



Improving discovery in maternity care: data-to-knowledge in maternal Learning Health Systems

by

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Abstract

Background

Maternity services in the UK face significant pressure and scrutiny. Simultaneously, electronic health record adoption and new technologies create opportunities to use data collected by maternity services for improvement. However, poor quality, inaccessible, and unstructured data limits its use for quality improvement and research, particularly for complex problems such as dramatic differences in maternal mortality rates between social groups. Learning Health Systems (LHS) approaches are an approach to strengthening continuous improvement in services by capturing practice as data, using data to generate new knowledge, and implementing new knowledge into practice.

Objectives

This thesis aims to improve the data-to-knowledge part of the Learning Health Systems in maternity services.

Methods

This thesis presents a series of studies that first explore how data-to-knowledge in LHS could support maternity services, then deploys infrastructure in a maternity service to build towards a LHS capable of using the solutions explored in earlier chapters.

To explore the use of LHS, a systematic review of Clinical Decision Support Systems in maternity, methods development for automated analytics of electronic

health records, and a cohort study of health inequalities in comorbidities at the start of pregnancy in primary care electronic health records were conducted.

A data platform was then deployed in a local maternity service, and two case studies demonstrate epidemiological analysis that could inform support maternity services in providing care.

Results

The systematic review showed that Clinical Decision Support Systems were effective in improving care, but careful attention to design and context are essential for success. Software for automated analysis is presented and evaluated in an ectopic pregnancy example. Systematic analysis of health inequalities shows systematic differences in diagnosis of health conditions amongst different social groups, with increased diagnoses in women from more deprived areas and reduced diagnoses in women from minoritised ethnic groups.

Deployment of the data platform enabled epidemiological studies using routinely collected care data. Two case studies showed that despite differences in access to induction between groups, there was no difference in outcomes achieved, and that eligibility for trial recruitment varied significantly by socioeconomic characteristics. This data was then used to target recruitment efforts to ensure representative inclusion in the trial.

Conclusions

This thesis demonstrates progress towards LHS and identifies future developments required to support maternity services. Careful attention to localised

context is required to effectively use data to generate actionable knowledge. Long term investment of informatics capabilities is required to support maternity services and improve outcomes for women and babies across society.

To NG, because of whom this thesis was almost never written.

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Contribution Statement

Two published manuscripts are included as chapters in this thesis and a third manuscript has been submitted for publication. All manuscripts contain statements of contributions; for all manuscripts, I conceptualised studies, designed methods, curated data, conducted analysis, and drafted the original and final versions of manuscripts, with the support of my supervisors Professor Krishnarajah Nirantharakumar, Professor Joht Singh Chandan, Dr Beck Taylor, and Professor William Parry-Smith.

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Thesis Format

This thesis is formatted in accordance with the University of Birmingham alternative format thesis guidelines [Regulation 7.4.1 \(g\)](#).

As a result, accepted, published or manuscripts under submission (Chapters 3-5) will be inserted directly into the thesis. As per the alternate thesis guidelines, the pages of publications will not be included in the pagination sequence of the submitted thesis. To maintain numerical clarity of the references, tables and figures, these are self-contained within each chapter.

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Glossary of Abbreviations

CAPE	Calcium supplementation for Prevention of pre-Eclampsia in high-risk women
CDSS	Clinical Decision Support System
CI	Confidence Interval
CLI	Command Line Interface
COC	Continuity of Carer
CPRD	Clinical Practice Research Datalink
DExtER	Data Extractor for Epidemiological Research
DWH	Data WareHouse
EHR	Electronic Health Records
ETL	Extract-Transform-Load
FUPS	Flawed, Uncertain, Proximate, and Sparse
HICs	High Income Countries
IMD	Index of Multiple Deprivation
IoM	Institute of Medicine
LHS	Learning Health Systems
LMICs	Low- and Middle-Income Countries
MBCK	Mobilising Biomedical Computable Knowledge
MLTCs	Multiple Long Term Conditions
MMAT	Mixed Methods Assessment Tool
MSDS	Maternity Services DataSet
NIHR	National Institute for Health Research
OR	Odds Ratio
PAS	Patient Administration System
RCT	Randomised Controlled Trial
RR	Risk Ratio
SaTH	Shrewsbury and Telford Hospitals trust
UoB	University of Birmingham

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1. Introduction

1.1. Maternity units are struggling to deliver safe and effective services

UK maternity services have faced intense pressure and scrutiny in recent years, and maternal mortality has risen from 8.5 deaths per 100,000 pregnancies in 2012-2014 to 13.6 deaths in every 100,000 pregnancies in 2020-2022.(1) Maternal health inequalities, which contribute to high mortality rates, have been a persistent and well-documented issue in the UK for decades.(1) Rising numbers of families living in poverty drive worse outcomes, and the health of women living in the most deprived areas is deteriorating across the board.(2,3) Although some gaps have narrowed, such as the maternal mortality rate in black women compared to white, this is due to outcomes getting worse for white women rather than improvements for black women.(1) Deteriorating outcomes occur despite the enormous growth in knowledge and technical capabilities in healthcare,(4) and for many population groups, effective solutions that close the gap in outcomes have yet to be developed and implemented.

The pressure on maternity services is further evidenced by the major maternity scandals that have affected several hospitals in the past decade, and NHS England's maternity safety programme has enrolled over 34 hospital trusts to address safety issues.(5) In 2022, the Ockenden report published findings on concerns in Shrewsbury and Telford Hospitals trust (SaTH). This report reviewed over 1,500 clinical incidents and stated that SaTH *"failed to investigate, failed to learn and failed to improve, and*

therefore often failed to safeguard mothers and their babies". Many of the recommendations in the report specifically addressed learning, for individual staff, the service, and the wider organisation, emphasising the need to proactively learn from experiences in the service. Learning encompasses not only the discovery of problems and solutions, but also includes changes in practice and error correction implemented as a result of discovery that leads to improving outcomes.(6,7)

1.2. Learning Health Systems can support maternity services by using data

Learning Health Systems (LHS) may offer a path forward to improving outcomes in maternity services by scaling up investigation, learning and improvement across the system.(8) LHS "marry together discovery and implementation" in learning cycles that support services to learn from every patient they care for.(9) Discovery and knowledge creation using data collected by maternity services can support improvement through several strategies, such as audit and feedback, and population health management.(10,11) LHS tend to be discussed in the context of new informatics technologies that enable pooling and assembling vast quantities of information to address health problems within a system.(12) The potential for services, such as a hospital-based maternity department, to utilise these technologies for learning may be a key solution to reversing the trends in maternal health outcomes.

Technologies such as electronic health records have enabled the generation, storage, and utilisation of vast quantities of data.(13) Concurrently, UK strategies have sought to improve secondary uses (non-clinical uses) of this data, for example through

professionalisation of the analyst workforce, programmes such as Making Data Count, and policy such as Data Saves Lives.(14–16) However, problems remain in the use of this data which is often poor quality, inaccessible, or unstructured, limiting the discovery that can be undertaken. The NHS maintains emphasis on curated datasets, and effective maternity data use remains an area of active research.(17,18)

SaTH underwent an improvement journey implementing the recommendations made in the two Ockenden reports,(6) and commissioned the University of Birmingham to deploy a data platform called “the Data Extractor for Epidemiological Research” (DExtER) for use with Electronic Health Record (EHR) data generated in delivering maternity care in the trust. This platform was commissioned with a LHS approach in mind; although wider organisational changes were not planned, the platform was intended to support continuous learning through governance and research mechanisms. The work of this thesis was conducted within the context of the SaTH-DExtER project, focussing on how to conduct discovery within a maternity service that can then support a service to work as a learning health system. Improving discovery could address part of the Ockenden critique on the lack of learning at SaTH, identify potential improvements in quality of care, and lead to better understanding of local population needs.

1.3. Research question, aims, and objectives

This thesis therefore seeks to answer “How can maternity services be supported to learn from data they capture?”. The aim of this thesis is to improve the data-to-knowledge part of the LHS in maternity services.

1.3.1. Objectives

1. To contextualise the potential of LHS in improving maternity services.
2. To synthesise and meta-analyse published evidence on Clinical Decision Support Systems (CDSS) use in maternity services as an element of the LHS.
3. To develop methods for routinely transforming data-to-knowledge using EHR in maternity services.
4. To systematically describe existing national health inequalities in pregnant women.
5. To demonstrate the data-to-knowledge element of LHS through case studies in maternal health inequalities.

1.4. The structure of this thesis

This thesis proposes that maternity services can support a LHS approach to improving outcomes and addressing health inequalities by using routinely generated data to create new knowledge. However, no explicit evidence exists on LHS use in maternity services, and so this thesis aims to synthesise and generate evidence on LHS approaches to discovery in maternity services. LHS may take many years to develop as they require the mobilisation of a complex system around new goals and implementing new technologies. Reaching the “full” LHS vision is therefore outside the scope of this PhD, but the deployment of the DExtER platform at SaTH offers the opportunity to observe the effects on a service of the impact of a data-to-knowledge intervention. The empirical components of this thesis therefore focus on data-to-knowledge approaches to managing health inequalities, but with reference to and

awareness of the importance of ensuring knowledge is implemented in practice and how practice is captured in data.

Chapter 2 further describes the background and context to the use of LHS in maternity services, considering in detail how LHS are theorised to work and how this could be applied in maternity services. It will then describe the issues of health inequalities in detail and consider how LHS approaches might address health inequalities, contributing to theory on how LHS can support maternity services.

Chapter 3 reports a systematic review of CDSS, which are used to implement knowledge into practice and hence are a common technique studied and utilised within LHS. This systematic review provides an overview of all evaluated systems designed for maternity care, reporting their effectiveness while identifying important design approaches and context on how they can be used effectively by services. Considering the purpose and mechanisms of these systems can help to identify whether they can be used to solve problems in maternity services.

Chapter 4 then outlines methods for automating the analysis of incidence and prevalence in open cohort designs, a type of epidemiological study design commonly used in EHR analysis. This is applied to ectopic pregnancies, and ethnic and socioeconomic deprivation inequalities in the diagnosis of ectopic pregnancy are identified to demonstrate how such automated analyses can be used to drive action on health inequalities.

Chapter 5 then extends these methods to a systematic analysis of inequalities in 79 health conditions in pregnancy, presenting a novel approach to identifying within- and between-group health inequalities using routinely collected data. Such an

approach can be used within a LHS to drive further learning cycles, directing attention towards important and tractable health inequalities.

