up to and including the birth
	OPCS-4: R17–R25	Coded for from 2003 to start of pregnancy
Obesity (261, 262)	ICD-10: E66 Z684	Any code from 5 years prior to pregnancy up to and including the birth

Appendix Table 4.2. Characteristics of women with both missing gestational age and birthweight. Number and percent N(%).

	Missing gestational age and birthweight		
	No	**Yes**	**Total**
	N(%)	**N(%)**	**N(%)**
Total	**3,594,932 (86.9)**	**541,631 (13.1)**	**4,136,563 (100.0)**
Composite IMD			
Most deprived 20%	912,155 (26.0)	136,232 (25.6)	1,048,387 (25.9)
More deprived 20-40%	796,240 (22.7)	120,178 (22.6)	916,418 (22.7)
Less deprived 40-60%	671,894 (19.1)	106,735 (20.1)	778,629 (19.3)
Less deprived 60-80%	593,039 (16.9)	93,189 (17.5)	686,228 (17.0)
Least deprived 80-100%	535,380 (15.3)	75,064 (14.1)	610,444 (15.1)
SMM			
No	3,532,641 (98.3)	530,106 (97.9)	4,062,747 (98.2)
Yes	61,322 (1.7)	11,525 (2.1)	72,847 (1.8)
Age group			
<20	110,308 (3.1)	15,919 (2.9)	126,227 (3.1)
20-25	494,996 (13.8)	71,366 (13.2)	566,362 (13.7)
25-30	972,636 (27.1)	142,179 (26.3)	1,114,815 (27.0)
30-35	1,164,508 (32.4)	178,285 (32.9)	1,342,793 (32.5)
35-40	680,202 (18.9)	106,529 (19.7)	786,731 (19.0)
>40	171,313 (4.8)	27,353 (5.1)	198,666 (4.8)
Ethnicity			
White	2,629,835 (76.8)	370,743 (73.4)	3,000,578 (76.4)
Black or Black British - Caribbean	31,932 (0.9)	6,031 (1.2)	37,963 (1.0)
Black or Black British - African	106,337 (3.1)	18,170 (3.6)	124,507 (3.2)
Asian or Asian British - Indian	123,313 (3.6)	18,115 (3.6)	141,428 (3.6)
Asian or Asian British - Pakistani	128,125 (3.7)	24,793 (4.9)	152,918 (3.9)
Asian or Asian British - Bangladeshi	52,150 (1.5)	6,070 (1.2)	58,220 (1.5)
Mixed	65,190 (1.9)	11,001 (2.2)	76,191 (1.9)
Other	287,812 (8.4)	50,264 (9.9)	338,076 (8.6)
Rural/Urban			
Urban	3,101,616 (87.1)	479,967 (89.3)	3,581,583 (87.4)
Rural	459,548 (12.9)	57,768 (10.7)	517,316 (12.6)
Parity			
Multiparous	2,158,905 (60.1)	266,210 (49.1)	2,425,115 (58.6)
Primiparous	1,435,058 (39.9)	275,421 (50.9)	1,710,479 (41.4)
Mode of birth			
Unassisted vertex vaginal birth	1,994,723 (55.5)	286,401 (53.6)	2,281,124 (55.3)
Instrumental birth	484,104 (13.5)	65,696 (12.3)	549,800 (13.3)
Breech	16,544 (0.5)	2,068 (0.4)	18,612 (0.5)
Elective caesarean birth	476,030 (13.3)	72,064 (13.5)	548,094 (13.3)
Emergency caesarean birth	590,922 (16.5)	108,139 (20.2)	699,061 (16.9)
Other methods of birth	29,859 (0.8)	240 (0.0)	30,099 (0.7)

	Missing gestational age and birthweight		
	No	**Yes**	**Total**
	N(%)	**N(%)**	**N(%)**
Birth onset method			
Spontaneous: the onset of regular contractions whether or not preceded by spontaneous rupture of the membranes	1,766,934 (52.8)	36,950 (55.6)	1,803,884 (52.9)
Any caesarean section carried out immediately following the onset of labour, when the decision was made before labour	559,883 (16.7)	8,902 (13.4)	568,785 (16.7)
Surgical induction by amniotomy	181,250 (5.4)	4,923 (7.4)	186,173 (5.5)
Medical induction	602,381 (18.0)	13,366 (20.1)	615,747 (18.0)
Combination of surgical induction and medical induction	235,220 (7.0)	2,353 (3.5)	237,573 (7.0)
Substance misuse or Smoking			
No	2,735,145 (76.1)	419,068 (77.2)	3,154,213 (76.3)
Yes	858,818 (23.9)	123,532 (22.8)	982,350 (23.7)
Pre-existing mental health condition			
No	3,166,603 (88.1)	473,074 (87.2)	3,639,677 (88.0)
Yes	427,360 (11.9)	69,526 (12.8)	496,886 (12.0)
Pre-existing medical conditions			
No	2,846,895 (79.2)	427,849 (78.9)	3,274,744 (79.2)
Yes	747,068 (20.8)	114,751 (21.1)	861,819 (20.8)
Obesity/ overweight			
No	2,842,653 (82.5)	426,225 (81.6)	3,268,878 (82.4)
Yes	601,881 (17.5)	95,922 (18.4)	697,803 (17.6)

Appendix Table 4.3. ICD-10 and OPCS-4 for the updated English Maternal Morbidity Outcome Indicator (EMMOI)(125).

Morbid event category (ICD-10 codes)	**Codes**
Acute abdomen	N733 Female acute pelvic peritonitis N735 Female pelvic peritonitis, unspecified K650 Acute peritonitis K659 Peritonitis, unspecified K35 Acute appendicitis K352 Acute appendicitis with generalized peritonitis K353 Acute appendicitis with localized peritonitis K358 Acute appendicitis, other and unspecified K37 Unspecified appendicitis K562 Volvulus K565 Intestinal adhesions (bands) with obstruction K566 Other and unspecified intestinal obstruction K593 Megacolon, not elsewhere classified
Acute renal failure	O904 Postpartum acute renal failure N17 Acute renal failure N170 Acute renal failure with tubular necrosis N171 Acute renal failure with acute cortical necrosis N172 Acute renal failure with medullary necrosis N178 Other acute renal failure N179 Acute renal failure, unspecified N19 Unspecified kidney failure N990 Postprocedural renal failure I120 Hypertensive renal disease with renal failure I131 Hypertensive heart and renal disease with renal failure
Acute psychosis	F23 Acute and transient psychotic disorders F230 Acute polymorphic psychotic disorder without symptoms of schizophrenia F231 Acute polymorphic psychotic disorder with symptoms of schizophrenia F232 Acute schizophrenia-like psychotic disorder F238 Other acute and transient psychotic disorders F239 Acute and transient psychotic disorder, unspecified F531 Severe mental and behavioural disorders associated with the puerperium, not elsewhere classified
Acute cardiac event (cardiac infarction, cardiac failure, cardiomyopathy and cardiac arrest)	O903 Cardiomyopathy in the puerperium I21 Acute myocardial infarction I210 Acute transmural myocardial infarction of anterior wall I211 Acute transmural myocardial infarction of inferior wall I212 Acute transmural myocardial infarction of other sites I213 Acute transmural myocardial infarction of unspecified site I214 Acute subendocardial myocardial infarction I219 Acute myocardial infarction, unspecified I42 Cardiomyopathy I420 Dilated cardiomyopathy I421 Obstructive hypertrophic cardiomyopathy I422 Other hypertrophic cardiomyopathy I423 Endomyocardial (eosinophilic) disease I424 Endocardial fibroelastosis I425 Other restrictive cardiomyopathy I426 Alcoholic cardiomyopathy I427 Cardiomyopathy due to drugs and other external agents I428 Other cardiomyopathies I429 Cardiomyopathy, unspecified I43* Cardiomyopathy in diseases classified elsewhere I430* Cardiomyopathy in infectious and parasitic diseases classified elsewhere I431* Cardiomyopathy in metabolic diseases I432* Cardiomyopathy in nutritional diseases I438* Cardiomyopathy in other diseases classified elsewhere I46 Cardiac arrest I460 Cardiac arrest with successful resuscitation I461 Sudden cardiac death, so described I469 Cardiac arrest, unspecified

	I50 Heart failure I500 Congestive heart failure I501 Left ventricular failure I509 Heart failure, unspecified I110 Hypertensive heart disease with (congestive) heart failure I119 Hypertensive heart disease without (congestive) heart failure I130 Hypertensive heart and renal disease with (congestive) heart failure I132 Hypertensive heart and renal disease with both (congestive) heart failure and renal failure
Acute respiratory compromise	J81 Pulmonary oedema J80 Adult respiratory distress syndrome
Cerebral oedema or coma	G936 Cerebral oedema R402 Coma, unspecified
Disseminated intravascular coagulopathy	O450 Premature separation of placenta with coagulation defect (including placental abruption with excessive haemorrhage associated with afibrinoginaemia, disseminated intravascular coagulation, hyperfibrinolysis, hyperfibrinogenaemia) O460 Antepartum haemorrhage with coagulation defect (antepartum haemorrhage (excessive) associated with afibrinoginaemia, disseminated intravascular coagulation, hyperfibrinolysis, hyperfibrinogenaemia) O670 Intrapartum haemorrhage with coagulation defect (intrapartum haemorrhage (excessive) associated with afibrinoginaemia, disseminated intravascular coagulation, hyperfibrinolysis, hyperfibrinogenaemia) D65 Disseminated intravascular coagulation (defibrination syndrome)
Cerebrovascular accident	I60 Subarachnoid haemorrhage I600 Subarachnoid haemorrhage from carotid siphon and bifurcation I601 Subarachnoid haemorrhage from middle cerebral artery I602 Subarachnoid haemorrhage from anterior communicating artery I603 Subarachnoid haemorrhage from posterior communicating artery I604 Subarachnoid haemorrhage from basilar artery I605 Subarachnoid haemorrhage from vertebral artery I606 Subarachnoid haemorrhage from other intracranial arteries I607 Subarachnoid haemorrhage from intracranial artery, unspecified I608 Other subarachnoid haemorrhage I609 Subarachnoid haemorrhage, unspecified I61 Intracerebral haemorrhage I610 Intracerebral haemorrhage in hemisphere, subcortical I611 Intracerebral haemorrhage in hemisphere, cortical I612 Intracerebral haemorrhage in hemisphere, unspecified I613 Intracerebral haemorrhage in brain stem I614 Intracerebral haemorrhage in cerebellum I615 Intracerebral haemorrhage, intraventricular I616 Intracerebral haemorrhage, multiple localized I618 Other intracerebral haemorrhage I619 Intracerebral haemorrhage, unspecified I62 Other nontraumatic intracranial haemorrhage I620 Subdural haemorrhage (acute)(nontraumatic) I621 Nontraumatic extradural haemorrhage I629 Intracranial haemorrhage (nontraumatic), unspecified I63 Cerebral infarction I630 Cerebral infarction due to thrombosis of precerebral arteries I631 Cerebral infarction due to embolism of precerebral arteries I632 Cerebral infarction due to unspecified occlusion or stenosis of precerebral arteries I633 Cerebral infarction due to thrombosis of cerebral arteries I634 Cerebral infarction due to embolism of cerebral arteries I635 Cerebral infarction due to unspecified occlusion or stenosis of cerebral arteries I638 Other cerebral infarction I639 Cerebral infarction, unspecified I64 Stroke, not specified as haemorrhage or infarction
Major complications of anaesthesia	O740 Aspiration pneumonitis due to anaesthesia during labour and birth O741 Other pulmonary complications of anaesthesia during labour and birth O742 Cardiac complications of anaesthesia during labour and birth O743 Central nervous system complications of anaesthesia during labour and birth O749 Complication of anaesthesia during labour and birth, unspecified O890 Pulmonary complications of anaesthesia during the puerperium O891 Cardiac complications of anaesthesia during the puerperium O892 Central nervous system complications of anaesthesia during the puerperium O290 Pulmonary complications of anaesthesia during pregnancy O291 Cardiac complications of anaesthesia during pregnancy

	O292 Central nervous system complications of anaesthesia during pregnancy O296 Failed or difficult intubation during pregnancy O293 Toxic reaction to local anaesthesia during pregnancy
Embolic event (pulmonary embolism, amniotic fluid embolism, septic embolism and air embolism)	O88 Obstetric embolism O880 Obstetric air embolism O881 Amniotic fluid embolism O882 Obstetric blood-clot embolism O883 Obstetric pyaemic and septic embolism O888 Other obstetric embolism I26 Pulmonary embolism I260 Pulmonary embolism with mention of acute cor pulmonale I269 Pulmonary embolism without mention of acute cor pulmonale
Shock	R570 Cardiogenic shock R571 Hypovolaemic shock R572 Septic shock R578 Other shock R579 Shock, unspecified O751 Shock during or following labour and birth T805 Anaphylactic shock due to serum T886 Anaphylactic shock due to adverse effect of correct drug or medicament properly administered T782 Anaphylactic shock, unspecified T780 Anaphylactic shock due to adverse food reaction A483 Toxic shock syndrome
Sickle cell anaemia with crisis	D570 Sickle-cell anaemia with crisis
Status asthmaticus	J46 Status asthmaticus
Status epilepticus	G41 Status epilepticus G410 Grand mal status epilepticus G411 Petit mal status epilepticus G412 Complex partial status epilepticus G418 Other status epilepticus G419 Status epilepticus, unspecified
Uterine rupture	O710 Rupture of uterus before onset of labour O711 Rupture of uterus during labour
Eclampsia	O15 Eclampsia O150 Eclampsia in pregnancy O151 Eclampsia in labour O152 Eclampsia in the puerperium O159 Eclampsia, unspecified as to time period
Sepsis	O85 Puerperal sepsis A40 Streptococcal sepsis A400 Sepsis due to streptococcus, group A A401 Sepsis due to streptococcus, group B A402 Sepsis due to streptococcus, group D A403 Sepsis due to Streptococcus pneumoniae A408 Other streptococcal sepsis A409 Streptococcal sepsis, unspecified A41 Other sepsis A410 Sepsis due to Staphylococcus aureus A411 Sepsis due to other specified staphylococcus A412 Sepsis due to unspecified staphylococcus A413 Sepsis due to Haemophilus influenzae A414 Sepsis due to anaerobes A415 Sepsis due to other Gram-negative organisms A418 Other specified sepsis A419 Sepsis, unspecified (including septicaemia) A327 Listerial sepsis
Cerebral venous thrombosis	O873 Cerebral venous thrombosis in the puerperium I636 Cerebral infarction due to cerebral venous thrombosis, nonpyogenic I676 Nonpyogenic thrombosis of intracranial venous system (including non-pyogenic thrombosis of cerebral vein and intracranial venous sinus)
Acute pancreatitis	K85 Acute pancreatitis K850 Idiopathic acute pancreatitis K851 Biliary acute pancreatitis K852 Alcohol-induced acute pancreatitis K853 Drug-induced acute pancreatitis

	K858 Other acute pancreatitis K859 Acute pancreatitis, unspecified K863 Pseudocyst of pancreas
Rupture of aortic aneurysm or dissection of aorta	I710 Dissection of aorta (any part) I711 Thoracic aortic aneurysm, ruptured I713 Abdominal aortic aneurysm, ruptured I715 Thoracoabdominal aortic aneurysm, ruptured I718 Aortic aneurysm of unspecified site, ruptured I722 Aneurysm and dissection of renal artery I723 Aneurysm and dissection of iliac artery I712 Thoracic aortic aneurysm, without mention of rupture I714 Abdominal aortic aneurysm, without mention of rupture I716 Thoracoabdominal aortic aneurysm, without mention of rupture I719 Aortic aneurysm of unspecified site, without mention of rupture
Diabetic ketoacidosis	E100 Diabetes mellitus with coma (including hyperglycaemic coma NOS, diabetic coma with or without ketoacidosis, diabetic hyperosmolar coma, diabetic hypoglycaemic coma) E101 Diabetes mellitus with ketoacidosis
Morbid event category (OPCS-4 codes)	**Codes**
Respiratory support	E851 Invasive ventilation (Includes endotracheal intermittent positive pressure ventilation) E852 Non-invasive ventilation NEC (Includes continuous positive airway pressure, intermittent positive pressure ventilation NEC, Negative pressure ventilation, Bilevel positive airway pressure, High flow continuous positive airway pressure) E421 Permanent tracheostomy E422 Cricothyroidostomy E423 Temporary tracheostomy (includes tracheostomy NEC, Traccheostomy, Placement of tracheostomy tube) E428 Other specified (Exteriorisation of trachea) E429 Unspecified (Exteriorisation of trachea) E856: Continuous positive airway pressure E858: Other specified ventilation support E859: Unspecified ventilation support E899: Unspecified other respiratory support E898: Other specified other respiratory support Y733: Ventilatory support Y731: Cardiopulmonary bypass Y732: Extracorporeal circulation NEC
Surgical evacuation of the uterus following birth	R281 Curettage of delivered uterus R288 Other specified (Instrumental removal of products of conception from delivered uterus) R289 Unspecified (Instrumental removal of products of conception from delivered uterus) Q10 Curettage of uterus Q101 Dilation of cervix uteri and curettage of products of conception from uterus Q102 Curettage of products of conception from uterus NEC Q103 Dilation of cervix uteri and curettage of uterus NEC Q108 Other specified Q109 Unspecified Q11 Other evacuation of contents of uterus Q111 Vacuum aspiration of products of conception from uterus NEC Q115 Vacuum aspiration of products of conception from uterus using rigid cannula Q116 Vacuum aspiration of products of conception from uterus using flexible cannula Q113 Evacuation of products of conception from uterus NEC
Dialysis	X40 Compensation for renal failure X401 Renal dialysis X402 Peritoneal dialysis NEC X403 Haemodialysis NEC X404 Haemofiltration X405 Automated peritoneal dialysis X406 Continuous ambulatory peritoneal dialysis X407 Haemoperfusion X408 Other specified X409 Unspecified X411 Insertion of ambulatory peritoneal dialysis catheter X421 Insertion of temporary peritoneal dialysis catheter

Management of intra-abdominal or pelvic collection	T341 Open drainage of subphrenic abscess T342 Open drainage of pelvic abscess T343 Open drainage of abdominal abscess NEC T451 Image controlled percutaneous drainage of subphrenic abscess T452 Image controlled percutaneous drainage of pelvic abscess T453 Image controlled percutaneous drainage of abdominal abscess NEC T454 Image controlled percutaneous drainage of lesion of abdominal cavity NEC Y22 Drainage of organ NOC Y221 Aspiration of haematoma of organ NOC T348 Other specified (open drainage of peritoneum) T349 Unspecified (open drainage of peritoneum) T468: Other specified other drainage of peritoneal cavity T469: Unspecified other drainage of peritoneal cavity T963: Debridement of soft tissue NEC Y055: Debridement of organ NOC Y228: Other specified drainage of organ NOC Y229: Unspecified drainage of organ NOC Y251: Suture of laceration of organ NOC Y252: Resuture of organ NOC Y321: Re-exploration of organ and surgical arrest of postoperative bleeding NOC Y322: Re-exploration of organ and other repair of organ NOC Y323: Re-exploration of organ and packing of organ NOC Y328: Other specified re-exploration of organ NOC Y329: Unspecified re-exploration of organ NOC T301: Reopening of abdomen and re-exploration of intra-abdominal operation site and surgical arrest of postoperative bleeding T302: Reopening of abdomen and re-exploration of intra-abdominal operation site NEC T303: Reopening of abdomen NEC H031: Drainage of abscess of appendix H581: Drainage of ischiorectal abscess H583: Drainage of perirectal abscess
Management of vulval or vaginal haematoma	P093 Evacuation of haematoma from vulva P271 Evacuation of haematoma from vagina
Hysterectomy	Q074 Total abdominal hysterectomy NEC Q075 Subtotal abdominal hysterectomy R251 Caesarean hysterectomy
Interventional and surgical procedures to arrest major haemorrhage following birth	L702 Open embolisation of artery NEC L703 Ligation of artery NEC L713 Percutaneous transluminal embolisation of artery L933 Ligation of vein NEC L941 Percutaneous transluminal embolisation of vein L995: Percutaneous transluminal occlusion of vein NEC L531: Repair of iliac artery NEC L538: Other specified other open operations on iliac artery L539: Unspecified other open operations on iliac artery L543: Arteriography of iliac artery L663: Percutaneous transluminal occlusion of artery L721: Arteriography NEC L937: Repair of vein NEC L974: Operations on artery NEC L975: Operations on vein NEC L974: Operations on artery NEC L975: Operations on vein NEC Y781: Arteriotomy approach to organ using image guidance with fluoroscopy Y782: Arteriotomy approach to organ using image guidance with computed tomography Y793: Transluminal approach to organ through femoral artery Y788: Other specified arteriotomy approach to organ under image control Y789: Unspecified arteriotomy approach to organ under image control Y798: Other specified approach to organ through artery Y799: Unspecified approach to organ through artery
Management of caesarean wound dehiscence	T283: Resuture of previous incision of anterior abdominal wall T288: Other specified other repair of anterior abdominal wall T289: Unspecified other repair of anterior abdominal wall
Repair of damage to bladder or urinary tract	M373: Repair of rupture of bladder M378: Other specified other repair of bladder M379: Unspecified other repair of bladder

	M736: Urethroplasty NEC M737: Repair of rupture of urethra NEC M738: Other specified repair of urethra M136: Percutaneous insertion of nephrostomy tube M182: Excision of segment of ureter M188: Other specified excision of ureter M189: Unspecified excision of ureter M191: Construction of ileal conduit M192: Creation of urinary diversion to intestine NEC M194: Cutaneous ureterostomy NEC M201: Bilateral replantation of ureter M202: Unilateral replantation of ureter M203: Replantation of ureter after urinary diversion M208: Other specified replantation of ureter M209: Unspecified replantation of ureter M211: Direct anastomosis of ureter to bladder M212: Anastomosis of ureter to bladder using flap of bladder M213: Ileal replacement of ureter M214: Colonic replacement of ureter M216: Ureteroureterostomy M221: Suture of ureter M222: Removal of ligature from ureter M228: Other specified repair of ureter M229: Unspecified repair of ureter M274: Ureteroscopic insertion of ureteric stent M277: Ureteroscopic dilation of ureter M278: Other specified therapeutic ureteroscopic operations on ureter M279: Unspecified therapeutic ureteroscopic operations on ureter M294: Endoscopic dilation of ureter M331: Percutaneous insertion of metallic stent into ureter M332: Percutaneous insertion of plastic stent into ureter M338: Other specified percutaneous ureteric stent procedures M339: Unspecified percutaneous ureteric stent procedures M734: Reconstruction of urethra M738: Other specified repair of urethra M739: Unspecified repair of urethra
Repair of damage to the intestine and management of intestinal obstruction	G581: Total jejunectomy and anastomosis of stomach to ileum G582: Total jejunectomy and anastomosis of duodenum to ileum G583: Total jejunectomy and anastomosis of duodenum to colon G584: Partial jejunectomy and anastomosis of jejunum to ileum G585: Partial jejunectomy and anastomosis of duodenum to colon G588: Other specified excision of jejunum G589: Unspecified excision of jejunum G691: Ileectomy and anastomosis of stomach to ileum G692: Ileectomy and anastomosis of duodenum to ileum G693: Ileectomy and anastomosis of ileum to ileum G694: Ileectomy and anastomosis of ileum to colon G698: Other specified excision of ileum G699: Unspecified excision of ileum G784: Closure of perforation of ileum G785: Exclusion of segment of ileum G786: Open intubation of ileum H061: Extended right hemicolectomy and end to end anastomosis H062: Extended right hemicolectomy and anastomosis of ileum to colon H069: Unspecified extended excision of right hemicolon H071: Right hemicolectomy and end to end anastomosis of ileum to colon H072: Right hemicolectomy and side to side anastomosis of ileum to transverse colon H073: Right hemicolectomy and anastomosis NEC H074: Right hemicolectomy and ileostomy HFQ H075: Right hemicolectomy and end to side anastomosis H078: Other specified other excision of right hemicolon H079: Unspecified other excision of right hemicolon H081: Transverse colectomy and end to end anastomosis H082: Transverse colectomy and anastomosis of ileum to colon H083: Transverse colectomy and anastomosis NEC H084: Transverse colectomy and ileostomy HFQ H085: Transverse colectomy and exteriorisation of bowel NEC

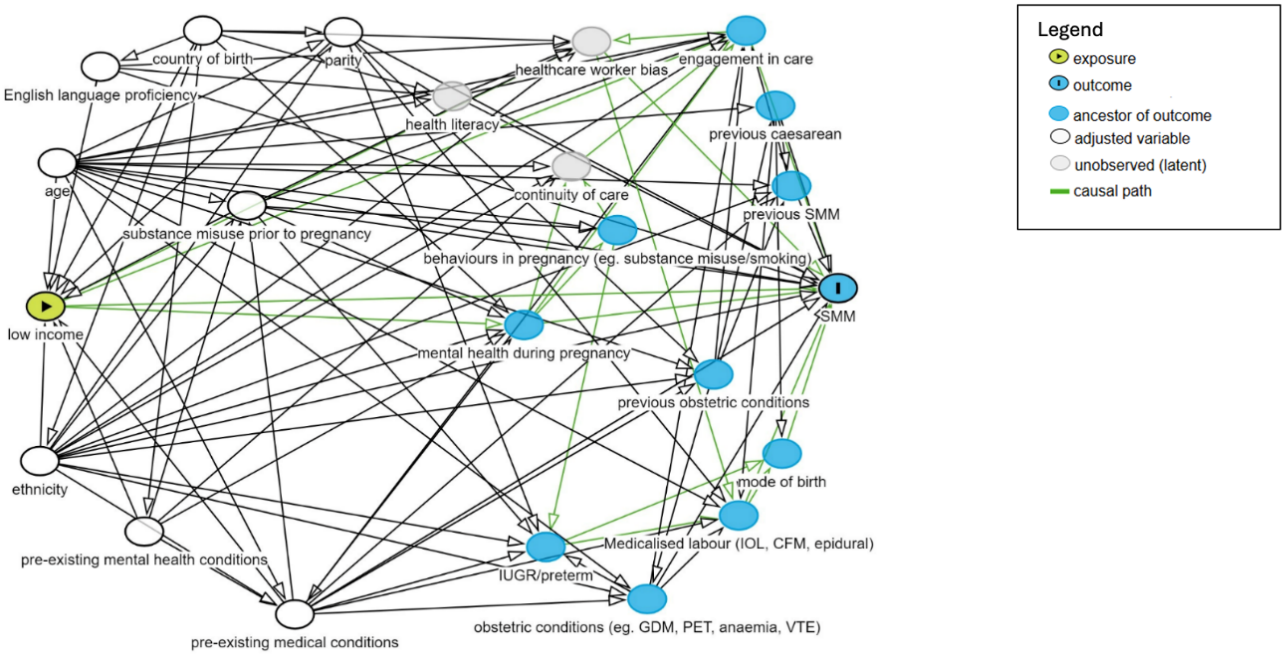
	H086: Transverse colectomy and end to side anastomosis H088: Other specified excision of transverse colon H089: Unspecified excision of transverse colon H091: Left hemicolectomy and end to end anastomosis of colon to rectum H092: Left hemicolectomy and end to end anastomosis of colon to colon H112: Colectomy and side to side anastomosis of ileum to colon NEC H113: Colectomy and anastomosis NEC H114: Colectomy and ileostomy NEC H115: Colectomy and exteriorisation of bowel NEC H116: Colectomy and end to side anastomosis NEC H118: Other specified other excision of colon H119: Unspecified other excision of colon H291: Subtotal excision of colon and rectum and creation of colonic pouch and anastomosis of colon to anus H292: Subtotal excision of colon and rectum and creation of colonic pouch NEC H293: Subtotal excision of colon and creation of colonic pouch and anastomosis of colon to rectum H294: Subtotal excision of colon and creation of colonic pouch NEC H295: Subtotal excision of colon and anastomosis of colon to ileum H298: Other specified subtotal excision of colon H299: Unspecified subtotal excision of colon H331: Abdominoperineal excision of rectum and end colostomy H332: Proctectomy and anastomosis of colon to anus H333: Anterior resection of rectum and anastomosis of colon to rectum using staples H334: Anterior resection of rectum and anastomosis NEC H335: Rectosigmoidectomy and closure of rectal stump and exteriorisation of bowel H336: Anterior resection of rectum and exteriorisation of bowel H337: Perineal resection of rectum HFQ H338: Other specified excision of rectum H339: Unspecified excision of rectum T374: Repair of mesentery of small intestine T384: Repair of mesentery of colon H172: Open reduction of volvulus of caecum H173: Open reduction of volvulus of sigmoid colon H174: Open reduction of volvulus of colon NEC H175: Open relief of strangulation of colon H176: Open relief of obstruction of colon NEC H158: Other specified other exteriorisation of colon H159: Unspecified other exteriorisation of colon H151: Loop colostomy H152: End colostomy H131: Bypass of colon by anastomosis of ileum to colon H132: Bypass of colon by anastomosis of caecum to sigmoid colon H133: Bypass of colon by anastomosis of transverse colon to sigmoid colon H134: Bypass of colon by anastomosis of transverse colon to rectum H135: Bypass of colon by anastomosis of colon to rectum NEC H138: Other specified bypass of colon H139: Unspecified bypass of colon H101: Sigmoid colectomy and end to end anastomosis of ileum to rectum H102: Sigmoid colectomy and anastomosis of colon to rectum H103: Sigmoid colectomy and anastomosis NEC H104: Sigmoid colectomy and ileostomy HFQ H105: Sigmoid colectomy and exteriorisation of bowel NEC H106: Sigmoid colectomy and end to side anastomosis H108: Other specified excision of sigmoid colon H109: Unspecified excision of sigmoid colon H051: Total colectomy and anastomosis of ileum to rectum H052: Total colectomy and ileostomy and creation of rectal fistula HFQ H053: Total colectomy and ileostomy NEC H058: Other specified total excision of colon H059: Unspecified total excision of colon G633: Closure of perforation of jejunum G721: Anastomosis of ileum to caecum G722: Anastomosis of ileum to transverse colon G723: Anastomosis of ileum to colon NEC G724: Anastomosis of ileum to rectum G725: Anastomosis of ileum to anus and creation of pouch HFQ G741: Creation of continent ileostomy

	G742: Creation of temporary ileostomy G743: Creation of defunctioning ileostomy G762: Open relief of strangulation of ileum G763: Open relief of obstruction of ileum NEC T305: Packing of abdominal cavity
Management of acute coronary syndrome	K634: Coronary arteriography using two catheters K635: Coronary arteriography using single catheter K636: Coronary arteriography NEC K638: Other specified contrast radiology of heart K639: Unspecified contrast radiology of heart K651: Catheterisation of combination of right and left side of heart NEC K652: Catheterisation of right side of heart NEC K653: Catheterisation of left side of heart NEC K654: Catheterisation of left side of heart via atrial transeptal puncture K658: Other specified catheterisation of heart K659: Unspecified catheterisation of heart K751: Percutaneous transluminal balloon angioplasty and insertion of 1-2 drug-eluting stents into coronary artery K752: Percutaneous transluminal balloon angioplasty and insertion of 3 or more drug-eluting stents into coronary artery K753: Percutaneous transluminal balloon angioplasty and insertion of 1-2 stents into coronary artery K754: Percutaneous transluminal balloon angioplasty and insertion of 3 or more stents into coronary artery NEC K758: Other specified percutaneous transluminal balloon angioplasty and insertion of stent into coronary artery K759: Unspecified percutaneous transluminal balloon angioplasty and insertion of stent into coronary artery L761: Endovascular placement of one metallic stent L762: Endovascular placement of one plastic stent L763: Endovascular placement of two metallic stents L764: Endovascular placement of two plastic stents L765: Endovascular placement of three or more metallic stents L766: Endovascular placement of three or more plastic stents L767: Endovascular placement of metallic stent with mechanical embolic protection L768: Other specified endovascular placement of stent L769: Unspecified endovascular placement of stent L891: Endovascular placement of two drug-eluting stents L892: Endovascular placement of two coated stents L893: Endovascular placement of three or more drug-eluting stents L894: Endovascular placement of three or more coated stents L895: Endovascular placement of one drug-eluting stent L896: Endovascular placement of one coated stent L898: Other specified other endovascular placement of stent L899: Unspecified other endovascular placement of stent
Interventional and surgical procedures to manage thromboembolism	L791: Insertion of filter into vena cava L124: Open embolectomy of pulmonary artery L131: Percutaneous transluminal embolectomy of pulmonary artery L961: Percutaneous mechanical thromboembolectomy L962: Percutaneous aspiration thromboembolectomy L968: Other specified percutaneous removal of thrombus from vein L969: Unspecified percutaneous removal of thrombus from vein L993: Percutaneous transluminal venous thrombolysis with reconstruction L994: Percutaneous transluminal venous thrombolysis NEC
Interventional and surgical procedures to manage major haemorrhage originating from the spleen	J691: Total excision of spleen and replantation of fragments of spleen J692: Total splenectomy J698: Other specified total excision of spleen J699: Unspecified total excision of spleen J701: Partial splenectomy J722: Embolisation of spleen J724: Repair of spleen J725: Banding of spleen
Interventional procedures to treat haemorrhagic or ischaemic stroke	L331: Excision of aneurysm of cerebral artery L332: Clipping of aneurysm of cerebral artery L333: Ligation of aneurysm of cerebral artery NEC L334: Obliteration of aneurysm of cerebral artery NEC L338: Other specified operations on aneurysm of cerebral artery L339: Unspecified operations on aneurysm of cerebral artery

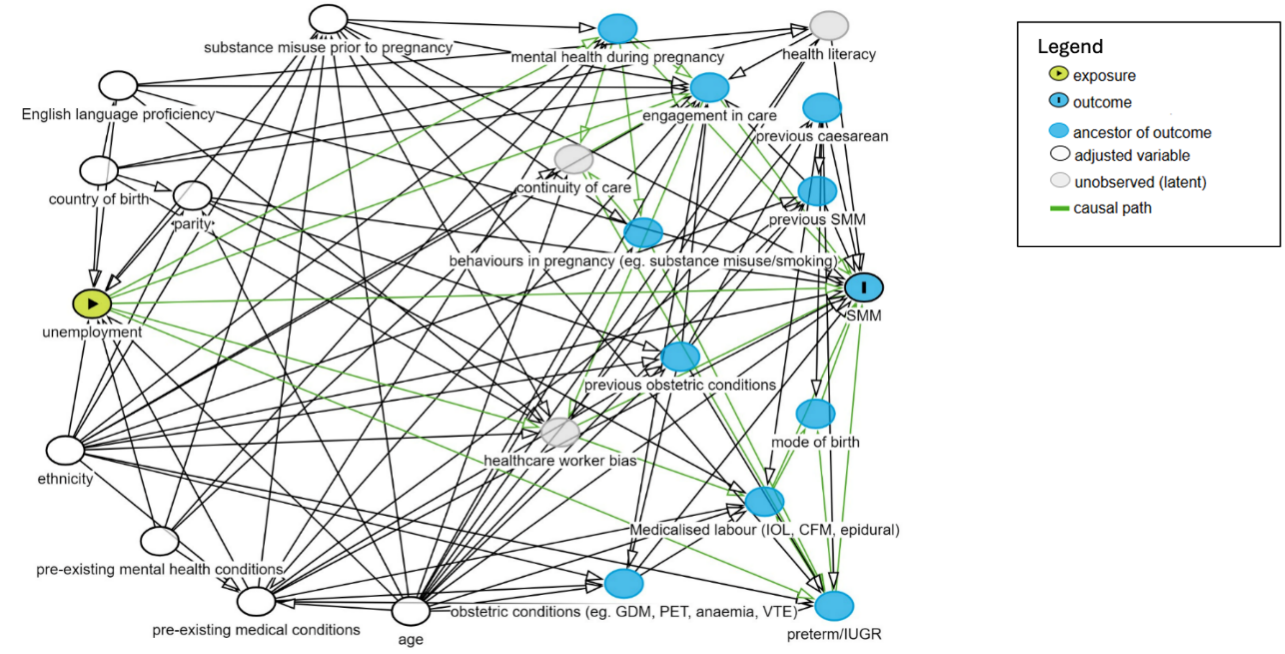
	L343: Open embolectomy of cerebral artery L344: Open embolisation of cerebral artery L351: Percutaneous transluminal embolisation of cerebral artery L352: Arteriography of cerebral artery L353: Percutaneous transluminal insertion of stent into cerebral artery L354: Percutaneous transluminal embolectomy of cerebral artery L358: Other specified transluminal operations on cerebral artery L359: Unspecified transluminal operations on cerebral artery L961: Percutaneous mechanical thromboembolectomy L962: Percutaneous aspiration thromboembolectomy O011: Percutaneous transluminal coil embolisation of small aneurysm of artery O012: Percutaneous transluminal coil embolisation of medium aneurysm of artery O013: Percutaneous transluminal coil embolisation of large aneurysm of artery O014: Percutaneous transluminal coil embolisation of giant aneurysm of artery O018: Other specified transluminal coil embolisation of aneurysm of artery O019: Unspecified transluminal coil embolisation of aneurysm of artery O021: Percutaneous transluminal balloon assisted coil embolisation of three or more aneurysms of artery O022: Percutaneous transluminal balloon assisted coil embolisation of two aneurysms of artery O023: Percutaneous transluminal balloon assisted coil embolisation of single aneurysm of artery O028: Other specified transluminal balloon assisted coil embolisation of aneurysm of artery O029: Unspecified transluminal balloon assisted coil embolisation of aneurysm of artery O031: Percutaneous transluminal stent assisted coil embolisation of three or more aneurysms of artery O032: Percutaneous transluminal stent assisted coil embolisation of two aneurysms of artery O033: Percutaneous transluminal stent assisted coil embolisation of single aneurysm of artery O034: Percutaneous transluminal flow diverting stent assisted coil embolisation of three or more aneurysms of artery O035: Percutaneous transluminal flow diverting stent assisted coil embolisation of two aneurysms of artery O036: Percutaneous transluminal flow diverting stent assisted coil embolisation of single aneurysm of artery O038: Other specified transluminal stent assisted coil embolisation of aneurysm of artery O039: Unspecified transluminal stent assisted coil embolisation of aneurysm of artery O041: Percutaneous transluminal liquid polymer embolisation of aneurysm of artery O042: Percutaneous transluminal stent assisted liquid polymer embolisation of aneurysm of artery O043: Percutaneous transluminal flow diverting stent embolisation of aneurysm of artery O048: Other specified other transluminal embolisation of aneurysm of artery O049: Unspecified other transluminal embolisation of aneurysm of artery
Repair of aortic aneurysm rupture or aortic dissection	L181: Emergency replacement of aneurysmal segment of ascending aorta by anastomosis of aorta to aorta L182: Emergency replacement of aneurysmal segment of thoracic aorta by anastomosis of aorta to aorta NEC L183: Emergency replacement of aneurysmal segment of suprarenal abdominal aorta by anastomosis of aorta to aorta L184: Emergency replacement of aneurysmal segment of infrarenal abdominal aorta by anastomosis of aorta to aorta L185: Emergency replacement of aneurysmal segment of abdominal aorta by anastomosis of aorta to aorta NEC L186: Emergency replacement of aneurysmal bifurcation of aorta by anastomosis of aorta to iliac artery L188: Other specified emergency replacement of aneurysmal segment of aorta L189: Unspecified emergency replacement of aneurysmal segment of aorta L191: Replacement of aneurysmal segment of ascending aorta by anastomosis of aorta to aorta NEC L192: Replacement of aneurysmal segment of thoracic aorta by anastomosis of aorta to aorta NEC L193: Replacement of aneurysmal segment of suprarenal abdominal aorta by anastomosis of aorta to aorta NEC L194: Replacement of aneurysmal segment of infrarenal abdominal aorta by anastomosis of aorta to aorta NEC L195: Replacement of aneurysmal segment of abdominal aorta by anastomosis of aorta to aorta NEC L196: Replacement of aneurysmal bifurcation of aorta by anastomosis of aorta to iliac artery NEC L198: Other specified other replacement of aneurysmal segment of aorta L199: Unspecified other replacement of aneurysmal segment of aorta L265: Percutaneous transluminal insertion of stent into aorta L266: Transluminal aortic stent graft with fenestration NEC L267: Transluminal aortic branched stent graft NEC L254: Operations on aneurysm of aorta NEC