Chapters 3, 4, and 5 together set out general tools and strategies that can be used to generate knowledge from data and implement knowledge into practice. Chapter 6 outlines the deployment of a data platform into a maternity service to support usage of routinely generated EHR data, then reports two case studies exemplifying how routinely collected data can be used for discovery within a framework of user journeys that describe how discovery can lead to action and care improvements.

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2. Background

This chapter will first outline theory around LHS, describing their role in meeting maternity service challenges.(1-3) It will then describe some of the challenges facing maternity services, outlining the deterioration in outcomes, the structural pressures on services, and the persistence and complexity of health inequalities. This will be followed by discussion of how LHS can support maternity services in learning to meet these challenges, with particular attention paid to the role of LHS in addressing maternal health inequalities.

Finally, the chapter will describe the data platform DExtER and the role of technology in enabling discovery within maternal LHS, describing some of the anticipated benefits of this technology in a maternity service.

2.1. What is a Learning Health System?

2.1.1. Defining Learning Health Systems

The LHS concept is usually attributed to the Institute of Medicine in 2007, who envisioned LHS as systems where *"science, informatics, incentives, and culture are aligned for continuous improvement and innovation"*.(1) The idea developed from business studies literature, where Learning Organisations were described as *"an organization skilled at creating, acquiring, and transferring knowledge, and at modifying its behaviour to reflect new knowledge and insights."*(2,3) Decades later, healthcare adapted the idea; LHS may consist of multiple organisations, and was conceived during a time of increasing

complexity in healthcare,(4), a focus on quality of healthcare,(5) and adoption of data infrastructure such as the Electronic Health Record (EHR).(6)

Since 2007, definitions have evolved. Friedman et al. (2014) interpreted the LHS in two ways: as *“a system that uses data and analytics to continuously learn from every patient”* and as *“an infrastructure underpinned by shared governance, incentives, and values”*.(7) The latter interpretation, focusing on socio-technical elements, has become a widely cited alternative.(8)

2.1.1.1. Data driven formulations

Pomare et al.’s bibliometric review found that most LHS literature operationalised the concept as the integration of data analysis into routine care, often prioritising informatics over organisational or cultural dimensions.(8) Somerville et al.’s review identified that data capture was the most common characteristic of LHS, while governance and culture features were the least commonly reported characteristics.(9) Enticott et al.’s review categorised papers as describing LHS based on a set of data utilisation criteria, and Hollestelle et al. mirror these data-focussed ideas when describing LHS to recently pregnant women in their study of public views.(10,11)

2.1.1.2. Organisational and implementation formulations

Recent contributions highlight the socio-technical and organisational aspects of LHS. Friedman’s later editorial describes three distinguishing features of LHS:

- 1) Continuity of a learning community.
- 2) Operating under uncertainty.

3) A socio-technical infrastructure that enables learning at scale.(12)

These characteristics differentiate LHS from other quality improvement systems. They also differ from earlier LHS concepts, by focusing less on technology and more on iterative, community-based learning.

Foley et al., in their guidance on building LHS, avoid proposing new definitions, instead describing LHS implementation as a set of decisions around technologies, context, and goals.(13) Structuring LHS as a set of clearly definable decisions that need execution will support the development of an evidence base. While the existence of many such frameworks fragment the field,(14,15) this may reflect Foley et al.'s advice to produce internal goals and strategies.

Ellis et al. observed this fragmentation in their scoping review of LHS implementation.(16) They found that only one out of 53 included studies used an established implementation framework; Nevedal et al. used the Consolidated Framework for Implementation Research.(17) By contrast, Ellis et al. found that five out of 76 included studies developed new frameworks.(16) Somerville et al.'s contemporaneous review of LHS implementation only included 35 studies, despite their similar designs.(9) After categorising implementation strategies, they found only eight studies reported influencing the health system to value learning and improvement.

Approaches to building LHS can be difficult to evidence through an implementation lens, which prefers clearly defined strategies to implement clearly defined interventions.(18) LHS interventions often need to be localised and developed in situ,(19) and Friedman argues that uncertainty about solutions is intrinsic to LHS; dynamically evolving implementations may be challenging to evaluate.(12)

2.1.1.3. *Implications of definitions*

Given the challenges in defining LHS, many evidence reviews leave it to primary studies to define themselves as LHS.(20–22) The proliferation of conceptual reviews and their inconsistent findings highlight both the evolving nature of LHS and a need for adaptable, context-sensitive definitions. The sustained use of the Institute of Medicine's (IoM) flexible formulation reflects this requirement.

Within this thesis, I will adopt the later Friedman conception of LHS as a learning community, operating under uncertainty, with a sociotechnical infrastructure that supports learning cycles. I will also specify that a learning community should have an explicit concept of itself and some of its members, and that learning will solve challenges that the learning community sets for itself. Learning will be considered to include both discovery of new knowledge, but more importantly improvement and use of knowledge. Organisational Learning, for example, is often defined as “error correction”.(3) However, as will be discussed in section 2.3, none of the empirical work of this thesis is conducted inside an active LHS. The aim of this work is to identify whether and how an LHS data-to-knowledge approach could support maternity services through systematic and contextualised learning methods. The next section will therefore review mid-range and program theory applied to LHS to consider how an LHS may improve health and care.

2.1.2. *How does a Learning Health System work?*

Learning is often cited as the mechanism for improvement in LHS.(12,21) Learning what works, ensuring timely dissemination of knowledge, and building systems that are good at learning are core themes in how LHS are theorised.

2.1.2.1. Learning cycles

Friedman et al expressed this core mechanism as learning cycles, where practice is captured as data, data generates new knowledge, and new knowledge is implemented into practice.(19) This iterative improvement cycle is acknowledged as rooted in the Plan-Do-Study-Act cycles of Deming, now heavily used in healthcare.(23,24) The cycle enables clear articulation of technical and procedural requirements as outlined in figure 2.1, and learning is thought of as the completion of a loop and not only discovery of new knowledge. Figure 2.1 shows how the three stages of the learning cycle can be broken down into additional steps that may be required in typical learning cycles.

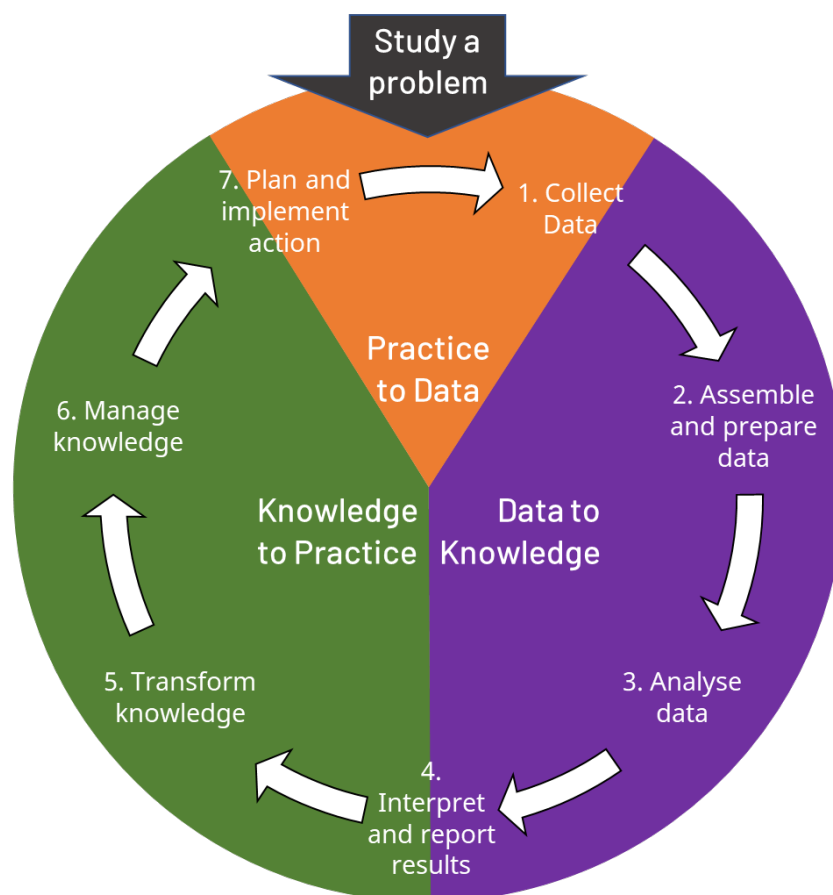


Figure 2.1: Learning cycles. Adapted from Flynn et al. (25) and Friedman (12)

LHS operate through nested cycles, addressing problems from improving data collection and to developing health policy.(12) Learning cycles may occur at different levels such as learning within machines, individuals, teams, or organisations. The most impactful changes may require learning across organisations, but organisational learning requires multiple steps before an idea is used in practice or otherwise adopted.

2.1.2.2. Absorptive capacity

Absorptive capacity refers to an organisation's ability to acquire, assimilate, transform, and apply new knowledge to generate improvements.(26) Harvey et al. identify determinants of absorptive capacity as internal factors, such as infrastructure, organisational strategy, and the mental models that shape action, and external factors such as knowledge sources, funding, policy and regulatory drivers.(27) For example, the technology supply of EHR and data science tools that enable discovery will be determined by broader market forces, standards and regulatory science, and policy decisions on which standards to adopt.(28–30)

The complexity of aligning these elements often obscures the value proposition of LHS. Many evaluations focus on quality improvement as a measurable outcome, yet foundational capabilities like absorptive capacity may need to precede observable impact.(31) Without a clear advantage over current systems, LHS implementation may face inertia, especially when services are under pressure; the next section will consider how LHS may add value to health activity.

2.1.2.3. Value creation modes

Stabell and Fjeldstad describe three healthcare production modes: value chains, shops, and networks.(32) The three modes refer to value chains, value shops, and value networks, described in table 2.1.

Table 2.1: Value creation in a maternity learning health system. Adapted from Fjeldstad and Fjeldstad. (33,34)

Value creation mode	Value chains	Value shops	Value networks
Description	Linear predictable healthcare processes	Clinical decision-making contexts	Collaborative relationships where information and resources are shared
Example	An operating theatre that receives a patient requiring a caesarean section, healthcare staff, and surgical equipment, and conducts a successful operation.	A specialist clinic managing pregnant women with gestational diabetes making a birth plan.	Patients with multiple long term conditions self-manage their conditions, seeking support as required from other patients, nurses, and doctors.
LHS Contribution	Quality Improvement (35)	Optimise Clinical Decision Support Systems (36)	Learning community Knowledge dissemination Scale (37)

Larger networks can link up more actors, with greater information sources and data assets, but the ever-growing connections within large networks make it harder to facilitate the high quality relationships that create value.