	L271: Endovascular insertion of stent graft for infrarenal abdominal aortic aneurysm L272: Endovascular insertion of stent graft for suprarenal aortic aneurysm L273: Endovascular insertion of stent graft for thoracic aortic aneurysm L274: Endovascular insertion of stent graft for aortic dissection in any position L275: Endovascular insertion of stent graft for aortic aneurysm of bifurcation NEC L276: Endovascular insertion of stent graft for aorto-uni-iliac aneurysm L278: Other specified transluminal insertion of stent graft for aneurysmal segment of aorta L279: Unspecified transluminal insertion of stent graft for aneurysmal segment of aorta L281: Endovascular insertion of stent for infrarenal abdominal aortic aneurysm L282: Endovascular insertion of stent for suprarenal aortic aneurysm L283: Endovascular insertion of stent for thoracic aortic aneurysm L284: Endovascular insertion of stent for aortic dissection in any position L285: Endovascular insertion of stent for aortic aneurysm of bifurcation NEC L286: Endovascular insertion of stent for aorto-uni-iliac aneurysm L288: Other specified transluminal operations on aneurysmal segment of aorta L289: Unspecified transluminal operations on aneurysmal segment of aorta O201: Endovascular placement of one branched stent graft O202: Endovascular placement of one fenestrated stent graft O203: Endovascular placement of one stent graft NEC O204: Endovascular placement of two stent grafts O205: Endovascular placement of three or more stent grafts O208: Other specified endovascular placement of stent graft O209: Unspecified endovascular placement of stent graft
Surgical management of acute pancreatitis	J601: Drainage of pancreatic duct J576: Pancreatic necrosectomy J602: Open removal of calculus from pancreatic duct J603: Insertion of T tube into pancreatic duct J612: Drainage of cyst of pancreas into transposed jejunum J613: Drainage of cyst of pancreas into jejunum NEC J614: Drainage of cyst of pancreas NEC

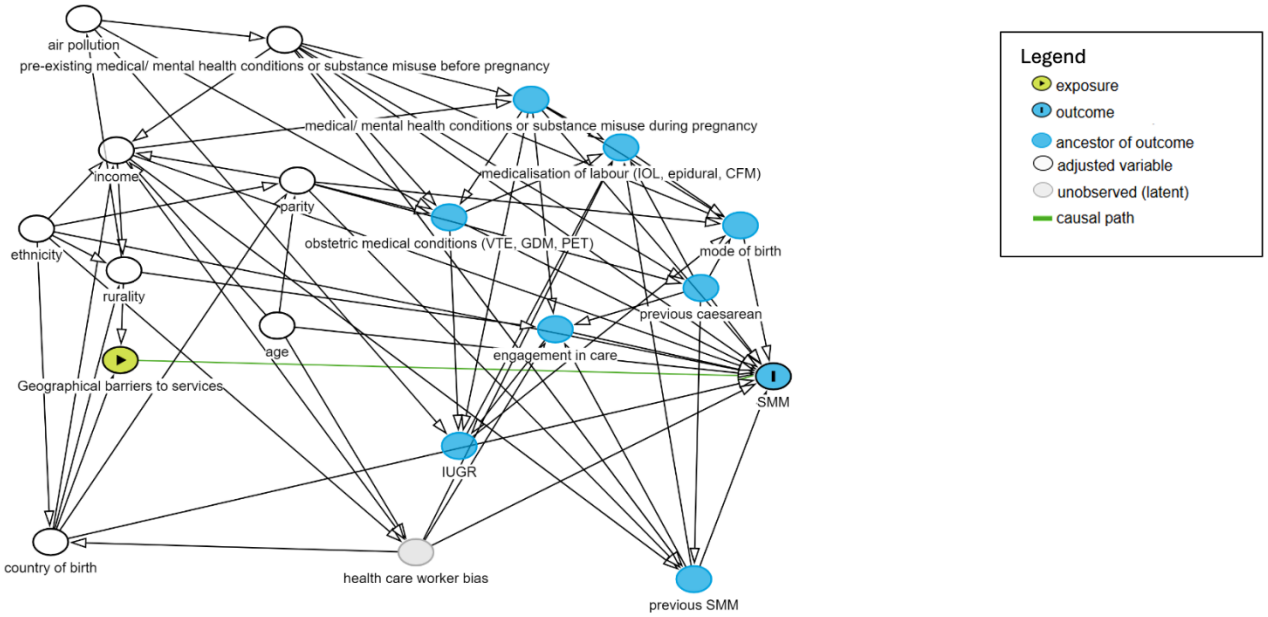
Appendix Figure 4.1. Income deprivation domains direct acyclic graph (DAG)



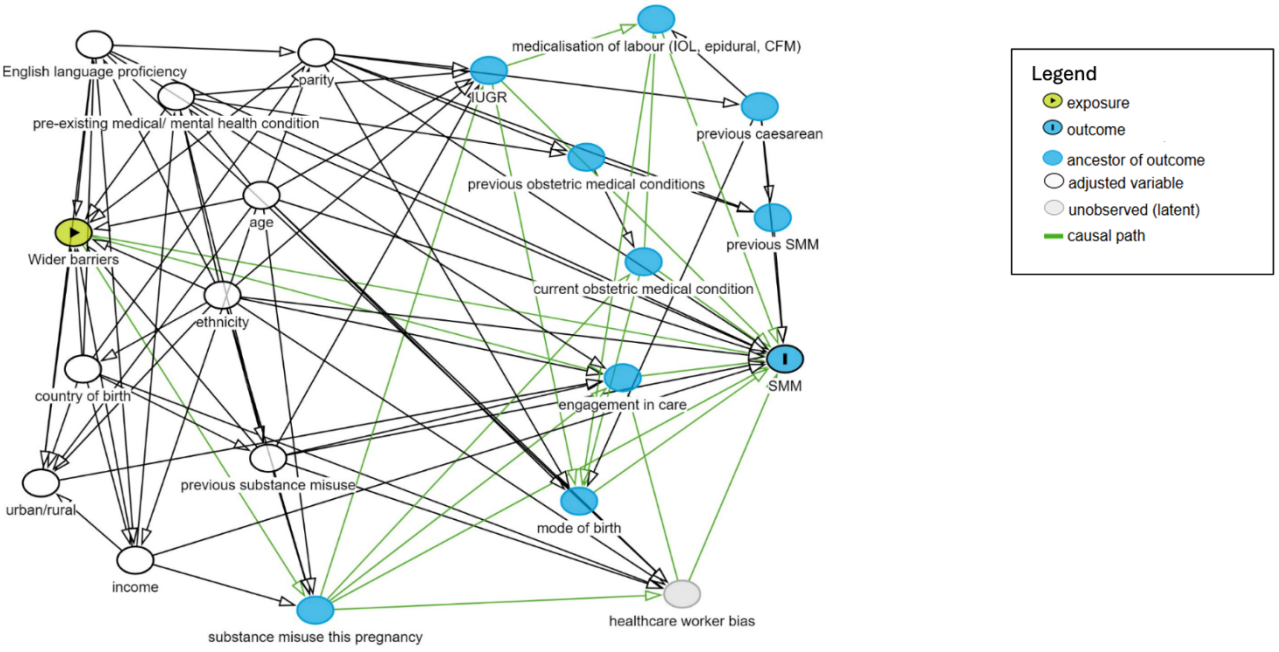
Appendix Figure 4.2. Employment deprivation domain direct acyclic graph (DAG)



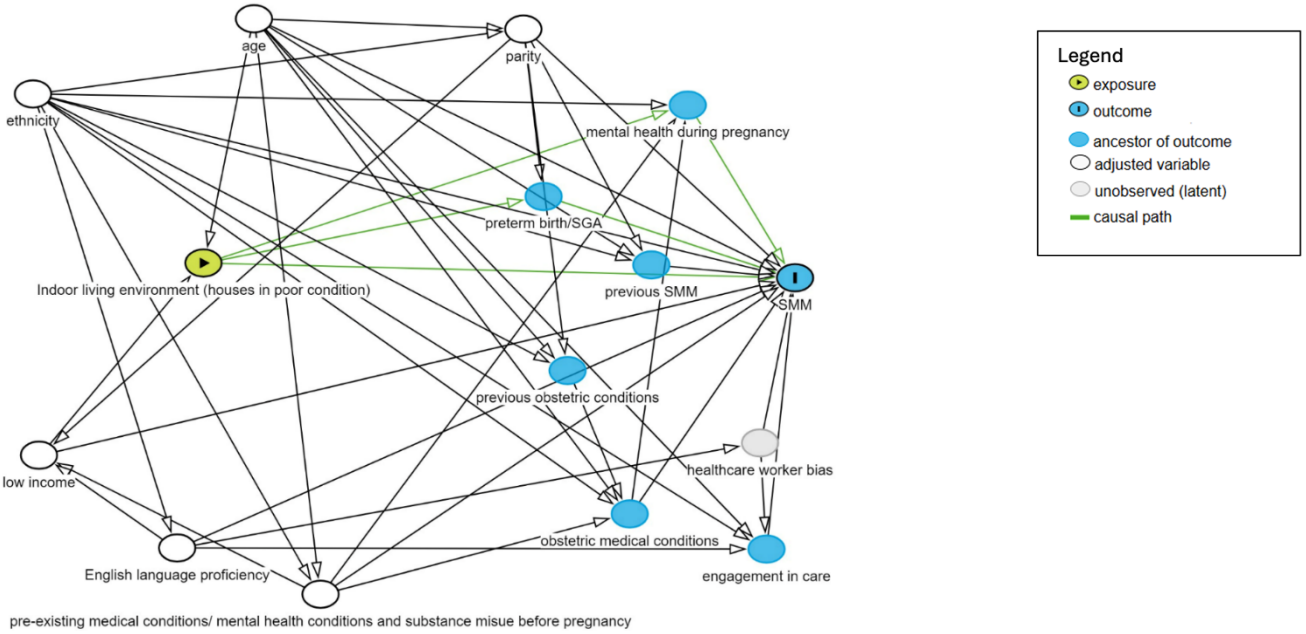
Appendix Figure 4.3. Geographical barriers deprivation subdomain direct acyclic graph (DAG)



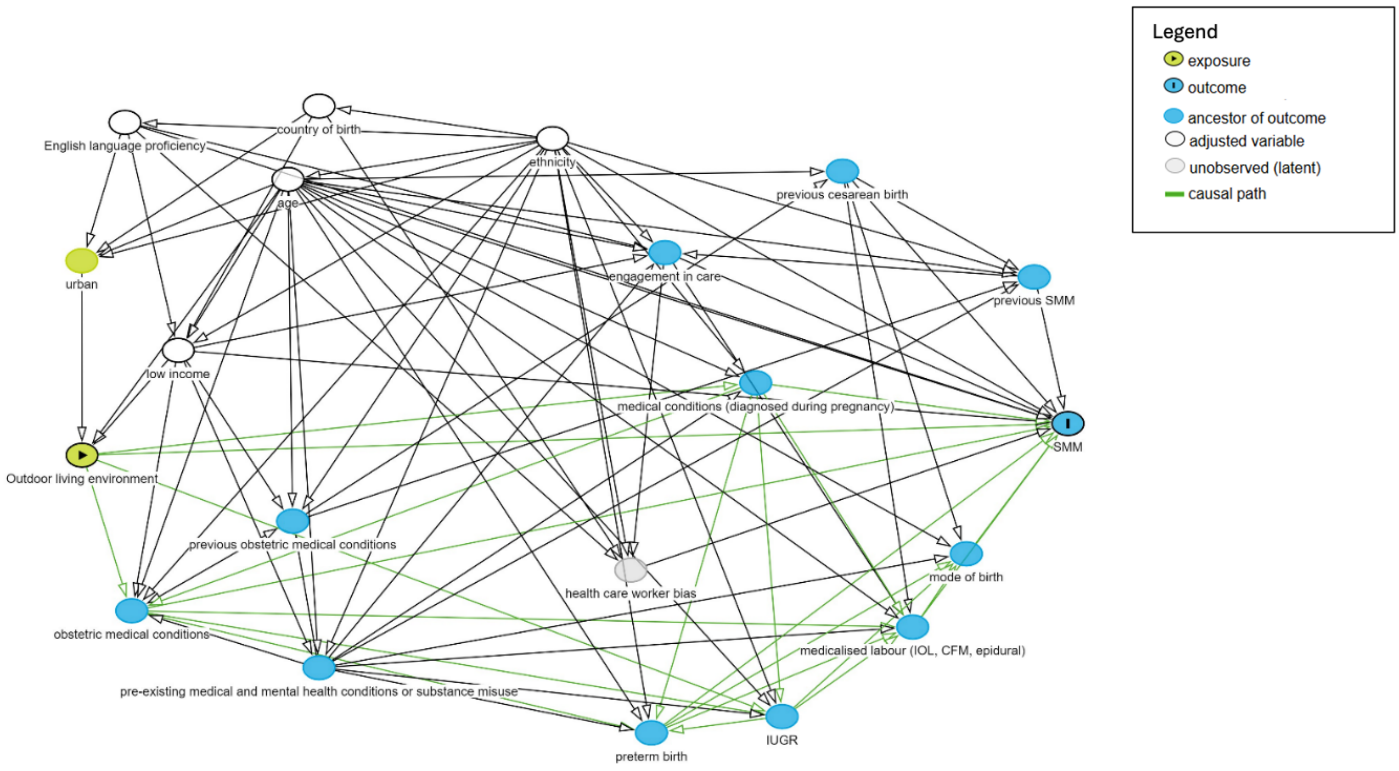
Appendix Figure 4.4. Wider barriers deprivation subdomain direct acyclic graph (DAG)



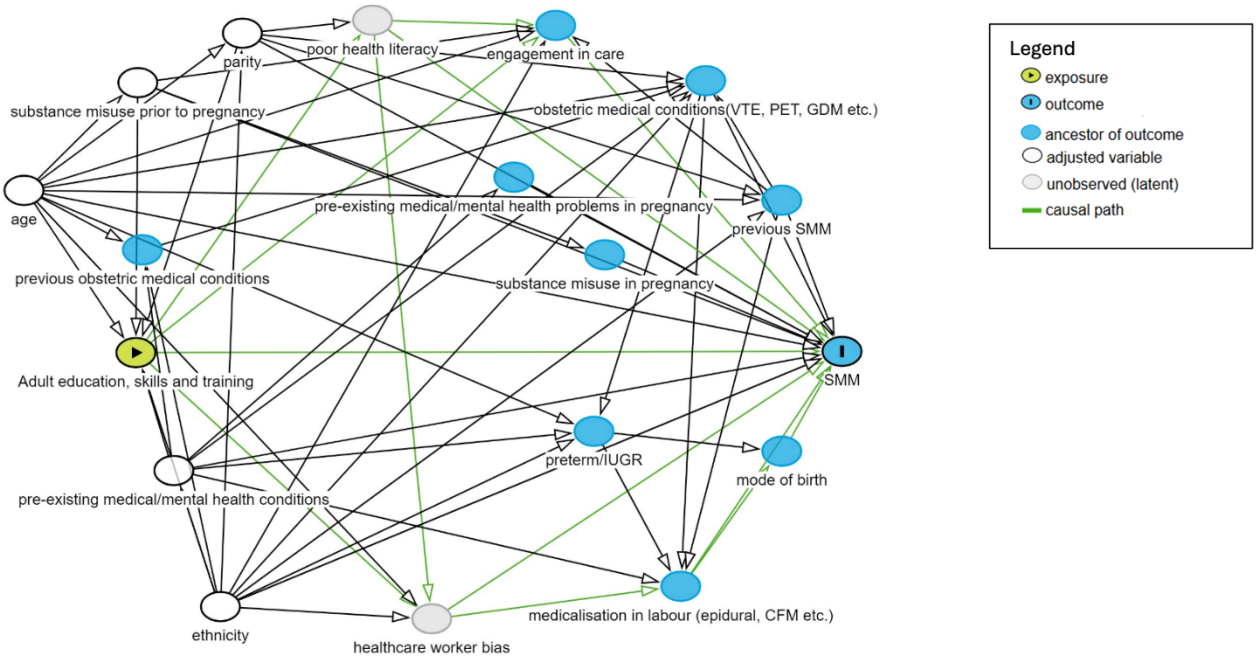
Appendix Figure 4.5. Indoor living environment deprivation subdomain direct acyclic graph (DAG)



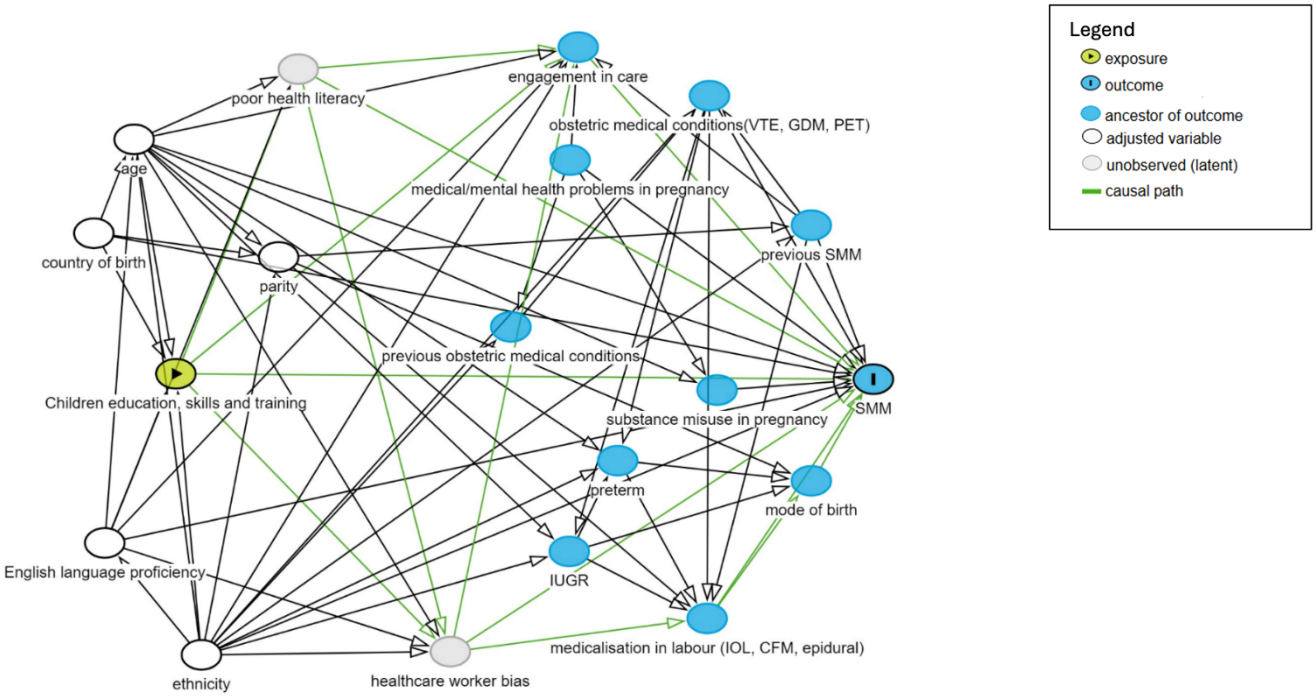
Appendix Figure 4.6. Outdoor living environment deprivation direct acyclic graph (DAG)



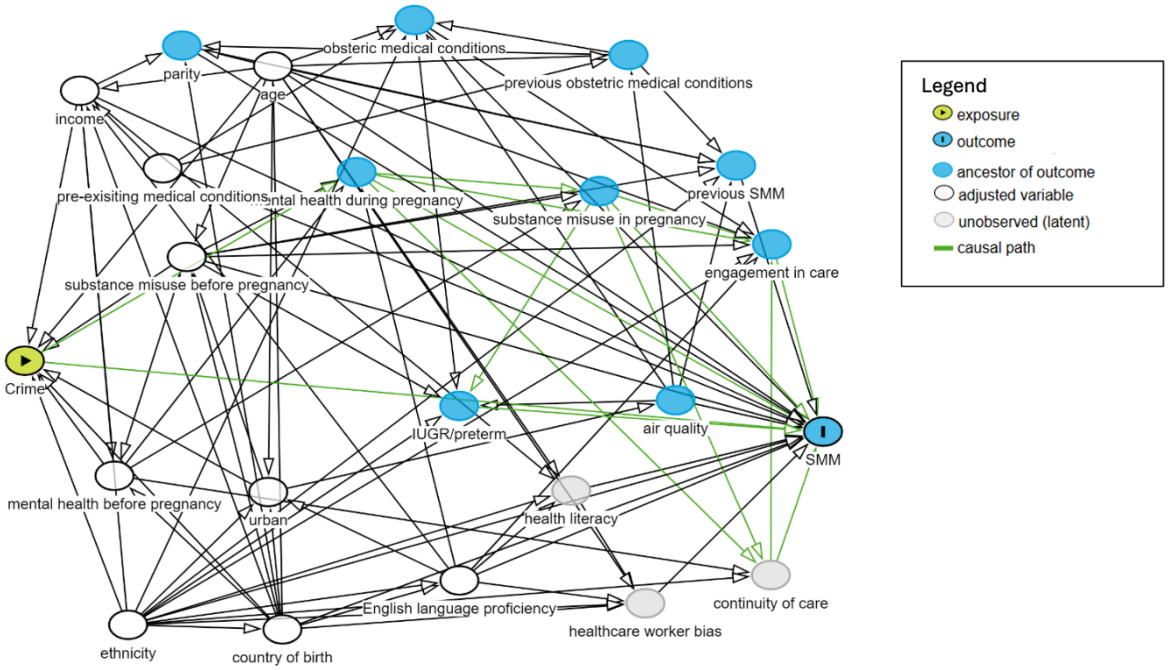
Appendix Figure 4.7. Adult skills subdomain deprivation direct acyclic graph (DAG)



Appendix Figure 4.8. Children and young people deprivation subdomain direct acyclic graph (DAG)



Appendix Figure 4.9. Crime deprivation domain direct acyclic graph (DAG)



Appendix Table 4.4. Characteristics of women with missing parity compared to complete (NUMPREG) in the additional maternity section of HES APC. Number and percent (N %).

	NUMPREG		
	Not missing	**Missing**	**Total**
	N(%)	**N(%)**	**N(%)**
Total	**2,598,118 (64.3)**	**1,441,988 (35.7)**	**4,040,106 (100.0)**
SMM			
No	2,553,982 (98.3)	1,414,706 (98.1)	3,968,688 (98.2)
Yes	44,136 (1.7)	27,282 (1.9)	71,418 (1.8)
Ethnicity			
White	1,869,824 (75.4)	1,069,865 (78.7)	2,939,689 (76.6)
Black or Black British - Caribbean	24,423 (1.0)	12,623 (0.9)	37,046 (1.0)
Black or Black British - African	80,103 (3.2)	39,388 (2.9)	119,491 (3.1)
Asian or Asian British - Indian	99,590 (4.0)	35,901 (2.6)	135,491 (3.5)
Asian or Asian British - Pakistani	96,605 (3.9)	53,275 (3.9)	149,880 (3.9)
Asian or Asian British - Bangladeshi	45,074 (1.8)	11,572 (0.9)	56,646 (1.5)
Mixed	48,611 (2.0)	25,731 (1.9)	74,342 (1.9)
Other	123,658 (5.0)	66,957 (4.9)	190,615 (5.0)
Other Asian	68,263 (2.8)	31,235 (2.3)	99,498 (2.6)
Other Black	23,435 (0.9)	13,023 (1.0)	36,458 (0.9)
Index of Multiple Deprivation			
Most deprived 20%%	666,760 (25.7)	381,627 (26.5)	1,048,387 (25.9)
More deprived 20-40%%	592,722 (22.8)	323,696 (22.4)	916,418 (22.7)
Less deprived 40-60%	498,064 (19.2)	280,565 (19.5)	778,629 (19.3)
Less deprived 60-80%	434,793 (16.7)	251,435 (17.4)	686,228 (17.0)
Least deprived 80-100%	405,779 (15.6)	204,665 (14.2)	610,444 (15.1)
Age group			
<20	73,109 (2.8)	50,747 (3.5)	123,856 (3.1)
20-25	345,550 (13.3)	208,001 (14.4)	553,551 (13.7)
25-30	698,499 (26.9)	388,822 (27.0)	1,087,321 (26.9)
30-35	848,835 (32.7)	462,274 (32.1)	1,311,109 (32.5)
35-40	504,109 (19.4)	265,602 (18.4)	769,711 (19.1)
>40	128,016 (4.9)	66,542 (4.6)	194,558 (4.8)
Mode of birth			
Unassisted vertex vaginal birth	1,447,448 (55.7)	780,069 (54.4)	2,227,517 (55.3)
Instrumental birth	346,503 (13.3)	190,517 (13.3)	537,020 (13.3)
Breech	11,607 (0.4)	6,499 (0.5)	18,106 (0.4)
Elective caesarean birth	347,910 (13.4)	188,057 (13.1)	535,967 (13.3)
Emergency caesarean birth	422,721 (16.3)	260,437 (18.2)	683,158 (16.9)
Other methods of birth	20,846 (0.8)	8,827 (0.6)	29,673 (0.7)

	NUMPREG		
	Not missing	**Missing**	**Total**
	N(%)	**N(%)**	**N(%)**
Birth onset method			
Spontaneous: the onset of regular contractions whether or not preceded by spontaneous rupture of the membranes	1,279,905 (52.7)	477,665 (53.1)	1,757,570 (52.8)
Any caesarean section carried out immediately following the onset of labour, when the decision was made before labour	416,487 (17.1)	139,064 (15.5)	555,551 (16.7)
Surgical induction by amniotomy	119,921 (4.9)	61,393 (6.8)	181,314 (5.4)
Medical induction	444,655 (18.3)	158,830 (17.7)	603,485 (18.1)
Combination of surgical induction and medical induction	169,278 (7.0)	62,773 (7.0)	232,051 (7.0)
Substance misuse or smoking			
No	1,969,664 (75.8)	1,105,451 (76.7)	3,075,115 (76.1)
Yes	628,454 (24.2)	336,537 (23.3)	964,991 (23.9)
Pre-existing medical conditions			
No	1,990,573 (76.6)	1,106,888 (76.8)	3,097,461 (76.7)
Yes	607,545 (23.4)	335,100 (23.2)	942,645 (23.3)
Pre-existing mental health condition			
No	2,288,331 (88.1)	1,261,624 (87.5)	3,549,955 (87.9)
Yes	309,787 (11.9)	180,364 (12.5)	490,151 (12.1)
Obesity/ overweight			
No	2,042,621 (82.0)	1,147,368 (82.9)	3,189,989 (82.3)
Yes	449,577 (18.0)	236,733 (17.1)	686,310 (17.7)

Appendix Table 4.5. The number and percentage of women with a birth code (R17-R25 from 2003 to the start of pregnancy) or code during this pregnancy (O342, O757, Z354, Z876 and Z875) suggesting a previous birth, stratified by the variable NUMPREG in the additional maternity section of the HES APC. Number and percent (N%).

	NUMPREG			
	0	**>0**	**Missing**	**Total**
	N(%)	**N(%)**	**N(%)**	**N(%)**
Total	**969,765 (24.0)**	**1,628,353 (40.3)**	**1,441,988 (35.7)**	**4,040,106 (100.0)**
Birth code R17-R25 > 9 months prior to birth				
No	880,834 (90.8)	478,168 (29.4)	851,768 (59.1)	2,210,770 (54.7)
Yes	88,931 (9.2)	1,150,185 (70.6)	590,220 (40.9)	1,829,336 (45.3)
Code during this pregnancy suggesting a previous birth				
No	947,744 (97.7)	1,529,905 (94.0)	1,388,578 (96.3)	3,866,227 (95.7)
Yes	22,021 (2.3)	98,448 (6.0)	53,410 (3.7)	173,879 (4.3)

Appendix Table 4.6. The number and percentage (%) of women in the new parity variable who had had a birth code (R17-R25) prior to this pregnancy (yes/no), had a birth code during this pregnancy suggesting a previous pregnancy (O342, O757, Z354, Z876 and Z875) or had NUMPREG coded as 0, >0 or missing. Number and percent (N%).

	New Parity Variable		
	Multiparous	**Primiparous**	**Total**
	N(%)	**N(%)**	**N(%)**
Total	**2,368,848 (58.6)**	**1,671,258 (41.4)**	**4,040,106 (100.0)**
Birth code R17-R25 > 9 months prior to birth			
No	539,512 (22.8)	1,671,258 (100.0)	2,210,770 (54.7)
Yes	1,829,336 (77.2)	0 (0.0)	1,829,336 (45.3)
Code during this pregnancy suggested of previous pregnancy			
No	2,194,969 (92.7)	1,671,258 (100.0)	3,866,227 (95.7)
Yes	173,879 (7.3)	0 (0.0)	173,879 (4.3)
NUMPREG			
0	109,158 (4.6)	860,607 (51.5)	969,765 (24.0)
>0	1,628,353 (68.7)	0 (0.0)	1,628,353 (40.3)
Missing	631,337 (26.7)	810,651 (48.5)	1,441,988 (35.7)

Appendix Table 4.7. The coding of mode of birth in the HES APC additional maternity section compared to the OPCS-4 code recorded. Number and percent (N %).

	Additional HES maternity section											
	Unassisted vertex vaginal birth	**Other vaginal birth**	**Low forceps birth**	**Other Forceps birth**	**Ventouse (Vacuum) birth**	**Breech birth (including extraction)**	**Breech birth**	**Elective caesarean birth**	**Emergency caesarean birth**	**Other methods of birth**	**Missing**	**Total**
	N(%)	**N(%)**	**N(%)**	**N(%)**	**N(%)**	**N(%)**	**N(%)**	**N(%)**	**N(%)**	**N(%)**	**N(%)**	**N(%)**
Total	**1,826,741 (45.2)**	**76,074 (1.9)**	**163,758 (4.1)**	**100,251 (2.5)**	**193,936 (4.8)**	**13,211 (0.3)**	**2,362 (0.1)**	**450,825 (11.2)**	**547,707 (13.6)**	**29,489 (0.7)**	**635,752 (15.7)**	**4,040,106 (100.0)**
OPCS-4 codes												
Unassisted vertex vaginal birth	1,791,661 (98.1)	58,747 (77.2)	2,259 (1.4)	725 (0.7)	23,905 (12.3)	2,142 (16.2)	142 (6.0)	522 (0.1)	991 (0.2)	12,054 (40.9)	323,131 (50.8)	**2,216,279 (54.9)**
Other vaginal birth	7,296 (0.4)	3,056 (4.0)	36 (0.0)	20 (0.0)	248 (0.1)	28 (0.2)	2 (0.1)	1 (0.0)	4 (0.0)	44 (0.1)	1,571 (0.2)	**12,306 (0.3)**
Low forceps birth	2,691 (0.1)	1,187 (1.6)	92,236 (56.3)	23,559 (23.5)	2,135 (1.1)	134 (1.0)	15 (0.6)	30 (0.0)	109 (0.0)	641 (2.2)	24,802 (3.9)	**147,539 (3.7)**
Other forceps birth	1,858 (0.1)	694 (0.9)	32,394 (19.8)	42,791 (42.7)	2,225 (1.1)	90 (0.7)	13 (0.6)	14 (0.0)	51 (0.0)	1,568 (5.3)	15,116 (2.4)	**96,814 (2.4)**
Ventouse (Vacuum) birth	9,951 (0.5)	872 (1.1)	1,896 (1.2)	4,358 (4.3)	162,730 (83.9)	3,366 (25.5)	9 (0.4)	145 (0.0)	84 (0.0)	2,715 (9.2)	39,157 (6.2)	**225,283 (5.6)**
Breech birth (including extraction) birth	432 (0.0)	48 (0.1)	111 (0.1)	60 (0.1)	82 (0.0)	197 (1.5)	280 (11.9)	16 (0.0)	18 (0.0)	5 (0.0)	202 (0.0)	**1,451 (0.0)**
Breech birth	2,644 (0.1)	408 (0.5)	217 (0.1)	130 (0.1)	362 (0.2)	6,196 (46.9)	795 (33.7)	32 (0.0)	23 (0.0)	99 (0.3)	2,331 (0.4)	**13,237 (0.3)**
Elective caesarean birth	2,574 (0.1)	415 (0.5)	7,811 (4.8)	130 (0.1)	68 (0.0)	393 (3.0)	756 (32.0)	393,426 (87.3)	31,831 (5.8)	2,973 (10.1)	85,142 (13.4)	**525,519 (13.0)**
Emergency caesarean birth	5,629 (0.3)	10,265 (13.5)	1,471 (0.9)	212 (0.2)	551 (0.3)	603 (4.6)	316 (13.4)	56,192 (12.5)	514,288 (93.9)	8,613 (29.2)	135,451 (21.3)	**733,591 (18.2)**
Other methods of birth	140 (0.0)	15 (0.0)	28 (0.0)	6 (0.0)	4 (0.0)	1 (0.0)	2 (0.1)	422 (0.1)	238 (0.0)	101 (0.3)	184 (0.0)	**1,141 (0.0)**
Missing	1,865 (0.1)	367 (0.5)	25,299 (15.4)	28,260 (28.2)	1,626 (0.8)	61 (0.5)	32 (1.4)	25 (0.0)	70 (0.0)	676 (2.3)	8,665 (1.4)	**66,946 (1.7)**

Appendix Table 4.8. Characteristics of study population including women with missing data. Number and percent (N %).

	Index of Multiple Deprivation Quintile						
	Most deprived 20%	**More deprived 20-40%**	**Less deprived 40-60%**	**Less deprived 60-80%**	**Least deprived 80-100%**	**Missing**	**Total**
	N(%)	**N(%)**	**N(%)**	**N(%)**	**N(%)**	**N(%)**	**N(%)**
Total	**1,048,387 (25.3)**	**916,418 (22.2)**	**778,629 (18.8)**	**686,228 (16.6)**	**610,444 (14.8)**	**96,457 (2.3)**	**4,136,563(100.0)**
SMM							
No	1,028,362 (98.1)	899,119 (98.1)	765,055 (98.3)	675,001 (98.4)	601,151 (98.5)	94,059 (98.5)	4,062,747 (98.2)
Yes	20,025 (1.9)	17,299 (1.9)	13,574 (1.7)	11,227 (1.6)	9,293 (1.5)	1,429 (1.5)	72,847 (1.8)
Age group							
<20	55,363 (5.3)	30,243 (3.3)	18,850 (2.4)	12,006 (1.7)	7,394(1.2)	2,371 (2.5)	126,227 (3.1)
20-25	207,037 (19.7)	140,181 (15.3)	95,759 (12.3)	66,879 (9.7)	43,695 (7.2)	12,811 (13.4)	566,362 (13.7)
25-30	313,768 (29.9)	262,243 (28.6)	209,558 (26.9)	170,878 (24.9)	130,874 (21.4)	27,494 (28.8)	1,114,815 (27.0)
30-35	281,696 (26.9)	284,168 (31.0)	263,127 (33.8)	248,454 (36.2)	233,664 (38.3)	31,684 (33.2)	1,342,793 (32.5)
35-40	149,881 (14.3)	158,938 (17.3)	153,684 (19.7)	150,808 (22.0)	156,400 (25.6)	17,020 (17.8)	786,731 (19.0)
>40	40,642 (3.9)	40,645 (4.4)	37,651 (4.8)	37,203 (5.4)	38,417 (6.3)	4,108 (4.3)	198,666 (4.8)
Ethnicity							
White	665,971 (63.5)	623,508 (68.0)	590,306 (75.8)	554,122 (80.7)	505,782 (82.9)	60,889 (63.1)	3,000,578 (72.5)
Black or Black British - Caribbean	16,363 (1.6)	11,260 (1.2)	5,304 (0.7)	2,602 (0.4)	1,517 (0.2)	917 (1.0)	37,963 (0.9)
Black or Black British - African	56,529 (5.4)	33,764 (3.7)	15,279 (2.0)	8,403 (1.2)	5,516 (0.9)	5,016 (5.2)	124,507 (3.0)
Asian or Asian British - Indian	28,995 (2.8)	39,187 (4.3)	29,243 (3.8)	20,346 (3.0)	17,720 (2.9)	5,937 (6.2)	141,428 (3.4)
Asian or Asian British - Pakistani	76,829 (7.3)	37,538 (4.1)	18,864 (2.4)	10,219 (1.5)	6,430 (1.1)	3,038 (3.1)	152,918 (3.7)
Asian or Asian British - Bangladeshi	29,469 (2.8)	16,301 (1.8)	6,208 (0.8)	2,968 (0.4)	1,700 (0.3)	1,574 (1.6)	58,220 (1.4)
Mixed	24,810 (2.4)	18,537 (2.0)	12,763 (1.6)	10,025 (1.5)	8,207 (1.3)	1,849 (1.9)	76,191(1.8)
Other	60,266 (6.0)	49,783 (5.7)	34,359 (4.7)	25,299 (3.9)	20,908 (3.6)	6,547(7.2)	197,162 (5.0)
Other Asian	26,605 (2.7)	28,187 (3.2)	20,346 (2.8)	13,833 (2.1)	10,527 (1.8)	3,540 (3.9)	103,038 (2.6)
Other Black	15,569 (1.6)	11,312 (1.3)	5,177 (0.7)	2,652 (0.4)	1,748 (0.3)	1,418 (1.6)	37,876 (1.0)
Missing	**46,981 (4.5)**	**47,041 (5.1)**	**40,780 (5.2)**	**35,759 (5.2)**	**30,389 (5.0)**	**5,732 (5.9)**	**206,682 (5.0)**

	Index of Multiple Deprivation Quintile						
	Most deprived 20%	**More deprived 20-40%**	**Less deprived 40-60%**	**Less deprived 60-80%**	**Least deprived 80-100%**	**Missing**	**Total**
	N(%)	**N(%)**	**N(%)**	**N(%)**	**N(%)**	**N(%)**	**N(%)**
Rural/Urban							
Urban	1,029,343 (98.2)	850,301 (92.8)	637,753 (81.9)	529,929 (77.2)	480,662 (78.7)	53,595 (55.6)	3,581,583 (86.6)
Rural	19,044 (1.8)	66,117 (7.2)	140,876 (18.1)	156,299 (22.8)	129,782 (21.3)	5,198 (5.4)	517,316 (12.5)
Parity							
Multiparous	659,764 (62.9)	537,140 (58.6)	438,060 (56.3)	382,215 (55.7)	351,669 (57.6)	56,267 (58.9)	2,425,115 (58.6)
Primiparous	388,623 (37.1)	379,278 (41.4)	340,569 (43.7)	304,013 (44.3)	258,775 (42.4)	39,221 (41.1)	1,710,479 (41.4)
Substance Misuse or Smoking							
No	727,128 (69.4)	683,531 (74.6)	603,359 (77.5)	550,446 (80.2)	510,651 (83.7)	79,098 (82.0)	3,154,213 (76.3)
Yes	321,259 (30.6)	232,887 (25.4)	175,270 (22.5)	135,782 (19.8)	99,793 (16.3)	17,359 (18.0)	982,350 (23.7)
Pre-existing medical conditions							
No	824,213 (78.6)	726,596 (79.3)	616,128 (79.1)	542,836 (79.1)	484,860 (79.4)	80,111 (83.1)	3,274,744 (79.2)
Yes	224,174 (21.4)	189,822 (20.7)	162,501 (20.9)	143,392 (20.9)	125,584 (20.6)	16,346 (16.9)	861,819 (20.8)
Pre-existing mental health conditions							
No	906,066 (86.4)	804,865 (87.8)	686,335 (88.1)	607,381 (88.5)	545,308 (89.3)	89,722 (93.0)	3,639,677 (88.0)
Yes	142,321 (13.6)	111,553 (12.2)	92,294 (11.9)	78,847 (11.5)	65,136 (10.7)	6,735(7.0)	496,886 (12.0)
Obesity/ Overweight							
No	779,597 (78.5)	714,653 (81.5)	622,088 (83.0)	559,458 (84.3)	514,193 (86.7)	78,889 (87.3)	3,268,878 (82.4)
Yes	213,613 (21.5)	161,788 (18.5)	127,704 (17.0)	104,319 (15.7)	78,886 (13.3)	11,493 (12.7)	697,803 (17.6)

	Index of Multiple Deprivation Quintile						
	Most deprived 20%	**More deprived 20-40%**	**Less deprived 40-60%**	**Less deprived 60-80%**	**Least deprived 80-100%**	**Missing**	**Total**
	N(%)	**N(%)**	**N(%)**	**N(%)**	**N(%)**	**N(%)**	**N(%)**
Mode of birth							
Unassisted vertex vaginal birth	609,611 (58.1)	505,708 (55.2)	421,923 (54.2)	366,773 (53.4)	323,502 (53.0)	53,607 (55.6)	2,281,124 (55.1)
Instrumental birth	122,666 (11.7)	124,866 (13.6)	108,112 (13.9)	96,084 (14.0)	85,292 (14.0)	12,780 (13.2)	549,800 (13.3)
Breech	4,624 (0.4)	3,964 (0.4)	3,502 (0.4)	2,858 (0.4)	3,158 (0.5)	506 (0.5)	18,612 (0.4)
Elective caesarean birth	124,545 (11.9)	114,158 (12.5)	104,524 (13.4)	99,477 (14.5)	93,263 (15.3)	12,127 (12.6)	548,094 (13.2)
Emergency caesarean birth	179,325 (17.1)	159,238 (17.4)	132,985 (17.1)	113,814 (16.6)	97,796 (16.0)	15,903 (16.5)	699,061 (16.9)
Other methods of birth	6,069 (0.6)	6,680 (0.7)	5,574 (0.7)	5,529 (0.8)	5,821 (1.0)	426 (0.4)	30,099 (0.7)
Missing	**1,547(0.1)**	**1,804 (0.2)**	**2,009 (0.3)**	**1,693 (0.2)**	**1,612 (0.3)**	**139 (0.1)**	**8,804 (0.2)**
Birth onset method							
Spontaneous: the onset of regular contractions whether or not preceded by spontaneous rupture of the membranes	449,318 (42.9)	398,247 (43.5)	339,729 (43.6)	298,449 (43.5)	271,827 (44.5)	46,314 (48.0)	1,803,884 (43.6)
Any caesarean section carried out immediately following the onset of labour, when the decision was made before labour	140,541 (13.4)	120,828 (13.2)	105,774 (13.6)	97,175 (14.2)	91,233 (14.9)	13,234 (13.7)	568,785 (13.8)
Surgical induction by amniotomy	47,538 (4.5)	40,232 (4.4)	35,785 (4.6)	30,227 (4.4)	27,532 (4.5)	4,859 (5.0)	186,173 (4.5)
Medical induction	159,652 (15.2)	139,533 (15.2)	116,190 (14.9)	101,196 (14.7)	86,914 (14.2)	12,262 (12.7)	615,747 (14.9)
Combination of surgical induction and medical induction	67,818 (6.5)	51,134 (5.6)	43,410 (5.6)	38,612 (5.6)	31,077 (5.1)	5,522 (5.7)	237,573 (5.7)
Missing	**183,520 (17.5)**	**166,444 (18.2)**	**137,741 (17.7)**	**120,569 (17.6)**	**101,861 (16.7)**	**14,266 (14.8)**	**724,401 (17.5)**

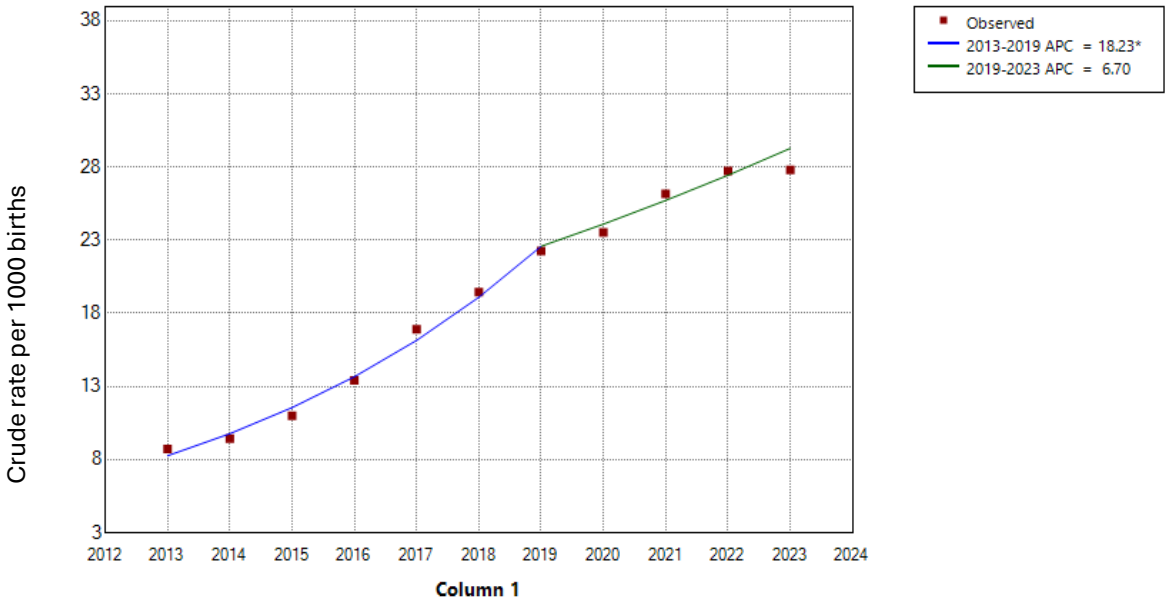
	Index of Multiple Deprivation Quintile						
	Most deprived 20%	**More deprived 20-40%**	**Less deprived 40-60%**	**Less deprived 60-80%**	**Least deprived 80-100%**	**Missing**	**Total**
	N(%)	**N(%)**	**N(%)**	**N(%)**	**N(%)**	**N(%)**	**N(%)**
Booked pregnancy ≥12 weeks gestation							
No	378,100 (36.1)	362,636 (39.6)	320,175 (41.1)	289,469 (42.2)	270,547 (44.3)	36,945 (38.3)	1,657,872 (40.1)
Yes	151,239 (14.4)	113,349 (12.4)	83,758 (10.8)	67,055 (9.8)	57,816 (9.5)	14,721 (15.3)	487,938 (11.8)
Missing	**519,048 (49.5)**	**440,433 (48.1)**	**374,696 (48.1)**	**329,704 (48.0)**	**282,081 (46.2)**	**44,791 (46.4)**	**1,990,753 (48.1)**

Appendix Table 4.9. Characteristics of women with missing data on Index of Multiple Deprivation. Number and percent (N %).

	Missing Index of Multiple Deprivation		
	No	**Yes**	**Total**
	N(%)	**N(%)**	**N(%)**
Total	**4,040,106 (97.7)**	**96,457 (2.3)**	**4,136,563 (100.0)**
SMM			
No	3,968,688 (98.2)	94,059 (98.5)	4,062,747 (98.2)
Yes	71,418 (1.8)	1,429 (1.5)	72,847 (1.8)
Age group			
<20	123,856 (3.1)	2,371 (2.5)	126,227 (3.1)
20-25	553,551 (13.7)	12,811 (13.4)	566,362 (13.7)
25-30	1,087,321 (26.9)	27,494 (28.8)	1,114,815 (27.0)
30-35	1,311,109 (32.5)	31,684 (33.2)	1,342,793 (32.5)
35-40	769,711 (19.1)	17,020 (17.8)	786,731 (19.0)
>40	194,558 (4.8)	4,108 (4.3)	198,666 (4.8)
Ethnicity			
White	2,939,689 (76.6)	60,889 (67.1)	3,000,578 (76.4)
Black or Black British - Caribbean	37,046 (1.0)	917 (1.0)	37,963 (1.0)
Black or Black British - African	119,491 (3.1)	5,016 (5.5)	124,507 (3.2)
Asian or Asian British - Indian	135,491 (3.5)	5,937 (6.5)	141,428 (3.6)
Asian or Asian British - Pakistani	149,880 (3.9)	3,038 (3.3)	152,918 (3.9)
Asian or Asian British - Bangladeshi	56,646 (1.5)	1,574 (1.7)	58,220 (1.5)
Mixed	74,342 (1.9)	1,849 (2.0)	76,191 (1.9)
Other	190,615 (5.0)	6,547 (7.2)	197,162 (5.0)
Other Asian	99,498 (2.6)	3,540 (3.9)	103,038 (2.6)
Other Black	36,458 (0.9)	1,418 (1.6)	37,876 (1.0)
Parity			
Multiparous	2,368,848 (58.6)	56,267 (58.9)	2,425,115 (58.6)
Primiparous	1,671,258 (41.4)	39,221 (41.1)	1,710,479 (41.4)
Rural/Urban			
Urban	3,527,988 (87.3)	53,595 (91.2)	3,581,583 (87.4)
Rural	512,118 (12.7)	5,198 (8.8)	517,316 (12.6)
Substance misuse or Smoking			
No	3,075,115 (76.1)	79,098 (82.0)	3,154,213 (76.3)
Yes	964,991 (23.9)	17,359 (18.0)	982,350 (23.7)
Pre-existing medical conditions			
No	3,097,461 (76.7)	77,381 (80.2)	3,174,842 (76.8)
Yes	942,645 (23.3)	19,076 (19.8)	961,721 (23.2)
Pre-existing mental health conditions			
No	3,549,955 (87.9)	89,722 (93.0)	3,639,677 (88.0)
Yes	490,151 (12.1)	6,735 (7.0)	496,886 (12.0)

	Missing Index of Multiple Deprivation		
	No	**Yes**	**Total**
	N(%)	**N(%)**	**N(%)**
Obesity/ overweight			
No	3,189,989 (82.3)	78,889 (87.3)	3,268,878 (82.4)
Yes	686,310 (17.7)	11,493 (12.7)	697,803 (17.6)
Mode of birth			
Unassisted vertex birth	2,227,517 (55.3)	53,607 (56.2)	2,281,124 (55.3)
Instrumental birth	537,020 (13.3)	12,780 (13.4)	549,800 (13.3)
Breech	18,106 (0.4)	506 (0.5)	18,612 (0.5)
Elective caesarean birth	535,967 (13.3)	12,127 (12.7)	548,094 (13.3)
Emergency caesarean birth	683,158 (16.9)	15,903 (16.7)	699,061 (16.9)
Other methods of birth	29,673 (0.7)	426 (0.4)	30,099 (0.7)
Birth onset method			
Spontaneous: the onset of regular contractions whether or not preceded by spontaneous rupture of the membranes	1,757,570 (52.8)	46,314 (56.3)	1,803,884 (52.9)
Any caesarean section carried out immediately following the onset of labour, when the decision was made before labour	555,551 (16.7)	13,234 (16.1)	568,785 (16.7)
Surgical induction by amniotomy	181,314 (5.4)	4,859 (5.9)	186,173 (5.5)
Medical induction	603,485 (18.1)	12,262 (14.9)	615,747 (18.0)
Combination of surgical induction and medical induction	232,051 (7.0)	5,522 (6.7)	237,573 (7.0)
Booked pregnancy ≥12 weeks gestation			
No	1,620,927 (77.4)	36,945 (71.5)	1,657,872 (77.3)
Yes	473,217 (22.6)	14,721 (28.5)	487,938 (22.7)

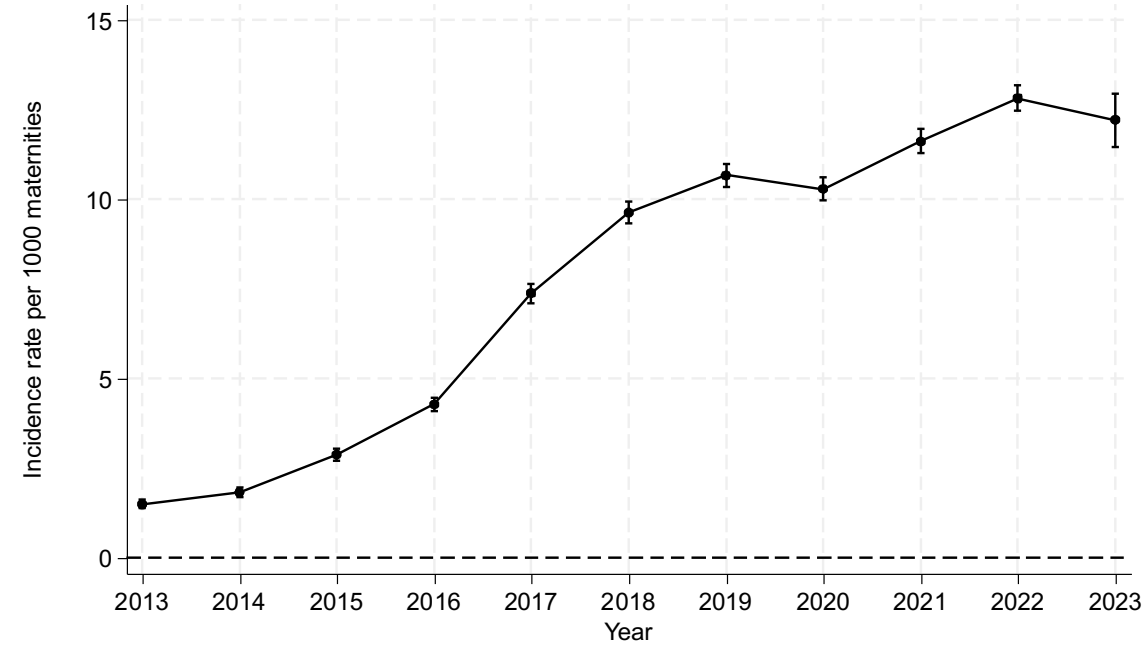
Appendix Figure 4.10. Joinpoint of composite SMM outcome per year.



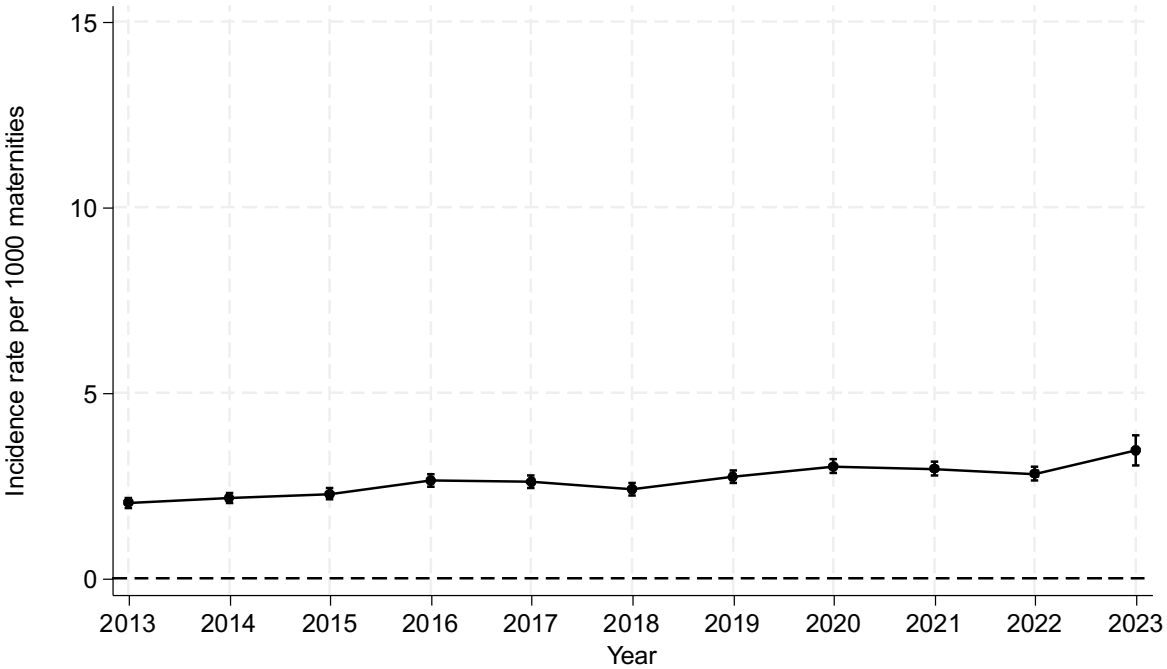
* Indicates that the Annual Percent Change (APC) is significantly different from zero at the alpha = 0.05 level.
-- Test Statistic and P-Value not available for the Empirical Quantile method.
Final Selected Model: 1 Joinpoint.

Appendix Figure 4.11. Incidence rate (and 95% confidence interval) of (A) sepsis, (B) management of vaginal or intra-abdominal collection (C) acute renal failure (D) all other SMM conditions.

A

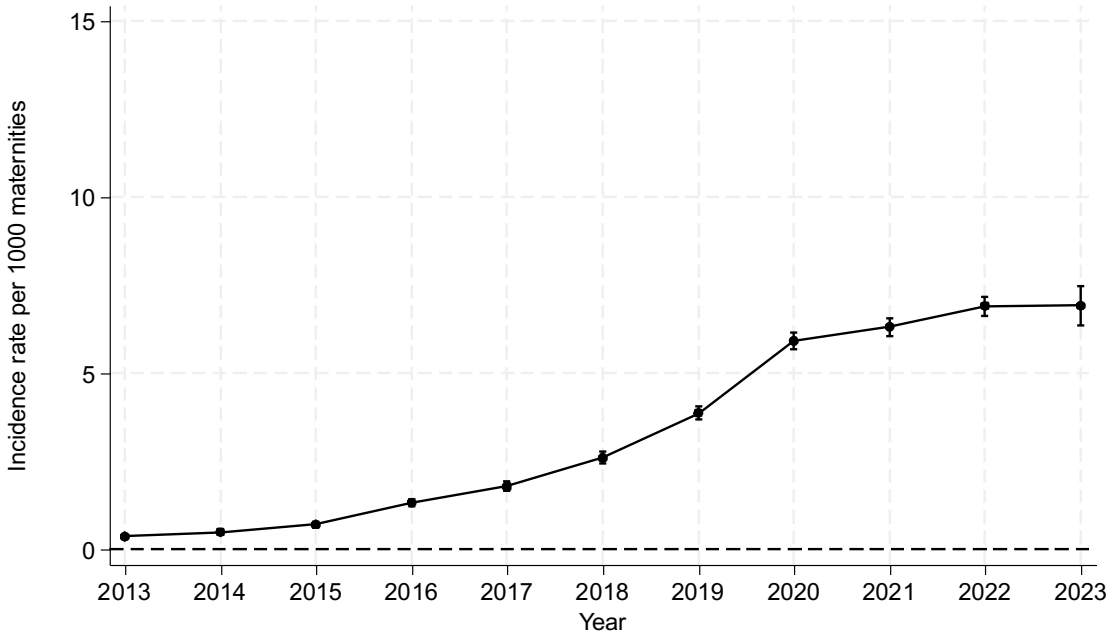


B

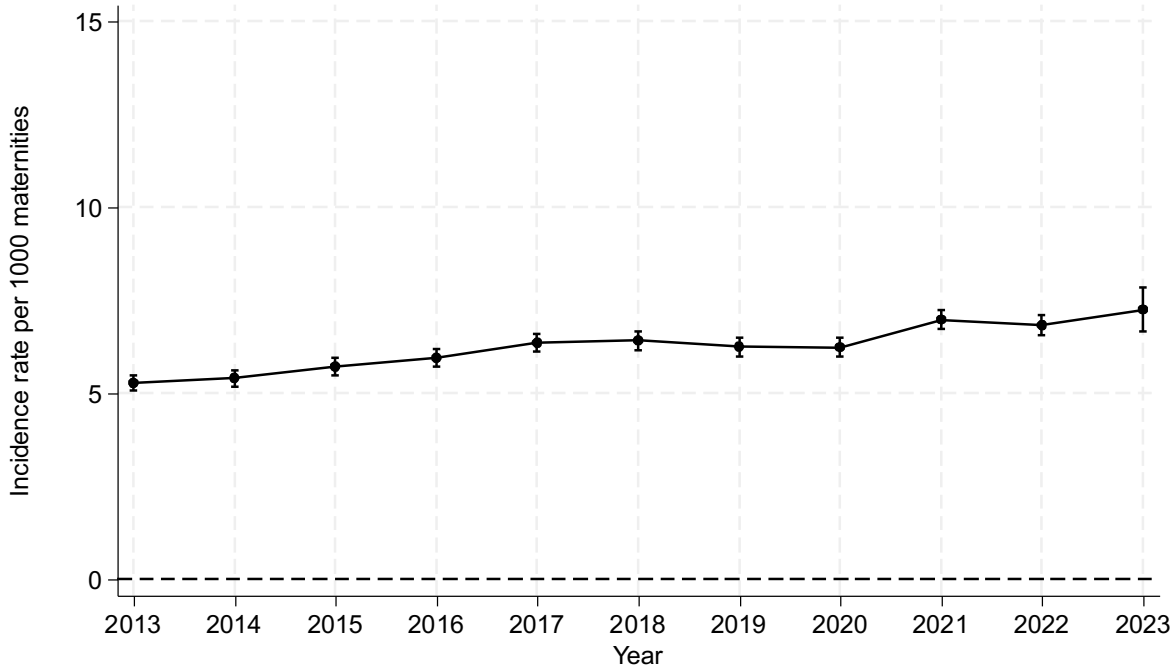


Appendix Figure 4.11. (Continued) Incidence rate (and 95% confidence intervals) of (A) sepsis, (B) management of vaginal or intra-abdominal collection (C) acute renal failure (D) all other SMM conditions.

C



D



Appendix Table 4.10. Number (N) and proportion of total composite outcome (%) of each SMM diagnosis (ICD-10) and procedure (OPCS-4) stratified by composite IMD quintile.

	Index of Multiple Deprivation					
	Most deprived 20%	**More deprived 20-40%**	**Less deprived 40-60%**	**Less deprived 60-80%**	**Least deprived 80-100%**	**Total**
	N(%)	**N(%)**	**N(%)**	**N(%)**	**N(%)**	**N(%)**
Total SMM*	**20,025 (1.9)**	**17,299(1.9)**	**13,574(1.7)**	**11,227(1.6)**	**9,293 (1.5)**	**71,418(1.8)**
Interventional and surgical procedures to arrest major haemorrhage following birth	38 (0.2)	25 (0.1)	27 (0.2)	14 (0.1)	22 (0.2)	126 (0.2)
Management of vulval or vaginal haematoma	175 (0.9)	142 (0.8)	150 (1.1)	145 (1.3)	134 (1.5)	746 (1.1)
Rupture of aortic aneurysm or dissection of aorta	29 (0.1)	29 (0.2)	27 (0.2)	27 (0.2)	24 (0.3)	136 (0.2)
Interventional and surgical procedure to treat thrombosis	6 (0.0)	2 (0.0)	5 (0.0)	4 (0.0)	4 (0.0)	21 (0.0)
Management of acute coronary syndrome	4 (0.0)	0 (0.0)	2 (0.0)	0 (0.0)	0 (0.0)	6 (0.0)
Repair of aortic aneurysm or aortic dissection	0 (0.0)	1 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.0)
Interventional procedures to treat haemorrhagic or ischaemic stroke	1 (0.0)	0 (0.0)	0 (0.0)	2 (0.0)	0 (0.0)	3 (0.0)
Interventional and surgical procedures to manage major haemorrhage originating from the spleen	2 (0.0)	5 (0.0)	3 (0.0)	0 (0.0)	1 (0.0)	11 (0.0)
Acute abdomen	119 (0.6)	118 (0.7)	82 (0.6)	71 (0.6)	81 (0.9)	471 (0.7)
Acute renal failure	2,366 (12.0)	2,402 (14.0)	2,093 (15.6)	1,815 (16.4)	1,450 (15.8)	10,126 (14.4)
Acute psychosis	157 (0.8)	145 (0.8)	123 (0.9)	78 (0.7)	81 (0.9)	584 (0.8)
Acute cardiac event (cardiac infarction, cardiac failure, cardiomyopathy and cardiac arrest)	582 (2.9)	451 (2.6)	372 (2.8)	332 (3.0)	285 (3.1)	2,022 (2.9)
Cerebral oedema or coma	38 (0.2)	30 (0.2)	20 (0.1)	26 (0.2)	23 (0.3)	137 (0.2)
Disseminated intravascular coagulopathy	451 (2.3)	328 (1.9)	247 (1.8)	213 (1.9)	187 (2.0)	1,426 (2.0)
Diabetic ketoacidosis	12 (0.1)	17 (0.1)	18 (0.1)	9 (0.1)	7 (0.1)	63 (0.1)
Cerebrovascular accident	38 (0.2)	27 (0.2)	36 (0.3)	24 (0.2)	13 (0.1)	138 (0.2)
Major complications of anaesthesia	25 (0.1)	24 (0.1)	9 (0.1)	14 (0.1)	10 (0.1)	82 (0.1)
Embolic event (pulmonary embolism, amniotic fluid embolism, septic embolism and air embolism	813 (4.1)	556 (3.2)	376 (2.8)	251 (2.3)	216 (2.4)	2,212 (3.1)
Shock	344 (1.7)	263 (1.5)	248 (1.8)	211 (1.9)	186 (2.0)	1,252 (1.8)
Sickle cell anaemia with crisis	91 (0.5)	70 (0.4)	29 (0.2)	16 (0.1)	6 (0.1)	212 (0.3)
Uterine rupture	836 (4.2)	673 (3.9)	576 (4.3)	485 (4.4)	439 (4.8)	3,009 (4.3)
Eclampsia	542 (2.7)	504 (2.9)	475 (3.5)	362 (3.3)	332 (3.6)	2,215 (3.1)
Respiratory support	327 (1.7)	261 (1.5)	182 (1.4)	167 (1.5)	133 (1.5)	1,070 (1.5)

	Index of Multiple Deprivation					
	Most deprived 20%	**More deprived 20-40%**	**Less deprived 40-60%**	**Less deprived 60-80%**	**Least deprived 80-100%**	**Total**
	N(%)	**N(%)**	**N(%)**	**N(%)**	**N(%)**	**N(%)**
Surgical evacuation of the uterus following birth	274 (1.4)	276 (1.6)	237 (1.8)	217 (2.0)	191 (2.1)	1,195 (1.7)
Dialysis	48 (0.2)	36 (0.2)	22 (0.2)	20 (0.2)	13 (0.1)	139 (0.2)
Hysterectomy	430 (2.2)	242 (1.4)	174 (1.3)	170 (1.5)	160 (1.7)	1,176 (1.7)
Acute pancreatitis	7 (0.0)	3 (0.0)	6 (0.0)	1 (0.0)	3 (0.0)	20 (0.0)
Interventional and surgical procedures to arrest major haemorrhage following birth	102 (0.5)	111 (0.6)	78 (0.6)	64 (0.6)	56 (0.6)	411 (0.6)
Management of caesarean wound dehiscence	89 (0.4)	66 (0.4)	61 (0.5)	54 (0.5)	46 (0.5)	316 (0.4)
Repair of damage to bladder or urinary tract	418 (2.1)	337 (2.0)	255 (1.9)	263 (2.4)	204 (2.2)	1,477 (2.1)
Sepsis	8,499 (42.9)	7,261 (42.4)	5,321 (39.6)	4,096 (37.0)	3,077 (33.6)	28,254 (40.0)
Repair of damage to the intestine and management of intestinal obstruction	111 (0.6)	84 (0.5)	65 (0.5)	52 (0.5)	37 (0.4)	349 (0.5)
Acute respiratory compromise	144 (0.7)	114 (0.7)	82 (0.6)	72 (0.6)	66 (0.7)	478 (0.7)
Management of intra-abdominal or pelvic collection	2,571 (13.0)	2,434 (14.2)	1,975 (14.7)	1,774 (16.0)	1,641 (17.9)	10,395 (14.7)
Status epilepticus	34 (0.2)	17 (0.1)	7 (0.1)	12 (0.1)	5 (0.1)	75 (0.1)
Status asthmaticus	72 (0.4)	65 (0.4)	38 (0.3)	17 (0.2)	17 (0.2)	209 (0.3)

*SMM total does not add up to total in columns as one maternity may have had more than one SMM diagnosis/ procedure

Appendix Table 4.11. Number (N) and proportion of total composite outcome (%) of each SMM diagnosis (ICD-10) and procedure (OPCS-4) per year.

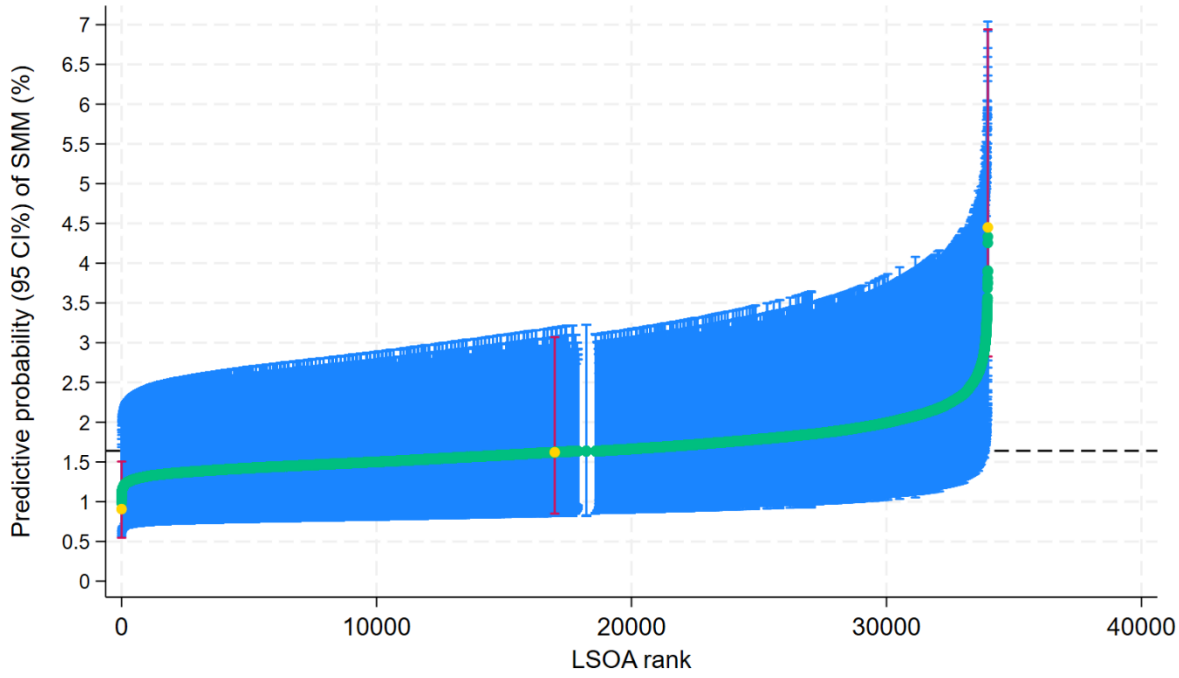
	Year											
	2013	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**Total**
	N(%)	**N(%)**	**N(%)**	**N(%)**	**N(%)**	**N(%)**	**N(%)**	**N(%)**	**N(%)**	**N(%)**	**N(%)**	**N(%)**
Total SMM*	**3,881 (0.9)**	**4,080 (0.9)**	**4,575 (1.1)**	**5,518 (1.3)**	**6,727 (1.7)**	**7,340 (2.0)**	**8,069 (2.2)**	**8,587 (2.4)**	**10,077 (2.6)**	**10,264 (2.7)**	**2,300 (2.8)**	**71,418 (1.8)**
Interventional and surgical procedures to arrest major haemorrhage following birth	39 (1.0)	48 (1.2)	52 (1.2)	58 (1.1)	58 (0.9)	47 (0.6)	34 (0.4)	23 (0.3)	31 (0.3)	37 (0.4)	9 (0.4)	436 (0.6)
Management of vulval or vaginal hematoma	101 (2.7)	88 (2.2)	75 (1.7)	90 (1.7)	78 (1.2)	68 (0.9)	51 (0.6)	61 (0.7)	61 (0.6)	62 (0.6)	12 (0.5)	747 (1.1)
Rupture of aortic aneurysm or dissection of aorta	5 (0.1)	7 (0.2)	11 (0.2)	11 (0.2)	23 (0.3)	14 (0.2)	13 (0.2)	9 (0.1)	18 (0.2)	20 (0.2)	5 (0.2)	136 (0.2)
Interventional and surgical procedure to treat thrombosis	3 (0.1)	4 (0.1)	0 (0.0)	1 (0.0)	2 (0.0)	3 (0.0)	2 (0.0)	3 (0.0)	1 (0.0)	2 (0.0)	0 (0.0)	21 (0.0)
Management of acute coronary syndrome	1 (0.0)	1 (0.0)	0 (0.0)	0 (0.0)	1 (0.0)	0 (0.0)	1 (0.0)	0 (0.0)	1 (0.0)	1 (0.0)	0 (0.0)	6 (0.0)
Repair of aortic aneurysm or aortic dissection	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.0)
Interventional procedures to treat haemorrhagic or ischemic stroke	1 (0.0)	1 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	3 (0.0)
Interventional and surgical procedures to manage major haemorrhage originating from the spleen	1 (0.0)	1 (0.0)	0 (0.0)	2 (0.0)	0 (0.0)	0 (0.0)	3 (0.0)	0 (0.0)	1 (0.0)	3 (0.0)	0 (0.0)	11 (0.0)
Acute abdomen	42 (1.1)	47 (1.2)	54 (1.2)	46 (0.9)	39 (0.6)	43 (0.6)	39 (0.5)	50 (0.6)	62 (0.6)	39 (0.4)	10 (0.4)	471 (0.7)
Acute renal failure	132 (3.5)	176 (4.4)	239 (5.3)	443 (8.2)	581 (8.7)	778 (10.7)	1,164 (14.6)	1,839 (21.6)	2,080 (20.9)	2,206 (21.7)	493 (21.6)	10,131 (14.4)
Acute psychosis	38 (1.0)	52 (1.3)	54 (1.2)	39 (0.7)	57 (0.9)	53 (0.7)	69 (0.9)	61 (0.7)	82 (0.8)	69 (0.7)	10 (0.4)	584 (0.8)
Acute cardiac event (cardiac infarction, cardiac failure, cardiomyopathy and cardiac arrest)	156 (4.1)	151 (3.8)	164 (3.7)	191 (3.5)	211 (3.2)	204 (2.8)	191 (2.4)	205 (2.4)	255 (2.6)	244 (2.4)	51 (2.2)	2,023 (2.9)
Cerebral oedema or coma	7 (0.2)	11 (0.3)	13 (0.3)	18 (0.3)	9 (0.1)	18 (0.2)	12 (0.2)	15 (0.2)	13 (0.1)	17 (0.2)	4 (0.2)	137 (0.2)
Disseminated intravascular coagulopathy	189 (5.0)	171 (4.3)	163 (3.6)	148 (2.7)	147 (2.2)	122 (1.7)	127 (1.6)	106 (1.2)	108 (1.1)	123 (1.2)	25 (1.1)	1,429 (2.0)
Diabetic ketoacidosis	9 (0.2)	6 (0.2)	8 (0.2)	12 (0.2)	6 (0.1)	3 (0.0)	6 (0.1)	4 (0.0)	4 (0.0)	5 (0.0)	0 (0.0)	63 (0.1)

	Year											
	2013	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**Total**
	3,881 (0.9)	**4,080 (0.9)**	**4,575 (1.1)**	**5,518 (1.3)**	**6,727 (1.7)**	**7,340 (2.0)**	**8,069 (2.2)**	**8,587 (2.4)**	**10,077 (2.6)**	**10,264 (2.7)**	**2,300 (2.8)**	**71,418 (1.8)**
Cerebrovascular accident	19 (0.5)	14 (0.4)	12 (0.3)	21 (0.4)	7 (0.1)	13 (0.2)	12 (0.2)	11 (0.1)	13 (0.1)	11 (0.1)	5 (0.2)	138 (0.2)
Major complications of anaesthesia	8 (0.2)	5 (0.1)	7 (0.2)	7 (0.1)	4 (0.1)	7 (0.1)	7 (0.1)	10 (0.1)	8 (0.1)	14 (0.1)	5 (0.2)	82 (0.1)
Embolic event (pulmonary embolism, amniotic fluid embolism, septic embolism and air embolism)	165 (4.3)	177 (4.4)	192 (4.3)	217 (4.0)	242 (3.6)	246 (3.4)	209 (2.6)	198 (2.3)	261 (2.6)	246 (2.4)	63 (2.8)	2,216 (3.1)
Shock	114 (3.0)	123 (3.1)	124 (2.8)	125 (2.3)	134 (2.0)	133 (1.8)	127 (1.6)	111 (1.3)	121 (1.2)	111 (1.1)	34 (1.5)	1,257 (1.8)
Sickle cell anaemia with crisis	24 (0.6)	29 (0.7)	16 (0.4)	19 (0.4)	20 (0.3)	24 (0.3)	16 (0.2)	24 (0.3)	14 (0.1)	22 (0.2)	5 (0.2)	213 (0.3)
Uterine rupture	269 (7.1)	255 (6.4)	272 (6.1)	224 (4.1)	273 (4.1)	278 (3.8)	355 (4.4)	319 (3.7)	366 (3.7)	322 (3.2)	82 (3.6)	3,015 (4.3)
Eclampsia	221 (5.8)	218 (5.5)	234 (5.2)	206 (3.8)	284 (4.3)	219 (3.0)	187 (2.3)	189 (2.2)	215 (2.2)	198 (1.9)	44 (1.9)	2,215 (3.1)
Respiratory support	82 (2.2)	75 (1.9)	91 (2.0)	128(2.4)	102(1.5)	85 (1.2)	81 (1.0)	92 (1.1)	191 (1.9)	134 (1.3)	28 (1.2)	1,089 (1.5)
Surgical evacuation of the uterus following birth	144 (3.8)	155 (3.9)	103 (2.3)	113 (2.1)	109 (1.6)	117 (1.6)	106 (1.3)	109 (1.3)	107 (1.1)	113 (1.1)	21 (0.9)	1,197 (1.7)
Dialysis	15 (0.4)	13 (0.3)	13 (0.3)	16 (0.3)	8 (0.1)	8 (0.1)	11 (0.1)	15 (0.2)	19 (0.2)	21 (0.2)	2 (0.1)	141 (0.2)
Hysterectomy	164 (4.3)	151 (3.8)	154 (3.4)	128 (2.4)	125 (1.9)	90 (1.2)	92 (1.2)	92 (1.1)	97 (1.0)	107 (1.1)	28 (1.2)	1,228 (1.7)
Acute pancreatitis	1 (0.0)	0 (0.0)	3 (0.1)	2 (0.0)	2 (0.0)	1 (0.0)	2 (0.0)	2 (0.0)	5 (0.1)	2 (0.0)	0 (0.0)	20 (0.0)
Management of caesarean wound dehiscence	34 (0.9)	32 (0.8)	32 (0.7)	42 (0.8)	28 (0.4)	37 (0.5)	23 (0.3)	31 (0.4)	22 (0.2)	27 (0.3)	8 (0.4)	316 (0.4)
Repair of damage to bladder or urinary tract	177 (4.6)	170 (4.3)	172 (3.8)	176 (3.3)	138 (2.1)	150 (2.1)	130 (1.6)	99 (1.2)	108 (1.1)	130 (1.3)	27 (1.2)	1,477 (2.1)
Sepsis	640 (16.8)	765 (19.2)	1,167 (26.0)	1,701 (31.5)	2,825 (42.5)	3,517 (48.2)	3,824 (47.8)	3,665 (43.0)	4,413 (44.3)	4,739 (46.5)	998 (43.8)	28,254 (40.0)
Repair of damage to the intestine and management of intestinal obstruction	36 (0.9)	32 (0.8)	29 (0.6)	47 (0.9)	33 (0.5)	33 (0.5)	31 (0.4)	24 (0.3)	40 (0.4)	36 (0.4)	8 (0.4)	349 (0.5)
Acute respiratory compromise	46 (1.2)	46 (1.2)	53 (1.2)	65 (1.2)	52 (0.8)	53 (0.7)	46 (0.6)	39 (0.5)	40 (0.4)	26 (0.3)	12 (0.5)	478 (0.7)

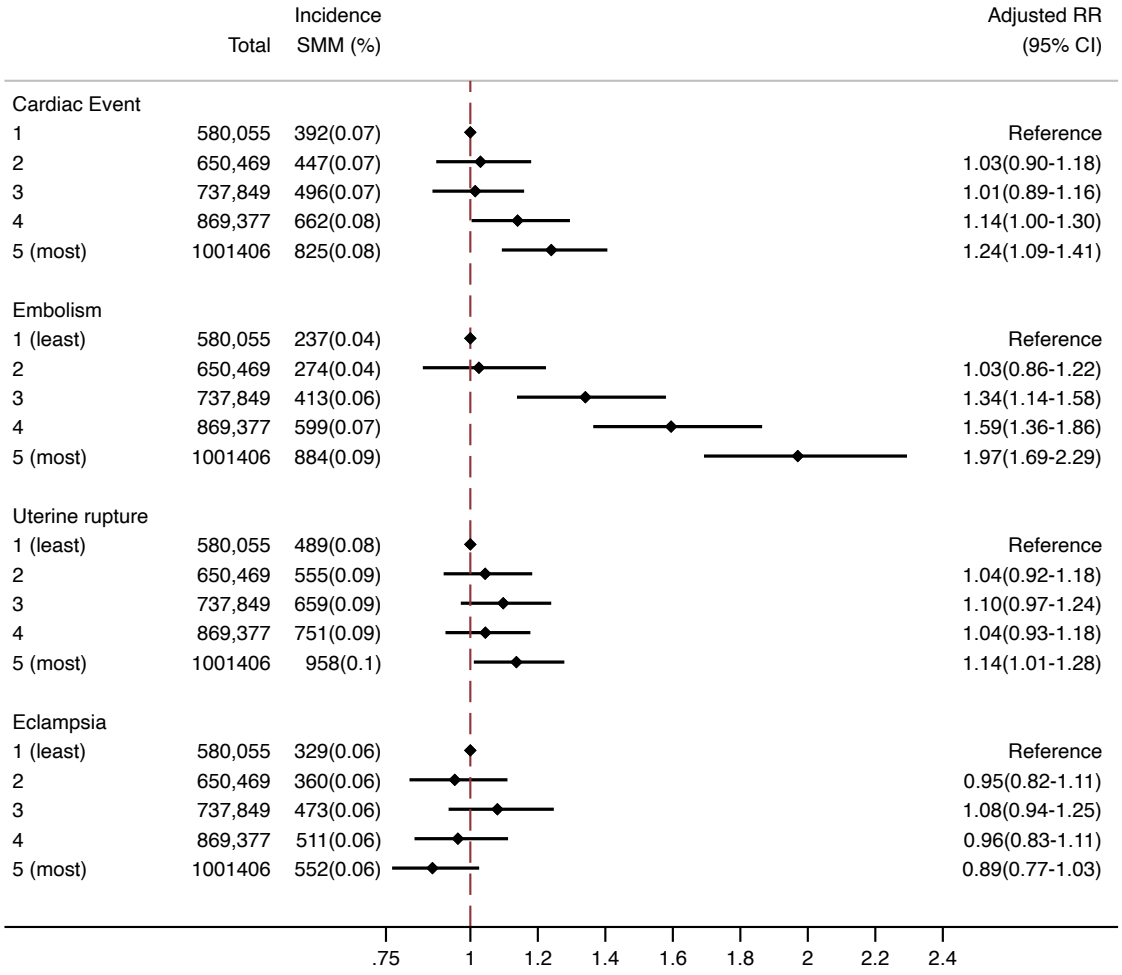
	Year											
	2013	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**Total**
	3,881 (0.9)	**4,080 (0.9)**	**4,575 (1.1)**	**5,518 (1.3)**	**6,727 (1.7)**	**7,340 (2.0)**	**8,069 (2.2)**	**8,587 (2.4)**	**10,077 (2.6)**	**10,264 (2.7)**	**2,300 (2.8)**	**71,418 (1.8)**
Management of intra-abdominal or pelvic collection	906 (23.8)	940 (23.6)	951 (21.2)	1,087 (20.1)	1,022 (15.4)	900 (12.3)	1,005 (12.6)	1,095 (12.8)	1,144 (11.5)	1,057 (10.4)	288 (12.6)	10,395 (14.7)
Status epilepticus	7 (0.2)	4 (0.1)	10 (0.2)	5 (0.1)	14 (0.2)	10 (0.1)	6 (0.1)	9 (0.1)	6 (0.1)	4 (0.0)	0 (0.0)	75 (0.1)
Status asthmaticus	15 (0.4)	15 (0.4)	14 (0.3)	16 (0.3)	9 (0.1)	17 (0.2)	15 (0.2)	17 (0.2)	46 (0.5)	41 (0.4)	4 (0.2)	209 (0.3)

*SMM total does not add up to total in columns as one maternity may have had more than one SMM diagnosis/ procedure

Appendix Figure 4.12. Caterpillar plot showing the predictive probabilities (and 95% confidence intervals) of SMM (%) in each LSOA.