Each mode benefits from LHS capabilities, but value networks are especially aligned with Friedman’s LHS principles: community co-production, management of uncertainty, and infrastructure for knowledge mobilisation.(12)

Networks facilitate coproduction, and Collaborative LHS models like ImproveCareNow exemplify coproduction with patients as active partners.(34,38)

Increasingly complicated care generates uncertainty, for example in multimorbidity where guidelines conflict with each other. Increasing levels of multimorbidity require involvement of multiple specialists, but the value shop model requires a physician to own the problem.(33,39) Hanley et al found pregnant women were required to take ownership of their care to navigate a network of individual value shop; a well-designed network would carry more of this responsibility.(40)

LHS must therefore enable clinicians to access diverse, synthesised information sources but such attempts have led to cognitive overload at the volume of information that physicians must manage.(41) With expanding knowledge assets, such as genomics, AI, and patient experiences, clinicians cannot maintain expertise across all domains. LHS must thus provide mechanisms for knowledge mobilisation beyond human expertise alone.(42) For example, Callahan et al. report an informatics consultation service, where they perform observational studies that inform a clinical decision on request, and Lai et al synthesise systematic review, observational study, and mendelian randomisation to inform a single clinical decision.(43,44) LHS must thus provide mechanisms for knowledge mobilisation beyond human expertise alone, and the learning community remains central to connecting these modes, especially under conditions of uncertainty, where actors depend on the system to locate and mobilise relevant expertise.(12,45,46)

Much of the technical work of LHS focuses on using and deploying informatics, but enabling these technologies to serve patients and populations to their full potential requires reconfiguring health services into LHS. Many novel informatics technologies

have been created but even old technologies have struggled to be implemented in healthcare.

2.2. Maternity services under pressure

2.2.1. Maternal health outcomes are deteriorating

The long running trend of improving health in the UK has stalled, and life expectancy for women living in the most deprived areas is falling.(47,48) Maternal health outcomes have been particularly affected, with the reversal of a decade of progress into reducing maternal mortality, a key international population health benchmark.(49,50) In 2020-2022, 13.6 mothers in every 100,000 pregnancies died, compared to the lowest rate in 2012-2014 of 8.5 deaths per 100,000 pregnancies.(49) For black women in 2020-2022, this rate was 2.9 times higher than white women's mortality rate, at 35.1 deaths per 100,000 pregnancies. Although the gap has narrowed since 2017-19, this is driven by rising mortality among white women in recent years, and the gap has remained present since 2010. Furthermore, while mortality amongst white women fell during early 2010s, amongst black women the trend appears to consistently rise.

Outcomes are deteriorating at a time when the absolute number of pregnancies is falling, and in 2022-2024 was 15% lower than in 2012-2014.(49) Falling numbers needing care might be expected to translate to falling demand, but increasing complexity has eaten away any possible slack. UK morbidity rates rose 7.2% between 2010 and 2021 for women aged 15-49,¹(51,52) and the average age of mothers at birth

¹ Morbidity calculated for women aged 15-49 years old using Years Lived with Disability (YLDs) data extracted from Global Burden of Disease(1) according to the PHE approach(2). 2010 YLDs 2503.3 per 100,000 women aged 15-49, in 2021 YLDs 2684.35 per 100,000 women aged 15-49

has increased to 30.9 in 2022, up from 29.5 in 2010.(53) These pressures have had a human cost in their impact on women's health and experiences in pregnancy and on babies' outcomes, but outcomes remain worse where inequalities existed.

2.2.2. Maternity care capacity is severely constrained

Maternity services are under significant and rising pressure in the UK. The Ockenden inquiry into SaTH marked the beginning of increasing concerns and inquiries into maternity care, followed by investigations at Nottingham and Kent,(54) and SaTH was also the first trust to enter the Maternity Safety Support Programme in July 2018, with the second trust entering in December 2019.(55) Between then and August 2023, a further 32 trusts entered the programme. At the same time, significant service stress has been generated by workforce shortages and Covid-19. The midwifery workforce has grown by 1.1% in the past 4 years while general NHS workforce has increased by 14.1%, and the disruptions and service reconfiguration required by Covid have increased the risk of long-term illness in workforce.(56–59)

Standards of care in maternity have also changed to require significantly more resource to deliver. For example, recent evidence has led to recommendations for many more women to receive induction of labour instead of labouring spontaneously.(60) Induction of labour requires greater resourcing; longer hospital stays, higher staffing intensities per pregnancy, and more medicalised care.(61) Similarly, before increases in demand for induction of labour came changes to scan pathways and the first Saving Babies Lives initiative in NHS England, which significantly increased demand for ultrasound scanning across the entire maternal population.(62) Continuity of Carer (COC) refers to women who receive all of their maternity care from

the same midwife or midwifery team. COC is associated with reduced intervention and better experiences of care during pregnancy,(63) and multiple policies implementing COC have been attempted in the UK.(64) However, rates of COC have been falling for all population groups in recent years, with the England average falling from 23.7% in September 2021 to 19.5% in July 2023.(65) This is despite COC being identified as a key NHS policy by the Core20PLUS5 approach and briefly implemented as a target for ethnic minority groups of 75%. COC rates fell following de-implementation of the target. In September 2021, 31.7% of pregnant women from the most deprived areas had a COC plan, while in least deprived areas this was 20.8%. In June 2022, after the target was both implemented and then de-implemented, 22.7% of women in most deprived areas had a COC plan while 28.2% of women in least deprived areas had a COC plan. The NHS has struggled to implement some of these resource intensive care policies, and has also struggled to target them towards populations most likely to benefit from these interventions.(64,66,67)

2.2.3. Inequalities in maternal outcomes are persistent, complex, and the gap is widening

Health inequalities are systematic differences in health between population groups,(68) implying injustice in social arrangements that reduce overall population wellbeing. While historic conceptions focused on socioeconomic status,(68) attention increasingly addresses exclusion based on ethnicity, gender, sexuality, and intersections between these characteristics.(69–71)

Pressures across the health ecosystem particularly affect women with pre-existing disadvantages.(48,49,55) Women in socioeconomically deprived areas face

higher pregnancy mortality rates: in the most deprived 20% of areas in England, 21.28 women died for every 100,000 pregnancies in 2021-2023, 2.2 times higher than in the least deprived areas. In 2017-19, mortality rates in the most deprived areas were 1.8 times higher than the least deprived areas.(49)

Many groups experience disproportionate adverse pregnancy outcomes. Higher rates of miscarriages and postpartum haemorrhage have been observed in sex workers compared to matched controls,(72) and elevated rates of preterm birth, low birth weight, and infant mortality in Gypsy, Roma and Traveller communities.(73) The odds of pregnant women in prisons giving birth preterm are 1.78 times higher than the general population,(74) while other important complications such as post-partum haemorrhage appear similar to the general population.(75) No analysis appears to have been published on outcomes in care leavers and young people looked after by local authorities, despite their specific vulnerabilities and limited family support during pregnancy.(76)

Health inequalities stem from complex drivers affecting both care quality and the wider determinants of health. Women from more deprived backgrounds face increased risks of adverse pregnancy outcomes due to rising income inequality, in-work poverty, and food insecurity.(47,77,78) Rates of disability in women living in the most deprived areas have increased from 9% in 2011 to 16% in 2021, and they are twice as likely to report poor health as women in the least deprived areas.(79)

Intersecting vulnerabilities compound these challenges. Non-white women, especially asylum seekers, are more likely to live in deprived areas. Undocumented migrant women receive substandard care with a reduced sense of control during

pregnancy due to precarious economic, legal, and social status.(80) Women whose preferred language is not English struggle accessing health information and interpreting services, frequently resulting in late booking appointments.(49) Few interventions to improve these issues have been robustly evaluated.(81) Vulnerable migrant pregnant women were more likely to have previous obstetric complications and less likely to take folic acid than non-migrants.(82)

2.2.4. Maternal health inequalities and the role of Learning Health Systems

Maternity services have limited influence over the wider social determinants of health but do address health inequalities through interventions during pregnancy and the postnatal period. However, available interventions are limited.(66) For example, in 2019, the National Institute for Care and Clinical Excellence (NICE) gave advice that black women should have a lower threshold for induction of labour to address the heightened risk of stillbirth in their pregnancies. However this policy was criticised as a blunt instrument that constrained women's choices without addressing causes.(83)

In contrast, ROSHNI-2 is a Randomised Controlled Trial (RCT) of a culturally adapted intervention for post-natal depression in 732 British south Asian women. Published in October 2024, it found an adjusted odds ratio for recovery from depression of 2.0 (95% Confidence Interval (CI) 1.3–3.1) at 4 months in those receiving the intervention, fading to 1.0 (95% CI 0.6 to 1.7) at 12 months.(84) The trial was funded £2.1 million in 2016, at which point the intervention itself had already been developed.(85) Developing and evaluating tailored interventions is a long and

expensive process, but health inequalities are urgent and maternity services are faced with many different health problems needing tailored intervention.

Table 2.2 outlines concepts and strategies for addressing health inequalities according to Benach et al. who outline a typology of 4 public health strategies.(86) Targeted interventions aimed at a specific population strata deliver improvement for worst off, but little change elsewhere. Universal policies with additional focus on gaps can address health inequalities while providing for others too, but can be inflexible to gradients in health inequalities. Redistributive policies are more attentive to the gradient in health inequalities, but the most advantaged see no benefit. Proportionate universalism (universal with sliding scale benefits gradient) enable all to benefit, with the greatest benefits accruing to those with the greatest need.

Table 2.2 Strategies to address health inequalities. Adapted from Benach et al. (86)

Approach	Examples	Programme Logic
Targeted interventions and/or health gap focus	Core20PLUS5 (87)	Specific targeting of health services and interventions to groups who experience health inequalities
Universal plus focus on gap	Continuity of Carer expansion in maternity (65)	Aim to increase availability for all pregnancies while focusing on ethnic minorities and deprived populations
Redistributive	Public funded healthcare available at the point of need (86)	Greater funding towards NHS provided by less deprived populations with fewer health needs
Proportionate universalism	Public health grant funding (88)	Funds granted to areas according to local need

NHS England advocates for maternity services to take a proportionate universal approach to health inequalities.(67) Maternal health inequalities are complicated by intersectionality, whereby multiple overlapping characteristics create a qualitatively different health experience that has an important impact on outcomes.(89) Examples such as elevated stillbirth rates among black women from the most deprived areas underscore the importance of the interaction of multiple disadvantages.(89,90) While

diverse population groups are cumulatively large enough that overall population health data registers their poor health, individual groups often lack sufficient statistical power for clear advocacy messages.