Appendix Figure 4.13. Adjusted risk ratios (and their 95% confidence intervals) of conditions which make up the largest proportion of 'all other SMM', in each of the composite Index of Multiple Deprivation quintiles compared to the least deprived quintile.



Appendix Table 4.12. The adjusted risk ratios* (and their 95% confidence intervals) of SMM in the adult skills compared to White women living in the least deprived adult skills quintile stratified by ethnicity.

	White	**Black or Black British - Caribbean**	**Black or Black British - African**	**Asian or Asian British - Indian**	**Asian or Asian British - Pakistani**	**Asian or Asian British - Bangladeshi**	**Mixed**	**Other**	**Other Asian**	**Other Black**
Adult Skills	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)
Least deprived 80-100%	1 (ref)	1.81 (1.53-2.15)	2.09 (1.90-2.30)	1.22 (1.11-1.34)	1.34 (1.17-1.54)	2.23 (1.91-2.61)	1.17 (1.04-1.32)	1.35 (1.26-1.44)	1.46 (1.33-1.60)	1.80 (1.53-2.11)
Less deprived 60-80%	1.02 (0.99-1.05)	2.05 (1.75-2.41)	1.85 (1.68-2.05)	1.33 (1.21-1.47)	1.70 (1.52-1.90)	1.99 (1.70-2.35)	1.32 (1.16-1.50)	1.35 (1.25-1.47)	1.49 (1.34-1.65)	1.93 (1.64-2.26)
Less deprived 40-60%	1.05 (1.01-1.08)	1.69 (1.46-1.96)	2.02 (1.87-2.20)	1.29 (1.18-1.41)	1.66 (1.51-1.83)	1.90 (1.70-2.35)	1.27 (1.12-1.43)	1.47 (1.36-1.58)	1.66 (1.51-1.81)	2.03 (1.78-2.32)
More deprived 20-40%	1.10 (1.07-1.14)	1.85 (1.62-2.10)	2.03 (1.89-2.18)	1.42 (1.31-1.54)	1.58 (1.46-1.72)	1.97 (1.78-2.17)	1.36 (1.21-1.52)	1.39 (1.29-1.50)	1.76 (1.61-1.91)	1.90 (1.68-2.16)
Most deprived 20%	1.12 (1.08-1.15)	1.73 (1.52-1.96)	2.04 (1.92-2.18)	1.50 (1.39-1.63)	1.60 (1.51-1.69)	1.99 (1.83-2.17)	1.26 (1.14-1.40)	1.36 (1.26-1.45)	1.65 (1.52-1.80)	1.89 (1.66-2.14)

*Adjusted for age, year and parity
Abbreviations: CI: Confidence Interval

Appendix Table 4.13. The adjusted risk ratios* (and their 95% confidence intervals) of SMM in the children and young people compared to White women living in the least deprived children and young people quintile stratified by ethnicity.

	White	Black or Black British - Caribbean	Black or Black British - African	Asian or Asian British - Indian	Asian or Asian British - Pakistani	Asian or Asian British - Bangladeshi	Mixed	Other	Other Asian	Other Black
Children and Young People	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)
Least deprived 80-100%	1 (ref)	1.38 (1.08-1.75)	1.90 (1.68-2.15)	1.16 (1.06-1.27)	1.43 (1.27-1.61)	1.94 (1.64-2.29)	1.15 (0.99-1.32)	1.12 (1.03-1.22)	1.24 (1.12-1.38)	1.88 (1.53-2.31)
Less deprived 60-80%	1.02 (0.99-1.05)	1.71 (1.48-1.99)	1.74 (1.59-1.90)	1.29 (1.19-1.40)	1.56 (1.42-1.72)	2.01 (1.81-2.24)	1.17 (1.03-1.33)	1.36 (1.27-1.47)	1.55 (1.42-1.69)	1.75 (1.51-2.03)
Less deprived 40-60%	1.03 (1.00-1.07)	1.61 (1.42-1.83)	1.86 (1.73-2.00)	1.23 (1.14-1.34)	1.39 (1.29-1.51)	1.72 (1.56-1.89)	1.37 (1.24-1.53)	1.34 (1.25-1.43)	1.59 (1.46-1.72)	1.74 (1.55-1.97)
More deprived 20-40%	1.06 (1.03-1.10)	1.65 (1.46-1.86)	1.90 (1.78-2.04)	1.27 (1.17-1.39)	1.44 (1.34-1.55)	1.82 (1.65-2.01)	1.14 (1.02-1.27)	1.30 (1.21-1.40)	1.49 (1.36-1.63)	1.76 (1.56-1.99)
Most deprived 20%	1.06 (1.02-1.09)	1.75 (1.52-2.02)	1.81 (1.69-1.95)	1.32 (1.18-1.46)	1.42 (1.32-1.53)	1.49 (1.29-1.71)	1.14 (1.02-1.28)	1.22 (1.13-1.31)	1.48 (1.34-1.63)	1.65 (1.43-1.91)

*Adjusted for age, year, parity, % not born in the UK and neighbourhood English language proficiency
Abbreviations: CI: Confidence Interval

Appendix Table 4.14. The total number (N) and incidence of SMM (%) in the adult skills and children and young people domain quintiles stratified by ethnicity. Q1 is least deprived and Q5, the most deprived quintile.

	Adult Skills		Children and Young People	
	Total (N)	**Incidence of SMM (%)**	**Total (N)**	**Incidence of SMM (%)**
White				
Q1 (least deprived)	499,332	1.55	457,901	1.53
Q2	548,550	1.55	533,188	1.56
Q3	580,183	1.55	575,867	1.58
Q4	624,521	1.59	632,160	1.60
Q5 (most deprived)	687,103	1.55	740,573	1.53
Black or Black British Caribbean				
Q1	5,022	2.77	2,789	2.40
Q2	5,048	3.09	5,947	3.03
Q3	7,344	2.51	9,534	2.72
Q4	9,226	2.67	11,053	2.52
Q5	10,406	2.43	7,723	2.51
Black or Black British African				
Q1	13,879	3.31	8,038	3.22
Q2	14,829	2.83	16,566	3.11
Q3	21,409	3.04	29,040	3.19
Q4	30,618	2.96	34,662	2.97
Q5	38,756	2.99	31,185	2.77
Asian or Asian British Indian				
Q1	24,358	1.93	27,819	1.94
Q2	21,959	2.08	31,231	2.21
Q3	26,846	2.00	31,349	2.08
Q4	30,775	2.15	26,926	2.10
Q5	31,553	2.24	18,166	2.14
Asian or Asian British Pakistani				
Q1	10,606	2.02	12,912	2.32
Q2	12,879	2.52	18,792	2.59
Q3	18,966	2.43	31,605	2.30
Q4	29,446	2.28	42,582	2.29
Q5	77,983	2.25	43,989	2.12
Asian or Asian British Bangladeshi				
Q1	4,891	3.39	4,374	3.41
Q2	5,147	3.01	10,216	3.80
Q3	8,779	2.88	16,261	2.93
Q4	15,429	2.92	16,064	2.72
Q5	22,400	2.80	9,731	2.09

	Adult Skills		Children and Young People	
	Total (N)	**Incidence of SMM (%)**	**Total (N)**	**Incidence of SMM (%)**
Mixed				
Q1	13,961	1.97	9,904	1.97
Q2	11,541	2.12	12,266	2.06
Q3	13,220	2.01	15,578	2.41
Q4	15,581	2.09	17,708	1.86
Q5	20,039	1.88	18,886	1.78
Other				
Q1	44,535	2.22	30,864	1.93
Q2	29,356	2.16	35,359	2.41
Q3	33,232	2.30	42,737	2.35
Q4	38,094	2.13	42,592	2.13
Q5	45,398	2.02	39,063	1.93
Other Asian				
Q1	18,828	2.40	16,363	2.16
Q2	15,951	2.36	20,634	2.71
Q3	20,170	2.55	23,302	2.76
Q4	22,601	2.69	21,621	2.47
Q5	21,948	2.53	17,578	2.38
Other Black				
Q1	5,469	2.72	2,790	3.30
Q2	5,516	2.88	5,877	3.13
Q3	7,533	2.99	9,653	2.93
Q4	9,064	2.77	10,517	2.69
Q5	8,876	2.81	7,621	2.51

Appendix Table 4.15. Adjusted risk ratios* (and their 95% confidence intervals) of SMM in each of the domain/subdomain quintiles compared to the least deprived quintile after excluding women with missing data on gestational age at birth and birthweight.

	Income	Employment	Crime	Adult Skills	Children and Young People	Geographical Barriers	Wider Barriers	Indoor Living Environment	Outdoor Living Environment
	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)
Most deprived 20%	1.16 (1.12-1.20)	1.15 (1.11-1.19)	1.00 (0.96-1.04)	1.10 (1.06-1.13)	1.07 (1.04-1.11)	0.92 (0.89-0.95)	1.14 (1.09-1.20)	1.06 (1.03-1.09)	1.03 (1.00-1.07)
More deprived 20-40%	1.12 (1.09-1.16)	1.13 (1.10-1.17)	1.01 (0.98-1.05)	1.11 (1.08-1.15)	1.08 (1.04-1.11)	0.94 (0.91-0.97)	1.01 (0.97-1.05)	1.05 (1.02-1.08)	1.01 (0.98-1.05)
Less deprived 40-60%	1.07 (1.04-1.11)	1.09 (1.06-1.13)	0.99 (0.96-1.03)	1.06 (1.02-1.10)	1.06 (1.02-1.09)	0.96 (0.94-0.99)	1.01 (0.98-1.05)	1.04 (1.01-1.07)	1.00 (0.97-1.04)
Less deprived 60-80%	1.04 (1.01-1.08)	1.08 (1.05-1.12)	0.98 (0.95-1.01)	1.02 (0.99-1.06)	1.06 (1.03-1.09)	0.95 (0.93-0.98)	1.00 (0.97-1.03)	1.04 (1.01-1.08)	0.99 (0.96-1.03)
Least deprived 80-100%	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)
ICC	0.030(0.028-0.033)	0.031(0.028-0.033)	0.030(0.028-0.033)	0.031(0.029-0.034)	0.031(0.028-0.034)	0.035(0.032-0.039)	0.030(0.027-0.033)	0.031(0.028-0.034)	0.031(0.028-0.034)

**All domains are adjusted for age, year, parity and ethnicity. Income and employment are additionally adjusted for neighbourhood % not born in the UK and neighbourhood English language proficiency. Indoor living environment is additionally adjusted for neighbourhood income and neighbourhood English language proficiency. Outdoor living environment is additionally adjusted for neighbourhood income, neighbourhood English language proficiency and neighbourhood % not born in the UK. Children and young people is additionally adjusted for % not born in the UK and neighbourhood English language proficiency. Wider barriers is additionally adjusted for neighbourhood income, neighbourhood English language proficiency, neighbourhood % not born in the UK and urban/rural. Geographical barriers is additionally adjusted for neighbourhood income, neighbourhood % not born in the UK, urban/rural and air pollution. Crime is additionally adjusted for neighbourhood income, neighbourhood % not born in the UK, neighbourhood English language proficiency and urban/rural. Abbreviations: CI: Confidence Interval. ICC: Intra-class coefficient*

Appendix Table 4.16. Adjusted risk ratios* (and their 95% confidence intervals) of SMM (using only ICD-10 codes) in each of the domain/subdomain quintiles compared to the least deprived quintile.

	Income	Employment	Crime	Adult Skills	Children and Young People	Geographical Barriers	Wider Barriers	Indoor Living Environment	Outdoor Living Environment
	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)
Most deprived 20%	1.17 (1.13-1.21)	1.14 (1.10-1.18)	0.96 (0.93-1.00)	1.10 (1.07-1.14)	1.05 (1.01-1.08)	0.93 (0.89-0.96)	1.18 (1.13-1.24)	1.07 (1.03-1.10)	1.09 (1.05-1.13)
More deprived 20-40%	1.11 (1.08-1.16)	1.12 (1.08-1.16)	0.98 (0.94-1.02)	1.11 (1.07-1.14)	1.08 (1.04-1.11)	0.92 (0.89-0.96)	1.02 (0.98-1.06)	1.06 (1.03-1.10)	1.02 (0.99-1.06)
Less deprived 40-60%	1.06 (1.02-1.10)	1.06 (1.03-1.10)	0.96 (0.93-1.00)	1.06 (1.03-1.09)	1.07 (1.03-1.10)	0.96 (0.92-0.99)	1.01 (0.97-1.05)	1.04 (1.01-1.07)	1.01 (0.98-1.04)
Less deprived 60-80%	1.05 (1.01-1.08)	1.07 (1.03-1.10)	0.98 (0.94-1.01)	1.04 (1.01-1.07)	1.06 (1.03-1.10)	0.95 (0.92-0.98)	1.01 (0.98-1.05)	1.04 (1.01-1.07)	1.00 (0.97-1.03)
Least deprived 80-100%	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)
ICC	0.037(0.034-0.040)	0.037(0.034-0.040)	0.037(0.034-0.041)	0.047(0.044 - 0.051)	0.038(0.035 -0.04)	0.037(0.034-0.040)	0.036(0.033-0.039)	0.034(0.032-0.038)	0.033(0.030-0.036)

**All domains are adjusted for age, year, parity and ethnicity. Income and employment are additionally adjusted for neighbourhood % not born in the UK and neighbourhood English language proficiency. Indoor living environment is additionally adjusted for neighbourhood income and neighbourhood English language proficiency. Outdoor living environment is additionally adjusted for neighbourhood income, neighbourhood English language proficiency and neighbourhood % not born in the UK. Children and young people is additionally adjusted for % not born in the UK and neighbourhood English language proficiency. Wider barriers is additionally adjusted for neighbourhood income, neighbourhood English language proficiency, neighbourhood % not born in the UK and urban/rural. Geographical barriers is additionally adjusted for neighbourhood income, neighbourhood % not born in the UK, urban/rural and air pollution. Crime is additionally adjusted for neighbourhood income, neighbourhood % not born in the UK, neighbourhood English language proficiency and urban/rural. Abbreviations: CI: Confidence Interval. ICC: Intra-class coefficient.*

Appendix Table 4.17. Adjusted risk ratios* (and their 95% confidence intervals) of SMM (excluding sepsis) in the composite Index of Multiple Deprivation and each of the domain/subdomain quintiles compared to the least deprived quintile.

	Composite Index of Multiple Deprivation	Income	Employment	Crime	Adult Skills	Children and Young People	Geographical Barriers	Wider Barriers	Indoor Living Environment	Outdoor Living Environment
	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)
Most deprived 20%	1.14 (1.10–1.17)	1.15 (1.10–1.20)	1.13 (1.08–1.17)	0.95 (0.91–0.99)	1.12 (1.08–1.16)	1.09 (1.05–1.13)	0.99 (0.95–1.03)	1.09 (1.04–1.15)	0.99 (0.96–1.03)	0.99 (0.95–1.03)
More deprived 20-40%	1.11 (1.06–1.14)	1.09 (1.05–1.15)	1.09 (1.06–1.13)	0.95 (0.91–0.99)	1.10 (1.07–1.14)	1.08 (1.04–1.12)	0.96 (0.92–1.00)	1.03 (0.99–1.08)	0.99 (0.96–1.03)	0.97 (0.94–1.01)
Less deprived 40-60%	1.06 (1.02–1.10)	1.07 (1.02–1.10)	1.05 (1.02–1.09)	0.97 (0.93–1.00)	1.07 (1.03–1.10)	1.06 (1.03–1.10)	0.99 (0.96–1.03)	1.00 (0.96–1.04)	0.98 (0.94–1.01)	0.98 (0.95–1.01)
Less deprived 60-80%	1.03 (1.00–1.07)	1.03 (0.99–1.07)	1.06 (1.02–1.09)	0.97 (0.93–1.01)	1.04 (1.00–1.07)	1.03 (1.00–1.07)	0.98 (0.94–1.01)	1.00 (0.97–1.04)	0.99 (0.96–1.02)	0.98 (0.94–1.01)
Least deprived 80-100%	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)
ICC	0.027(0.024-0.029)	0.027(0.024-0.029)	0.028(0.024-0.030)	0.027(0.024-0.029)	0.028(0.024-0.030)	0.028(0.024-0.030)	0.030(0.026-0.033)	0.028(0.024-0.030)	0.028(0.024-0.030)	0.028(0.024-0.030)

**All domains are adjusted for age, year, parity and ethnicity. Income and employment are additionally adjusted for neighbourhood % not born in the UK and neighbourhood English language proficiency. Indoor living environment is additionally adjusted for neighbourhood income and neighbourhood English language proficiency. Outdoor living environment is additionally adjusted for neighbourhood income, neighbourhood English language proficiency and neighbourhood % not born in the UK. Children and young people is additionally adjusted for % not born in the UK and neighbourhood English language proficiency. Wider barriers is additionally adjusted for neighbourhood income, neighbourhood English language proficiency, neighbourhood % not born in the UK and urban/rural. Geographical barriers is additionally adjusted for neighbourhood income, neighbourhood % not born in the UK, urban/rural and air pollution. Crime is additionally adjusted for neighbourhood income, neighbourhood % not born in the UK, neighbourhood English language proficiency and urban/rural. Abbreviations: CI: Confidence Interval. ICC: Intra-class coefficient*

Appendix Table 4.18. Adjusted risk ratios* (and their 95% confidence intervals) of SMM (if sepsis plus length of hospital admission 3 days or more) in the composite Index of Multiple Deprivation and each of the domain/subdomain quintiles compared to the least deprived quintile.

	Composite Index of Multiple Deprivation	Income	Employment	Crime	Adult Skills	Children and Young People	Geographical Barriers	Wider Barriers	Indoor Living Environment	Outdoor Living Environment
	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)
Most deprived 20%	1.22 (1.18–1.25)	1.16 (1.12–1.20)	1.14 (1.10–1.17)	0.98 (0.94–1.01)	1.11 (1.08–1.14)	1.06 (1.03–1.09)	0.94 (0.91–0.98)	1.15 (1.10–1.20)	1.06 (1.03–1.09)	1.06 (1.03 1.10)
More deprived 20-40%	1.19 (1.15–1.22)	1.10 (1.07–1.14)	1.11 (1.08–1.14)	0.98 (0.95–1.01)	1.10 (1.07–1.13)	1.07 (1.04–1.10)	0.93 (0.90–0.96)	1.02 (0.98–1.06)	1.06 (1.03–1.09)	1.02 (0.99 1.05)
Less deprived 40-60%	1.11 (1.08–1.15)	1.06 (1.03–1.09)	1.06 (1.03–1.09)	0.98 (0.95–1.01)	1.05 (1.02–1.08)	1.05 (1.02–1.08)	0.97 (0.94–1.00)	1.00 (0.97–1.04)	1.03 (1.00–1.06)	1.01 (0.98 1.04)
Less deprived 60-80%	1.06 (1.02–1.09)	1.03 (1.00–1.06)	1.06 (1.03–1.09)	0.98 (0.95–1.01)	1.02 (0.99–1.05)	1.04 (1.01–1.07)	0.96 (0.93–0.98)	1.01 (0.98–1.04)	1.04 (1.01–1.07)	1.00 (0.97 1.03)
Least deprived 80-100%	1(ref)	1(ref)	1(ref)	1(ref)	1(ref)	1(ref)	1(ref)	1(ref)	1(ref)	1(ref)
ICC	0.027(0.024-0.029)	0.027(0.024-0.029)	0.028(0.024-0.030)	0.027(0.024-0.029)	0.028(0.024-0.030)	0.028(0.024-0.030)	0.030(0.026-0.033)	0.028(0.024-0.030)	0.028(0.024-0.030)	0.028(0.024-0.030)

**All domains are adjusted for age, year, parity and ethnicity. Income and employment are additionally adjusted for neighbourhood % not born in the UK and neighbourhood English language proficiency. Indoor living environment is additionally adjusted for neighbourhood income and neighbourhood English language proficiency. Outdoor living environment is additionally adjusted for neighbourhood income, neighbourhood English language proficiency and neighbourhood % not born in the UK. Children and young people is additionally adjusted for % not born in the UK and neighbourhood English language proficiency. Wider barriers is additionally adjusted for neighbourhood income, neighbourhood English language proficiency, neighbourhood % not born in the UK and urban/rural. Geographical barriers is additionally adjusted for neighbourhood income, neighbourhood % not born in the UK, urban/rural and air pollution. Crime is additionally adjusted for neighbourhood income, neighbourhood % not born in the UK, neighbourhood English language proficiency and urban/rural. Abbreviations: CI: Confidence Interval. ICC: Intra-class coefficient.*

Appendix Table 4.19. Adjusted risk ratios* (and their 95% confidence intervals) of SMM (with sepsis only included if length of hospital stay was 3 days) or more in the adult skills domain quintiles compared to White women living in the least deprived adult skills quintile stratified by ethnicity.

	White	**Black or Black British - Caribbean**	**Black or Black British - African**	**Asian or Asian British - Indian**	**Asian or Asian British - Pakistani**	**Asian or Asian British - Bangladeshi**	**Mixed**	**Other**	**Other Asian**	**Other Black**
Adult Skills	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)
Least deprived 80-100%	1 (ref)	1.87 (1.58–2.22)	2.14 (1.94–2.35)	1.23 (1.12–1.35)	1.37 (1.19–1.57)	2.26 (1.93–2.66)	1.14 (1.00–1.29)	1.36 (1.27–1.45)	1.46 (1.32–1.61)	1.80 (1.52–2.13)
Less deprived 60-80%	1.02 (0.98–1.05)	2.12 (1.80–2.49)	1.88 (1.70–2.08)	1.35 (1.22–1.49)	1.71 (1.53–1.92)	2.01 (1.70–2.37)	1.31 (1.15–1.49)	1.37 (1.26–1.49)	1.49 (1.34–1.66)	1.95 (1.66–2.29)
Less deprived 40-60%	1.05 (1.01–1.08)	1.76 (1.52–2.04)	2.05 (1.89–2.23)	1.29 (1.18–1.41)	1.67 (1.51–1.84)	1.90 (1.66–2.17)	1.27 (1.12–1.44)	1.47 (1.36–1.59)	1.66 (1.52–1.83)	2.14 (1.87–2.45)
More deprived 20-40%	1.11 (1.07–1.14)	1.89 (1.66–2.16)	2.07 (1.93–2.23)	1.44 (1.32–1.56)	1.61 (1.48–1.75)	1.97 (1.78–2.18)	1.33 (1.18–1.49)	1.40 (1.30–1.51)	1.77 (1.62–1.92)	1.86 (1.63–2.12)
Most deprived 20%	1.13 (1.09 1.16)	1.77 (1.55–2.01)	2.09 (1.96–2.23)	1.53 (1.41–1.66)	1.62 (1.53–1.71)	2.06 (1.89–2.24)	1.28 (1.15–1.42)	1.38 (1.28–1.48)	1.67 (1.53–1.83)	1.92 (1.68–2.18)

*Adjusted for age, year and parity
Abbreviations: CI: Confidence Interval

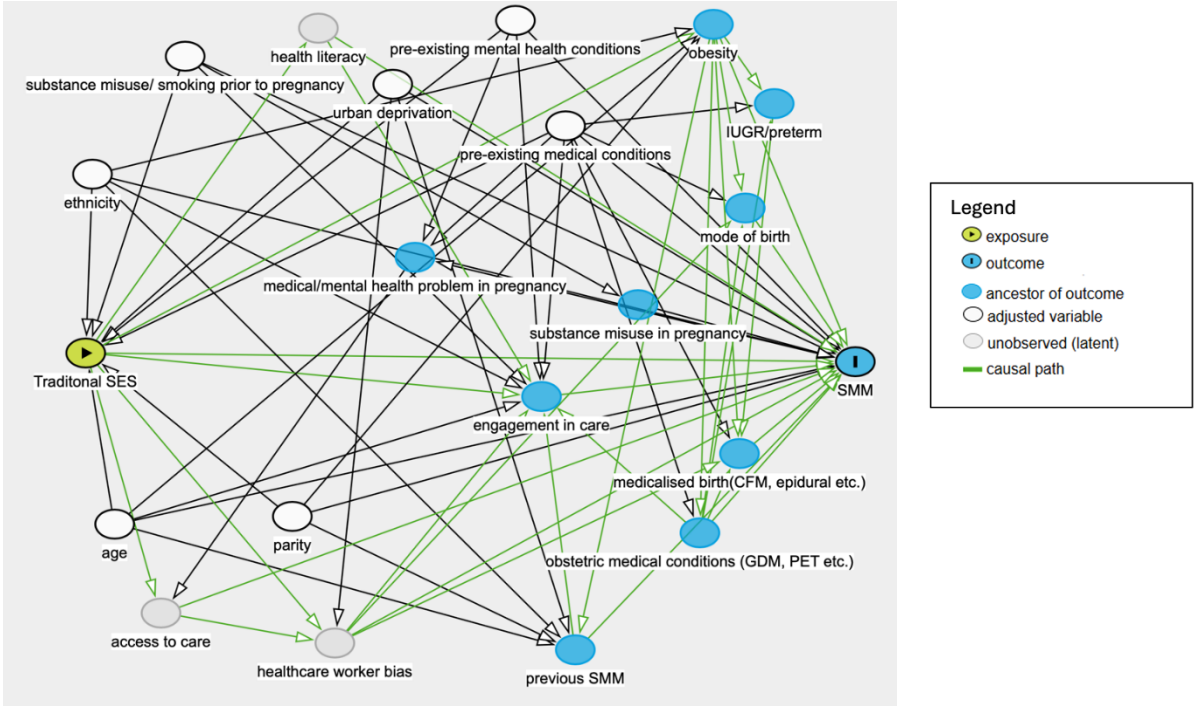
Appendix Table 4.20. Adjusted risk ratios* (and their 95% confidence intervals) of SMM (with sepsis only included if length of hospital stay was 3 days) or more in the children and young people domain quintiles compared to White women living in the least deprived children and young people quintile stratified by ethnicity.

	White	Black or Black British - Caribbean	Black or Black British - African	Asian or Asian British - Indian	Asian or Asian British - Pakistani	Asian or Asian British - Bangladeshi	Mixed	Other	Other Asian	Other Black
Children and Young People	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)
Least deprived 80-100%	1 (ref)	1.38 (1.08–1.77)	1.94 (1.71–2.20)	1.16 (1.06–1.27)	1.43 (1.27–1.62)	1.89 (1.59–2.24)	1.12 (0.97–1.30)	1.13 (1.04–1.23)	1.25 (1.12–1.40)	1.91 (1.55–2.36)
Less deprived 60-80%	1.01 (0.98–1.05)	1.76 (1.51–2.05)	1.75 (1.60–1.92)	1.31 (1.21–1.42)	1.57 (1.42–1.73)	2.01 (1.80–2.24)	1.15 (1.01–1.31)	1.37 (1.27–1.47)	1.53 (1.40–1.67)	1.74 (1.49–2.02)
Less deprived 40-60%	1.03 (1.00–1.07)	1.68 (1.48–1.91)	1.89 (1.76–2.03)	1.24 (1.14–1.35)	1.40 (1.29–1.52)	1.74 (1.58–1.92)	1.33 (1.20–1.49)	1.36 (1.27–1.45)	1.59 (1.47–1.74)	1.76 (1.56–1.99)
More deprived 20-40%	1.06 (1.02–1.09)	1.68 (1.49–1.90)	1.94 (1.81–2.08)	1.29 (1.18–1.41)	1.45 (1.35–1.56)	1.85 (1.67–2.04)	1.13 (1.00–1.26)	1.30 (1.21–1.39)	1.50 (1.37–1.64)	1.81 (1.60–2.04)
Most deprived 20%	1.06 (1.03–1.10)	1.79 (1.55–2.07)	1.84 (1.71–1.98)	1.31 (1.18–1.46)	1.44 (1.34–1.55)	1.54 (1.34–1.78)	1.16 (1.04–1.30)	1.23 (1.13–1.33)	1.48 (1.34–1.64)	1.64 (1.41–1.90)

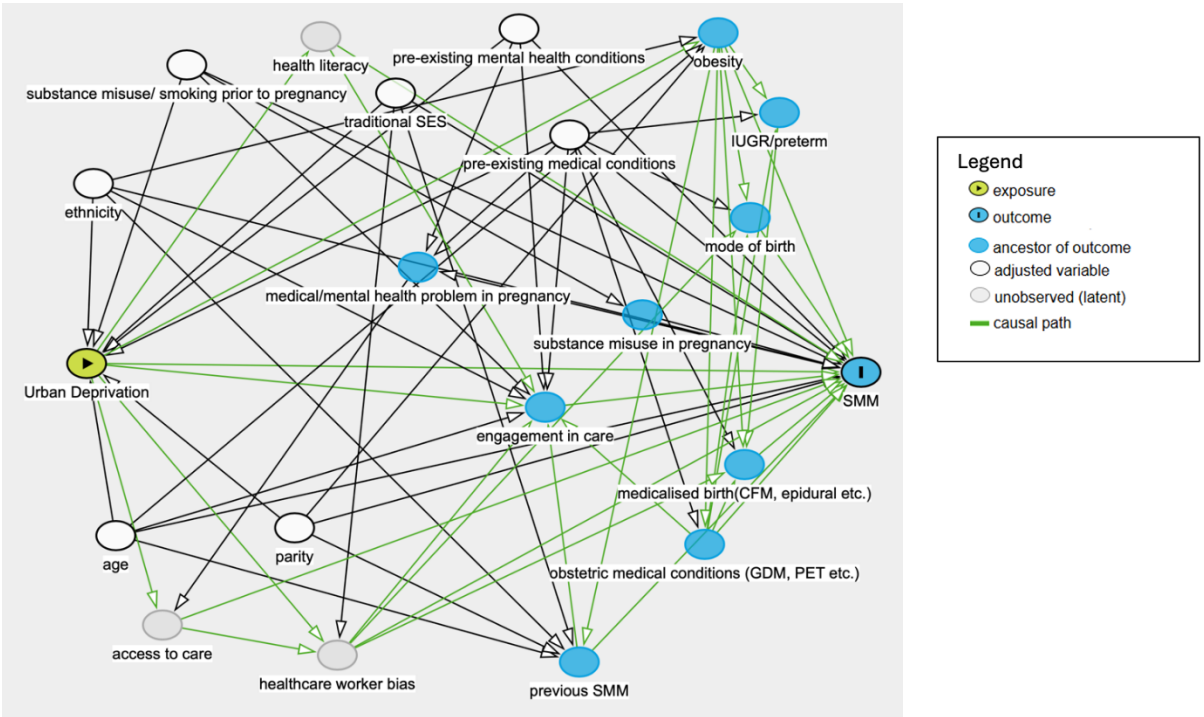
*Adjusted for age, year, parity, % not born in the UK and neighbourhood English language proficiency
Abbreviations: CI: Confidence Interval

Appendix Chapter 5

Appendix Figure 5.1. Direct Acyclic Graph (DAG) between Traditional Socioeconomic Status (SES) (income, employment and education) and SMM.



Appendix Figure 5.2. Direct Acyclic Graph (DAG) between Urban Deprivation (homelessness, household overcrowding, air pollution, road traffic accidents, access to services) and SMM.

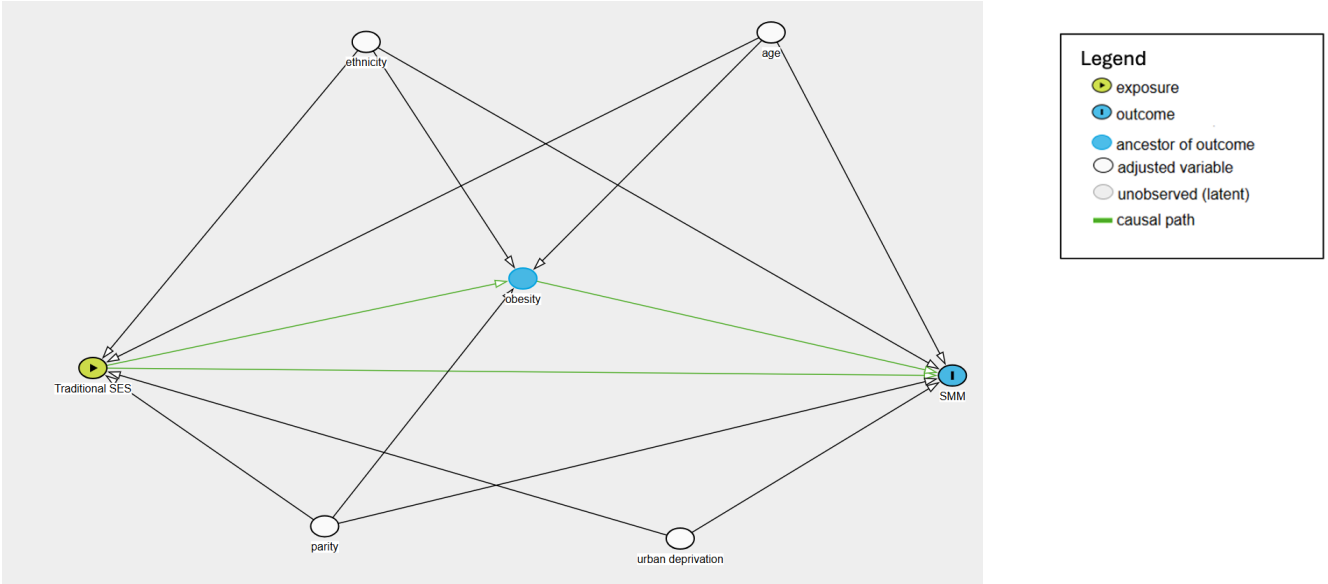


Appendix Table 5.1. Med4way decomposition.