Effectively addressing this diversity requires healthcare systems to first understand, describe, and identify solutions for varied populations, moving beyond a single-risk factor approach to understanding inequalities.⁽⁹¹⁾ Using the data-to-knowledge component of a learning health system to discover what the health problems are and to monitor and evaluate health services towards what works, building the strengths of applied health research into services.⁽⁹²⁾

However, major challenges exist in describing different population groups, in data quality, and in identifying and prioritising the breadth of needs. UK data limitations significantly constrain understanding of health inequalities. For example, socioeconomic deprivation measured using the Scottish and English Index of Multiple Deprivation (IMD) not interchangeable and comparison is challenging.⁽⁹³⁾ Ethnicity categories correspond better to race as described internationally,⁽⁹⁴⁾ while data systems often push de-contextualised constructs between countries.⁽⁹⁵⁾ Much maternity data is poorly coded, with limited coding expertise and frequently changing datasets resulting in weak standards.⁽⁹⁶⁾

Delivering tailored services remains poorly understood and resource-intensive, as developing bespoke services for varied populations poses significant challenges.⁽⁹⁷⁾ Meeting the highly varied needs of the increasingly diverse UK population requires managing enormous complexity, particularly difficult for struggling services against a background of rising pressure on maternity care and worsening outcomes. While data-

to-knowledge approaches offer valuable tools, they are not a silver bullet and require substantial investment in data infrastructure, analytical capabilities, and service redesign capacity.

2.3. Where do learning health systems fit into maternity services?

2.3.1. A maternal health learning cycle

Maternity services increasingly use learning cycles to improve quality and safety, optimize resource use, and evaluate new care delivery methods.(92,98) A LHS approach to maternity services would aim to scale up learning cycles, increasing the volume, speed, and productivity of learning to increase adoption of learning approaches.

For example, clinicians refer women identified as smokers to stop smoking service, where they receive intensive smoking cessation counselling and support.(99) When services identify improving attendance rates as a priority to enhance cessation outcomes, they can implement a systematic learning cycle.(100,101)

Practice-to-data: Electronic health record systems capture information on eligible women, referrals made, attendance rates, cessation support received, successful quit rates, and pregnancy outcomes. Understanding this flow requires assembling data from multiple record systems while recognizing local data limitations.

Data-to-knowledge: Analysis of this data reveals where the care pathway fails and identifies groups of women less likely to receive optimal treatment. This generates operational insights for immediate action, alongside strategic insights about data quality issues and service cost-effectiveness.

Knowledge-to-practice: Services act on these insights by increasing capacity at identified bottlenecks, training clinicians to improve referrals for specific population groups, addressing data collection weaknesses, and using cost-effectiveness evidence to advocate for program expansion.

Subsequent learning cycles can use the same structures, such as data analyses, mobilised stakeholders and expertise, and appetite for change and improvement, to evaluate and refine these interventions. A LHS should aim to support maternity services by organising processes and technology to enable each of the steps in the learning cycle, and this thesis focuses on enabling the data-to-knowledge step of the learning circle.

2.3.2. Enabling data-to-knowledge in maternity services

Data that can inform learning loops is increasingly captured in Electronic Health Records (EHRs). UK maternity services capture data in a variety of EHRs, which have received broad adoption over the past two decades.⁽²⁹⁾ Some standardisation of data occurs through billing using ICD-10 codes and through submission to the Maternity Services DataSet.⁽¹⁰²⁾ Data is otherwise collected and structured according to record system design and local practice.

Significant variation exists in data collection practices between pregnancies, influenced by presentation of women to services, individual health care staff practices, concurrent service pressure, condition-specific features hospital-level record systems and guidance, and many other factors.^(30,103) Much relevant data is captured in unstructured clinical notes unsuitable for quantitative analysis, and while natural

language processing of these notes into structured data is possible, few algorithms or validated software packages exist in maternity.(96)

Despite these limitations, NHS services increasingly use this data for discovery—enhancing patient care through audit, quality improvement, surveillance, population health management, and research.(104,105) The widespread adoption of electronic health records and advances in data science technologies create opportunities to enable more systematic discovery using routinely collected health data.

To address this opportunity, Chapters 4, 5, and 6 will demonstrate how the DExtER software platform can analyze routinely collected maternity data, partially automating the "Assemble and prepare data" step of the learning cycle described in Figure 2.1. This approach supports the transition from data collection to actionable knowledge, enabling maternity services to implement more effective, evidence-based improvements in care delivery.

2.3.3. The Data Extractor for Epidemiological Research

DExtER is the Data Extractor for Epidemiological Research and was developed to prepare Primary Care data for epidemiological analysis, historically using prepared datasets from Clinical Practice Research Datalink and The Health Improvement Network.(106) It is centred on an Extract-Transform-Load (ETL) architecture to provide users with analysis-ready datasets based on three epidemiological study designs: cohort, cross-sectional, and case-control studies. Extracts from DExtER are referred to as studies, reflecting the academic environment it was developed for. DExtER is therefore an expert system that abstracts the technical process of preparing data for

epidemiological analysis. Users were previously epidemiologists who understood principles of study designs and had technical analysis skills.

SaTH maternity services undertook a Maternity Transformation Programme in response to findings from the Ockenden Report.⁽⁵⁴⁾ This improvement journey was seen as an opportunity to trial new organisational and technical approaches:

“Continuous evaluation of this [programme] from the outset provides an opportunity to create a LHS, with technical, procedural, and cultural orientation of the services around continuous quality improvement” (Appendix 2.1 “Project Initiation Document”, page 1). The concept for this LHS developed in March 2021 is presented in Figure 2.2, with the combination of DExtER and electronic health records playing a central role in learning cycles for quality improvement and research. Using DExtER for quality improvement was a novel application, but was presumed to have fewer technical requirements in data preparation and that the available study designs could be used to serve data needs within the maternity service.

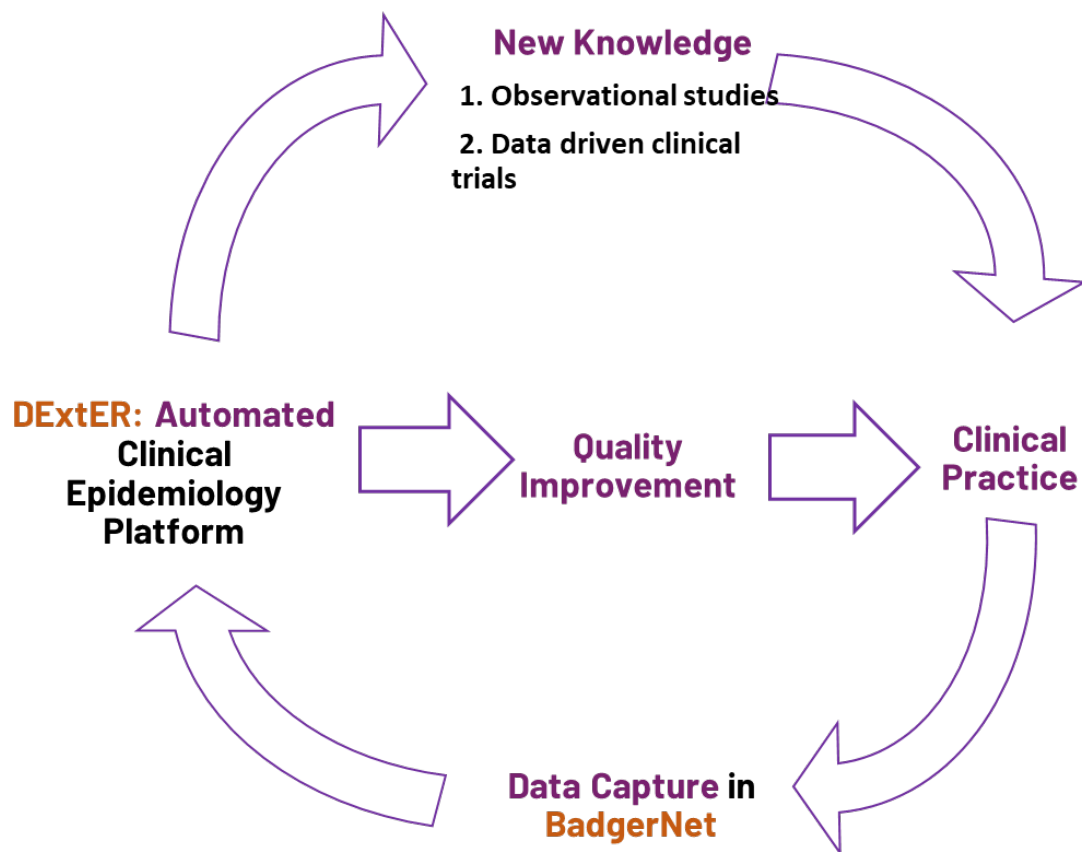


Figure 2.2 A Learning Health System for Shrewsbury and Telford Hospitals trust.

2.3.4. Maternity services can be supported by turning Data into Knowledge

2.3.4.1. *Scaling up what works*

Semi-automated approaches like DExtER can increase EHR data availability for secondary use, reducing costs while improving the speed and rigor of improvement cycles. Although audit and feedback represent a well-evidenced strategy for implementing effective care, variable cost-effectiveness limits their widespread application.(107) These data can improve health services in multiple ways, including by addressing health inequalities through need assessments,(108) population health

management,(109) and public accountability which can maintain trust.(110) Greater data linkage and curation enables richer insights and more targeted interventions.

Many hospitals and health systems implement similar analysis and reporting structures to understand local health needs, but transportability of such analyses are limited. Professionalisation of analytical staff has helped to share learning,(111) but open science principles emphasising open code and reproducibility has had limited uptake.(112) Transportability of learning can be achieved throughout the learning cycle, reusing the knowledge outputs, the learning process, and even the problem statement and solution requirements identified. Adoption of standards may facilitate learning through the system, but the digital maturity that drives such work varies between settings and so standards will not achieve uniform impact.(113)

Specific challenges to scaling up all kinds of learning exist, and so LHS will need to make trade-offs about what learning needs to be scaled and what infrastructures to scale. The political work of agreeing standards, technical work of designing and deploying standards, developing tools that allow the standards to drive value, and variation in capabilities across systems, emphasises the challenge of developing digital maturity that supports LHS.(19) Scaling the work of the LHS is neither the start point, which is technically unfeasible, nor the endpoint, as infrastructure alone does not deliver health benefits. Scale will vary throughout the LHS, just as learning cycles themselves vary in scale.

2.3.4.2. Working with uncertainty

The solutions to many maternal health problems remain uncertain, especially when tailoring care amongst diverse populations. While many interventions have been

developed and increasing policy attention is focussed on reducing disparities in maternal health,(84,114,115) research gaps persist, and trials and guidance that could reduce uncertainty have long production timelines and limited scope due to expense.

Given this uncertainty, systems must attempt untested solutions, ranging from novel interventions to complex systems change and reform. Consistent evaluation is essential to ensure learning from effective approaches, yet a systematic review of quality improvement programs in English maternity services found none received rigorous evaluation.(116) Stronger evaluative and meta-learning capabilities within systems will support dissemination throughout the system, generating momentum and insights for effective scale up,(117) while improving absorptive capacity for both internal and external knowledge sources. For example, the researcher-in-residence model, where researchers work within an organisation according to service-based priorities and processes, has been found to produce strong research outputs while supporting quality improvement through the application of theory and evaluation.(118,119)

2.3.4.3. LHS should support the increasingly high volumes of expertise required to deliver care

The enormous growth in medical knowledge is increasingly difficult for individual clinicians to manage.(40,120,121) As more interventions are developed for diverse health problems, more specialists may need involvement in individual care, challenging the traditional patient-doctor dyad discussed in section 2.1.2.3. Clinical care must increasingly operate within facilitated networks, where clinicians or patients who “own” care are comfortable working under uncertainty and beyond the limits of their

competence by using the expertise available in the network, as reflected in the new fetal medicine networks.(54,122) Expertise includes actors such as experts by experience, and all cadres of healthcare staff, but also information assets.

Many of these information assets are not new. CDSS, developed in the 1970s,(123) sit at the pinnacle of Haynes' hierarchy of evidence sources for their ability to give patient-specific advice linked to current, evidence-based guidelines.(124) Human authored, expert advice systems have become ubiquitous in EHR and evidence generally points towards effectiveness in improving care processes,(125) but also to diminishing returns as cognitive overload and assertive designs disrupt clinical workflows.(126) Development of CDSS that represent guidelines have long production timelines due to the many intermediate steps between guideline development and CDSS deployment. This can leave the CDSS up to date with relevant evidence for only a short period due to the rapid development cycles of new evidence and technology.(127)

Unwarranted variation in care within maternity services could be addressed using CDSS to drive standardisation. When evidence does not yet exist to inform individual care needs, information assets could be mined to provide evidence on-demand. For example, Stanford's data science consult describes an Informatics Consultation service for observational causal inference studies to inform complex, rare decisions beyond specialist knowledge.(128) New research techniques, performed on vast, contemporaneous datasets compliment traditional bibliographic searches. Lai et al demonstrate this approach for Warfarin use for patients with cirrhosis,(44) identifying no randomized trials to inform this decision but conducting systematic reviews of

observational studies, new on-demand studies, and Mendelian randomization studies, finding concordance across approaches.

Many proponents of LHS have argued that technologies like CDSS and Informatics Consultations are key to future care delivery, and not only shapers of organisational structures.(19,42,110,129) New clinical knowledge must be acquired continuously, with knowledge exploitation extending beyond local adoption of guidelines to include technologies that can manage the increasingly cluttered information environment. Investment must therefore go beyond technical infrastructure and ensure strong absorptive capacity within the LHS, as rapid technology lifecycles mean speedy deployments will be key to realising benefits to maternity services.

2.4. Conclusions

Maternity services must continue to improve services, learning from experience and applying new knowledge, and LHS approaches can help to build this into organisations to deliver learning at scale. Data-to-knowledge processes in particular can increase the productivity of approaches such as quality improvement, identify health inequalities, or evaluate effectiveness of new approaches. Dexter can be used to scale up discovery by semi-automating data-to-knowledge steps, as will be demonstrated in Chapters 4, 5, and 6. However, increasing the scale of discovery will also require information management in clinical contexts, and so the next chapter will consider the role CDSS by conducting a systematic review of CDSS used in maternity care.

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3. Clinical Decision Support Systems for Maternal Health

Chapter 1 outlined the concept of LHS and the potential for reducing health inequalities. Chapter 2 presents a manuscript for a systematic review of CDSS and their use in maternal health. CDSS receive significant attention within the Learning Health Systems literature as a mechanism for representing the knowledge generated from data. No reviews existed of the use of CDSS within maternity care prior to this study, and few studies considered the impacts of using CDSS on health inequalities. Given the lack of evidence empirical literature on health inequalities, this chapter synthesises the broader evidence base for CDSS in maternity care.

Manuscript 1: Clinical decision support systems for maternity care: a systematic review and meta- analysis

Clinical decision support systems for maternity care: a systematic review and meta-analysis

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Summary

Background The use of Clinical Decision Support Systems (CDSS) is increasing throughout healthcare and may be able to improve safety and outcomes in maternity care, but maternity care has key differences to other disciplines that complicate the use of CDSS. We aimed to identify evaluated CDSS and synthesise evidence of their impact on maternity care.

Methods We conducted a systematic review for articles published before 24th May 2024 that described i) CDSS that ii) investigated the impact of their use iii) in maternity settings. Medline, CINAHL, CENTRAL and HMIC were searched for articles relating to evaluations of CDSS in maternity settings, with forward- and backward-citation tracing conducted for included articles. Risk of bias was assessed using the Mixed Methods Assessment Tool, and CDSS were described according to the clinical problem, purpose, design, and technical environment. Quantitative results from articles reporting appropriate data were meta-analysed to estimate odds of a CDSS achieving its desired outcome using a multi-level random effects model, first by individual CDSS and then across all CDSS. PROSPERO ID: CRD42022348157.

Findings We screened 12,039 papers and included 87 articles describing 47 unique CDSS. 24 articles (28%) described randomised controlled trials, 30 (34%) described non-randomised interventional studies, 10 (11%) described mixed methods studies, 10 (11%) described qualitative studies, 7 (8%) described quantitative descriptive studies, and 7 (8%) described economic evaluations. 49 (56%) were in High-Income Countries and 38 (44%) in Low- and Middle-Income countries, with no CDSS trialled in both income categories. Meta-analysis of 35 included studies found an odds ratio for improved outcomes of 1.69 (95% confidence interval 1.24–2.30). There was substantial variation in effects, aims, CDSS types, context, study designs, and outcomes.

Interpretation Most CDSS evaluations showed improvements in outcomes, but there was heterogeneity in all aspects of design and evaluation of systems. CDSS are increasingly important in delivering healthcare, and Electronic Health Records and mHealth will increase their availability, but traditional epidemiological methods may be limited in guiding design and demonstrating effectiveness due to rapid CDSS development lifecycles and the complex systems in which they are embedded. Development methods that are attentive to context, such as Human Centred Design, will help to meet this need.

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Keywords: Clinical decision support; Systematic review; Maternity; Obstetrics; mHealth

Introduction

Preventing maternal mortality and morbidity is a core objective for health systems and forms a key metric for

health performances, part of both Millenium Development Goals and Sustainable Development Goals.^{1,2} However, progress is faltering in both the Global



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Research in context

Evidence before this study

Clinical Decision Support Systems (CDSS) have been used in healthcare for decades to improve medical decision making. Systematic reviews of both generalist and specialist CDSS have identified modest improvements in care using CDSS, but searching for CDSS and maternity in Medline, PROSPERO, and Cumulative Index to Nursing and Allied Health Literature (CINAHL) identified no reviews of CDSS use in maternity care, which is complicated by unique decision problems and risk management and thus requires its own evidence synthesis.

Added value of this study

This study identifies evaluations of CDSS in maternity care, providing the first systematic review of all evaluated CDSS and synthesising a varied evidence base. It finds that evaluated CDSS generally succeed in achieving the stated aims of CDSS,

and provides a database of CDSS and their features that will aid clinicians, developers, implementers, and researchers of CDSS in maternity care in building and evaluating future CDSS.

Implications of all the available evidence

CDSS can make substantial contributions to maternity outcomes and care, but effective CDSS interventions in one context may not translate to other settings. CDSS are designed and deployed throughout maternal healthcare but few receive robust evaluations in healthcare practice and the breadth of designs in CDSS require a wide variety of disciplinary expertise to effectively research and deploy. Further research into the key ingredients of CDSS and robust design methods may help to support future implementations.

North and South with the world's maternal mortality rate unchanged since 2013 after falling by 30% between 2000 and 2013.³ Khalil et al. report eight countries with significant rises in maternal mortality between 2000 and 2020, six of which are Low and Middle-Income Countries (LMICs) and two of which are High Income Countries (HICs).⁴ The burden of mortality is unequally distributed; in 2020, maternal mortality rate per 100,000 live births ranged from 1222.5 in South Sudan to 1.1 in Belarus.

Safe maternity care is a particular challenge to health systems. Maternity care is a safety critical speciality; even in HICs where adverse event rates are low,⁵ any adverse events can have tragic lifelong consequences for a child, mother or family.^{6,7} Conversely, maternity is a normal physiological process and so intervention should only take place where indicated to improve safety, the birthing experience, and to avoid unnecessary resource utilisation.^{5,8} Maternity care also faces decision challenges unique to healthcare in balancing risks between mother and foetus, such as in pre-eclampsia where earlier delivery treats a life threatening maternal condition, but can increase harm to a baby through preterm birth.⁹ Increased litigation rates exist in this pressured environment, and in 2018/2019 obstetrics accounted for 50% of medical litigation costs in the National Health Service (NHS).¹⁰ Reports into maternity care in the UK frequently highlight unsafe care, often focusing on variation in practice between settings and lack of risk assessment.^{11–13} There is therefore a need to standardise practice, support risk stratification, improve safety and inform decision making. Clinical Decision Support Systems have been proposed to achieve these goals.

Clinical Decision Support Systems (CDSS) are typically electronic tools that provide information to users that alters healthcare decision making.¹⁴ CDSS therefore

improve care by firstly altering decisions,¹⁵ usually of healthcare staff although some target patients, leading to altered behaviour.¹⁶ CDSS that target safety of care or changes in practice can be viewed as implementation strategies, aiming to improve uptake of desired processes of care that lead to improved outcomes. For example, a CDSS may aim to increase rates of a process such as blood pressure monitoring according to guidelines, which leads to better treatment and fewer adverse outcomes such as eclampsia.¹⁷ Meta analyses often find modest impacts on measures of processes measures but few identify meaningful impacts on clinical outcomes,^{18,19} and there is little evidence to support relationships between specific CDSS features and the prediction of improvements in outcomes. Matching features to context may be key,^{20,21} and a USA-based study found that in a safety test of 8 Electronic Health Record (EHR) systems with built-in prescribing support deployed across 62 hospitals, variation in hospital safety was greater within systems than between systems.²² The maturity of these systems within hospitals, staff resources and buy-in, and hospital expertise were identified as affecting safety. Interactions between CDSS and their environment may lead to unintended consequences such as workflow interruption and alert fatigue,^{23–25} and case studies have reported lethal consequences varying from cognitive disruptions during complex tasks, to delaying essential and emergency care.²⁶

A wide variety of CDSS exist which could be used to address maternal health problems.²⁷ No systematic reviews of maternity CDSS have been published or registered to date. Speciality-specific or non-speciality systematic reviews of CDSS have been undertaken, which tend to exclude systems used in maternity care as they may be CDSS with multidisciplinary users or which use specialist software.^{17–19}

Most maternity CDSS are developed for local or national implementation, with international tools such as the WHO's SMART guidelines requiring local adaptation to deploy.²⁸ The unique nature of maternity care decisions means that specialist CDSS tailored to individual contexts are likely to be required. This study therefore aims to answer the questions "What CDSS have been deployed and evaluated in maternity settings?" and "Are CDSS able to improve maternity care?"