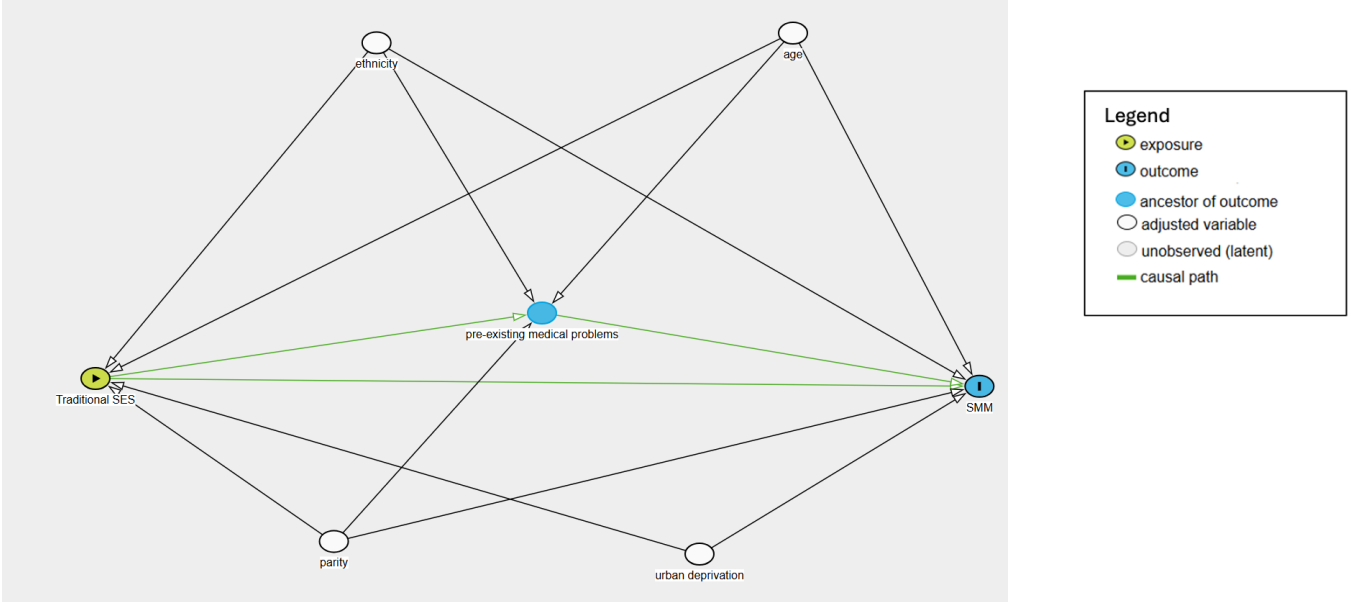
Effect	Counterfactual Definition[a]	Interpretation	Contextual definition
Total effect	$Y_a - Y_{a^*}$	Total effect of exposure A (changing from a* to a) on the outcome Y	Overall effect
Pure indirect effect or mediated main effect	$(Y_{a^*m} - Y_{a^*m^*})$ $(M_a - M_{a^*})$	Effect of the mediator (changing from m* to m) on outcome Y when exposure A is a, multiplied by the effect of exposure A (changing from a* to a) on the mediator M	Due to mediation only
Reference interaction	$(Y_{am} - Y_{am^*} - Y_{a^*m} + Y_{a^*m^*})$ (M_{a^*})	An additive interaction that operates only if the mediator is present ($M_{a^*} \neq 0$) when the exposure A is a	Due to interaction only
Mediated interaction	$(Y_{am} - Y_{am^*} - Y_{a^*m} + Y_{a^*m^*})$ $(M_a - M_{a^*})$	An additive interaction that operates only if the exposure A (changing from a* to a) has an effect on the mediator M ($M_a - M_{a^*} \neq 0$)	Due to mediation and interaction
Controlled direct effect	$(Y_{am^*} - Y_{a^*m^*})$	Effect of exposure A (changing from a* to a) on outcome Y intervening to fix the mediator M to m	Due neither to mediation nor interaction

Y is the outcome, A is the exposure of interest and M is the potential mediator. For example, Y_{am} is denoted as the value of the outcome Y that would have been observed when exposure A is set to level a, and mediator M is set to level m. M_a is denoted as the value of the mediator M that would have been observed when the exposure A is set to level a.

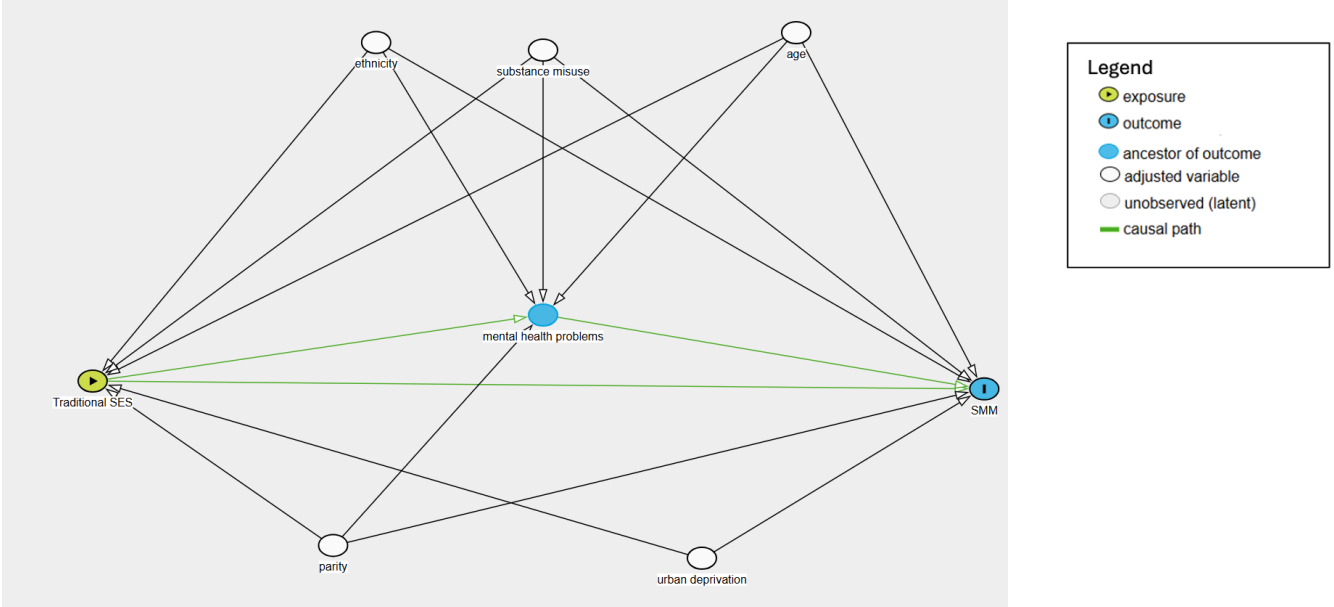
Appendix Figure 5.3. Direct Acyclic Graph (DAG) between Traditional SES and SMM mediated by obesity.



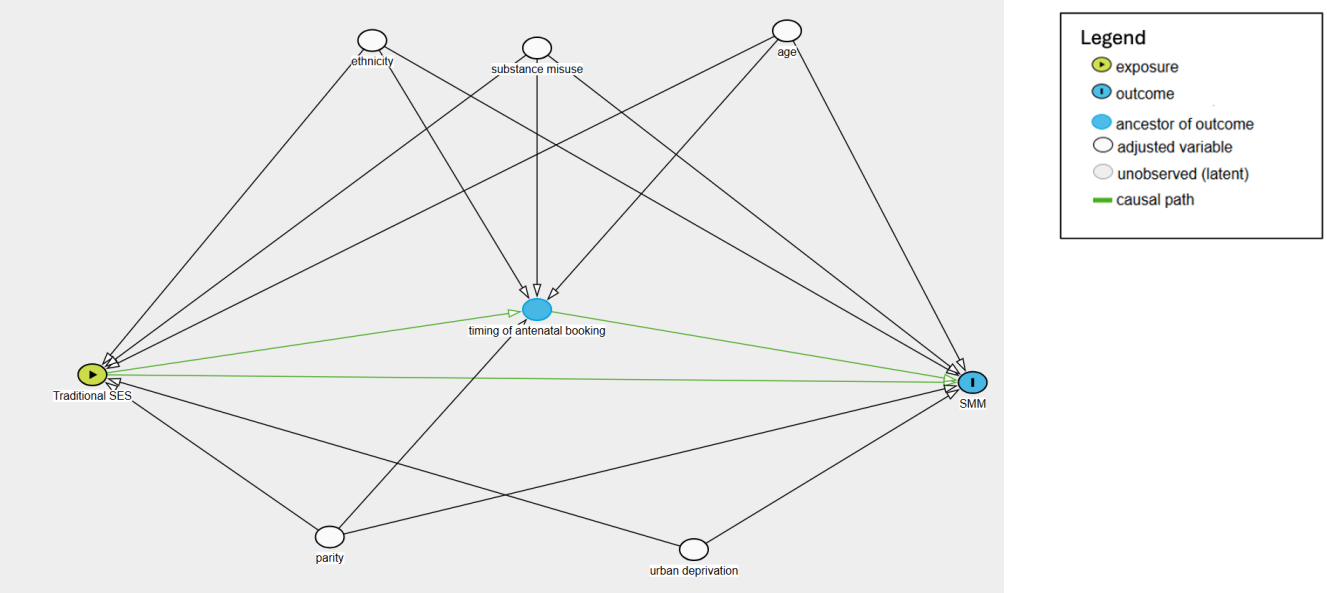
Appendix Figure 5.4. Direct Acyclic Graph (DAG) between Traditional SES and SMM mediated by pre-existing medical conditions (excluding hypertension, diabetes and ischaemic heart disease).



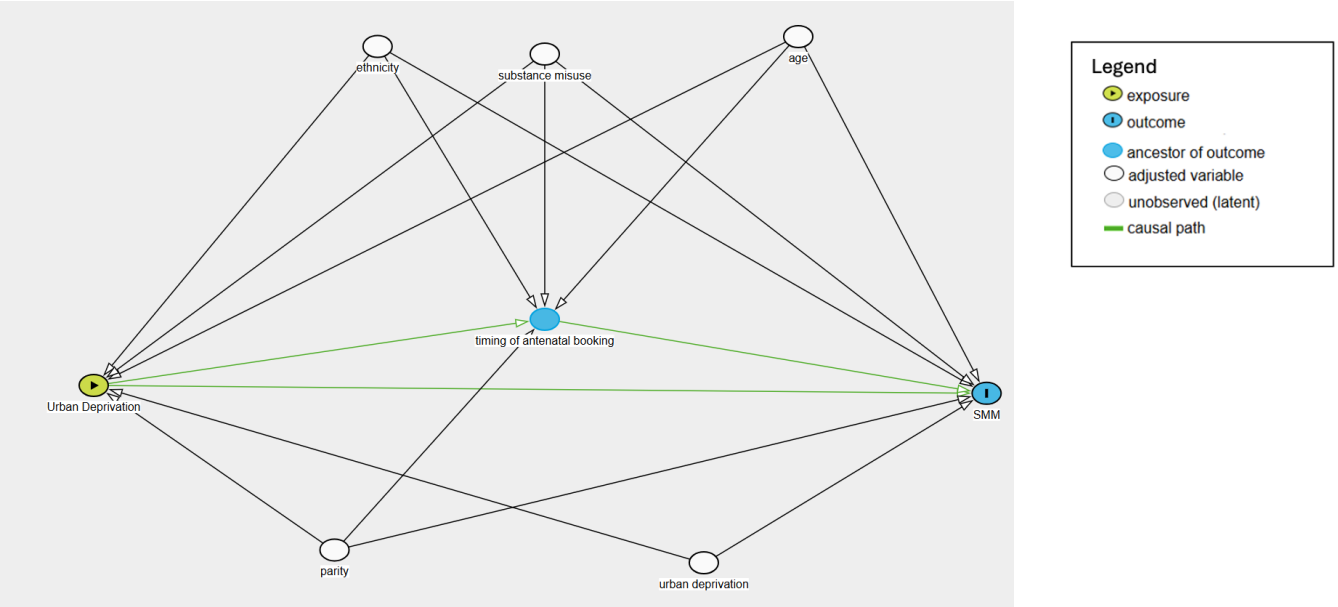
Appendix Figure 5.5. Direct Acyclic Graph (DAG) between Traditional SES and SMM mediated by mental health problems.



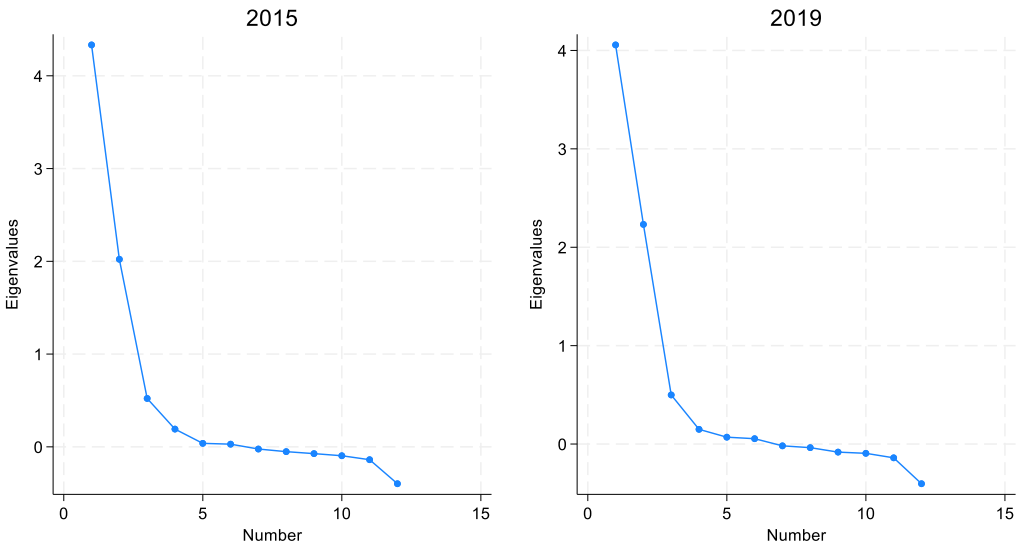
Appendix Figure 5.6. Direct Acyclic Graph (DAG) between Traditional SES and SMM mediated by timing of antenatal booking with midwife ≥12 weeks.



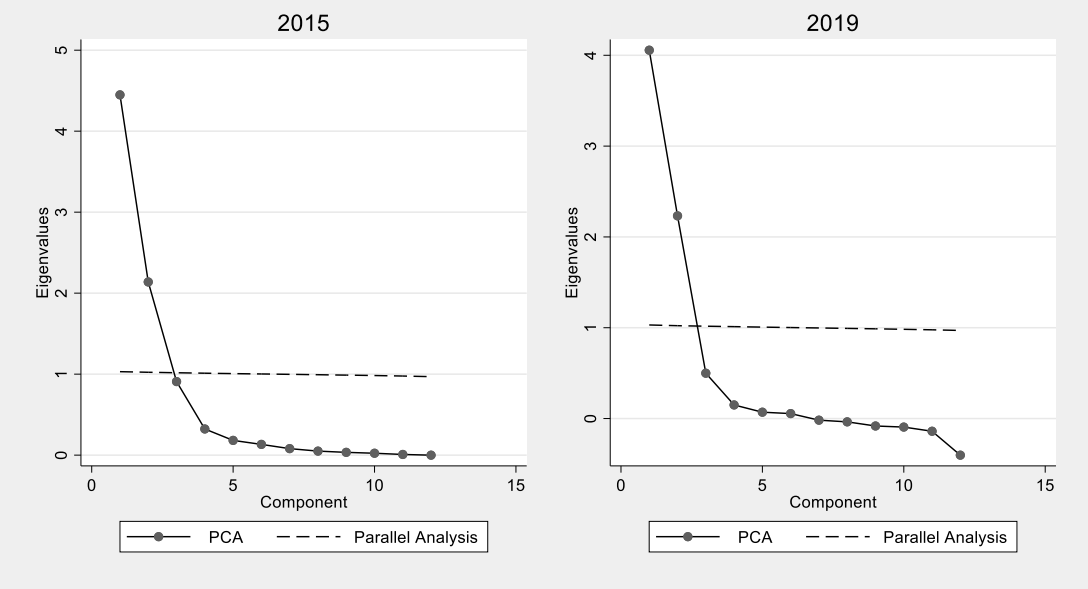
Appendix Figure 5.7. Direct Acyclic Graph (DAG) between Urban Deprivation and SMM mediated by timing of antenatal booking with midwife ≥12 weeks.



Appendix Figure 5.8. Scree plot of eigenvalues for 2015 and 2019.



Appendix Figure 5.9. Parallel analysis for 2015 and 2019.



Appendix Table 5.2. Factor loadings (pattern coefficients) with crime and housing affordability indices. Blue= saliently loaded on to Factor 1, Red= saliently loaded onto Factor 2.

	2015			**2019**		
Indices	Factor 1	Factor 2	Uniqueness	Factor1	Factor2	Uniqueness
Houses in poor condition	0.0385	0.0202	0.9981	0.0646	0.292	0.9106
Household overcrowding	0.3023	0.8417	0.2003	0.3136	0.8222	0.2256
Homelessness	-0.0673	0.6233	0.607	-0.021	0.5266	0.7223
English language proficiency	0.154	0.7821	0.3646	0.1658	0.7659	0.3858
Adult qualifications	0.7624	-0.2758	0.3428	0.7809	-0.2993	0.3006
Houses without heating	0.1926	0.3522	0.8389	0.1665	0.4101	0.8041
Road traffic accidents	0.0017	0.5142	0.7356	0.0847	0.6381	0.5856
Air quality	-0.0137	0.8162	0.3336	0.0619	0.7192	0.4789
Income	0.9085	0.3684	0.0389	0.8960	0.397	0.0396
Employment	0.9408	0.192	0.078	0.9236	0.246	0.0864
Children and young people	0.8080	-0.0108	0.347	0.8026	0.061	0.3521
Geographical barriers	-0.2733	-0.5618	0.6096	-0.2526	-0.6185	0.5536
Crime	0.5502	0.4810	0.466	0.4647	0.6427	0.371
Housing affordability	0.5175	0.5907	0.4021	0.5891	0.5740	0.3235

Appendix Table 5.3. Number (N) and proportion of total composite outcome (%) of each SMM diagnosis (ICD-10) and procedure (OPCS-4) stratified by Traditional SES.

	Traditional SES					
	Most deprived 20%	**More deprived 20-40%**	**Less deprived 40-60%**	**Less deprived 60-80%**	**Least deprived 80-100%**	**Total**
	N(%)	**N(%)**	**N(%)**	**N(%)**	**N(%)**	**N(%)**
Total SMM*	**17,643 (1.8)**	**17,662 (1.9)**	**15,578 (1.8)**	**12,629 (1.7)**	**7,897 (1.6)**	**71,418 (1.8)**
Interventional and surgical procedures to arrest major haemorrhage following birth	39 (0.2)	27 (0.2)	27 (0.2)	17 (0.1)	16 (0.2)	126 (0.2)
Management of vulval or vaginal haematoma	162 (0.9)	145 (0.8)	176 (1.1)	142 (1.1)	121 (1.6)	746 (1.1)
Rupture of aortic aneurysm or dissection of aorta	32 (0.2)	30 (0.2)	30 (0.2)	25 (0.2)	19 (0.2)	136 (0.2)
Interventional and surgical procedure to treat thrombosis	8 (0.0)	2 (0.0)	4 (0.0)	4 (0.0)	3 (0.0)	21 (0.0)
Management of acute coronary syndrome	4 (0.0)	0 (0.0)	2 (0.0)	0 (0.0)	0 (0.0)	6 (0.0)
Repair of aortic aneurysm or aortic dissection	1 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.0)
Interventional procedures to treat haemorrhagic or ischaemic stroke	1 (0.0)	0 (0.0)	1 (0.0)	0 (0.0)	1 (0.0)	3 (0.0)
Interventional and surgical procedures to manage major haemorrhage originating from the spleen	2 (0.0)	5 (0.0)	3 (0.0)	0 (0.0)	1 (0.0)	11 (0.0)
Acute abdomen	101 (0.6)	118 (0.7)	87 (0.6)	86 (0.7)	79 (1.0)	471 (0.7)
Acute renal failure	2,135 (12.2)	2,450 (14.0)	2,296 (14.9)	1,994 (16.0)	1,251 (16.1)	10,126 (14.4)
Acute psychosis	135 (0.8)	140 (0.8)	137 (0.9)	98 (0.8)	74 (1.0)	584 (0.8)
Acute cardiac event (cardiac infarction, cardiac failure, cardiomyopathy and cardiac arrest)	554 (3.2)	468 (2.7)	427 (2.8)	341 (2.7)	232 (3.0)	2,022 (2.9)
Cerebral oedema or coma	34 (0.2)	30 (0.2)	32 (0.2)	27 (0.2)	14 (0.2)	137 (0.2)
Disseminated intravascular coagulopathy	397 (2.3)	367 (2.1)	272 (1.8)	255 (2.0)	135 (1.7)	1,426 (2.0)
Diabetic ketoacidosis	16 (0.1)	15 (0.1)	18 (0.1)	8 (0.1)	6 (0.1)	63 (0.1)
Cerebrovascular accident	34 (0.2)	28 (0.2)	37 (0.2)	20 (0.2)	19 (0.2)	138 (0.2)
Major complications of anaesthesia	27 (0.2)	12 (0.1)	23 (0.1)	10 (0.1)	10 (0.1)	82 (0.1)
Embolic event (pulmonary embolism, amniotic fluid embolism, septic embolism and air embolism)	786 (4.5)	570 (3.3)	392 (2.5)	303 (2.4)	161 (2.1)	2,212 (3.1)
Shock	315 (1.8)	302 (1.7)	251 (1.6)	237 (1.9)	147 (1.9)	1,252 (1.8)
Sickle cell anaemia with crisis	45 (0.3)	85 (0.5)	54 (0.4)	21 (0.2)	7 (0.1)	212 (0.3)
Uterine rupture	764 (4.4)	728 (4.2)	659 (4.3)	528 (4.2)	330 (4.2)	3,009 (4.3)

	Traditional SES					
	Most deprived 20%	**More deprived 20-40%**	**Less deprived 40-60%**	**Less deprived 60-80%**	**Least deprived 80-100%**	**Total**
	N(%)	**N(%)**	**N(%)**	**N(%)**	**N(%)**	**N(%)**
Eclampsia	488 (2.8)	545 (3.1)	520 (3.4)	393 (3.2)	269 (3.5)	2,215 (3.1)
Respiratory support	337 (1.9)	240 (1.4)	218 (1.4)	173 (1.4)	102 (1.3)	1,070 (1.5)
Surgical evacuation of the uterus following birth	235 (1.3)	296 (1.7)	268 (1.7)	239 (1.9)	157 (2.0)	1,195 (1.7)
Dialysis	45 (0.3)	35 (0.2)	25 (0.2)	19 (0.2)	15 (0.2)	139 (0.2)
Hysterectomy	407 (2.3)	254 (1.5)	217 (1.4)	186 (1.5)	112 (1.4)	1,176 (1.7)
Acute pancreatitis	5 (0.0)	5 (0.0)	4 (0.0)	4 (0.0)	2 (0.0)	20 (0.0)
Interventional and surgical procedures to arrest major haemorrhage following birth	84 (0.5)	115 (0.7)	95 (0.6)	70 (0.6)	47 (0.6)	411 (0.6)
Management of caesarean wound dehiscence	90 (0.5)	69 (0.4)	60 (0.4)	59 (0.5)	38 (0.5)	316 (0.4)
Repair of damage to bladder or urinary tract	416 (2.4)	336 (1.9)	295 (1.9)	261 (2.1)	169 (2.2)	1,477 (2.1)
Sepsis	7,107 (40.8)	7,319 (41.9)	6,214 (40.4)	4,807 (38.5)	2,807 (36.1)	28,254 (40.0)
Repair of damage to the intestine and management of intestinal obstruction	88 (0.5)	97 (0.6)	76 (0.5)	56 (0.4)	32 (0.4)	349 (0.5)
Acute respiratory compromise	113 (0.6)	116 (0.7)	111 (0.7)	82 (0.7)	56 (0.7)	478 (0.7)
Management of intra-abdominal or pelvic collection	2,320 (13.3)	2,457 (14.1)	2,313 (15.0)	1,973 (15.8)	1,332 (17.1)	10,395 (14.7)
Status epilepticus	28 (0.2)	18 (0.1)	13 (0.1)	11 (0.1)	5 (0.1)	75 (0.1)
Status asthmaticus	77 (0.4)	55 (0.3)	37 (0.2)	27 (0.2)	13 (0.2)	209 (0.3)

*SMM total does not add up to total in columns as one maternity may have had more than one SMM diagnosis/ procedure

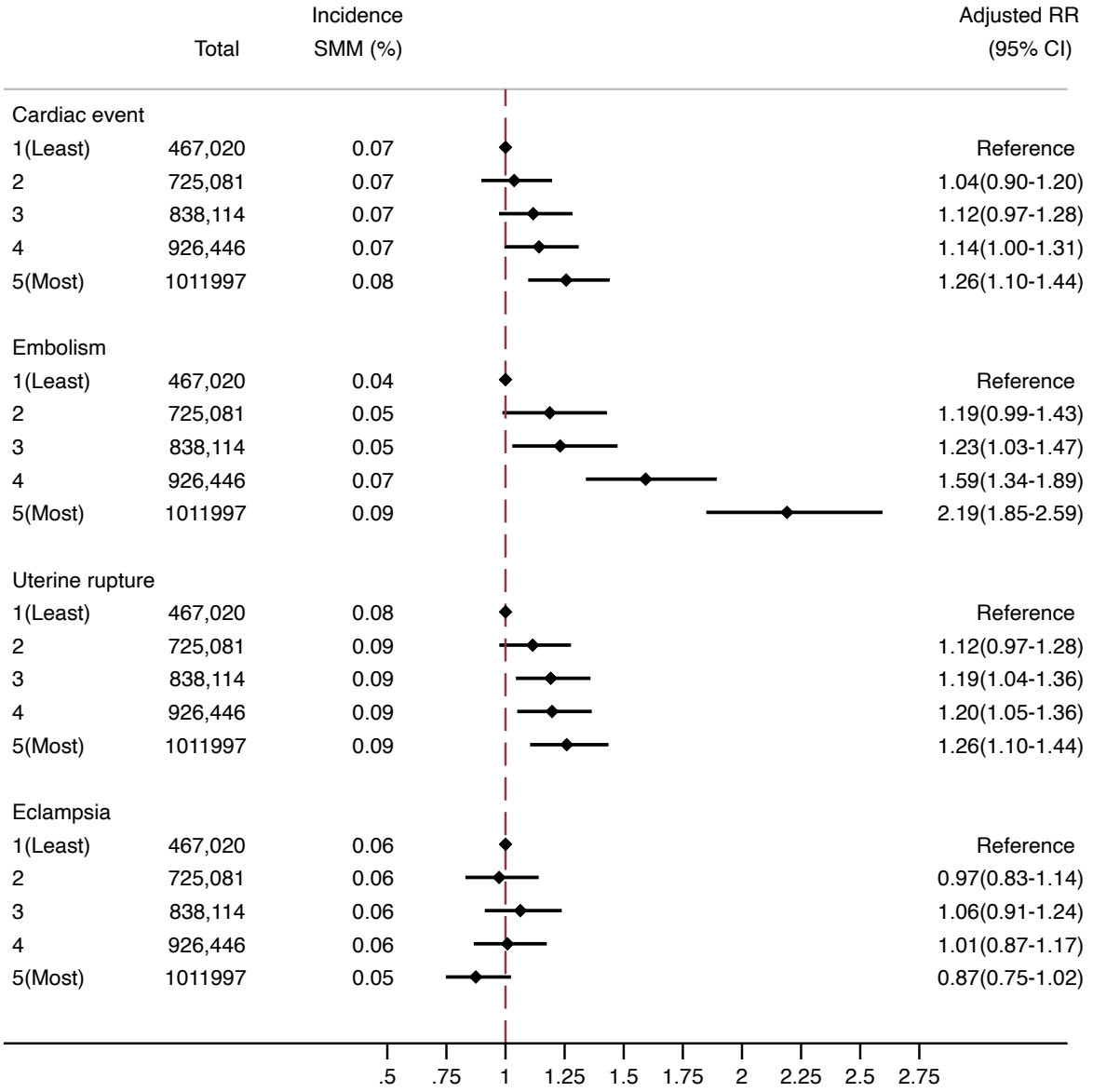
Appendix Table 5.4. Number (N) and proportion of total composite outcome (%) of each SMM diagnosis (ICD-10) and procedure (OPCS-4) stratified by Urban Deprivation.

	Urban Deprivation					
	Most deprived 20%	**More deprived 20-40%**	**Less deprived 40-60%**	**Less deprived 60-80%**	**Least deprived 80-100%**	**Total**
	N(%)	**N(%)**	**N(%)**	**N(%)**	**N(%)**	**N(%)**
SMM total*	**25,505 (2.2)**	**16,665 (1.7)**	**12,559 (1.6)**	**10,401 (1.5)**	**6,288 (1.5)**	**71,418 (1.8)**
Interventional and surgical procedures to arrest major haemorrhage following birth	25 (0.1)	44 (0.3)	25 (0.2)	23 (0.2)	9 (0.1)	126 (0.2)
Management of vulval or vaginal haematoma	224 (0.9)	144 (0.9)	156 (1.3)	134 (1.3)	88 (1.4)	746 (1.1)
Rupture of aortic aneurysm or dissection of aorta	34 (0.1)	22 (0.1)	31 (0.2)	28 (0.3)	21 (0.3)	136 (0.2)
Interventional and surgical procedure to treat thrombosis	1 (0.0)	3 (0.0)	4 (0.0)	7 (0.1)	6 (0.1)	21 (0.0)
Management of acute coronary syndrome	3 (0.0)	3 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	6 (0.0)
Repair of aortic aneurysm or aortic dissection	0 (0.0)	1 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.0)
Interventional procedures to treat haemorrhagic or ischaemic stroke	0 (0.0)	3 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	3 (0.0)
Interventional and surgical procedures to manage major haemorrhage originating from the spleen	5 (0.0)	1 (0.0)	4 (0.0)	1 (0.0)	0 (0.0)	11 (0.0)
Acute abdomen	162 (0.6)	113 (0.7)	68 (0.5)	81 (0.8)	47 (0.8)	471 (0.7)
Acute renal failure	3,411 (13.5)	2,251 (13.7)	1,865 (15.0)	1,626 (15.9)	973 (15.7)	10,126 (14.4)
Acute psychosis	249 (1.0)	123 (0.7)	100 (0.8)	86 (0.8)	26 (0.4)	584 (0.8)
Acute cardiac event (cardiac infarction, cardiac failure, cardiomyopathy and cardiac arrest)	564 (2.2)	511 (3.1)	418 (3.4)	335 (3.3)	194 (3.1)	2,022 (2.9)
Cerebral oedema or coma	44 (0.2)	34 (0.2)	24 (0.2)	23 (0.2)	12 (0.2)	137 (0.2)
Disseminated intravascular coagulopathy	439 (1.7)	341 (2.1)	284 (2.3)	229 (2.2)	133 (2.1)	1,426 (2.0)
Diabetic ketoacidosis	14 (0.1)	14 (0.1)	15 (0.1)	12 (0.1)	8 (0.1)	63 (0.1)
Cerebrovascular accident	56 (0.2)	38 (0.2)	19 (0.2)	13 (0.1)	12 (0.2)	138 (0.2)
Major complications of anaesthesia	29 (0.1)	22 (0.1)	17 (0.1)	9 (0.1)	5 (0.1)	82 (0.1)
Embolic event (pulmonary embolism, amniotic fluid embolism, septic embolism and air embolism	738 (2.9)	554 (3.4)	364 (2.9)	299 (2.9)	257 (4.1)	2,212 (3.1)
Shock	352 (1.4)	302 (1.8)	247 (2.0)	217 (2.1)	134 (2.2)	1,252 (1.8)
Sickle cell anaemia with crisis	145 (0.6)	46 (0.3)	14 (0.1)	5 (0.0)	2 (0.0)	212 (0.3)
Uterine rupture	933 (3.7)	667 (4.1)	550 (4.4)	470 (4.6)	389 (6.3)	3,009 (4.3)
Eclampsia	694 (2.8)	533 (3.2)	437 (3.5)	354 (3.5)	197 (3.2)	2,215 (3.1)

	Urban Deprivation					
	Most deprived 20%	**More deprived 20-40%**	**Less deprived 40-60%**	**Less deprived 60-80%**	**Least deprived 80-100%**	**Total**
	N(%)	**N(%)**	**N(%)**	**N(%)**	**N(%)**	**N(%)**
Respiratory support	321 (1.3)	270 (1.6)	200 (1.6)	178 (1.7)	101 (1.6)	1,070 (1.5)
Surgical evacuation of the uterus following birth	396 (1.6)	268 (1.6)	238 (1.9)	186 (1.8)	107 (1.7)	1,195 (1.7)
Dialysis	59 (0.2)	36 (0.2)	22 (0.2)	15 (0.1)	7 (0.1)	139 (0.2)
Hysterectomy	352 (1.4)	319 (1.9)	208 (1.7)	175 (1.7)	122 (2.0)	1,176 (1.7)
Acute pancreatitis	10 (0.0)	4 (0.0)	1 (0.0)	3 (0.0)	2 (0.0)	20 (0.0)
Interventional and surgical procedures to arrest major haemorrhage following birth	149 (0.6)	108 (0.7)	69 (0.6)	60 (0.6)	25 (0.4)	411 (0.6)
Management of caesarean wound dehiscence	99 (0.4)	80 (0.5)	54 (0.4)	48 (0.5)	35 (0.6)	316 (0.4)
Repair of damage to bladder or urinary tract	418 (1.7)	342 (2.1)	287 (2.3)	247 (2.4)	183 (3.0)	1,477 (2.1)
Sepsis	11,530 (45.7)	6,554 (39.8)	4,537 (36.6)	3,615 (35.2)	2,018 (32.5)	28,254 (40.0)
Repair of damage to the intestine and management of intestinal obstruction	135 (0.5)	81 (0.5)	61 (0.5)	51 (0.5)	21 (0.3)	349 (0.5)
Acute respiratory compromise	205 (0.8)	107 (0.7)	81 (0.7)	54 (0.5)	31 (0.5)	478 (0.7)
Management of intra-abdominal or pelvic collection	3,344 (13.3)	2,435 (14.8)	1,974 (15.9)	1,643 (16.0)	999 (16.1)	10,395 (14.7)
Status epilepticus	24 (0.1)	29 (0.2)	6 (0.0)	10 (0.1)	6 (0.1)	75 (0.1)
Status asthmaticus	71 (0.3)	53 (0.3)	33 (0.3)	20 (0.2)	32 (0.5)	209 (0.3)

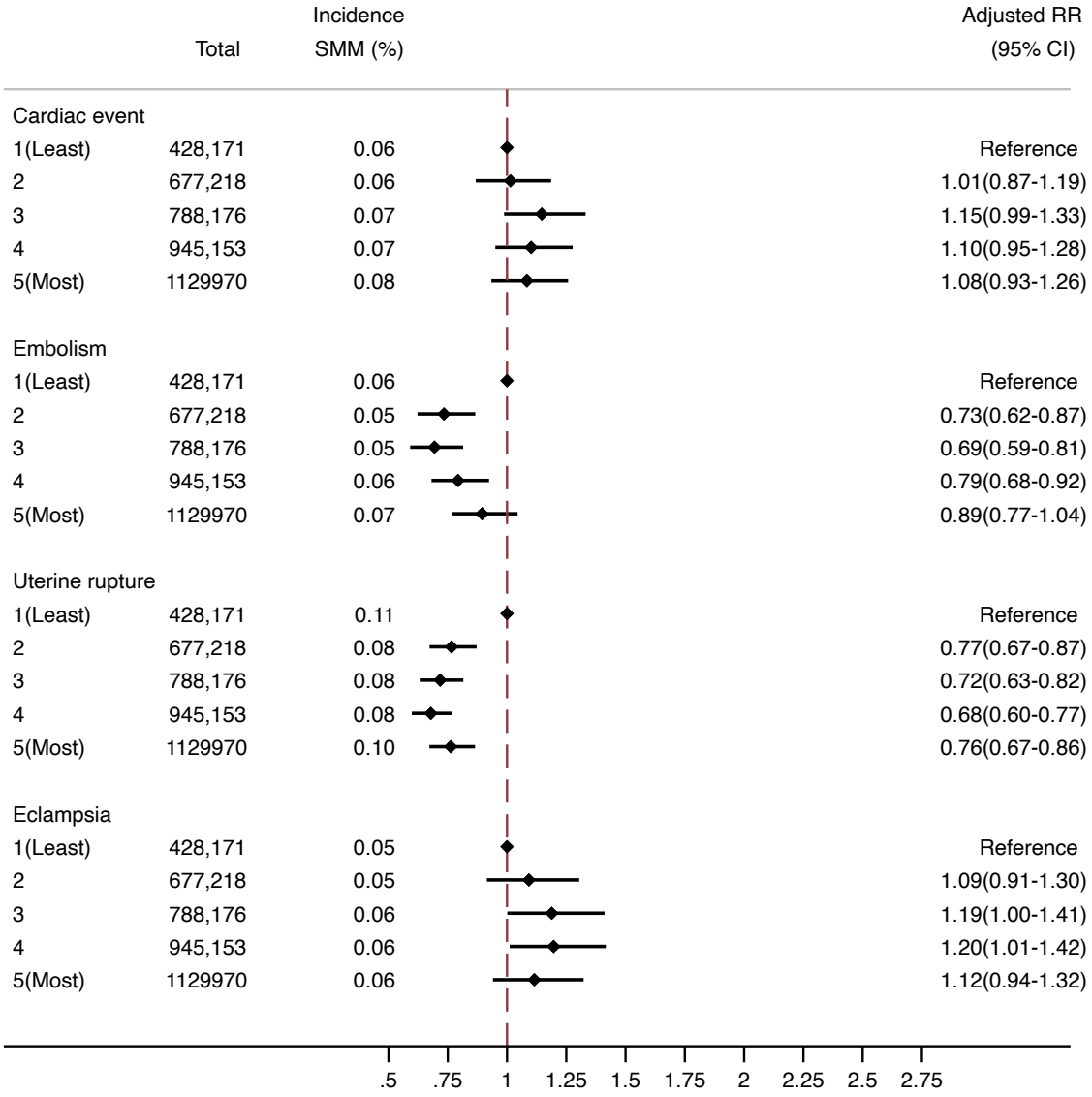
*SMM total does not add up to total in columns as one maternity may have had more than one SMM diagnosis/ procedure

Appendix Figure 5.10. Adjusted risk ratios* (and their 95% confidence intervals) of the most common of 'all other SMM conditions' (acute cardiac event, embolism, uterine rupture and eclampsia) in the Traditional SES quintiles compared to the least deprived quintile.



* *Adjusted for age, year, parity, ethnicity and Traditional SES*

Appendix Figure 5.11. Adjusted risk ratios* (and their 95% confidence intervals) of the most common of 'all other SMM conditions' (acute cardiac event, embolism, uterine rupture and eclampsia) in the Urban Deprivation quintiles compared to the least deprived quintile.



* *Adjusted for age, year, parity, ethnicity and Urban Deprivation*

Appendix Table 5.5. Adjusted risk ratios* (and their 95% confidence intervals) of SMM in the **Traditional SES** and **Urban Deprivation** quintiles compared to the White women living in least deprived quintile stratified by ethnicity.