Methods

This review was pre-registered to PROSPERO CRD42022348157 and written according to PRISMA guidelines.

Information sources and search strategy

Articles from peer-reviewed journals identified via electronic database searches and citation tracing were included in this review. We performed database searches on 17th August 2022 without date restrictions and updated in Medline on May 24th 2024. We searched CINAHL, Medline, HMIC and CENTRAL using the search strategy in [Supplementary File 1](#), which required search terms describing maternity care, such as "pregnancy", and a health informatics resource, such as "decision support". We performed forward and backward citation tracing in articles included for full-text review in Web of Science™ by extracting all references from papers and all articles citing the included paper. These papers were then included for screening, and this process was repeated until saturation was reached and no new papers included.

Eligibility criteria

We included all articles investigating the impact of a CDSS in maternity care decisions. Wyatt et al. define a CDSS as a "system that uses two or more items of patient data to generate case-specific or encounter-specific advice".²⁹ CDSS can have a variety of different functions to support healthcare decision making including, but not limited to:

- Providing prognosis and risk-stratification advice.³⁰
- Ensuring safety of care processes e.g. medication errors,³¹ antibiotic stewardship,³² guideline compliance.³³
- Task-shifting to support new cadres of healthcare staff perform tasks.³⁴
- Knowledge management and implementation of practice changes.^{35,36}
- Supporting patients to understand outcomes of different courses of action and make informed decisions.¹⁶

We therefore included articles meeting the following three criteria:

- 1) Maternity care decisions could include decisions made by patients or practitioners, but must pertain to healthcare at any stage of pregnancy; we included deployments of risk calculators but excluded studies evaluating non-medical behaviour change only, such as weight loss advice, or neonatal care only.
- 2) An 'impact' study evaluating a deployed CDSS that was used to support real-world clinical decisions and could have changed practice, outcomes, and patient experiences during the study. We excluded studies such as simulations or laboratory studies of a CDSS, comparisons with expert opinion, or development and validation of risk calculators.
- 3) We use Wyatt's definition of a decision support system,²⁹ including studies where any component of the intervention was a CDSS.

No language restrictions were used in screening.

Procedures

Searches were exported into Endnote v20 from the different databases and deduplicated using the method by Bramer et al.³⁷ A copy of this library was shared between reviewers, and recombined following screening to review discrepancies in inclusion. NC and CO independently performed a two-step process screening first titles and abstracts, and then full-text articles, for studies meeting our eligibility criteria. Discrepancies in inclusion were resolved by discussion between screeners. Adjudication by a third reviewer was available but never required.

Data were extracted from included articles into an Excel spreadsheet extraction form ([Supplementary 2](#)). Data was extracted by multiple reviewers for 30% of papers, ensuring that all reviewers cross-checked against every other reviewer and agreed finalised extractions, to ensure consistency across all reviewers. Disagreements were resolved by discussion or adjudicated by a third author if agreement could not be reached.

Where possible, quantitative results were extracted as odds ratios (OR) for binary outcomes with control groups, n (%) for binary outcomes without control groups, mean differences for continuous outcomes with control groups and mean (sd) for continuous outcomes without control groups. These items were calculated where feasible if not available in the original articles. Adjusted results from author analyses were extracted if presented as either OR and RR and compared the effect of a CDSS group to another group.

Text describing rationale and design of systems was copied from articles for content analysis to taxonomise the types of tools.

Statistics

We used the Mixed Methods Assessment Tool (MMAT) to assess studies for risk of bias,³⁸ except for economic studies which were assessed using the Drummond checklist.³⁹ Studies were considered to be at low risk of

bias overall if every dimension of the tool was low risk of bias.

Included results were summarised in tables and meta-analysed. Content analysis of decision problems, rationales, types of CDSS, and CDSS environment was used to systematically describe papers. We used the Wright taxonomy to categorise CDSS into 6 types: Expert Systems, Point of Care Alerts and Reminders, Workflow Support, Order Facilitators, Relevant Information Display, and Medication Dosing Support.²⁷ We meta-analysed all quantitative binary outcomes available across included interventional studies, using a multi-level random effects model from the metafor R package⁴⁰ that first estimated effects at the level of individual tools, then combined effects across all tools. We also meta-analysed by RCT and non-randomised interventional study subgroups. Heterogeneity was assessed using Cochran's Q and I² statistics. Publication bias was assessed using funnel plots and Egger's test. A sensitivity analysis was conducted using studies considered at low risk of bias, with further details included in [Supplementary 3](#).

Role of funding source

This study was not funded by any external body.

Results

Study selection

The initial search query was run on 17th August 2022. 7 rounds of citation tracing are described further in [Supplementary 4](#) and a repeat in Medline only

conducted on 24th May 2024. Most records were retrieved from database and register searches (9072 unique records) and supplemented by citation tracing (2967 records) ([Fig. 1](#)).

Study characteristics

[Table 1](#) describes characteristics of 87 reports included, of which 30 (34%) were quantitative non-randomised intervention designs and 24 (28%) were randomised controlled trials. Seven (8%) were quantitative descriptive designs, ten (11%) were qualitative and ten (11%) were mixed methods designs integrating both a qualitative and quantitative component. Seven (8%) were economic evaluations. 38 (44%) studies were conducted in LMICs, six of which took place in both Low and Lower-middle income countries. 73 studies (83%) were conducted in secondary care or tertiary settings compared with 35 (40%) in primary care settings such as community midwifery. 68 (78%) studies focused on interventions and decisions in antenatal care, with 38 (44%) investigating intrapartum decisions and only four (5%) investigating postpartum care. [Fig. 2](#) shows the number of published articles by country, with the United Kingdom having the largest number of identified publications (19, 22%) and publications heavily concentrated in English speaking countries.

Risk of bias in studies

Full risk of bias assessments are presented in [Supplementary 5](#). Eleven out of 87 studies were assessed as low risk of bias: one RCT,⁴² five qualitative studies,^{43–47}

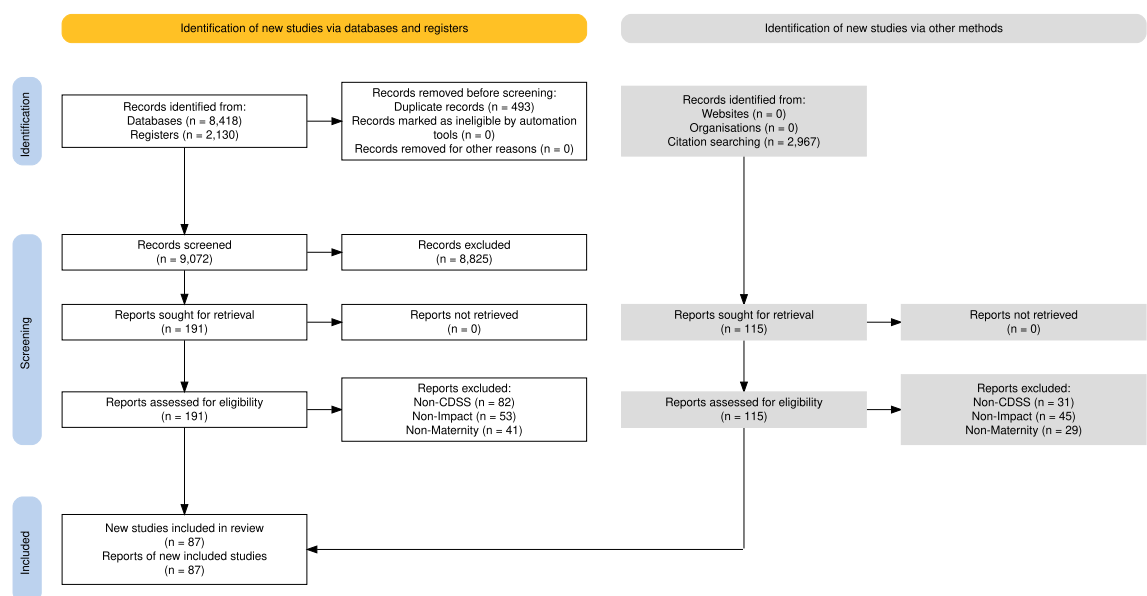


Fig. 1: PRISMA flow diagram of article selection for this study.⁴¹ Period from September-2022 to May 2024 updated in medline only. CINAHL: Cumulative Index to Nursing and Allied Health Literature; CENTRAL: Cochrane Central Register of Controlled Trials; HMCIC: The Health Management Information Consortium database.

Article	Name	Additional description of CDSS	Decision problem	System rational	CDSS type level 1	CDSS environment	Study type	Country, year	Level of healthcare
Klumpner et al., 2020	AlertWatch OB	electronic maternal surveillance system to generate automated alerts on the labor and delivery unit based on alert criteria from he Maternal Early Warning Criteria (MEWC)	Monitoring	Trigger referral for critically ill patients; prevent missed diagnoses; improve clinical effectiveness;	Point-of-care alerts/ reminders;	Software program	Qualitative	USA, April 2017–February 2019	Secondary care or higher;
Klumpner et al., 2018	AlertWatch OB	electronic maternal surveillance system to generate automated alerts on the labor and delivery unit based on alert criteria from he Maternal Early Warning Criteria (MEWC)	Monitoring	Trigger referral for critically ill patients; prevent missed diagnoses; improve clinical effectiveness;	Point-of-care alerts/ reminders;	Software program	Quantitative descriptive	USA, April 2017–July 2017	Secondary care or higher;
Abasian Kasegari et al., 2020	Active labour diagnosis admission protocol	Admission protocol for women in active labour	Monitoring	standardise care; prevent missed diagnoses; Guideline adherence	Expert systems;	Paper;	RCT	Iran, September 2017–December 2017	Secondary care or higher;
Cheyne et al., 2008	Active labour diagnosis algorithm	Algorithm to improve the diagnosis of active labour in primiparous women	Monitoring	standardise care; prevent missed diagnoses; Guideline adherence	Expert systems;	Paper	RCT	UK, April 2005–June 2007	Secondary care or higher;
Usmanova et al., 2020	ASMAN	Alliance for Saving Mothers and Newborns. Provider-facing electronic platform for peripartum care including Safe Childbirth Checklist and embedded Safe Delivery App	Monitoring	Trigger referral; Guideline adherence;	Workflow Support;	Phone App;	Qualitative	India, June 2017–May 2020	Primary care; Secondary care or higher;
Usmanova et al., 2021	ASMAN	Alliance for Saving Mothers and Newborns. Provider-facing electronic platform for peripartum care including Safe Childbirth Checklist and embedded Safe Delivery App	Monitoring	Trigger referral; Guideline adherence;	Workflow Support;	Phone App;	Quantitative non-randomised	India, August 2017–March 2020	Primary care; Secondary care or higher;
Horner et al., 2013	BACIS program	The Bacis (Basic Antenatal Care Information System) Program designed to improve compliance with South African antenatal guidelines	Screening	guideline adherence; improve clinical effectiveness; standardise care	Point of care alerts/ reminders; Workflow support	Software program	Quantitative non-randomised	South Africa, January 2011–June 2011	Primary care;
Luitjes et al., 2020	BIG CHANGE	BOS supported Implementation of Guidelines on Clinical Hypertension and its mANagement in GEstation trial. Computerised DSS to improve implementation of evidence-based guidelines on the management of hypertension in pregnancy	Medical conditions and prescribing	Guideline adherence; standardise care;	Expert Systems;	Software program; EHR; paper guideline	Economic evaluation	Netherlands, April 2010–May 2011	Secondary care or higher;
Luitjes et al., 2018	BIG CHANGE	BOS supported Implementation of Guidelines on Clinical Hypertension and its mANagement in GEstation trial. Computerised DSS to improve implementation of evidence-based guidelines on the management of hypertension in pregnancy	Medical conditions and prescribing	Guideline adherence; standardise care;	Expert Systems;	Software program; EHR; paper guideline	RCT	Netherlands, April 2010–May 2011	Secondary care or higher;

(Table 1 continues on next page)

Article	Name	Additional description of CDSS	Decision problem	System rational	CDSS type level 1	CDSS environment	Study type	Country, year	Level of healthcare
(Continued from previous page)									
Abejirinde et al., 2018a	Bliss4Midwives	Diagnostic decision support for antenatal care in rural settings to reduce pregnancy-related complications by improving quality antenatal care (ANC) through non-invasive diagnostic tests supported by decision algorithms.	Screening	Trigger referral; improve safety; provide information on risks and benefits; Guideline adherence; improve clinical effectiveness	Expert systems; Relevant information display	Phone App; Software program; Device	Mixed methods	Ghana, June 2016–April 2017	Primary care; Secondary care or higher
Abejirinde et al., 2018b	Bliss4Midwives	Diagnostic decision support for antenatal care in rural settings to reduce pregnancy-related complications by improving quality antenatal care (ANC) through non-invasive diagnostic tests supported by decision algorithms.	Screening	Trigger referral; improve safety; provide information on risks and benefits; Guideline adherence; improve clinical effectiveness	Expert systems; Relevant information display	Phone App; Software program; Device	Qualitative	Ghana, June 2016–April 2017	Primary care; Secondary care or higher
Abejirinde et al., 2019	Bliss4Midwives	Diagnostic decision support for antenatal care in rural settings to reduce pregnancy-related complications by improving quality antenatal care (ANC) through non-invasive diagnostic tests supported by decision algorithms.	Screening	Trigger referral; improve safety; provide information on risks and benefits; Guideline adherence; improve clinical effectiveness	Expert systems; Relevant information display	Phone App; Software program; Device	Quantitative descriptive	Ghana, June 2016–April 2017	Primary care; Secondary care or higher
Carroll et al., 2013	CHICA	The Child Health Improvement through Computer Automation (CHICA) system. Decision support and electronic medical record system for maternal depression screening	Mental Health	improve clinical effectiveness; Trigger referral; prevent missed diagnoses;	Expert System;	EPR; Software; Paper;	RCT	USA, October 2007–July 2009	Secondary care or higher;
Long et al., 2012	Computerised Physician Order Entry system (CPOE)	Computerised physician order entry system (CPOE) Taiwan	Medical conditions and prescribing	Aid external information acquisition; improve safety	Point of care alerts/ reminders	EHR	Quantitative descriptive	Taiwan, 1-year period in 2006	Secondary care or higher;
Vousden et al., 2019a	Cradle VSA	Device to measure hypovolaemic or septic shock and alert users to abnormalities in Zambia and Haiti	Monitoring	Trigger referral for critically ill patients; improve safety; better target scarce resources	Point of care alerts/ reminder; Expert System	Device	Mixed methods	Kenya, Zambia, Malawi, Haiti, Sierra Leone, Zimbabwe, Uganda, India, April 2016–November 2017	Primary care; Secondary care or higher;
Vousden et al., 2018	Cradle VSA	Device to measure hypovolaemic or septic shock and alert users to abnormalities	Monitoring	Trigger referral for critically ill patients; improve safety; better target scarce resources	Point of care alerts/ reminder; Expert System	Device	Mixed methods	Zimbabwe, Ethiopia, India, November 2015–January 2016	Primary care; Secondary care or higher;
Nathan et al., 2018	Cradle VSA	Device to measure hypovolaemic or septic shock and alert users to abnormalities	Monitoring	Trigger referral for critically ill patients; improve safety; better target scarce resources	Point of care alerts/ reminder; Expert System	Device	Qualitative	India, Mozambique, Nigeria, South Africa, February 2014–April 2016	Primary care; Secondary care or higher;
Vousden et al., 2019b	Cradle VSA	Device to measure hypovolaemic or septic shock and alert users to abnormalities	Monitoring	Trigger referral for critically ill patients; improve safety; better target scarce resources	Point of care alerts/ reminder; Expert System	Device	RCT	Kenya, Zambia, Malawi, Haiti, Sierra Leone, Zimbabwe, Uganda, India, April 2016–November 2017	Primary care; Secondary care or higher;

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Article	Name	Additional description of CDSS	Decision problem	System rational	CDSS type level 1	CDSS environment	Study type	Country, year	Level of healthcare
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Vousden et al., 2019c	Cradle VSA	Device to measure hypovolaemic or septic shock and alert users to abnormalities	Monitoring	Trigger referral for critically ill patients; improve safety; better target scarce resources	Point of care alerts/reminder; Expert System	Device	RCT	Kenya, Zambia, Malawi, Haiti, Sierra Leone, Zimbabwe, Uganda, India, April 2016–Nov 2017	Primary care; Secondary care or higher;
Giblin et al., 2021	Cradle VSA	Device to measure hypovolaemic or septic shock and alert users to abnormalities	Monitoring	Trigger referral for critically ill patients; improve safety; better target scarce resources	Point of care alerts/reminder; Expert System	Device	RCT	Kenya, Zambia, Malawi, Haiti, Sierra Leone, Zimbabwe, Uganda, India, April 2016–Nov 2017	Primary care; Secondary care or higher;
Gardosi et al., 1999	Customised fundal height charts assessing growth	Customised antenatal growth chart displaying computer-generated curves for fetal weight and fundal height	Screening	Prevent missed diagnoses; trigger referral;	Workflow support; Expert system;	Paper;	Quantitative non-randomised	UK, May 1994–March 1995	Secondary care or higher;
Montgomery et al., 2007	Diamond study decision aid	VBAC Decision Aid	Mode of delivery	Aid external information acquisition; Patient empowerment and education; standardise care; provide information on risks and benefits; improve patient satisfaction	Expert systems; Relevant information display	Software program	RCT	UK, May 2004–August 2006	Secondary care or higher;
Hollinghurst et al., 2010	Diamond study decision aid	VBAC Decision Aid	Mode of delivery	Aid external information acquisition; standardise care; provide information on risks and benefits; Patient empowerment and education	Expert systems; Relevant information display	Software program	Economic evaluation	UK, May 2004–January 2006	Secondary care or higher;
Emmett et al., 2007	Diamond study decision aid	VBAC Decision Aid	Mode of delivery	Aid external information acquisition; standardise care; provide information on risks and benefits; Patient empowerment and education	Expert systems; Relevant information display	Software program	Qualitative	UK, February 2004–April 2004	Secondary care or higher;
Rees et al., 2009	Diamond study decision aid	VBAC Decision Aid	Mode of delivery	Aid external information acquisition; standardise care; provide information on risks and benefits; Patient empowerment and education	Expert systems; Relevant information display	Software program	Qualitative	UK, February 2004–April 2004	Secondary care or higher;
Venkateswaran et al., 2022	eRegQual	Palestinian integrated antenatal CDSS	Screening	Guideline adherence; improve clinical effectiveness	Expert systems	EHR	RCT	Palestine, March 2017–June 2018	Primary care;
Relph et al., 2022	GAP protocol	Growth Assessment Protocol (GAP) is a complex antenatal intervention (which trains midwives and healthcare professionals in fetal growth assessment and the use of customized centiles) that aims to increase the rate of antenatal detection of SGA and reduce stillbirth	Screening	guideline adherence; improve safety; Standardise care	Expert systems;	Software program; Paper;	Mixed methods	UK, November 2016–February 2019	Secondary care or higher;
Iliodromiti et al., 2020	GAP protocol	Growth Assessment Protocol (GAP) is a complex antenatal intervention that aims to increase the rate of antenatal detection of SGA and reduce stillbirth	Screening	guideline adherence; improve safety; Standardise care	Expert systems;	Software program; Paper;	Quantitative non-randomised	UK, 2000–2015	Secondary care or higher;