	White	**Black or Black British - Caribbean**	**Black or Black British - African**	**Asian or Asian British - Indian**	**Asian or Asian British - Pakistani**	**Asian or Asian British - Bangladeshi**	**Mixed**	**Other**	**Other Asian**	**Other Black**
	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)
Traditional SES										
Least deprived 80-100%	1 (ref)	1.88 (1.65–2.14)	1.88 (1.63–2.17)	1.30 (1.18–1.44)	1.26 (1.06–1.49)	2.13 (1.68–2.69)	1.07 (0.90–1.26)	1.28 (1.17–1.40)	1.39 (1.24–1.57)	1.87 (1.46–2.39)
Less deprived 60-80%	1.07 (1.04–1.11)	1.51 (1.24–1.84)	1.92 (1.72–2.13)	1.17 (1.07–1.29)	1.57 (1.40–1.76)	2.00 (1.70–2.35)	1.26 (1.11–1.43)	1.28 (1.18–1.39)	1.46 (1.32–1.61)	1.67 (1.39–2.01)
Less deprived 40-60%	1.09 (1.05–1.13)	1.82 (1.59–2.08)	1.91 (1.76–2.06)	1.35 (1.25–1.45)	1.66 (1.52–1.80)	1.77 (1.58–1.98)	1.24 (1.11–1.39)	1.45 (1.35–1.55)	1.66 (1.53–1.80)	2.01 (1.78–2.28)
More deprived 20-40%	1.14 (1.10–1.18)	1.68 (1.50–1.88)	1.93 (1.81–2.06)	1.42 (1.31–1.55)	1.52 (1.42–1.64)	1.98 (1.82–2.15)	1.43 (1.30–1.58)	1.40 (1.31–1.50)	1.65 (1.52–1.80)	1.82 (1.64–2.03)
Most deprived 20%	1.17 (1.13–1.21)	1.95 (1.50–2.53)	2.09 (1.95–2.23)	1.43 (1.29–1.58)	1.55 (1.46–1.66)	1.88 (1.69–2.10)	1.24 (1.11–1.38)	1.31 (1.22–1.42)	1.61 (1.45–1.77)	1.84 (1.61–2.11)
Urban Deprivation										
Least deprived 80-100%	1 (ref)	1.18 (0.53–2.63)	2.11 (1.54–2.88)	1.27 (0.93–1.73)	2.07 (1.39–3.10)	1.46 (0.70–3.08)	1.18 (0.90–1.55)	1.27 (1.03–1.56)	1.84 (1.42–2.38)	1.74 (0.99–3.07)
Less deprived 60-80%	1.01 (0.98–1.05)	2.30 (1.65–3.21)	1.73 (1.42–2.10)	1.23 (1.04–1.47)	1.27 (0.98–1.65)	2.22 (1.57–3.12)	1.12 (0.93–1.35)	1.14 (0.98–1.31)	1.60 (1.34–1.91)	1.30 (0.87–1.94)
Less deprived 40-60%	1.03 (0.99–1.06)	1.41 (1.07–1.88)	1.70 (1.48–1.95)	1.20 (1.06–1.36)	1.48 (1.29–1.70)	1.57 (1.21–2.03)	0.94 (0.80–1.10)	1.27 (1.14–1.41)	1.52 (1.33–1.74)	1.74 (1.35–2.23)
More deprived 20-40%	1.07 (1.04–1.11)	1.67 (1.44–1.94)	1.90 (1.76–2.05)	1.27 (1.17–1.37)	1.48 (1.37–1.59)	1.61 (1.40–1.85)	1.28 (1.16–1.42)	1.30 (1.21–1.40)	1.49 (1.36–1.63)	1.73 (1.49–2.00)
Most deprived 20%	1.20 (1.16–1.24)	1.89 (1.74–2.04)	2.12 (2.01–2.22)	1.49 (1.41–1.57)	1.65 (1.57–1.74)	2.10 (1.98–2.24)	1.43 (1.32–1.54)	1.49 (1.42–1.57)	1.70 (1.61–1.80)	2.03 (1.88–2.20)

*Adjusted for age, year and parity
Abbreviations: CI: Confidence Intervals

Appendix Table 5.6. The total number (N) and incidence of SMM (%) in the **Traditional SES** and **Urban Deprivation** domain quintiles stratified by ethnicity. Q1 is least deprived and Q5, the most deprived quintile.

	Traditional SES		Urban Deprivation	
	Total (N)	Incidence of SMM (%)	Total (N)	Incidence of SMM (%)
White				
Q1 (least deprived)	372,178	1.47	387,955	1.48
Q2	568,715	1.57	615,396	1.49
Q3	610,035	1.57	688,776	1.50
Q4	641,592	1.60	715,379	1.56
Q5 (most deprived)	747,169	1.55	532,183	1.80
Black or Black British Caribbean				
Q1	1,864	3.11	349	1.72
Q2	4,335	2.40	1,010	3.47
Q3	8,441	2.80	2,332	2.10
Q4	13,116	2.55	7,523	2.45
Q5	9,290	2.65	25,832	2.73
Black or Black British African				
Q1	6,562	2.97	1,287	3.11
Q2	12,293	3.03	3,867	2.61
Q3	24,931	2.97	8,616	2.56
Q4	41,548	2.97	26,699	2.89
Q5	34,157	3.09	79,022	3.12
Asian or Asian British Indian				
Q1	19,823	2.01	2,197	1.87
Q2	27,836	1.87	7,029	1.85
Q3	31,329	2.14	14,937	1.80
Q4	37,193	2.22	33,600	1.94
Q5	19,310	2.20	77,728	2.24
Asian or Asian British Pakistani				
Q1	7,474	1.85	761	3.15
Q2	14,236	2.37	3,121	1.89
Q3	27,064	2.44	10,196	2.17
Q4	42,367	2.24	40,725	2.21
Q5	58,739	2.28	95,077	2.33
Asian or Asian British Bangladeshi				
Q1	2,147	3.31	322	3.07
Q2	4,902	3.18	1,018	2.33
Q3	12,764	2.80	2,485	2.33
Q4	22,559	3.05	9,016	2.33
Q5	14,274	2.66	43,805	3.07

	Traditional SES		Urban Deprivation	
	Total (N)	Incidence of SMM (%)	Total (N)	Incidence of SMM (%)
Mixed				
Q1	8,201	1.76	2,887	1.84
Q2	11,928	2.05	6,502	1.77
Q3	15,524	2.00	10,698	1.46
Q4	19,314	2.26	20,569	1.99
Q5	19,375	1.82	33,686	2.24
Other				
Q1	26,958	2.09	4,514	1.97
Q2	32,621	2.11	11,099	1.77
Q3	42,790	2.34	19,144	1.97
Q4	47,835	2.22	41,655	2.03
Q5	40,411	1.97	114,203	2.28
Other Asian				
Q1	12,683	2.26	2,078	2.79
Q2	18,958	2.35	4,985	2.51
Q3	25,493	2.68	9,363	2.38
Q4	24,949	2.64	22,280	2.35
Q5	17,415	2.49	60,792	2.60
Other Black				
Q1	2,150	3.02	458	2.62
Q2	4,377	2.65	1,167	2.06
Q3	8,695	3.07	2,343	2.69
Q4	13,298	2.76	6,907	2.66
Q5	7,938	2.75	25,583	2.93

Appendix Table 5.7. Four-way decomposition of the association between **Traditional SES** and SMM. CDE is for the mediator=1 and the reference interaction is for mediator=0. Mediators are obesity, pre-existing medical conditions, mental health problems and antenatal booking ≥ 12 weeks.

	Obesity	**Pre-existing medical conditions**	**Mental health problems**	**Antenatal care booking > 12 weeks**
Four-way decomposition	**Coefficient (95% CI)**	**Coefficient (95% CI)**	**Coefficient (95% CI)**	**Coefficient (95% CI)**
Total Excess Relative Risk	0.19 (0.16-0.23)	0.20 (0.17-0.24)	0.20 (0.17-0.24)	0.18 (0.13-0.23)
Controlled Direct Effect	0.19 (0.10-0.28)	0.31 (0.23-0.39)	0.30 (0.20-0.39)	0.28 (0.18-0.37)
Reference Interaction	-0.03 (-0.12-0.05)	-0.12 (-0.19 to -0.05)	-0.10 (-0.19 to -0.01)	-0.10 (-0.19 to -0.02)
Mediated Interaction	0.00 (-0.01-0.01)	0.00 (0.00-0.01)	0.00 (0.00-0.00)	0.00 (0.00-0.00)
Pure Indirect Effect	0.04 (0.03-0.04)	0.01 (0.01-0.01)	0.00 (0.00-0.00)	0.00 (0.00-0.00)
Total Excess Relative Risk	1.19 (1.16-1.23)	1.20 (1.17-1.24)	1.20 (1.17-1.24)	1.18 (1.13-1.23)
Proportions four-way decomposition	**Proportion (%) (95% CI)**	**Proportion (%) (95% CI)**	**Proportion (%) (95% CI)**	**Proportion (%) (95% CI)**
Controlled Direct Effect	97.3 (53.7-140.9)	151.4 (117.7-185.2)	145.9 (99.7-192.1)	157.3 (104.1-210.5)
Reference Interaction	*17.1 (-62.1-27.9)	*59.3 (-93.8 to -24.8)	*48.5 (-95.1-1.9)	*59.0 (-112.7 to -5.3)
Mediated Interaction	1.8 (-2.9-6.5)	2.4 (1.0-3.8)	0.8 (0.0-1.6)	1.0 (0.1-1.8)
Pure Indirect Effect	18.0 (13.1-22.9)	5.4 (4.0-6.8)	1.8 (1.1-2.4)	0.8 (0.1-1.4)
Overall Proportion Mediated	19.8 (15.7-23.9)	7.8 (6.4-9.3)	2.6 (2.0-3.2)	1.7 (1.0-2.4)
Overall Proportion Attributable to Interaction	*15.3 (-55.6-25.0)	*56.9 (-90.0to -23.8)	*47.7 (-93.5-1.9)	*58.0 (-110.8to -5.2)

**These are negative numbers*

Appendix Table 5.8. Four-way decomposition of the association between **Traditional SES** and SMM. CDE is for mediator=1 and the reference interaction is for mediator=0. The mediator is pre-existing medical conditions including conditions closely obesity: diabetes ischaemic heart disease and hypertension.

Four-way Decomposition	**Coefficient (95% CI)**
Total excess relative risk	51.8 (11.8-91.8)
Excess relative risk due to controlled direct effect	47.8 (6.3-89.2)
Excess relative risk due to reference interaction	*10.6 (-19.8 to-1.4)
Excess relative risk due to mediated interaction	11.0 (2.7-19.3)
Excess relative risk due to pure indirect effect	0.4 (-3.4-4.2)
Total effect risk ratio	37.2 (4.9-69.5)
Proportions Four-way Decomposition	**Proportion (%) (95% CI)**
Proportion controlled direct effect	177.0 (144.3-209.7)
Proportion reference interaction	*90.5 (-124.5 to -56.6)
Proportion mediated interaction	4.9 (3.0-6.7)
Proportion pure indirect effect	8.6 (6.7-10.6)
Overall proportion mediated	13.5 (11.2-15.8)
Overall proportion attributable to interaction	*5.7 (-117.8 to -53.5)

**These are negative numbers*

Appendix Table 5.9. Four-way decomposition of the association between **Urban Deprivation** and SMM. CDE is for the mediator=1 and the reference interaction is for mediator=0. The mediator is antenatal booking ≥ 12 weeks.

Four-way Decomposition	**Coefficient (95% CI)**
Total excess relative risk	0.24 (0.19-0.29)
Excess relative risk due to controlled direct effect	0.12 (0.01-0.23)
Excess relative risk due to reference interaction	0.11 (0.02-0.21)
Excess relative risk due to mediated interaction	-0.03 (-0.05-0.00)
Excess relative risk due to pure indirect effect	0.03 (0.01-0.04)
Total effect risk ratio	1.24 (1.19-1.29)
Proportions Four-way Decomposition	**Proportion (%) (95% CI)**
Proportion controlled direct effect	51.8 (11.8-91.8)
Proportion reference interaction	47.8 (6.3-89.2)
Proportion mediated interaction	*10.6 (-19.8 to -1.4)
Proportion pure indirect effect	11.0 (2.7-19.3)
Overall proportion mediated	0.4 (-3.4-4.2)
Overall proportion attributable to interaction	37.2 (4.9-69.5)

**These are negative numbers*

Appendix Table 5.10. Adjusted risk ratios* (and their 95% confidence intervals) of SMM (excluding sepsis) and SMM (plus length of hospital stay > 3 days) and SMM with ICD-10 codes only included in each **Traditional SES** and **Urban Deprivation** quintile compared to the least deprived quintile.

	SMM excluding sepsis		**SMM (with sepsis plus hospital stay > 3 days)**		**SMM with ICD-10 codes only**	
	Traditional SES	**Urban Deprivation**	**Traditional SES**	**Urban Deprivation**	**Traditional SES**	**Urban Deprivation**
	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)
Most deprived 20%	1.14 (1.10-1.18)	1.03 (0.99-1.07)	1.15 (1.12-1.19)	1.19 (1.15-1.23)	1.18 (1.14-1.22)	1.27 (1.23-1.32)
More deprived 20-40%	1.11 (1.07-1.15)	0.98 (0.95-1.02)	1.13 (1.10-1.16)	1.07 (1.03-1.10)	1.16 (1.12-1.20)	1.08 (1.04-1.12)
Less deprived 40-60%	1.08 (1.04-1.12)	0.97 (0.94-1.01)	1.10 (1.06-1.13)	1.02 (0.98-1.05)	1.12 (1.08-1.16)	1.02 (0.98-1.06)
Less deprived 60-80%	1.05 (1.01-1.09)	0.97 (0.93-1.01)	1.06 (1.03-1.09)	1.00 (0.97-1.04)	1.08 (1.04-1.12)	1.00 (0.97-1.04)
Least deprived 80-100%	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)
ICC	0.027 (0.024-0.029)	0.027 (0.024-0.029)	0.027 (0.025-0.029)	0.027 (0.025-0.029)	0.027 (0.025-0.029)	0.027 (0.025-0.029)

*Adjusted for age, year and parity
**Abbreviations: CI: Confidence Intervals , ICC: Intra-class Correlation Coefficient

Appendix Table 5.11. Adjusted risk ratios* (and their 95% confidence intervals) of SMM (excluding sepsis) in the **Traditional SES** and **Urban Deprivation** quintiles compared to the White women living in least deprived quintile stratified by ethnicity.

	White	**Black or Black British - Caribbean**	**Black or Black British - African**	**Asian or Asian British - Indian**	**Asian or Asian British - Pakistani**	**Asian or Asian British - Bangladeshi**	**Mixed**	**Other**	**Other Asian**	**Other Black**
	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)
Traditional SES										
Least deprived 80-100%	1(ref)	2.00 (1.45–2.75)	1.87 (1.57–2.24)	1.12 (0.98–1.28)	1.01 (0.80–1.27)	1.73 (1.24–2.40)	1.02 (0.83–1.26)	1.14 (1.02–1.28)	1.24 (1.06–1.45)	1.72 (1.25–2.37)
Less deprived 60-80%	1.06 (1.02–1.11)	1.62 (1.28–2.06)	1.96 (1.72–2.24)	1.01 (0.89–1.14)	1.37 (1.18–1.59)	1.59 (1.27–2.00)	1.26 (1.07–1.48)	1.02 (0.91–1.14)	1.28 (1.12–1.45)	1.80 (1.44–2.25)
Less deprived 40-60%	1.07 (1.03–1.12)	2.06 (1.76–2.41)	2.06 (1.87–2.26)	1.12 (1.01–1.24)	1.47 (1.32–1.64)	1.33 (1.13–1.56)	1.21 (1.04–1.40)	1.28 (1.16–1.40)	1.36 (1.21–1.52)	1.87 (1.59–2.19)
More deprived 20-40%	1.12 (1.07–1.17)	1.85 (1.62–2.12)	2.09 (1.93–2.26)	1.14 (1.02–1.27)	1.23 (1.11–1.35)	1.52 (1.35–1.71)	1.25 (1.09–1.42)	1.25 (1.15–1.37)	1.35 (1.21–1.52)	1.88 (1.64–2.15)
Most deprived 20%	1.16 (1.11–1.21)	1.84 (1.57–2.17)	2.07 (1.90–2.25)	1.25 (1.10–1.43)	1.29 (1.19–1.41)	1.54 (1.33–1.79)	1.21 (1.05–1.39)	1.15 (1.04–1.27)	1.47 (1.30–1.68)	2.10 (1.79–2.47)
Urban Deprivation										
Least deprived 80-100%	1(ref)	0.82 (0.26–2.54)	1.89 (1.29–2.78)	0.94 (0.62–1.43)	1.60 (0.93–2.77)	1.50 (0.62–3.60)	1.20 (0.87–1.66)	0.92 (0.69–1.24)	1.37 (0.96–1.95)	1.64 (0.82–3.28)
Less deprived 60-80%	0.97 (0.93–1.01)	2.03 (1.33–3.09)	1.51 (1.18–1.93)	1.07 (0.86–1.34)	1.07 (0.77–1.50)	1.53 (0.94–2.51)	1.08 (0.86–1.35)	1.04 (0.87–1.24)	1.23 (0.97–1.56)	1.23 (0.75–2.01)
Less deprived 40-60%	0.98 (0.94–1.02)	1.10 (0.75–1.60)	1.64 (1.39–1.92)	1.04 (0.89–1.22)	1.18 (0.99–1.41)	1.20 (0.84–1.70)	0.91 (0.75–1.10)	1.04 (0.90–1.19)	1.23 (1.03–1.47)	1.59 (1.17–2.17)
More deprived 20-40%	0.99 (0.95–1.03)	1.50 (1.25–1.81)	1.81 (1.65–1.98)	1.01 (0.91–1.12)	1.13 (1.03–1.24)	1.12 (0.92–1.36)	1.12 (0.98–1.27)	1.02 (0.93–1.13)	1.29 (1.15–1.45)	1.71 (1.43–2.04)
Most deprived 20%	1.01 (0.97–1.05)	1.84 (1.68–2.03)	1.94 (1.83–2.06)	1.05 (0.97–1.13)	1.20 (1.12–1.29)	1.43 (1.31–1.56)	1.15 (1.04–1.27)	1.13 (1.07–1.21)	1.22 (1.13–1.32)	1.80 (1.64–1.98)

*Adjusted for age, year and parity

**Abbreviations: CI: Confidence Intervals , ICC: Intra-class Correlation Coefficient

Appendix Table 5.12. The total number (N) and incidence of SMM (without sepsis) (%) in the **Traditional SES** and **Urban Deprivation** quintiles stratified by ethnicity. Q1 is least deprived and Q5 the most deprived quintile.

	Traditional SES		Urban Deprivation	
	Total (N)	Incidence of SMM (%)	Total (N)	Incidence of SMM (%)
White				
Q1 (least deprived)	372,178	0.99	387,955	1.02
Q2	568,715	1.02	615,396	0.99
Q3	610,035	1.01	688,776	0.99
Q4	641,592	1.01	715,379	0.99
Q5 (most deprived)	747,169	0.99	532,183	1.06
Black or Black British Caribbean				
Q1	1,864	2.04	349	0.86
Q2	4,335	1.61	1,010	2.18
Q3	8,441	1.98	2,332	1.16
Q4	13,116	1.75	7,523	1.57
Q5	9,290	1.66	25,832	1.89
Black or Black British African				
Q1	6,562	1.92	1,287	2.02
Q2	12,293	1.99	3,867	1.66
Q3	24,931	2.03	8,616	1.80
Q4	41,548	2.03	26,699	1.99
Q5	34,157	1.98	79,022	2.05
Asian or Asian British Indian				
Q1	19,823	1.14	2,197	1.00
Q2	27,836	1.03	7,029	1.15
Q3	31,329	1.11	14,937	1.12
Q4	37,193	1.11	33,600	1.10
Q5	19,310	1.22	77,728	1.11
Asian or Asian British Pakistani				
Q1	7,474	0.96	761	1.71
Q2	14,236	1.31	3,121	1.12
Q3	27,064	1.36	10,196	1.22
Q4	42,367	1.13	40,725	1.18
Q5	58,739	1.19	95,077	1.21
Asian or Asian British Bangladeshi				
Q1	2,147	1.68	322	1.55
Q2	4,902	1.55	1,018	1.57
Q3	12,764	1.26	2,485	1.25
Q4	22,559	1.41	9,016	1.15
Q5	14,274	1.38	43,805	1.44

	Traditional SES		Urban Deprivation	
	Total (N)	Incidence of SMM (%)	Total (N)	Incidence of SMM (%)
Mixed				
Q1	8,201	1.07	2,887	1.28
Q2	11,928	1.29	6,502	1.17
Q3	15,524	1.20	10,698	0.96
Q4	19,314	1.20	20,569	1.18
Q5	19,375	1.09	33,686	1.23
Other				
Q1	26,958	1.19	4,514	1.02
Q2	32,621	1.05	11,099	1.14
Q3	42,790	1.28	19,144	1.13
Q4	47,835	1.22	41,655	1.11
Q5	40,411	1.08	114,203	1.21
Other Asian				
Q1	12,683	1.29	2,078	1.49
Q2	18,958	1.30	4,985	1.36
Q3	25,493	1.36	9,363	1.37
Q4	24,949	1.33	22,280	1.43
Q5	17,415	1.44	60,792	1.31
Other Black				
Q1	2,150	1.77	458	1.75
Q2	4,377	1.80	1,167	1.37
Q3	8,695	1.79	2,343	1.75
Q4	13,298	1.78	6,907	1.85
Q5	7,938	1.98	25,583	1.85

Appendix Table 5.13. Adjusted risk ratios* (and their 95% confidence intervals) of SMM (only including sepsis if length of admission > 3 days) in the **Traditional SES** and **Urban Deprivation** quintiles compared to the White women living in least deprived quintile stratified by ethnicity.

	White	**Black or Black British - Caribbean**	**Black or Black British - African**	**Asian or Asian British - Indian**	**Asian or Asian British - Pakistani**	**Asian or Asian British - Bangladeshi**	**Mixed**	**Other**	**Other Asian**	**Other Black**
	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)
Traditional SES										
Least deprived 80-100%	1(ref)	2.01 (1.55–2.61)	1.95 (1.68–2.25)	1.30 (1.17–1.45)	1.26 (1.06–1.49)	2.06 (1.61–2.63)	1.06 (0.90–1.26)	1.27 (1.16–1.39)	1.42 (1.26–1.61)	1.81 (1.41–2.34)
Less deprived 60-80%	1.07 (1.03–1.11)	1.53 (1.25–1.87)	1.92 (1.73–2.14)	1.19 (1.09–1.31)	1.59 (1.42–1.79)	2.04 (1.73–2.40)	1.21 (1.06–1.38)	1.30 (1.20–1.41)	1.48 (1.34–1.63)	1.71 (1.42–2.07)
Less deprived 40-60%	1.09 (1.05–1.13)	1.90 (1.66–2.17)	1.96 (1.81–2.12)	1.36 (1.26–1.47)	1.67 (1.53–1.82)	1.76 (1.57–1.98)	1.23 (1.09–1.38)	1.47 (1.37–1.58)	1.65 (1.52–1.80)	2.01 (1.77–2.29)
More deprived 20-40%	1.14 (1.10–1.18)	1.74 (1.55–1.95)	1.97 (1.84–2.10)	1.45 (1.33–1.57)	1.55 (1.44–1.67)	2.00 (1.84–2.18)	1.40 (1.27–1.55)	1.41 (1.31–1.51)	1.63 (1.50–1.78)	1.86 (1.67–2.08)
Most deprived 20%	1.18 (1.13–1.22)	1.90 (1.66–2.17)	2.12 (1.98–2.27)	1.45 (1.31–1.60)	1.57 (1.47–1.67)	1.95 (1.75–2.18)	1.27 (1.14–1.42)	1.32 (1.22–1.43)	1.65 (1.50–1.83)	1.87 (1.63–2.15)
Urban Deprivation										
Least deprived 80-100%	1(ref)	1.03 (0.43–2.47)	1.93 (1.38–2.69)	1.29 (0.95–1.76)	2.17 (1.45–3.25)	1.32 (0.59–2.93)	1.14 (0.86–1.52)	1.22 (0.98–1.51)	1.75 (1.34–2.30)	1.67 (0.92–3.02)
Less deprived 60-80%	1.01 (0.97–1.04)	2.40 (1.72–3.35)	1.77 (1.45–2.16)	1.19 (0.99–1.43)	1.31 (1.01–1.70)	2.25 (1.59–3.19)	1.08 (0.89–1.31)	1.14 (0.98–1.32)	1.55 (1.29–1.87)	1.30 (0.86–1.96)
Less deprived 40-60%	1.03 (0.99–1.06)	1.39 (1.04–1.85)	1.76 (1.53–2.01)	1.19 (1.05–1.35)	1.49 (1.30–1.71)	1.55 (1.19–2.03)	0.93 (0.79–1.10)	1.29 (1.16–1.44)	1.53 (1.33–1.75)	1.78 (1.39–2.29)
More deprived 20-40%	1.07 (1.04–1.11)	1.69 (1.45–1.96)	1.92 (1.78–2.08)	1.28 (1.18–1.39)	1.51 (1.40–1.62)	1.62 (1.40–1.86)	1.29 (1.17–1.43)	1.31 (1.21–1.41)	1.50 (1.37–1.65)	1.73 (1.49–2.01)
Most deprived 20%	1.19 (1.14–1.23)	1.94 (1.79–2.10)	2.13 (2.03–2.24)	1.50 (1.41–1.58)	1.64 (1.56–1.73)	2.12 (1.98–2.25)	1.39 (1.29–1.51)	1.49 (1.42–1.57)	1.70 (1.60–1.80)	2.04 (1.89–2.21)

*Adjusted for age, year and parity
**Abbreviations: CI: Confidence Intervals

Appendix Chapter 6

Appendix Table 6.1. International Classification of Diseases, Tenth Revision (ICD-10) and International Classification of Diseases, Ninth Revision (ICD-9) codes for covariates.

Pre-existing Medical Condition (125)	**ICD-10 code (169)**	**Timing**	**ICD-9 code**
Diabetes	G590 G632 H280 H360 M142 N083 O240 O241 O243 H350 H352 E103 E113 E123 E133 E143 E10-E14	Any code from 2003 to start of pregnancy	250
Heart disease - ischaemic	I252 I20 I21 I22 I23 I24 I25 I270 I272	Any code from 2003 to start of pregnancy	410-414
Heart disease – heart failure and cardiomyopathy	I43 I50 I130 I110 I132	Any code from 2003 to start of pregnancy	425 428
Heart disease- congenital	Q20-Q26	Any code from 2003 to start of pregnancy	745 746 747
Heart disease – valve	I34 I35 I05-I08	Any code from 2003 to start of pregnancy	424
Hypertension	I10-I13 I15	Any code from 2003 to start of pregnancy	401 402 403 404
Thyroid disease	E035 E038 E039 E050 E051 E052 E055 E058 E059 E062 E063 E065 E069 H062	Any code from 2003 to start of pregnancy	240-246
Obstructive lung disorders – cystic fibrosis	E84	Any code from 2003 to start of pregnancy	2770
Restrictive lung disorders	J60 J61 J62 J63 J64 J65 J66 J67 J84 J841 J701 J703 J704 G532 M633 D86	Any code from 2003 to start of pregnancy	500 501 502 503 504 505 515 516 508 3526 135
Polyarthropothies	I730 J990 M350 M05 M06 M34 L93 M32	Any code from 2003 to start of pregnancy	714 7102 4330 7148 7101 7100 6954
Obstructive lung disorders	J45, J46	Any code from 2003 to start of pregnancy	493
Inflammatory bowel disease	K51 K50	Any code from 2003 to start of pregnancy	555, 556
Coeliac	K900	Any code from 2003 to start of pregnancy	5790
Infective Hepatitis	B150 B160 B190 B18	Any code from 2003 to start of pregnancy	0700 0707 0702 0703 0704 5714 5722
Alcohol related liver disease	K701 K702 K703 K704 K70	Any code from 2003 to start of pregnancy	5710 5711 5712 5713
Cirrhosis and liver failure	K717 K740 K741 K742 K744 K745 K746 K72	Any code from 2003 to start of pregnancy	4561 5712 5715 4560, 5722 5723 5724 7824 7895 1550 4562 V427 5719

Pre-existing Medical Condition (125)	ICD-10 code (169)	Timing	ICD-9 code
Other liver disease	K743 K754 K711 K762 K763	Any code from 2003 to start of pregnancy	570 5730 5714 5733
Cerebrovascular disease	I61 I64 I60 I65 I66 I691 I630 I631 I632 I633 I634 I635 I638 I639 I693 G463 G464 G465 G466 G467 G468 I694 I690 G450 G451 G452 G453 G454 G458 G459 G460 G461 G462	Any code from 2003 to start of pregnancy	430 - 438
Epilepsy	G40 G41	Any code from aged 11+ to start of pregnancy	345
Chronic kidney disease	N185 T824 Y602 Y612 Y841 Z491 Z492 Z992 N165 T861 Z940 N183 N184 N187 N188 N189 N186	Any code from 2003 to start of pregnancy	585
Psoriasis and Eczema	l20 l40 M090	Any code from aged 11+ to start of pregnancy	696 692
HIV	F024 B20 B21 B22 B23 B24 R75 Z21	Any code from 2003 to start of pregnancy	042 V08
Cancer	C880 C882 C221 C751 C752 C753 C754 C755 C220 C222 C223 C224 C227 C229 C268 C269 C300 C301 C380 C381 C382 C383 C384 C388 C390 C398 C399 C750 C758 C759 C883 C884 C887 C889 C797 C795 C784 C785 C793 C794 C787 C780 C781 C783 C788 C790 C791 C792 C796 C798 C799 C786 C782 C81 C91- C95 C82-C85 C86 C90 C40 C41 C70 – C72 C51-C53 C31-C34 C43-C49 C64-C67 C97 C00-C21 C23-C25 C37 C57 C58 C60 C63 C68 C69 C74 C76 C80 C96 C56 C73 C54 C55 C77 C50 D05	Any code from 2003 to start of pregnancy	140-239
Transplant	Z94	Any code from 2003 to start of pregnancy	V42 5569 5059 3350-3352 336 5280 4697 9968 5569 5059 3350, 3351 3352 336 5280 4697 556
Fibroids	D25	Any code from 2003 to start of pregnancy	218
Endometriosis	N80	Any code from 5 years prior to pregnancy to start of pregnancy	6170
Inflammatory bowel syndrome	K58	Any code from 5 years prior to pregnancy to start of pregnancy	5641

Pre-existing Medical Condition (125)	**ICD-10 code (169)**	**Timing**	**ICD-9 code**
Post viral and related fatigue	G933	Any code from 5 years prior to pregnancy to start of pregnancy	7808
Fibromyalgia	M797	Any code from 5 years prior to pregnancy to start of pregnancy	7291
Thrombophilia and thromboembolic disease	D68, I74-I76, I26, I80-I82	Any code from 2003 to start of pregnancy	4151 4511 4512 4518 4519 452 453 2898
Obesity	E66, Z684	Any code from 5 years prior to pregnancy up to and including the delivery episode	2780
Substance misuse (130)	**Coded from 5 years prior to index pregnancy up unto the start of pregnancy**		
ICD10 condition	**ICD-10 code**	**ICD-9 condition**	**ICD-9 code (263)**
Mental and behavioural disorders due to psychoactive substance use	F11-F17, F19 (not F171)	Alcohol use and alcohol-related disorders	2910 2911 2912 2913 2914 2915 2918 2919 3030 3039 3050 3575 4255 5353 4571 5711 5712 5713 E860
Finding of drugs not normally found in blood	R781-R785	Amphetamines	3044 3057
Poisoning by drugs, medicaments and biological substances	T36-T50 (not T506)	Cannabis	3043 3052
Poisoning, undetermined intent	Y10-Y14	Cannabis dependence	3042 3056 9685 E938
Drug rehabilitation	Z503	Cocaine	3045 3053 9696 E854 E939
Drug abuse counselling and surveillance	Z715	Drug-induced mental disorders	2920 2921 2922 2928 2929
Drug use	Z722	Hallucinogens	3041 3054 9696 E854 E969
Personal history of psychoactive substance abuse	Z864	Opioids	3040 3047 3055 9650 E850 E935
Mental and behavioural disorders due to use of volatile solvents	F18	Sedatives, hypnotics, anxiolytics, tranquilizers, barbiturates	3041 3054
Accidental poisoning by and exposure to noxious substances	X40–X44, X46-X49	Other	3046 3048 3049 3059 6483 V654
Poisoning by chemical or noxious substance, undetermined intent	Y16-Y19		

Substance misuse (130)	**Coded from 5 years prior to index pregnancy up unto the start of pregnancy**		
ICD10 condition	**ICD-10 code**	**ICD-9 condition**	**ICD-9 code (263)**
Special epileptic syndromes - (related to alcohol, drugs, etc)	G405		
Blood-alcohol and blood-drug test	Z040		
Alcohol-induced pseudo-Cushing's syndrome	244		
Mental and behavioural disorders due to use of alcohol	F10		
Degeneration of nervous system due to alcohol	G312		
Alcoholic polyneuropathy	G621		
Alcoholic myopathy	G721		
Alcoholic cardiomyopathy	I426		
Alcoholic gastritis	K292		
Alcoholic liver disease	K70		
Alcohol-induced acute pancreatitis	K852		
Alcohol-induced chronic pancreatitis	K860		
Finding of alcohol in blood	R780		
Poisoning: antidotes and chelating agents, not elsewhere classified	T506		
Toxic effect of alcohol	T51		
Accidental poisoning by exposure to alcohol	X45		
Poisoning by exposure to alcohol, undetermined intent	Y15		
Evidence of alcohol involvement determined by blood alcohol level	Y90		
Evidence of alcohol involvement determined by level of intoxication	Y91		
Alcohol rehabilitation	Z502		
Alcohol abuse counselling and surveillance	Z714		
Alcohol use	Z721		
Mental Health conditions/ behavioural disorders (130)	**Coded from 5 years prior to index pregnancy to the start of pregnancy**		
ICD-10 condition	**ICD-10 code**	**ICD-9 condition**	**ICD-9 code (263)**
Organic, including symptomatic, mental disorders	F00-F09	Organic psychotic conditions	290–294
Schizophrenia, schizotypal and delusional disorders	F20-F29	Schizophrenic disorders	295
Mood (affective) disorders	F30-F39	No schizophrenic psychotic disorders	297 298
Neurotic, stress-related and somatoform disorders	F40-F48	Episodic mood disorders	296 311
Behavioural syndromes associated with physiological disturbances and physical factors	F50-F59	Anxiety, dissociative, and somatoform disorders	300

Mental Health conditions/ behavioural disorders (130)	**Coded from 5 years prior to index pregnancy to the start of pregnancy**		
ICD-10 condition	**ICD-10 code**	**ICD-9 condition**	**ICD-9 code (263)**
Disorders of adult personality and behaviour	F60-F69	Physiological malfunction arising from mental factors	306
Mental retardation	F70-F79	Personality disorders and certain other nonpsychotic mental disorders	301
Disorders of psychological development	F80-F89	Mental health diagnoses of childhood	312-316, 299
Behavioural and emotional disorders with onset usually occurring in childhood and adolescence	F90-F98	Specific delays in development	317-319
Unspecified mental disorder	F99	Unspecified nonpsychotic mental disorder	307-310
Sedatives, hypnotics and antianxiety drugs	Y47	Personal history of mental disorder	V11
Psychotropic drugs, not elsewhere classified	Y49		
Personal history of other mental and behavioural disorders	Z865		

Appendix Table 6.2. Incidence of SMM condition in 2013-2021 cohort in DIAPER compared to incidence in other peer-reviewed studies and assessment of plausibility (Yes if the DIAPER incidence is like other studies/English data incidence). In *italics* if implausible**.**

Condition	Cases	Incidence (%)	Reference	Comparison Incidence (%)	Considered Plausible
Rupture of aortic aneurysm or dissection	60	0.01	Jarvis S, Van den Akker T, Knight M, Dhanjal M. 404. A nationwide prospective study of aortic dissection in pregnancy using the UK Obstetric Surveillance System (UKOSS). Pregnancy Hypertension. 2018 Oct 1;13:S48-9.	0.001 aortic dissection	Yes Higher in DIAPER but includes ruptured aortic aneurysm
Acute abdomen (minus appendicitis codes)	179	0.02	Augustin G, Majerovic M. Non-obstetrical acute abdomen during pregnancy. European Journal of Obstetrics & Gynecology and Reproductive Biology. 2007 Mar 1;131(1):4-12.	0.02	Yes
Acute renal failure	441	0.05	Taber-Hight E, Shah S. Acute Kidney Injury in Pregnancy. Adv Chronic Kidney Dis. 2020 Nov;27(6):455-460. PMID: 33328061; PMCID: PMC7751749.	0.04-0.12	Yes Large range but this fits within
Acute psychosis	84	0.01	Rodriguez-Cabezas L, Clark C. Psychiatric Emergencies in Pregnancy and Postpartum. Clin Obstet Gynecol. 2018 Sep;61(3):615-627. PMID: 29794819; PMCID: PMC6143388.	0.01	Yes
Acute cardiac event	721	0.09	N/A as composite	N/A	Yes similar to English data
Cerebral oedema or coma	15	0.00	N/A	N/A	Yes similar to English data
Disseminated intravascular coagulopathy	449	0.05	Drez O, Othman M, Rabinovich A, et al. DIC in pregnancy–pathophysiology, clinical characteristics, diagnostic scores, and treatments. Journal of Blood Medicine. 2022 Jan 6:21-44.	0.03-0.30	Yes

Condition	Cases	Incidence (%)	Reference	Comparison Incidence (%)	Considered Plausible
Diabetic ketoacidosis	309	0.04	Diguisto C, Strachan MWJ, Churchill D, et al. A study of diabetic ketoacidosis in the pregnant population in the UK. Diabet Med. 2022 Apr;39(4):e14743. PMID: 34778994; PMCID: PMC7612514.	0.01-0.08	Yes
Cerebrovascular accident	619	0.07	Swartz RH, Cayley ML, Foley N, et al. The incidence of pregnancy-related stroke: A systematic review and meta-analysis. International Journal of Stroke. 2017;12(7):687-697.	0.03	Yes
Major complications of anaesthesia	21	0.00	Bamber JH, Lucas DN, et al. Obstetric anaesthetic practice in the UK: a descriptive analysis of the National Obstetric Anaesthetic Database 2009–14. British Journal of Anaesthesia. 2020 Oct 1;125(4):580-7.	0.01	Yes
Embolic event	1,236	0.15	N/A as composite	N/A	Yes similar to English data
Shock	625	0.08	N/A as composite	N/A	Yes similar to English data
Sickle cell anaemia with crisis	61	0.01	Oteng-Ntim E, Ayensah B, Knight M, Howard J. Pregnancy outcome in patients with sickle cell disease in the UK. British Journal of Haematology. 2015 Apr;169(1):129-37.	0.05	Yes
Uterine rupture	1,061	0.13	Zwart JJ, Richters JM, et al. Uterine rupture in the Netherlands. BJOG. 2009 Jul;116(8):1069-80.	0.60	Twice as high but similar to English data
Eclampsia	759	0.09	Zwart JJ, Richters A, et al. Eclampsia in the Netherlands. Obstetrics & Gynecology. 2008 Oct 1;112(4):820-7.	0.06	Yes
Cerebral venous thrombosis	69	0.01	Swartz RH, Cayley ML, Foley N, et al. The incidence of pregnancy-related stroke: A systematic review and meta-analysis. International Journal of Stroke. 2017;12(7):687-697.	0.001-0.02	Yes

Condition	Cases	Incidence (%)	Reference	Comparison Incidence (%)	Considered Plausible
Acute pancreatitis	1,041	0.13	Pitchumoni CS, Yegneswaran B. Acute pancreatitis in pregnancy. World Journal of Gastroenterology. 2009 Dec 12;15(45):5641.	0.01-0.1	Yes but high. Have done sensitivity analysis with the composite without acute pancreatitis
Sepsis	5,442	0.65	Knowles SJ, O'Sullivan NP, et al. Maternal sepsis incidence, aetiology, and outcome for mother and fetus: a prospective study. BJOG. 2015 Apr;122(5):663-71.	0.10	High but likely over diagnosed similar to UK. Have done sensitivity analysis with it removed
Acute respiratory compromise	80	0.01	N/A	N/A	N/A
Status epilepticus	38	0.01	Rosenow F, Mann C. Status epilepticus in pregnancy. Epilepsy & Behavior. 2023 Jan 1;138:109034.	0.01	Yes
Status asthmaticus	103	0.01	N/A	N/A	Yes similar to English data
Acute abdomen with appendicitis	*6,422*	*0.77*	*Zingone F, Sultan AA, et al. Risk of acute appendicitis in and around pregnancy. Annals of Surgery. 2015 Feb;261(2):332-7.*	*0.06*	*Unrealistic as 13x's higher and making up a significant proportion of SMM*

Appendix Table 6.3. Number (N) and proportion of total composite outcome (%) of each SMM diagnosis (ICD-10) per year.

Year	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**Total**
	N(%)	**N(%)**	**N(%)**	**N(%)**	**N(%)**	**N(%)**	**N(%)**	**N(%)**	**N(%)**	**N(%)**
Total SMM	**1,422 (1.4)**	**1,619(1.7)**	**1,515 (1.7)**	**1,448(1.7)**	**1,416(1.7)**	**1,386(1.7)**	**1,553(1.7)**	**1,466(1.5)**	**1,543(1.5)**	**13,413(1.6)**
Rupture of aortic aneurysm or dissection of aorta	NA	NA	NA	NA	NA	NA	NA	NA	NA	60 (0.4)
Acute abdomen	31 (2.2)	26 (1.6)	21 (1.4)	21 (1.5)	11 (0.8)	18 (1.3)	17 (1.1)	14 (1.0)	20 (1.3)	179 (1.3)
Acute renal failure	24 (1.7)	41 (2.5)	37 (2.4)	46 (3.2)	50 (3.4)	44 (3.2)	63 (4.1)	76 (5.2)	60 (3.9)	441 (3.3)
Acute psychosis	NA	20 (1.2)	NA	14 (1.0)	NA	NA	NA	NA	NA	84 (0.6)
Acute cardiac event (cardiac infarction, cardiac failure, cardiomyopathy and cardiac arrest)	103 (7.2)	116 (7.2)	68 (4.5)	76 (5.3)	69 (4.7)	56 (4.0)	87 (5.6)	74 (5.1)	72 (4.7)	721 (5.4)
Cerebral oedema or coma	NA	NA	NA	NA	NA	NA	NA	NA	NA	15 (0.1)
Disseminated intravascular coagulopathy	39 (2.7)	45 (2.8)	45 (3.0)	39 (2.7)	55 (3.8)	56 (4.0)	59 (3.8)	57 (3.9)	54 (3.5)	449 (3.4)
Diabetic ketoacidosis	26 (1.8)	35 (2.2)	34 (2.2)	43 (3.0)	35 (2.4)	34 (2.5)	28 (1.8)	33 (2.3)	41 (2.7)	309 (2.3)
Cerebrovascular accident	108 (7.6)	100 (6.2)	83 (5.5)	70 (4.8)	58 (4.0)	50 (3.6)	59 (3.8)	53 (3.6)	38 (2.5)	619 (4.6)
Major complications of anaesthesia	NA	NA	NA	NA	NA	NA	NA	NA	NA	21 (0.2)

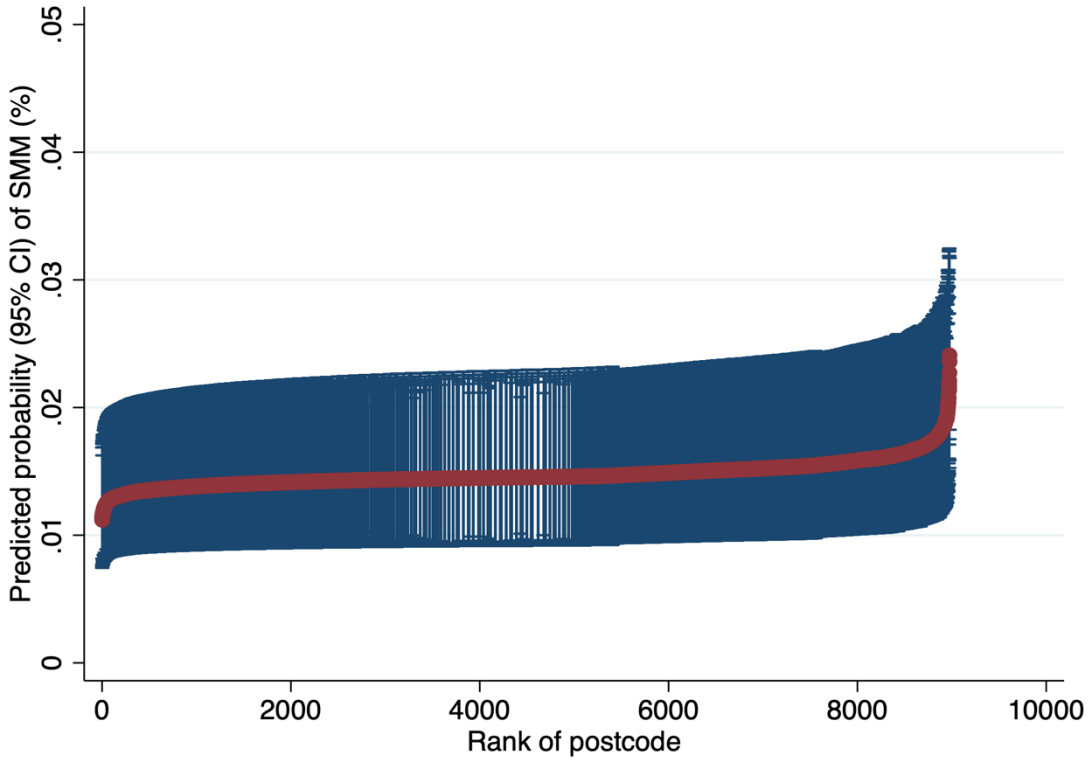
Year	2013	2014	2015	2016	2017	2018	2019	2020	2021	Total
	N(%)	N(%)	N(%)	N(%)	N(%)	N(%)	N(%)	N(%)	N(%)	N(%)
Embolic event (pulmonary embolism, amniotic fluid embolism, septic embolism, and air embolism)	169 (11.9)	155 (9.6)	144 (9.5)	126 (8.7)	121 (8.3)	140 (10.1)	131 (8.4)	106 (7.2)	144 (9.3)	1236 (9.2)
Shock	49 (3.5)	52 (3.2)	62 (4.1)	61 (4.2)	75 (5.1)	70 (5.0)	90 (5.8)	78 (5.3)	88 (5.7)	625 (4.7)
Sickle cell anaemia with crisis	12 (0.8)	NA	NA	NA	NA	NA	NA	NA	10 (0.7)	61 (0.5)
Uterine rupture	31 (2.2)	117 (7.2)	122 (8.1)	110 (7.6)	137 (9.4)	98 (7.1)	122 (7.9)	128 (8.7)	196 (12.7)	1061 (7.9)
Eclampsia	69 (4.9)	83 (5.1)	94 (6.2)	80 (5.5)	84 (5.8)	77 (5.6)	100 (6.4)	84 (5.7)	88 (5.7)	759 (5.7)
Cerebral venous thrombosis	NA	NA	11 (0.7)	NA	NA	NA	NA	10 (0.7)	NA	69 (0.5)
Acute pancreatitis	145 (10.2)	128 (7.9)	116 (7.7)	105 (7.3)	115 (7.9)	110 (7.9)	103 (6.6)	128 (8.7)	91 (5.9)	1041 (7.8)
Sepsis	569 (40.0)	653 (40.3)	629 (41.5)	602 (41.6)	610 (41.8)	577 (41.6)	634 (40.8)	585 (39.9)	583 (37.8)	5442 (40.6)
Acute respiratory compromise	NA	NA	NA	11 (0.8)	NA	12 (0.9)	12 (0.8)	NA	16 (1.0)	80 (0.6)
Status epilepticus	NA	NA	NA	NA	NA	NA	NA	NA	NA	38 (0.3)
Status asthmaticus	14 (1.0)	18 (1.1)	15 (1.0)	NA	NA	NA	NA	NA	13 (0.8)	103 (0.8)

Appendix Table 6.4. Number (N) and proportion of total composite outcome (%) of each SMM diagnosis (ICD-10) per SES-WOA.

SES-WOA	Most disadvantaged 20%	More disadvantaged 20-40%	Less disadvantaged 40-60%	Less disadvantaged 60-80%	Least disadvantaged 80-100%	Total
	N(%)	N(%)	N(%)	N(%)	N(%)	N(%)
Total SMM	**4,552 (1.9)**	**2,967(1.6)**	**2,442(1.5)**	**2,002(1.5)**	**1,450(1.4)**	**13,413(1.6)**
Rupture of aortic aneurysm or dissection of aorta	15 (0.3)	19 (0.6)	NA	12 (0.6)	NA	60 (0.5)
Acute abdomen	53 (1.2)	37 (1.2)	36 (1.5)	30 (1.5)	23 (1.6)	179 (1.3)
Acute renal failure	141 (3.1)	105 (3.5)	86 (3.5)	63 (3.2)	46 (3.2)	441 (3.3)
Acute psychosis	18 (0.4)	23 (0.8)	12 (0.5)	21 (1.1)	NA	NA
Acute cardiac event (cardiac infarction, cardiac failure, cardiomyopathy and cardiac arrest)	271 (5.9)	161 (5.4)	125 (5.1)	92 (4.6)	72 (5.0)	721 (5.4)
Cerebral oedema or coma	NA	NA	NA	NA	NA	15 (0.1)
Disseminated intravascular coagulopathy	141 (3.1)	97 (3.3)	107 (4.4)	60 (3.0)	44 (3.0)	449 (3.4)
Diabetic ketoacidosis	124 (2.7)	68 (2.3)	60 (2.5)	36 (1.8)	21 (1.5)	309 (2.3)
Cerebrovascular accident	221 (4.9)	158 (5.3)	104 (4.3)	71 (3.6)	65 (4.5)	619 (4.6)
Major complications of anaesthesia	NA	NA	NA	NA	NA	21 (0.2)
Embolic event (pulmonary embolism, amniotic fluid embolism, septic embolism and air embolism)	442 (9.7)	282 (9.5)	239 (9.8)	163 (8.1)	110 (7.6)	1,236 (9.2)
Shock	180 (4.0)	128 (4.3)	138 (5.7)	108 (5.4)	71 (4.9)	625 (4.7)
Sickle cell anaemia with crisis	39 (0.9)	NA	NA	NA	NA	61 (0.5)
Uterine rupture	337 (7.4)	230 (7.8)	178 (7.3)	185 (9.2)	131 (9.0)	1,061 (7.9)
Eclampsia	243 (5.3)	178 (6.0)	145 (5.9)	101 (5.0)	92 (6.3)	759 (5.7)
Cerebral venous thrombosis	23 (0.5)	20 (0.7)	NA	NA	10 (0.7)	69 (0.5)

SES-WOA	Most disadvantaged 20%	More disadvantaged 20-40%	Less disadvantaged 40-60%	Less disadvantaged 60-80%	Least disadvantaged 80-100%	Total
	N(%)	N(%)	N(%)	N(%)	N(%)	N(%)
Acute pancreatitis	364 (8.0)	247 (8.3)	190 (7.8)	154 (7.7)	86 (5.9)	1,041 (7.8)
Sepsis	1,834 (40.3)	1,157 (39.0)	965 (39.5)	853 (42.6)	633 (43.7)	5,442 (40.6)
Acute respiratory compromise	31 (0.7)	17 (0.6)	12 (0.5)	12 (0.6)	NA	NA
Status epilepticus	15 (0.3)	NA	NA	NA	NA	38 (0.3)
Status asthmatics	45 (1.0)	19 (0.6)	11 (0.5)	21 (1.1)	NA	NA

Appendix Figure 6.1. Caterpillar plot showing the predictive probabilities (and 95% confidence intervals) of SMM (%) in each postcode (PC4).



Appendix Table 6.5. Cross-tabulation of the individual-level measures of socioeconomic disadvantage. Number and percent (N %).

	Individual Educational Attainment			**Individual Employment**	
	Low	**Medium**	**High**	**Unemployed**	**Employed**
	N=95,845	**N=270,252**	**N=285,074**	**N=200,699**	**N=632,167**
Household Disposable Income (euros)					
<€20,000	41,673 (44.1)	37,219 (13.8)	9,159 (3.2)	75,370 (43.1)	35,720 (6.3)
€20-39,999	19,777 (20.9)	41,626 (15.5)	14,282 (5.0)	34,503 (19.7)	55,823 (9.9)
€40-59,999	15,852 (16.8)	65,330 (24.3)	34,544 (12.2)	25,126 (14.4)	107,882 (19.1)
€60-79,999	11,248 (11.9)	77,498 (28.8)	79,248 (27.9)	18,763 (10.7)	167,420 (29.6)
€80-100,00	5,980 (6.3)	47,627 (17.7)	147,120 (51.7)	21,323 (12.2)	199,018 (35.2)
Individual Educational Attainment					
Low				50,600 (36.9)	45,245 (8.8)
Medium				54,047 (39.4)	216,205 (42.1)
High				32,641 (23.8)	252,433 (49.1)

Appendix Table 6.6. Number of SMM cases (N), total (N) in each group, rate of SMM (%), and adjusted risk ratios (and their 95% confidence intervals) of SMM for unemployed women compared to Caucasian employed women stratified by ethnic group and adjusted for age, parity, year and migration status.

Employment Status	SMM N	Total N	Rate (%)	Risk ratio (95% CI)
Caucasian				
Employed	7,676	539,282	1.42	1(ref)
Unemployed	2,209	120,002	1.84	1.30(1.24-1.37)
Mediterranean ((North African + Turkish)				
Employed	138	6,763	2.04	1.59 (1.33-1.90)
Unemployed	158	5,758	2.74	2.13 (1.81-2.52)
Other African				
Employed	198	8,724	2.27	1.69 (1.46-1.96)
Unemployed	259	10,053	2.58	1.95 (1.71-2.22)
Other Asian				
Employed	337	20,088	1.68	1.25 (1.11-1.40)
Unemployed	338	18,561	1.82	1.37 (1.22-1.54)
Other including Mixed				
Employed	781	41,919	1.86	1.38 (1.27-1.50)
Unemployed	849	40,954	2.07	1.55 (1.43-1.69)

Abbreviations: CI: Confidence Interval

Appendix Table 6.7. Number of SMM cases (N), total in each group (N), rate of SMM (%), and adjusted risk ratios (and their 95% confidence intervals) of SMM for each household disposable income quintile and SMM, compared to the Caucasian women with a household disposable income €80,000-€100,000, stratified by ethnic group adjusted for age, parity, year and migration status.

Household Disposable Income (euros)	SMM N	Total N	Rate (%)	Risk Ratio (95% CI)
Caucasian				
€80-100,00	2,793	194,001	1.44	1 (ref)
€60-79,999	2,429	162,811	1.49	1.06 (1.00 1.12)
€40-59,999	1,785	109,497	1.63	1.18 (1.11 1.25)
€20-39,999	1,157	63,881	1.81	1.30 (1.21 1.40)
<€20,000	1,136	58,699	1.94	1.39 (1.29 1.50)
Mediterranean ((North African + Turkish)				
€80-100,00	30	1,547	1.94	1.52 (1.06 2.19)
€60-79,999	31	1,850	1.68	1.34 (0.93 1.91)
€40-59,999	53	1,977	2.68	2.14 (1.62 2.82)
€20-39,999	66	2,162	3.05	2.43 (1.89 3.12)
<€20,000	96	3,505	2.74	2.18 (1.77 2.70)
Other African				
€80-100,00	19	1,120	1.70	1.26 (0.80 1.98)
€60-79,999	40	1,434	2.79	2.09 (1.52 2.86)
€40-59,999	42	1,869	2.25	1.70 (1.25 2.32)
€20-39,999	90	3,115	2.89	2.20 (1.77 2.73)
<€20,000	230	8,825	2.61	2.03 (1.76 2.35)
Other Asian				
€80-100,00	133	7,515	1.77	1.31 (1.10 1.57)
€60-79,999	92	5,321	1.73	1.30 (1.05 1.61)
€40-59,999	81	5,108	1.59	1.20 (0.96 1.50)
€20-39,999	95	5,475	1.74	1.32 (1.07 1.63)
<€20,000	204	10,291	1.98	1.53 (1.32 1.78)
Other including Mixed				
€80-100,00	176	10,733	1.64	1.21 (1.03 1.41)
€60-79,999	220	10,392	2.12	1.59 (1.38 1.83)
€40-59,999	259	11,399	2.27	1.73 (1.51 1.98)
€20-39,999	288	13,418	2.15	1.63 (1.43 1.86)
<€20,000	557	26,642	2.09	1.61 (1.45 1.78)

Abbreviations: CI: Confidence Interval

Appendix Table 6.8. Number of SMM cases (N), total in each quintile (N), rate of SMM (%) and adjusted risk ratios (and their 95% confidence intervals) of SMM for each SES-WOA Education quintile compared to Caucasian women living in the least disadvantaged SES-WOA Education quintile stratified by ethnic group and adjusted for age, parity, year and migration status.

SESWOA Education Quintile	SMM N	Total N	Rate %	Risk Ratio (95% CI)
Caucasian				
Least disadvantaged 20%	1,848	133,785	1.38	1(ref)
Less disadvantaged 20-40%	1,503	108,005	1.39	1.01 (0.95-1.09)
Less disadvantage 40-60%	1,774	119,752	1.48	1.09 (1.02-1.16)
More disadvantaged 60-80%	2,253	148,578	1.52	1.12 (1.05-1.19)
Most disadvantaged 80-100%	2,507	149,164	1.68	1.23 (1.15-1.31)
Mediterranean (North African + Turkish)				
Least disadvantaged 20%	30	1,229	2.44	1.91 (1.32-2.75)
Less disadvantaged 20-40%	36	1,161	3.10	2.44 (1.75-3.42)
Less disadvantage 40-60%	24	1,236	1.94	1.55 (1.03-2.33)
More disadvantaged 60-80%	45	2,088	2.16	1.75 (1.29-2.36)
Most disadvantaged 80-100%	161	6,807	2.37	1.88 (1.58-2.23)
Other African				
Least disadvantaged 20%	41	1,808	2.27	1.69 (1.23-2.31)
Less disadvantaged 20-40%	46	1,537	2.99	2.25 (1.67-3.03)
Less disadvantage 40-60%	50	1,986	2.52	1.92 (1.44-2.56)
More disadvantaged 60-80%	98	3,863	2.54	1.96 (1.59-2.42)
Most disadvantaged 80-100%	222	9,583	2.32	1.73 (1.49-2.01)
Other Asian				
Least disadvantaged 20%	116	8,384	1.38	1.03 (0.85-1.25)
Less disadvantaged 20-40%	84	5,167	1.63	1.22 (0.98-1.53)
Less disadvantage 40-60%	102	4,972	2.05	1.56 (1.27-1.92)
More disadvantaged 60-80%	123	7,228	1.70	1.31 (1.08-1.58)
Most disadvantaged 80-100%	250	12,898	1.94	1.48 (1.28-1.70)
Other including Mixed				
Least disadvantaged 20%	204	11,487	1.78	1.31 (1.13-1.52)
Less disadvantaged 20-40%	146	8,522	1.71	1.28 (1.08-1.53)
Less disadvantage 40-60%	211	9,826	2.15	1.62 (1.39-1.88)
More disadvantaged 60-80%	317	15,381	2.06	1.58 (1.39-1.80)
Most disadvantaged 80-100%	752	37,657	2.00	1.51 (1.37-1.67)

Abbreviations: CI: Confidence Interval

Appendix Table 6.9. Adjusted risk ratios (and their 95% confidence intervals) of Model 1 (adjusting for year, age, parity, migration status and ethnicity) between the different measures of disadvantage and SMM with pancreatitis excluded from the composite outcome, compared to the least disadvantaged group.

	SESWOA	**SESWOA Education**	**SESWOA Employment**	**SESWOA Welfare**	**Livability**	**Household Disposable Income**		**Employment Status**		**Individual Educational Attainment**	
	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)		Risk Ratio (95% CI)		Risk Ratio (95% CI)		Risk Ratio (95% CI)
Most disadvantage 20%	1.20 (1.12–1.29)	1.17 (1.10–1.25)	1.17 (1.09–1.24)	1.22 (1.12–1.31)	1.10 (1.01–1.20)	**<€20,000**	1.26 (1.18–1.35)	**Unemployed**	1.23 (1.18-1.29)	**Low**	1.35 (1.27–1.44)
More disadvantaged 20-40%	1.08 (1.01–1.16)	1.11 (1.04–1.18)	1.05 (0.98–1.12)	1.09 (1.01–1.18)	1.10 (1.01–1.20)	**€20-39,999**	1.24 (1.16–1.32)	**Employed**	1(ref)	**Medium**	1.24 (1.18–1.29)
More disadvantaged 40-60%	1.09 (1.01–1.17)	1.09 (1.02–1.16)	1.06 (0.98–1.13)	1.12 (1.03–1.21)	1.01 (0.95–1.07)	**€40-59,999**	1.14 (1.07–1.21)			**High**	1(ref)
Less disadvantaged 20-40%	1.06 (0.98–1.14)	1.01 (0.95–1.08)	1.00 (0.93–1.08)	1.06 (0.97–1.15)	0.99 (0.93–1.05)	**€60-79,999**	1.05 (0.99–1.11)				
Least disadvantaged 20%	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)	**€80-100,00**	1 (ref)				

**Abbreviations: CI: Confidence interval*

Appendix Table 6.10. Number of SMM cases (N), total in each group (N), rate of SMM (%) and adjusted risk ratios (and their 95% confidence intervals) for household disposable income quintile and SMM, compared to Caucasian women with a household disposable income €80,000-€100,000 stratified by ethnicity and migration status and adjusted for age, parity and year.

Household Disposable Income (euros)	SMM N	Total N	Rate %	Risk Ratio (95% CI)
Caucasian and Dutch native				
€80-100,00	2,438	170,405	1.43	1 (ref)
€60-79,999	2,140	144,122	1.48	1.06 (1.00-1.13)
€40-59,999	1,550	93,322	1.66	1.20 (1.13-1.29)
€20-39,999	959	50,277	1.91	1.37 (1.27-1.48)
<€20,000	856	40,863	2.09	1.49 (1.37-1.61)
Caucasian and non-Dutch native				
€80-100,00	355	23,596	1.50	1.04 (0.93-1.16)
€60-79,999	289	18,689	1.55	1.09 (0.96-1.23)
€40-59,999	235	16,175	1.45	1.03 (0.90-1.18)
€20-39,999	198	13,604	1.46	1.03 (0.89-1.19)
<€20,000	280	17,836	1.57	1.11 (0.98-1.26)
Minoritised ethnicity and Dutch native				
€80-100,00	30	1,535	1.95	1.02 (0.73-1.44)
€60-79,999	31	1,836	1.69	1.29 (0.92-1.81)
€40-59,999	53	1,962	2.70	1.38 (0.93-2.05)
€20-39,999	66	2,141	3.08	1.32 (0.83-2.10)
<€20,000	96	3,479	2.76	1.57 (1.06-2.34)
Other including Mixed and non-Dutch native				
€80-100,00	18	1,067	1.69	1.20 (1.03-1.38)
€60-79,999	39	1,378	2.83	1.50 (1.31-1.72)
€40-59,999	41	1,802	2.28	1.59 (1.40-1.80)
€20-39,999	88	3,022	2.91	1.54 (1.36-1.73)
<€20,000	225	8,704	2.59	1.52 (1.38-1.66)
Mediterranean (North African + Turkish) and non-Dutch native				
€80-100,00	84	4,917	1.71	1.43 (1.00-2.06)
€60-79,999	50	3,207	1.56	1.26 (0.88-1.79)
€40-59,999	43	3,173	1.36	2.01 (1.53-2.64)
€20-39,999	51	3,504	1.46	2.29 (1.79-2.92)
<€20,000	148	8,139	1.82	2.05 (1.67-2.51)
Other African and non-Dutch native				
€80-100,00	87	4,047	2.15	1.16 (0.73-1.85)
€60-79,999	53	3,290	1.61	1.97 (1.43-2.70)
€40-59,999	57	2,083	2.74	1.60 (1.17-2.18)
€20-39,999	35	1,191	2.94	2.06 (1.66-2.55)
<€20,000	25	1,103	2.27	1.86 (1.62-2.14)

Household Disposable Income Quintile (euros)	SMM N	Total N	Rate %	Risk Ratio (95% CI)
Other Asian and non-Dutch native				
€80-100,00	31	1,378	2.25	1.18 (0.95-1.47)
€60-79,999	38	1,085	3.50	1.09 (0.82-1.44)
€40-59,999	24	1,075	2.23	0.95 (0.70-1.29)
€20-39,999	28	1,084	2.58	1.03 (0.78-1.36)
<€20,000	61	2,025	3.01	1.30 (1.10-1.54)
Missing ethnicity and Dutch native				
€80-100,00	34	2,313	1.47	1.55 (1.25-1.92)
€60-79,999	34	1,873	1.82	1.18 (0.90-1.55)
€40-59,999	25	1,286	1.94	2.03 (1.56-2.64)
€20-39,999	18	964	1.87	2.15 (1.54-3.00)
<€20,000	25	1,124	2.22	1.65 (1.11-2.45)
Missing ethnicity and non-Dutch native				
€80-100,00	192	11,083	1.73	1.59 (1.12-2.27)
€60-79,999	229	10,703	2.14	2.52 (1.83-3.48)
€40-59,999	273	12,130	2.25	1.61 (1.08-2.41)
€20-39,999	316	14,539	2.17	1.85 (1.28-2.69)
<€20,000	593	27,817	2.13	2.20 (1.70-2.83)
All minoritised ethnicity and non-Dutch native				
€80-100,00	324	18,602	1.74	1.21(1.07-1.36)
€60-79,999	349	17,124	2.04	1.43(1.28-1.60)
€40-59,999	410	19,067	2.15	1.52(1.37-1.69)
€20-39,999	521	23,206	2.25	1.59(1.45-1.75)
<€20,000	1,062	48,139	2.21	1.58(1.46-1.70)

Abbreviations: CI: Confidence Interval

Appendix Table 6.11. Number of SMM cases (N), total in each group (N), rate of SMM (%) and adjusted risk ratios (and their 95% confidence intervals) of unemployed women and SMM compared to Caucasian employed women stratified by ethnic and migration status and adjusted for age, parity and year.

Employment	SMM N	Total N	Rate	Risk Ratio (95% CI)
Caucasian and Dutch native				
Employed	6,680	467,259	1.43	1 (ref)
Unemployed	1,716	88,415	1.94	1.35 (1.28-1.42)
Caucasian and non-Dutch native				
Employed	996	72,023	1.38	0.95 (0.89-1.02)
Unemployed	493	31,587	1.56	1.07 (0.98-1.18)
Minoritised ethnicity and Dutch native				
Employed	110	6,779	1.62	1.12 (0.93-1.36)
Unemployed	41	1,700	2.41	1.66 (1.22-2.25)
Other including Mixed and non-Dutch native				
Employed	829	43,403	1.91	1.32 (1.22-1.41)
Unemployed	910	43,768	2.08	1.44 (1.34-1.54)
Mediterranean (North African + Turkish) and non-Dutch native				
Employed	138	6,694	2.06	1.49 (1.26-1.77)
Unemployed	158	5,733	2.76	1.98 (1.69-2.33)
Other African and non-Dutch native				
Employed	191	8,434	2.26	1.56 (1.35-1.80)
Unemployed	254	9,900	2.57	1.79 (1.58-2.03)
Other Asian and non-Dutch native				
Employed	186	12,184	1.53	1.05 (0.91-1.22)
Unemployed	241	14,225	1.69	1.17 (1.03-1.34)
Missing ethnicity and Dutch native				
Employed	208	10,924	1.90	1.36 (1.19-1.57)
Unemployed	66	2,134	3.09	2.19 (1.72-2.79)
Missing ethnicity and non-Dutch native				
Employed	108	4,467	2.42	1.70 (1.41-2.06)
Unemployed	88	3,237	2.72	1.92 (1.55-2.37)
All minoritised ethnicity and non-Dutch native				
Employed	1,344	70,715	1.9	1.31(1.24-1.39)
Unemployed	1,563	73,626	2.12	1.47(1.39-1.56)

Abbreviations: CI: Confidence Interval

Appendix Table 6.12. Number of SMM cases (N), total in each group (N), rate of SMM (%) and adjusted risk ratios (and their 95% confidence intervals) for women in each educational attainment group and SMM, compared to the women with the Caucasian women with the highest educational attainment stratified by ethnicity and migration status and adjusted for age, parity and year.

Individual Educational Attainment	SMM N	Total N	Rate %	Risk Ratio (95% CI)
White and Dutch native				
High	3,037	223,295	1.36	1 (ref)
Medium	3,398	194,186	1.75	1.32 (1.25-1.39)
Low	999	46,839	2.13	1.59 (1.48-1.71)
White and non-Dutch native				
High	429	28,079	1.53	1.10 (1.00-1.22)
Medium	437	26,814	1.63	1.21 (1.09-1.34)
Low	250	15,083	1.66	1.22 (1.07-1.39)
Minoritised ethnicity and Dutch native				
High	37	2,845	1.30	0.95 (0.69-1.32)
Medium	64	3,229	1.98	1.48 (1.15-1.89)
Low	27	1,168	2.31	1.73 (1.18-2.52)
Other including Mixed and non-Dutch native				
High	271	14,126	1.92	1.39 (1.23-1.58)
Medium	575	24,926	2.31	1.71 (1.57-1.88)
Low	427	18,660	2.29	1.67 (1.51-1.85)
Mediterranean (North African + Turkish) and non-Dutch native				
High	50	2,018	2.48	1.93 (1.46-2.56)
Medium	119	4,527	2.63	2.08 (1.73-2.51)
Low	56	2,217	2.53	1.91 (1.46-2.49)
Other African and non-Dutch native				
High	46	2,081	2.21	1.60 (1.20-2.14)
Medium	152	5,805	2.62	1.95 (1.66-2.30)
Low	157	5,485	2.86	2.13 (1.81-2.51)
Other Asian and non-Dutch native				
High	82	5,595	1.47	1.06 (0.85-1.32)
Medium	76	4,196	1.81	1.34 (1.07-1.69)
Low	73	3,936	1.85	1.35 (1.07-1.71)
Missing ethnicity and Dutch native				
High	101	5,476	1.84	1.40 (1.15-1.71)
Medium	111	4,616	2.40	1.86 (1.54-2.25)
Low	36	1,172	3.07	2.35 (1.69-3.27)
Missing ethnicity and non-Dutch native				
High	31	1,559	1.99	1.47 (1.03-2.10)
Medium	63	1,953	3.23	2.46 (1.92-3.16)
Low	40	1,285	3.11	2.33 (1.70-3.19)

Individual Educational Attainment	SMM N	Total N	Rate %	Risk Ratio (95% CI)
All minoritised ethnicity and non-Dutch native				
High	449	23,820	1.88	1.37(1.24-1.52)
Medium	922	39,454	2.34	1.75(1.62-1.88)
Low	713	30,298	2.35	1.73(1.59-1.88)

Abbreviations: CI: Confidence Interval

Appendix Table 6.13. Cross-tabulation of number of women (Number and percent (N %)) in each individual educational attainment group living in each SES-WOA Education quintile stratified by ethnicity.

Individual Educational Attainment	Most disadvantaged SES-WOA Education 20%	More disadvantaged SES-WOA Education 20-40%	Less disadvantaged SES-WOA Education 40-60%	Less disadvantaged SES-WOA Education 60-80%	Least disadvantaged SES-WOA Education 80-100%	Total
	N(%)	N(%)	N(%)	N(%)	N(%)	N(%)
Caucasian						
low	25,476 (21.3)	15,464 (12.9)	9,348 (9.6)	6,676 (7.6)	4,958 (4.5)	61,922 (11.6)
medium	61,364 (51.2)	57,562 (47.9)	42,052 (43.3)	33,092 (37.8)	26,930 (24.5)	221,000 (41.4)
high	32,977 (27.5)	47,068 (39.2)	45,642 (47.0)	47,809 (54.6)	77,878 (71.0)	251,374 (47.1)
Mediterranean						
low	1,397 (29.1)	375 (25.6)	185 (22.5)	147 (16.9)	138 (15.5)	2,242 (25.3)
medium	2,543 (53.0)	773 (52.7)	433 (52.7)	435 (49.9)	389 (43.8)	4,573 (51.7)
high	859 (17.9)	318 (21.7)	203 (24.7)	289 (33.2)	362 (40.7)	2,031 (23.0)
Other African						
low	3,179 (43.6)	1,129 (41.4)	600 (43.7)	344 (31.9)	358 (28.2)	5,610 (40.8)
medium	3,318 (45.5)	1,205 (44.2)	525 (38.2)	475 (44.1)	470 (37.0)	5,993 (43.6)
high	802 (11.0)	395 (14.5)	249 (18.1)	259 (24.0)	443 (34.9)	2,148 (15.6)
Other Asian						
low	2,656 (34.4)	1,205 (29.8)	598 (22.7)	528 (17.5)	522 (11.9)	5,509 (25.2)
medium	3,280 (42.5)	1,492 (36.9)	1,007 (38.3)	1,043 (34.6)	1,123 (25.5)	7,945 (36.4)
high	1,791 (23.2)	1,351 (33.4)	1,027 (39.0)	1,447 (48.0)	2,761 (62.7)	8,377 (38.4)
Other including Mixed						
low	10,256 (38.6)	3,471 (33.4)	1,903 (29.2)	1,250 (21.7)	1,225 (17.2)	18,105 (32.1)
medium	11,972 (45.0)	4,662 (44.8)	2,726 (41.8)	2,366 (41.1)	2,446 (34.4)	24,172 (42.9)
high	4,360 (16.4)	2,275 (21.9)	1,890 (29.0)	2,139 (37.2)	3,445 (48.4)	14,109 (25.0)

Appendix Table 6.14. Cross-tabulation of number of women (Number and percent (N %)) in each individual household income group living in each SES-WOA Welfare quintile stratified by ethnicity.

Household Disposable Income	Most disadvantaged SES-WOA Welfare 20%	More disadvantaged SES-WOA Welfare 20-40%	Less disadvantaged SES-WOA Welfare 40-60%	Less disadvantaged SES-WOA Welfare 60-80%	Least disadvantaged SES-WOA Welfare 80-100%	Total
	N(%)	N(%)	N(%)	N(%)	N(%)	N(%)
Caucasian						
<€20,000	28,391 (19.3)	14,049 (9.8)	8,750 (6.6)	5,150 (4.7)	2,359 (4.2)	58,699 (10.0)
€20-39,999	23,525 (16.0)	17,585 (12.3)	12,313 (9.4)	7,538 (6.8)	2,920 (5.2)	63,881 (10.9)
€40-59,999	28,845 (19.6)	30,392 (21.2)	25,555 (19.4)	17,785 (16.1)	6,920 (12.4)	109,497 (18.6)
€60-79,999	32,759 (22.3)	41,221 (28.7)	40,601 (30.8)	33,556 (30.4)	14,674 (26.2)	162,811 (27.7)
€80-100,00	33,567 (22.8)	40,305 (28.1)	44,472 (33.8)	46,520 (42.1)	29,137 (52.0)	194,001 (32.9)
Mediterranean						
<€20,000	2,446 (35.1)	600 (31.9)	246 (23.3)	180 (20.3)	33 (14.1)	3,505 (31.8)
€20-39,999	1,464 (21.0)	353 (18.8)	192 (18.2)	124 (14.0)	29 (12.4)	2,162 (19.6)
€40-59,999	1,266 (18.1)	327 (17.4)	195 (18.4)	157 (17.7)	32 (13.7)	1,977 (17.9)
€60-79,999	1,065 (15.3)	326 (17.3)	226 (21.4)	178 (20.1)	55 (23.5)	1,850 (16.8)
€80-100,00	738 (10.6)	276 (14.7)	199 (18.8)	249 (28.0)	85 (36.3)	1,547 (14.0)
Other African						
<€20,000	6,028 (57.0)	1,569 (53.7)	750 (49.5)	391 (37.8)	87 (27.9)	8,825 (53.9)
€20-39,999	2,169 (20.5)	519 (17.8)	259 (17.1)	140 (13.5)	28 (9.0)	3,115 (19.0)
€40-59,999	1,194 (11.3)	314 (10.8)	168 (11.1)	152 (14.7)	41 (13.1)	1,869 (11.4)
€60-79,999	779 (7.4)	286 (9.8)	167 (11.0)	147 (14.2)	55 (17.6)	1,434 (8.8)
€80-100,00	412 (3.9)	232 (8.0)	171 (11.3)	204 (19.7)	101 (32.4)	1,120 (6.8)

Household Disposable Income	Most disadvantaged SES-WOA Welfare 20%	More disadvantaged SES-WOA Welfare 20-40%	Less disadvantaged SES-WOA Welfare 40-60%	Less disadvantaged SES-WOA Welfare 60-80%	Least disadvantaged SES-WOA Welfare 80-100%	Total
	N(%)	N(%)	N(%)	N(%)	N(%)	N(%)
Other Asian						
<€20,000	5,891 (39.2)	2,197 (31.1)	1,251 (24.6)	734 (15.8)	218 (11.7)	10,291 (30.5)
€20-39,999	2,832 (18.8)	1,202 (17.0)	721 (14.2)	562 (12.1)	158 (8.5)	5,475 (16.2)
€40-59,999	2,240 (14.9)	1,085 (15.4)	800 (15.7)	726 (15.6)	257 (13.8)	5,108 (15.2)
€60-79,999	2,014 (13.4)	1,090 (15.4)	943 (18.5)	923 (19.9)	351 (18.9)	5,321 (15.8)
€80-100,00	2,069 (13.8)	1,485 (21.0)	1,379 (27.1)	1,705 (36.7)	877 (47.1)	7,515 (22.3)
Other including Mixed						
<€20,000	17,614 (43.2)	4,748 (35.2)	2,462 (28.6)	1,440 (20.2)	378 (14.9)	26,642 (36.7)
€20-39,999	8,567 (21.0)	2,418 (17.9)	1,342 (15.6)	870 (12.2)	221 (8.7)	13,418 (18.5)
€40-59,999	6,342 (15.5)	2,229 (16.5)	1,378 (16.0)	1,137 (16.0)	313 (12.3)	11,399 (15.7)
€60-79,999	4,825 (11.8)	2,077 (15.4)	1,470 (17.1)	1,476 (20.8)	544 (21.4)	10,392 (14.3)
€80-100,00	3,476 (8.5)	2,036 (15.1)	1,947 (22.6)	2,190 (30.8)	1,084 (42.7)	10,733 (14.8)

Appendix Table 6.15. Cross-tabulation of number of unemployed/employed women (Number and percent (N %)) group living in each SES-WOA Employment quintile stratified by ethnicity.

Employment status	Most disadvantaged SES-WOA Employment 20%	More disadvantaged SES-WOA Employment 20-40%	Less disadvantaged SES-WOA Employment 40-60%	Less disadvantaged SES-WOA Employment 60-80%	Least disadvantaged SES-WOA Employment 80-100%	Total
	N(%)	N(%)	N(%)	N(%)	N(%)	N(%)
Caucasian						
Unemployed	40,120 (26.0)	27,567 (18.6)	21,444 (15.7)	16,602 (14.9)	14,269 (13.0)	120,002 (18.2)
Employed	114,361 (74.0)	120,306 (81.4)	114,859 (84.3)	94,523 (85.1)	95,233 (87.0)	539,282 (81.8)
Mediterranean						
Unemployed	3,810 (49.6)	952 (44.2)	444 (42.4)	262 (38.1)	290 (30.5)	5,758 (46.0)
Employed	3,872 (50.4)	1,201 (55.8)	604 (57.6)	426 (61.9)	660 (69.5)	6,763 (54.0)
Other African						
Unemployed	6,399 (53.5)	1,836 (57.1)	981 (55.9)	490 (51.2)	347 (39.6)	10,053 (53.5)
Employed	5,574 (46.6)	1,380 (42.9)	774 (44.1)	467 (48.8)	529 (60.4)	8,724 (46.5)
Other Asian						
Unemployed	9,063 (53.1)	3,998 (50.3)	2,391 (45.7)	1,655 (43.4)	1,454 (31.9)	18,561 (48.0)
Employed	8,011 (46.9)	3,958 (49.8)	2,847 (54.4)	2,161 (56.6)	3,111 (68.2)	20,088 (52.0)
Other including Mixed						
Unemployed	24,509 (54.0)	7,601 (48.4)	4,155 (45.8)	2,479 (40.6)	2,210 (33.4)	40,954 (49.4)
Employed	20,854 (46.0)	8,105 (51.6)	4,911 (54.2)	3,635 (59.5)	4,414 (66.6)	41,919 (50.6)

Appendix Table 6.16. Cross-tabulation of number of women (Number and percent (N %)) in each individual educational attainment group living in each SES-WOA Education quintile stratified by ethnicity and migration status.

Individual Educational Attainment	Most disadvantaged SES-WOA Education 20%	More disadvantaged SES-WOA Education 20-40%	Less disadvantaged SES-WOA Education 40-60%	Less disadvantaged SES-WOA Education 60-80%	Least disadvantaged SES-WOA Education 80-100%	Total
	N(%)	N(%)	N(%)	N(%)	N(%)	N(%)
Caucasian Dutch native						
low	18,291 (18.7)	12,061 (11.4)	7,417 (8.5)	5,292 (6.8)	3,778 (4.0)	46,839 (10.1)
medium	51,304 (52.5)	51,460 (48.6)	38,160 (43.9)	29,753 (38.1)	23,509 (24.6)	194,186 (41.8)
high	28,055 (28.7)	42,371 (40.0)	41,301 (47.5)	43,104 (55.2)	68,464 (71.5)	223,295 (48.1)
Caucasian non-Dutch native						
low	7,185 (32.4)	3,403 (24.0)	1,931 (19.0)	1,384 (14.7)	1,180 (8.4)	15,083 (21.6)
medium	10,060 (45.4)	6,102 (43.0)	3,892 (38.3)	3,339 (35.4)	3,421 (24.4)	26,814 (38.3)
high	4,922 (22.2)	4,697 (33.1)	4,341 (42.7)	4,705 (49.9)	9,414 (67.2)	28,079 (40.1)
Dutch native minoritised ethnicity						
low	486 (28.6)	273 (18.0)	175 (13.0)	122 (9.4)	112 (8.2)	1,168 (16.1)
medium	884 (52.0)	755 (49.8)	630 (46.8)	543 (41.6)	417 (30.3)	3,229 (44.6)
high	331 (19.5)	487 (32.2)	541 (40.2)	640 (49.0)	846 (61.5)	2,845 (39.3)
Non-Dutch native minoritised ethnicity						
low	17,002 (38.0)	5,907 (34.5)	3,111 (31.1)	2,147 (22.8)	2,131 (17.3)	30,298 (32.4)
medium	20,229 (45.2)	7,377 (43.1)	4,061 (40.6)	3,776 (40.1)	4,011 (32.6)	39,454 (42.2)
high	7,481 (16.7)	3,852 (22.5)	2,828 (28.3)	3,494 (37.1)	6,165 (50.1)	23,820 (25.5)

Appendix Table 6.17. Cross-tabulation of number of women (Number and percent (N %)) in each individual household income group living in each SES-WOA Welfare quintile stratified by ethnicity and migration status.

Household Disposable Income	Most disadvantaged SES-WOA Welfare 20%	More disadvantaged SES-WOA Welfare 20-40%	Less disadvantaged SES-WOA Welfare 40-60%	Less disadvantaged SES-WOA Welfare 60-80%	Least disadvantaged SES-WOA Welfare 80-100%	Total
	N(%)	N(%)	N(%)	N(%)	N(%)	N(%)
Caucasian Dutch native						
<€20,000	18,382 (16.4)	10,219 (8.3)	6,623 (5.7)	3,845 (3.9)	1,794 (3.6)	40,863 (8.2)
€20-39,999	16,715 (14.9)	14,364 (11.7)	10,433 (9.0)	6,277 (6.4)	2,488 (5.0)	50,277 (10.1)
€40-59,999	22,316 (19.9)	26,261 (21.4)	22,693 (19.5)	15,864 (16.2)	6,188 (12.5)	93,322 (18.7)
€60-79,999	26,825 (23.9)	36,664 (29.9)	36,865 (31.7)	30,463 (31.1)	13,305 (26.8)	144,122 (28.9)
€80-100,00	27,866 (24.9)	35,337 (28.8)	39,694 (34.1)	41,582 (42.4)	25,926 (52.2)	170,405 (34.2)
Caucasian non-Dutch native						
<€20,000	10,009 (28.6)	3,830 (18.5)	2,127 (13.8)	1,305 (10.4)	565 (9.0)	17,836 (19.8)
€20-39,999	6,810 (19.5)	3,221 (15.6)	1,880 (12.2)	1,261 (10.1)	432 (6.9)	13,604 (15.1)
€40-59,999	6,529 (18.7)	4,131 (20.0)	2,862 (18.6)	1,921 (15.4)	732 (11.6)	16,175 (18.0)
€60-79,999	5,934 (17.0)	4,557 (22.0)	3,736 (24.3)	3,093 (24.7)	1,369 (21.7)	18,689 (20.8)
€80-100,00	5,701 (16.3)	4,968 (24.0)	4,778 (31.1)	4,938 (39.4)	3,211 (50.9)	23,596 (26.3)
Dutch native minoritised ethnicity						
<€20,000	628 (28.6)	261 (14.1)	120 (8.2)	89 (6.3)	26 (4.1)	1,124 (14.9)
€20-39,999	443 (20.2)	239 (13.0)	149 (10.1)	91 (6.4)	42 (6.6)	964 (12.8)
€40-59,999	391 (17.8)	337 (18.3)	272 (18.5)	217 (15.4)	69 (10.9)	1,286 (17.0)
€60-79,999	391 (17.8)	512 (27.7)	396 (26.9)	413 (29.3)	161 (25.4)	1,873 (24.8)
€80-100,00	345 (15.7)	497 (26.9)	533 (36.3)	602 (42.6)	336 (53.0)	2,313 (30.6)

Household Disposable Income	Most disadvantaged SES-WOA Welfare 20%	More disadvantaged SES-WOA Welfare 20-40%	Less disadvantaged SES-WOA Welfare 40-60%	Less disadvantaged SES-WOA Welfare 60-80%	Least disadvantaged SES-WOA Welfare 80-100%	Total
	N(%)	N(%)	N(%)	N(%)	N(%)	N(%)
Non-Dutch native minoritised ethnicity						
<€20,000	31,351 (44.0)	8,853 (37.6)	4,589 (31.0)	2,656 (21.6)	690 (16.0)	48,139 (38.2)
€20-39,999	14,589 (20.5)	4,253 (18.1)	2,365 (16.0)	1,605 (13.1)	394 (9.1)	23,206 (18.4)
€40-59,999	10,651 (15.0)	3,618 (15.4)	2,269 (15.3)	1,955 (15.9)	574 (13.3)	19,067 (15.1)
€60-79,999	8,292 (11.6)	3,267 (13.9)	2,410 (16.3)	2,311 (18.8)	844 (19.6)	17,124 (13.6)
€80-100,00	6,350 (8.9)	3,532 (15.0)	3,163 (21.4)	3,746 (30.5)	1,811 (42.0)	18,602 (14.8)

Appendix Table 6.18. Cross-tabulation of number of unemployed/employed women (Number and percent (N %)) group living in each SES-WOA Employment quintile stratified by ethnicity and migration status.

Employment Status	Most disadvantaged SES-WOA Employment 20%	More disadvantaged SES-WOA Employment 20-40%	Less disadvantaged SES-WOA Employment 40-60%	Less disadvantaged SES-WOA Employment 60-80%	Least disadvantaged SES-WOA Employment 80-100%	Total
	N(%)	N(%)	N(%)	N(%)	N(%)	N(%)
Caucasian Dutch native						
Unemployed	25,765 (22.3)	20,183 (16.3)	16,985 (14.2)	13,622 (13.8)	11,860 (12.1)	88,415 (15.9)
Employed	89,742 (77.7)	103,643 (83.7)	102,504 (85.8)	85,448 (86.3)	85,922 (87.9)	467,259 (84.1)
Caucasian non-Dutch native						
Unemployed	14,355 (36.8)	7,384 (30.7)	4,459 (26.5)	2,980 (24.7)	2,409 (20.6)	31,587 (30.5)
Employed	24,619 (63.2)	16,663 (69.3)	12,355 (73.5)	9,075 (75.3)	9,311 (79.5)	72,023 (69.5)
Dutch native minoritised ethnicity						
Unemployed	692 (28.7)	373 (18.8)	246 (15.2)	191 (15.2)	198 (16.2)	1,700 (20.1)
Employed	1,716 (71.3)	1,609 (81.2)	1,370 (84.8)	1,062 (84.8)	1,022 (83.8)	6,779 (79.9)
Non-Dutch native minoritised ethnicity						
Unemployed	43,089 (54.1)	14,014 (51.8)	7,725 (49.9)	4,695 (45.5)	4,103 (34.8)	73,626 (51.0)
Employed	36,595 (45.9)	13,035 (48.2)	7,766 (50.1)	5,627 (54.5)	7,692 (65.2)	70,715 (49.0)

Appendix Table 6.19. The number (N) and proportion (%) of pre-existing medical and mental health problems in each ethnic and migration group.

	Caucasian and Dutch native	Caucasian and non-Dutch native	Minoritised ethnicity and Dutch native	Other including mixed and non-Dutch native	Mediterranean and non-Dutch native	Other African and non-Dutch native	Other Asian and non-Dutch native	Missing ethnicity and Dutch native	Missing ethnicity and non-Dutch native	Total
	N(%)	N(%)	N(%)	N(%)	N(%)	N(%)	N(%)	N(%)	N(%)	N(%)
Pre-existing medical conditions (with obesity related conditions)	174,003 (31.4)	22,642 (21.9)	2,558 (30.2)	21,865 (25.1)	3,191 (25.7)	4,752 (26.0)	3,665 (13.9)	3,979 (30.5)	1,588 (20.6)	238,243 (28.6)
Pre-existing medical conditions (without obesity related conditions)	167,760 (30.2)	21,899 (21.4)	2,478 (29.2)	21,086 (24.2)	3,067 (24.7)	4,583 (25.0)	3,540 (13.3)	3,844 (29.4)	1,532 (19.9)	229,723 (27.6)
Mental health problems	68,184 (12.3)	8,679 (8.4)	1,038 (12.3)	8,691 10.0)	1,253 (10.1)	2,005 (11.0)	1,223 (4.6)	1,613 (12.4)	635 (8.3)	93,321 (11.2)

Appendix Table 6.20. Adjusted risk ratios (and their 95% confidence intervals) of Model 1 (adjusted for age, ethnicity, migration status, year and parity) where SES-WOA Welfare has been re-categorised to be the same size in each group as household disposable income and number and percent (N (%)) of SMM in each of the new groups.

SES-WOA Welfare	SMM N	Total N	Rate %	Risk Ratio (95% CI)
Most disadvantaged 20%	2,351	117,443	2.00	1.25 (1.17-1.33)
More disadvantaged 20-40%	1,840	108,932	1.69	1.09 (1.02-1.16)
Less disadvantaged 40-60%	2,431	151,747	1.60	1.07 (1.02-1.14)
Less disadvantaged 60-80%	3,131	206,046	1.52	1.04 (0.99-1.09)
Least disadvantaged 100%	3,660	248,698	1.47	1 (ref)
ICC				0.014(0.010-0.018)

Abbreviations: ICC: Intra-class Correlation Coefficient, CI: Confidence interval

Appendix Table 6.21. Adjusted risk ratios (and their 95% confidence intervals) of Model 1 (adjusted for age, ethnicity, migration status, year and parity) where SES-WOA employment has been re-categorised to be the same size in each group individual employment status and number and percent (N (%)) of SMM in each of the new groups.

SES-WOA Employment	SMM N	Total N	Rate %	Risk Ratio (95% CI)
Low	3,772	200,065	1.89	1.14 (1.09-1.19)
High	9,641	632,801	1.52	1.00 (ref)
ICC				0.013 (0.010-0.018)

Abbreviations: ICC: Intra-class Correlation Coefficient, CI: Confidence interval

Appendix Table 6.22. Adjusted risk ratios (and their 95% confidence intervals) of Model 1 (adjusted for age, ethnicity, migration status, year and parity) where SES-WOA Education has been re-categorised to be the same size in each group individual educational attainment and number and percent (N (%)) of SMM in each of the new groups.

SES-WOA Education	SMM N	Total N	Rate %	Risk Ratio (95% CI)
Low	2,462	126,663	1.94	1.22 (1.15-1.28)
Medium	5,506	343,138	1.60	1.08 (1.03-1.12)
High	5,292	354,988	1.49	1.00 (ref)
ICC				0.013(0.010-0.018)

Abbreviations: ICC: Intra-class Correlation Coefficient, CI: Confidence interval

Appendix Table 6.23. Adjusted risk ratios (and their 95% confidence intervals) of Model 1 (adjusting for year, age, parity, migration status, and ethnicity) between the different measures of disadvantage and SMM with sepsis excluded from the composite outcome, compared to the least disadvantaged group.

	SESWOA	**SESWOA Education**	**SESWOA Employment**	**SESWOA Welfare**	**Livability**	**Household Disposable Income**		**Employment Status**		**Individual Educational Attainment**	
	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)		Risk Ratio (95% CI)		Risk Ratio (95% CI)		Risk Ratio (95% CI)
Most disadvantage 20%	1.44 (1.33-1.57)	1.48 (1.37-1.59)	1.32 (1.22-1.42)	1.45 (1.32-1.59)	1.33 (1.19-1.47)	**<€20,000**	1.69 (1.56-1.83)	**Unemployed**	1.42 (1.35-1.49)	**Low**	1.95 (1.81-2.10)
More disadvantaged 20-40%	1.22 (1.12-1.33)	1.30 (1.21-1.40)	1.14 (1.05-1.23)	1.25 (1.13-1.37)	1.29 (1.17-1.43)	**€20-39,999**	1.59 (1.46-1.72)	**Employed**	1(ref)	**Medium**	1.57 (1.48-1.66)
More disadvantaged 40-60%	1.20 (1.10-1.31)	1.22 (1.33-1.32)	1.08 (1.00-1.18)	1.21 (1.09-1.34)	1.16 (1.07-1.25)	**€40-59,999**	1.37 (1.28-1.48)			**High**	1(ref)
Less disadvantaged 20-40%	1.09 (1.00-1.20)	1.12 (1.03-1.21)	1.05 (0.96-1.14)	1.11 (1.01-1.23)	1.10 (1.02-1.19)	**€60-79,999**	1.11 (1.04-1.19)				
Least disadvantaged 20%	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)	**€80-100,00**	1 (ref)				

Abbreviations: CI: Confidence interval

Appendix Table 6.24. Characteristics of women with and without missing data for SES-WOA (number and percent (N (%)). Women with missing data on SES-WOA were excluded from the study population.

	SES-WOA	
	Not missing	**Missing**
	N(%)	**N(%)**
Total	**832,866(89.5)**	**97,307(10.5)**
SMM		
No	819,453 (98.4)	95,974 (98.6)
Yes	13,413 (1.6)	1,333 (1.4)
Parity		
Primiparous	412,058 (49.5)	51,242 (52.7)
Multiparous	420,808 (50.5)	46,065 (47.3)
Age group		
<20	7,843 (0.9)	1,061 (1.1)
20-25	70,118 (8.4)	7,317 (7.5)
25-30	248,572 (29.9)	23,626 (24.3)
30-35	319,468 (38.4)	37,561 (38.6)
35-40	154,420 (18.5)	22,244 (22.9)
>40	32,366 (3.9)	5,498 (5.7)
Ethnicity		
Caucasian	659,284 (81.2)	65,439 (67.3)
Mediterranean (North African + Turkish)	12,521 (1.5)	2,248 (2.3)
Other African	18,777 (2.3)	5,605 (5.8)
Asian	38,649 (4.8)	4,466 (4.6)
Other including Mixed	82,873 (10.2)	19,637 (20.2)
Mode of birth onset		
Induction	199,691 (24.8)	23,354 (24.0)
Primary Caesarean Birth	67,077 (8.3)	7,580 (7.8)
Spontaneous Birth	538,852 (66.9)	65,964 (67.8)
Place of birth		
At home	102,636 (12.4)	11,327 (11.6)
Birth centre	21,755 (2.6)	3,055 (3.1)
Hospital (1st line)	84,096 (10.2)	9,059 (9.3)
Hospital (2nd line)	619,364 (74.8)	73,846 (75.9)
En route	73 (0.01)	NA
Mode of birth		
Unassisted vaginal birth	579,552 (72.8)	71,657 (73.6)
Assisted vaginal birth	70,459 (8.9)	8,076 (8.3)
Elective caesarean birth	71,171 (8.9)	8,154 (8.4)
Emergency caesarean birth	74,620 (9.4)	9,380 (9.6)
Termination of pregnancy	256 (0.03)	49 (0.05)
Migration background		
Dutch native	577,211 (69.3)	50,658 (52.1)
Moroccan	29,986 (3.6)	6,695 (6.9)
Other non-western	71,381 (8.6)	12,883 (13.2)
Other western	94,429 (11.3)	15,764 (16.2)
Surinamese	18,666 (2.2)	5,670 (5.8)
Turkish	29,544 (3.6)	4,145 (4.3)
Netherlands Antilles	11,649 (1.4)	1,479 (1.5)

	SES-WOA	
	Not missing	Missing
	N(%)	N(%)
Year		
2013	101,995 (12.3)	11,171 (11.5)
2014	96,687 (11.6)	10,966 (11.3)
2015	87,025 (10.5)	10,139 (10.4)
2016	85,903 (10.3)	9,993 (10.3)
2017	84,364 (10.1)	9,818 (10.1)
2018	84,058 (10.1)	9,993 (10.3)
2019	91,526 (11.0)	10,889 (11.2)
2020	99,592 (12.0)	12,115 (12.5)
2021	101,716 (12.2)	12,222 (12.6)
Pre-existing medical conditions		
No	594,185 (71.3)	71,345 (73.3)
Yes	238,681 (28.7)	25,962 (26.7)
Substance misuse or smoking		
No	811,888 (97.5)	95,049 (97.7)
Yes	20,978 (2.5)	2,258 (2.3)
Mental health problems		
No	739,352 (88.8)	86,525 (88.9)
Yes	93,514 (11.2)	10,782 (11.1)
Obesity		
No	805,829 (96.8)	94,339 (97.0)
Yes	27,037 (3.2)	2,968 (3.1)

Appendix Table 6.25. Characteristics of women with and without missing data (number and percent (N (%)) for household disposable income, individual educational attainment and liveability.

	Household Disposable Income		Individual Educational Attainment		Liveability	
	Not missing	Missing	Not missing	Missing	Not missing	Missing
	N(%)	N(%)	N(%)	N(%)	N(%)	N(%)
	740,948(89.0)	**91,918(11.0)**	**651,171(78.2)**	**181,695(21.8)**	**738,887(88.7)**	**93,979(11.3)**
SMM						
No	728407 (98.3)	91046 (99.0)	640027 (98.3)	179426 (98.8)	727088 (98.4)	92365 (98.3)
Yes	12541 (1.7)	872 (1.0)	11144 (1.7)	2269 (1.3)	11799 (1.6)	1614 (1.7)
Parity						
Primiparous	361649 (50.8)	46407 (49.5)	327717 (44.6)	80339 (49.5)	361744 (49.3)	46312 (49.5)
Multiparous	371701 (49.2)	44996 (50.5)	316689 (55.4)	100008 (50.5)	369082 (50.7)	47615 (50.5)
Age group						
<20	6763 (0.9)	1080 (1.2)	6561 (1.0)	1282 (0.7)	7006 (1.0)	837 (0.9)
20-25	61174 (8.3)	8944 (9.7)	56803 (8.7)	13315 (7.3)	62276 (8.4)	7842 (8.3)
25-30	220849 (29.8)	27723 (30.2)	205238 (31.5)	43334 (23.9)	220110 (29.8)	28462 (30.3)
30-35	285368 (38.5)	34100 (37.1)	249820 (38.4)	69648 (38.3)	283497 (38.4)	35971 (38.3)
35-40	137891 (18.6)	16529 (18.0)	110881 (17.0)	43539 (24.0)	137179 (18.6)	17241 (18.3)
>40	28835 (3.9)	3531 (3.8)	21812 (3.4)	10554 (5.8)	28746 (3.9)	3620 (3.9)
Ethnicity						
Caucasian	588889 (81.5)	70395 (78.6)	534296 (84.1)	124988 (70.6)	583348 (81.0)	75936 (82.8)
Mediterranean (North African + Turkish)	11041 (1.5)	1480 (1.7)	8846 (1.4)	3675 (2.1)	11339 (1.6)	1182 (1.3)
Other African	16363 (2.3)	2414 (2.7)	13751 (2.2)	5026 (2.8)	16824 (2.3)	1953 (2.1)
Asian	33710 (4.7)	4939 (5.5)	21831 (3.4)	16818 (9.5)	34475 (4.8)	4174 (4.6)
Other including Mixed	72584 (10.1)	10289 (11.5)	56386 (8.9)	26487 (15.0)	74425 (10.3)	8448 (9.2)
Mode of birth onset						
Induction	177752 (24.8)	21939 (24.7)	156779 (24.9)	42912 (24.5)	177275 (24.8)	22416 (24.6)
Primary Caesarean Birth	59574 (8.3)	7503 (8.4)	49817 (7.9)	17260 (9.8)	59347 (8.3)	7730 (8.5)
Spontaneous Birth	479446 (66.9)	59406 (66.9)	423651 (67.2)	115201 (65.7)	477787 (66.9)	61065 (67.0)

	Household Disposable Income		Individual Educational Attainment		Liveability	
	Not missing	Missing	Not missing	Missing	Not missing	Missing
	N(%)	N(%)	N(%)	N(%)	N(%)	N(%)
Place of birth						
At home	91,955 (12.5)	10,681 (11.7)	82,902 (12.8)	19,734 (10.9)	90,654 (12.3)	11,982 (12.8)
Birth centre	19,297 (2.6)	2,458 (2.7)	17,035 (2.6)	4,720 (2.6)	19,397 (2.6)	2,358 (2.5)
Hospital (1st line)	74,976 (10.2)	9,120 (10.0)	65,861 (10.2)	18,235 (10.1)	74,718 (10.2)	9,378 (10.0)
Hospital (2nd line)	550,277 (74.7)	69,087 (75.6)	481,530 (74.4)	137,834 (76.4)	549,627 (74.8)	69,737 (74.6)
En route	59 (0.0)	14 (0.0)	56 (0.0)	17 (0.0)	69 (0.0)	NA
Mode of birth						
Unassisted vaginal birth	516,153 (72.9)	63,399 (72.3)	456,617 (73.3)	122,935 (71.0)	514,323 (72.8)	65,229 (72.7)
Assisted vaginal birth	62,523 (8.8)	7,936 (9.1)	55,579 (8.9)	14,880 (8.6)	62,534 (8.9)	7,925 (8.8)
Elective caesarean birth	63,222 (8.9)	7,949 (9.1)	52,841 (8.5)	18,330 (10.6)	62,966 (8.9)	8,205 (9.1)
Emergency caesarean birth	66,227 (9.4)	8,393 (9.6)	57,742 (9.3)	16,878 (9.8)	66,246 (9.4)	8,374 (9.3)
Termination of pregnancy	222 (0.0)	34 (0.0)	202 (0.0)	54 (0.0)	223 (0.0)	33 (0.0)
Migration background						
Dutch native	518,263 (70.0)	58,948 (64.1)	482,826 (74.2)	94,385 (52.0)	510,236 (69.1)	66,975 (71.3)
Moroccan	26,592 (3.6)	3,394 (3.7)	22,464 (3.5)	7,522 (4.1)	26,934 (3.7)	3,052 (3.3)
Other non-western	61,637 (8.3)	9,744 (10.6)	39,800 (6.1)	31,581 (17.4)	63,821 (8.6)	7,560 (8.0)
Other western	81,217 (11.0)	13,212 (14.4)	57,962 (8.9)	36,467 (20.1)	83,943 (11.4)	10,486 (11.2)
Surinamese	16,661 (2.2)	2,005 (2.2)	15,751 (2.4)	2,915 (1.6)	16,819 (2.3)	1,847 (2.0)
Turkish	26,247 (3.5)	3,297 (3.6)	22,259 (3.4)	7,285 (4.0)	26,774 (3.6)	2,770 (3.0)
Netherlands Antilles	10,331 (1.4)	1,318 (1.4)	10,109 (1.6)	1,540 (0.9)	10,360 (1.4)	1,289 (1.4)
Dutch native						
Yes	518,263 (70.0)	58,948 (64.1)	482,826 (74.2)	94,385 (52.0)	510,236 (69.1)	66,975 (71.3)
No	222,685 (30.0)	32,970 (35.9)	168,345 (25.8)	87,310 (48.1)	228,651 (31.0)	27,004 (28.7)

	Household Disposable Income		Individual Educational Attainment		Liveability	
	Not missing	Missing	Not missing	Missing	Not missing	Missing
	N(%)	N(%)	N(%)	N(%)	N(%)	N(%)
Year						
2013	91,122 (12.3)	10,873 (11.8)	76,288 (11.7)	25,707 (14.2)	90,733 (12.3)	11,262 (12.0)
2014	86,147 (11.6)	10,540 (11.5)	73,717 (11.3)	22,970 (12.6)	86,093 (11.7)	10,594 (11.3)
2015	77,398 (10.5)	9,627 (10.5)	67,209 (10.3)	19,816 (10.9)	77,288 (10.5)	9,737 (10.4)
2016	76,240 (10.3)	9,663 (10.5)	67,357 (10.3)	18,546 (10.2)	76,233 (10.3)	9,670 (10.3)
2017	74,675 (10.1)	9,689 (10.5)	66,179 (10.2)	18,185 (10.0)	74,694 (10.1)	9,670 (10.3)
2018	74,667 (10.1)	9,391 (10.2)	66,360 (10.2)	17,698 (9.7)	74,364 (10.1)	9,694 (10.3)
2019	81,207 (11.0)	10,319 (11.2)	72,592 (11.2)	18,934 (10.4)	81,203 (11.0)	10,323 (11.0)
2020	88,779 (12.0)	10,813 (11.8)	79,665 (12.2)	19,927 (11.0)	88,278 (12.0)	11,314 (12.0)
2021	90,713 (12.2)	11,003 (12.0)	81,804 (12.6)	19,912 (11.0)	90,001 (12.2)	11,715 (12.5)
Pre-existing medical conditions						
No	526,509 (71.1)	67,676 (73.6)	457,442 (70.2)	136,743 (75.3)	527,440 (71.4)	66,745 (71.0)
Yes	214,439 (28.9)	24,242 (26.4)	193,729 (29.8)	44,952 (24.7)	211,447 (28.6)	27,234 (29.0)
Substance misuse or smoking						
No	722,075 (97.4)	89,813 (97.7)	633,902 (97.4)	177,986 (98.0)	720,295 (97.5)	91,593 (97.5)
Yes	18,873 (2.6)	2,105 (2.3)	17,269 (2.6)	3,709 (2.0)	18,592 (2.5)	2,386 (2.5)
Mental health problems						
No	656,956 (88.7)	82,396 (89.6)	575,349 (88.4)	164,003 (90.3)	656,164 (88.8)	83,188 (88.5)
Yes	83,992 (11.3)	9,522 (10.4)	75,822 (11.6)	17,692 (9.7)	82,723 (11.2)	10,791 (11.5)
Obesity						
No	716,599 (96.7)	89,230 (97.1)	629,117 (96.6)	176,712 (97.3)	714,912 (96.8)	90,917 (96.7)
Yes	24,349 (3.3)	2,688 (2.9)	22,054 (3.4)	4,983 (2.7)	23,975 (3.2)	3,062 (3.3)

Appendix Table 6.26. Risk ratios (and their 95% confidence intervals) of the association between household disposable income quintiles and SMM compared to the highest household disposable income quintile using multiple imputation for missing data. Model 1* adjusted for age, ethnicity, migration status, year and parity. Model 2** additionally adjusted for pre-existing medical conditions, substance misuse, pre-existing mental health conditions.

Household Disposable Income Quintile	**Univariable**	**Model 1***	**Model 2****
	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)
<€20,000	1.39 (1.32–1.47)	1.34 (1.26–1.43)	1.27 (1.20–1.35)
€20-39,999	1.30 (1.23–1.38)	1.30 (1.22–1.38)	1.23 (1.16–1.31)
€40-59,999	1.16 (1.10–1.22)	1.19 (1.12–1.26)	1.15 (1.08–1.21)
€60-79,999	1.05 (1.00–1.10)	1.07 (1.02–1.13)	1.05 (1.00–1.11)
€80-100,00	1 (ref)	1 (ref)	1 (ref)
FMI	0.0635	0.0658	0.060

Abbreviations: CI: Confidence Interval, FMI: Fraction of Missing Information

Appendix Table 6.27. Risk ratios (and their 95% confidence intervals) of the association between individual educational attainment level and SMM compared to the highest educational attainment level using multiple imputation for missing data. Model 1* adjusted for age, ethnicity, migration status, year and parity. Model 2** additionally adjusted for pre-existing medical conditions, substance misuse, pre-existing mental health conditions.

Individual Educational Attainment	**Univariable**	**Model 1***	**Model 2****
	Risk Ratio (95% CI)	Risk Ratio (95% CI)	Risk Ratio (95% CI)
Low	1.47 (1.40–1.55)	1.41 (1.33–1.50)	1.30 (1.29–1.39)
Medium	1.28 (1.23–1.32)	1.28 (1.23–1.34)	1.21 (1.15–1.26)
High	1 (ref)	1 (ref)	1 (ref)
FMI	0.1485	0.1741	0.1755

Abbreviations: CI: Confidence Interval, FMI: Fraction of Missing Information

Appendix Table 6.28. Characteristics of the study population with missing data. Number and percent N (%).

	Most disadvantaged 20%	More disadvantaged 20-40%	Less disadvantaged 40-60%	Less disadvantaged 60-80%	Least disadvantaged 80-100%	Total
	N=245,783	**N=191,521**	**N=158,269**	**N=134,403**	**N=102,890**	**N=832,866**
SMM						
No	241,231 (98.2)	188,554 (98.4)	155,827 (98.5)	132,401 (98.5)	101,440 (98.6)	819,453 (98.4)
Yes	4,552 (1.9)	2,967 (1.6)	2,442 (1.5)	2,002 (1.5)	1,450 (1.4)	13,413 (1.6)
Age Group						
<20	3,982 (1.6)	1,755 (0.9)	1,049 (0.7)	724 (0.5)	333 (0.3)	7,843 (0.9)
20-25	31,066 (12.6)	17,166 (9.0)	11,137 (7.0)	7,150 (5.3)	3,599 (3.5)	70,118 (8.4)
25-30	77,825 (31.7)	60,478 (31.6)	47,919 (30.3)	37,738 (28.1)	24,612 (23.9)	248,572 (29.9)
30-35	81,913 (33.3)	72,504 (37.9)	63,203 (39.9)	56,595 (42.1)	45,253 (44.0)	319,468 (38.4)
35-40	41,040 (16.7)	32,981 (17.2)	29,016 (18.3)	26,938 (20.0)	24,445 (23.8)	154,420 (18.5)
>40	9,934 (4.0)	6,616 (3.5)	5,932 (3.8)	5,243 (3.9)	4,641 (4.5)	32,366 (3.9)
Missing	**23 (0.0)**	**21 (0.0)**	**13 (0.0)**	**15 (0.0)**	**NA**	**NA**
Parity						
Primiparous	122,848 (50.0)	98,377 (51.4)	77,741 (49.1)	65,603 (48.8)	47,489 (46.2)	412,058 (49.5)
Multiparous	122,935 (50.0)	93,144 (48.6)	80,528 (50.9)	68,800 (51.2)	55,401 (53.8)	420,808 (50.5)
Missing	**0 (0.0)**	**0 (0.0)**	**0 (0.0)**	**0 (0.0)**	**0 (0.0)**	**0 (0.0)**
Ethnicity						
Caucasian	157,668 (64.2)	157,983 (82.5)	137,056 (86.6)	116,946 (87.0)	89,631 (87.1)	659,284 (79.2)
Mediterranean (North African + Turkish)	7,846 (3.2)	2,071 (1.1)	1,026 (0.7)	939 (0.7)	639 (0.6)	12,521 (1.5)
Other African	11,897 (4.8)	3,376 (1.8)	1,673 (1.1)	1,139 (0.9)	692 (0.7)	18,777 (2.3)
Asian	16,658 (6.8)	7,846 (4.1)	5,349 (3.4)	4,771 (3.6)	4,025 (3.9)	38,649 (4.6)
Other including mixed	45,401 (18.5)	15,366 (8.0)	9,159 (5.8)	7,454 (5.6)	5,493 (5.3)	82,873 (10.0)
Missing	**6,313 (2.6)**	**4,879 (2.6)**	**4,006 (2.5)**	**3,154 (2.4)**	**2,410 (2.3)**	**20,762 (2.5)**
Mode of birth onset						
Induction	61,873 (25.2)	46,807 (24.4)	37,621 (23.8)	30,789 (22.9)	22,601 (22.0)	199,691 (24.0)
Elective Caesarean Birth	20,121 (8.2)	15,095 (7.9)	12,847 (8.1)	10,614 (7.9)	8,400 (8.2)	67,077 (8.1)
Spontaneous Birth	154,092 (62.7)	123,600 (64.5)	103,117 (65.2)	89,048 (66.3)	68,995 (67.1)	538,852 (64.7)
Missing	**9,697 (4.0)**	**6,019 (3.1)**	**4,684 (3.0)**	**3,952 (2.9)**	**2,894 (2.8)**	**27,246 (3.3)**

	Most disadvantaged 20%	More disadvantaged 20-40%	Less disadvantaged 40-60%	Less disadvantaged 60-80%	Least disadvantaged 80-100%	Total
	N=245,783	**N=191,521**	**N=158,269**	**N=134,403**	**N=102,890**	**N=832,866**
Place of birth						
At home	20,408 (8.3)	24,259 (12.7)	22,868 (14.4)	19,695 (14.7)	15,406 (15.0)	102,636 (12.3)
Birth centre	8,351 (3.4)	4,533 (2.4)	3,253 (2.1)	3,309 (2.5)	2,309 (2.2)	21,755 (2.6)
Hospital (1st line)*	24,008 (9.8)	18,686 (9.8)	15,671 (9.9)	13,846 (10.3)	11,885 (11.6)	84,096 (10.1)
Hospital (2nd line)**	191,240 (77.8)	142,901 (74.6)	115,586 (73.0)	96,842 (72.1)	72,795 (70.8)	619,364 (74.4)
En route	26 (0.0)	15 (0.0)	17 (0.0)	NA	NA	73 (0.0)
Missing	**1,750 (0.7)**	**1,127 (0.6)**	**874 (0.6)**	**703 (0.5)**	**488 (0.5)**	**4,942 (0.6)**
Mode of birth						
Unassisted vaginal birth	168,322 (68.5)	133,006 (69.4)	110,767 (70.0)	94,303 (70.2)	73,154 (71.1)	579,552 (69.6)
Assisted vaginal birth	20,426 (8.3)	16,617 (8.7)	13,438 (8.5)	11,509 (8.6)	8,469 (8.2)	70,459 (8.5)
Elective caesarean birth	21,378 (8.7)	16,047 (8.4)	13,601 (8.6)	11,262 (8.4)	8,883 (8.6)	71,171 (8.6)
Emergency caesarean birth	23,983 (9.8)	17,567 (9.2)	13,673 (8.6)	11,277 (8.4)	8,120 (7.9)	74,620 (9.0)
Termination of pregnancy	56 (0.0)	56 (0.0)	47 (0.0)	53 (0.0)	44 (0.0)	256 (0.0)
Missing	**11,618 (4.7)**	**8,228 (4.3)**	**6,743 (4.3)**	**5,999 (4.5)**	**4,220 (4.1)**	**36,808 (4.4)**
Migration background						
Dutch native	124,212 (50.5)	139,803 (73.0)	124,926 (78.9)	106,999 (79.6)	81,271 (79.0)	577,211 (69.3)
Moroccan	18,633 (7.6)	5,076 (2.7)	2,563 (1.6)	2,139 (1.6)	1,575 (1.6)	29,986 (3.6)
Other non-western	33,436 (13.6)	14,904 (7.8)	9,812 (6.2)	7,458 (5.6)	5,771 (5.6)	71,381 (8.6)
Other western	33,308 (13.6)	22,209 (11.6)	15,801 (10.0)	12,903 (9.6)	10,208 (9.9)	94,429 (11.3)
Surinamese	9,954 (4.1)	3,094 (1.6)	2,040 (1.3)	1,963 (1.5)	1,615 (1.6)	18,666 (2.2)
Turkish	19,029 (7.7)	4,542 (2.4)	2,102 (1.3)	2,114 (1.6)	1,757 (1.7)	29,544 (3.6)
Netherlands Antilles	7,211 (2.9)	1,893 (1.0)	1,025 (0.7)	827 (0.6)	693 (0.7)	11,649 (1.4)
Missing	**0 (0.0)**	**0 (0.0)**	**0 (0.0)**	**0 (0.0)**	**0 (0.0)**	**0 (0.0)**

	Most disadvantaged 20%	More disadvantaged 20-40%	Less disadvantaged 40-60%	Less disadvantaged 60-80%	Least disadvantaged 80-100%	Total
	N=245,783	**N=191,521**	**N=158,269**	**N=134,403**	**N=102,890**	**N=832,866**
Year						
2013	29,582 (12.0)	23,289 (12.2)	20,018 (12.7)	16,491 (12.3)	12,624 (12.3)	101,004 (12.1)
2014	33,402 (13.6)	27,076 (14.1)	22,668 (14.4)	18,647 (13.9)	14,461 (14.0)	116,254 (14.0)
2015	38,446 (15.7)	29,301 (15.2)	23,793 (15.1)	20,481 (15.4)	15,402 (15.0)	127,423 (15.3)
2016	42,960 (17.4)	31,976 (16.6)	26,649 (17.0)	22,501 (16.8)	17,439 (17.0)	141,525 (17.0)
2017	40,391 (16.5)	30,366 (15.8)	25,624 (16.3)	21,442 (16.0)	16,354 (15.9)	134,177 (16.1)
2018	31,981 (13.0)	25,776 (13.4)	20,697 (13.1)	17,135 (12.8)	12,965 (12.7)	108,554 (13.1)
2019	17,595 (7.2)	12,538 (6.5)	10,533 (6.7)	8,756 (6.5)	6,736 (6.6)	56,158 (6.7)
2020	7,536 (3.1)	5,707 (3.0)	4,301 (2.7)	3,802 (2.8)	3,042 (3.0)	24,388 (2.9)
2021	2,530 (1.0)	1,483 (0.8)	1,324 (0.8)	1,305 (1.0)	1,230 (1.2)	7,872 (0.9)
Missing	**0 (0.0)**	**0 (0.0)**	**0 (0.0)**	**0 (0.0)**	**0 (0.0)**	**0 (0.0)**

*1st line = midwifery and GP led care, 2nd line= obstetrician led care