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Article	Name	Additional description of CDSS	Decision problem	System rational	CDSS type level 1	CDSS environment	Study type	Country, year	Level of healthcare
(Continued from previous page)									
Ravula et al., 2022	GAP protocol	Growth Assessment Protocol (GAP) is a complex antenatal intervention that aims to increase the rate of antenatal detection of SGA and reduce stillbirth	Screening	guideline adherence; improve safety; Standardise care	Expert systems;	Software program; Paper;	Quantitative non-randomised	India, 2011–2018	Secondary care or higher;
Hugh et al., 2020	GAP protocol	Growth Assessment Protocol (GAP) is a complex antenatal intervention that aims to increase the rate of antenatal detection of SGA and reduce stillbirth	Screening	guideline adherence; improve safety; Standardise care	Expert systems;	Software program; Paper;	Quantitative non-randomised	UK, 2008–2017	Secondary care or higher;
Cowan et al., 2021	GAP protocol	Growth Assessment Protocol (GAP) is a complex antenatal intervention that aims to increase the rate of antenatal detection of SGA and reduce stillbirth	Screening	guideline adherence; improve safety; Standardise care	Expert systems;	Software program; Paper;	Quantitative non-randomised	New Zealand, 2012–2017	Secondary care or higher;
Vieira et al., 2022	GAP protocol	Growth Assessment Protocol (GAP) is a complex antenatal intervention that aims to increase the rate of antenatal detection of SGA and reduce stillbirth	Screening	guideline adherence; improve safety; Standardise care	Expert systems;	Software program; Paper;	RCT	UK, November 2016–February 2019	Secondary care or higher;
Vos et al., 2017	Health Pregnancy 4 All scorecard	Healthy Pregnancy 4 All' Scorecard-based antenatal risk assessment, care pathways and interdisciplinary consultation	Screening	Improved clinical effectiveness; standardise care; trigger referral	Expert systems;	Paper	Mixed methods	Netherlands, Years not provided	Primary care;
Bartlett et al., 2021	iDeliver	Digital health tool for skilled birth attendants to support maternity care in Kenya	Monitoring	Standardise care; improve clinical effectiveness; guideline adherence	Expert System; Relevant Information display; Order facilitators;	EHR; Software program	Qualitative	Kenya, December 2018–September 2020	Primary care; Secondary care or higher;
Dinh et al., 2022	iDeliver	Digital health tool for skilled birth attendants to support maternity care in Kenya	Monitoring	standardise care; improve clinical effectiveness; guideline adherence	Expert System; Relevant Information display; Order facilitators;	EHR; Software program	Quantitative non-randomised	Kenya, December 2018–September 2022	Primary care; Secondary care or higher;
Schroeder et al., 2021	INFANT	INFANT CDSS for CTG interpretation	Monitoring	improve clinical effectiveness, improve safety	Expert systems; Point of care alerts/reminders	EHR	Economic evaluation	UK; Ireland, 2010–2013	Secondary care or higher;
Wilson et al., 2021	INFANT	INFANT CDSS for CTG interpretation	Monitoring	improve clinical effectiveness, improve safety	Expert systems; Point of care alerts/reminders	EHR	Quantitative non-randomised	Australia, 2016–2019	Secondary care or higher;
Brocklehurst et al., 2017	INFANT	INFANT CDSS for CTG interpretation	Monitoring	improve clinical effectiveness, improve safety	Expert systems; Point of care alerts/reminders	EHR	RCT	UK; Ireland, 2010–2013	Secondary care or higher;
Shah et al., 2019	ImTeCHO	Innovative Mobile-phone Technology for Community Health Operations (ImTeCHO). Mobile phone application as job aid for CHWs to increase the coverage of maternal, newborn and child health services in rural India	Multi-faceted	Patient empowerment and education; improve clinical effectiveness; standardise care; guideline adherence;	Expert system; Order facilitators; workflow support;	Phone App;	Mixed methods	India, August 2013–February 2014	Primary care;

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Article	Name	Additional description of CDSS	Decision problem	System rational	CDSS type level 1	CDSS environment	Study type	Country, year	Level of healthcare
(Continued from previous page)									
Haberman et al., 2009	IPROB	Clinical-Decision Support for documentation compliance adherence mechanism on the documentation of the estimated fetal weight and of indications for labor induction in an Electronic Medical Record clinical-decision support system	Peripartum management	Guideline adherence; standardise care	Workflow support; point of care alerts/reminders	EHR	Quantitative non-randomised	USA	Secondary care or higher;
Valdera Simbron et al., 2021	M4	Performance of the M4 model for predicting the final outcome of pregnancies resulting from ART that show low I^2 -hCG (LB-ART) in early gestation.	Ectopic	Better target scarce resources; prevent missed diagnoses; standardise care	Expert System	Excel	Quantitative descriptive	Spain, July 2017–July 2018	Secondary care or higher;
Bobdiwala et al., 2016	M4	Performance of the M4 model for predicting the final outcome of pregnancies resulting from ART that show low I^2 -hCG (LB-ART) in early gestation.	Ectopic	Better target scarce resources; prevent missed diagnoses; standardise care	Expert System	Excel	Quantitative non-randomised	UK, August 2012–December 2013	Secondary care or higher;
McNabb et al., 2015	m4Change App	mHeaLTH mobile phone app-based decision support and data collection app intervention for ANC in Nigeria with 4 app modules; client registration, client follow up, lab/examination and health counselling messages.	Screening	Improve patient satisfaction; guideline adherence;	point of care alerts/reminders; Order facilitators; Relevant information display;	Phone App;	Quantitative non-randomised	Nigeria, December 2012–December 2013	Primary care;
Bobdiwala et al., 2020	M6	M6 Triage of Pregnancy of Unknown Location	Ectopic	Better target scarce resources; prevent missed diagnoses; standardise care	Expert Systems	Excel	Quantitative non-randomised	UK, January 2015–January 2017	Secondary care or higher;
Blumenthal et al., 2021	MEWT	Maternity Early Warning Trigger	Monitoring	Trigger referral for critically ill patients, improve clinical outcomes	Expert system	EHR	Quantitative non-randomised	USA, year not provided	Secondary care or higher;
Shields et al., 2016	MEWT	Maternity Early Warning Trigger	Monitoring	Trigger referral for critically ill patients, improve clinical outcomes; prevent missed diagnosis	Expert system	EHR	Quantitative non-randomised	USA, January 2012–October 2015	Secondary care or higher;
Amoakoh et al., 2018	mCDMSi	mHealth clinical decision-making support intervention (mCDMSi). mHealth intervention with 4 elements: phone calls, text messaging, access to the internet, access to an unstructured supplementary service data in Eastern Region of Ghana	Multi-faceted	Guideline adherence; Improve clinical effectiveness; Standardise care	Expert systems	SMS	Mixed methods	Ghana, August 2015–January 2017	Primary care; Secondary care or higher;
Amoakoh et al., 2019a	mCDMSi	mHealth clinical decision-making support intervention (mCDMSi). mHealth intervention with 4 elements: phone calls, text messaging, access to the internet, access to an unstructured supplementary service data in Eastern Region of Ghana	Multi-faceted	Guideline adherence; Improve clinical effectiveness; Standardise care	Expert systems	SMS	Quantitative descriptive	Ghana, August 2015–January 2017	Primary care; Secondary care or higher;

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Article	Name	Additional description of CDSS	Decision problem	System rational	CDSS type level 1	CDSS environment	Study type	Country, year	Level of healthcare
(Continued from previous page)									
Amoakoh et al., 2020	mCDMSi	mHealth clinical decision-making support intervention (mCDMSi). mHealth intervention with 4 elements: phone calls, text messaging, access to the internet, access to an unstructured supplementary service data in Eastern Region of Ghana	Multi-faceted	Guideline adherence; Improve clinical effectiveness; Standardise care	Expert systems	SMS	Quantitative non-randomised	Ghana, August 2015–January 2017	Primary care; Secondary care or higher;
Amoakoh et al., 2019b	mCDMSi	mHealth clinical decision-making support intervention (mCDMSi). mHealth intervention with 4 elements: phone calls, text messaging, access to the internet, access to an unstructured supplementary service data in Eastern Region of Ghana	Multi-faceted	Guideline adherence; Improve clinical effectiveness; Standardise care	Expert systems	SMS	RCT	Ghana, August 2015–January 2017	Primary care; Secondary care or higher;
Mackintosh et al., 2014	MOEWS	Modified Obstetric Early Warning System (MOEWS) in managing maternal complications in the peripartum period	Monitoring	Trigger referral, optimise selected patients for theatre, Trigger referral for critically ill patients	Expert system; Point of care alerts/reminders	Paper	Qualitative	UK, February 2010–August 2010	Secondary care or higher
Merriel et al., 2016	MOEWS	Modified Early Obstetric Warning System (MEOWS) in managing maternal complications in the peripartum period	Monitoring	Trigger referral, better target scarce resources, optimise selected patients for theatre, Trigger referral for critically ill patients	Expert system; Point of care alerts/reminders	Paper	Quantitative non-randomised	Zimbabwe, 2013	Primary care; Secondary care or higher;
Sheikh et al., 2017	NEWS score	NEWS tool for the management of obstetrics patients in off-work hours.	Monitoring	Trigger referral for critically ill patients, improve clinical outcomes; prevent missed diagnosis; improve safety;	Expert systems;	Paper	Quantitative non-randomised	India, September 2013–August 2014	Primary care; Secondary care or higher;
Trick et al., 2010	postpartum dTAP vaccination ordering	Computer-based clinical decision-support algorithm to increase Tdap vaccine to postpartum women according to Advisory Committee of Immunization Practices guidelines	Preventative care	Guideline adherence; standardise care	Order facilitators;	EHR	Quantitative non-randomised	USA, January 2009–April 2009	Secondary care or higher;
Benski et al., 2017	PANDA	The PANDA (Pregnancy And Newborn Diagnosis Assessment) system supports community healthcare workers in delivering antenatal care. 1. PANDA Phone: Android application to collect patient information including medical and obstetric history, to support clinical screening and provide a guide for dispensing health education. 2. PANDA point of care: biometric and pathology testing. 3. PANDA medical unit: a hospital record, allows doctors to review patients	Screening	standardise care; improve clinical effectiveness; Patient empowerment and education	Expert system	Phone App;	Quantitative descriptive	Madagascar, January 2015–March 2015	Primary care;

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Article	Name	Additional description of CDSS	Decision problem	System rational	CDSS type level 1	CDSS environment	Study type	Country, year	Level of healthcare
(Continued from previous page)									
Kuppermann et al., 2009	Prenatal genetic testing tool	Computerized Interactive Prenatal Genetic Testing Decision-Assisting Tool in USA	Screening	Patient empowerment and education; improve patient satisfaction; provide information on risks and benefits	Expert Systems;	Software program;	RCT	USA, April 2001–April 2003	Secondary care or higher;
Carlson et al., 2019	Prenatal genetic testing tool	Computerized Interactive Prenatal Genetic Testing Decision-Assisting Tool in USA	Screening	Patient empowerment and education; improve patient satisfaction; provide information on risks and benefits	Expert Systems;	Software program;	RCT	USA, January 2017–October 2017	Secondary care or higher;
Lopes-Pereira et al., 2018	Omniview-SisPorto program	Omniview-SisPorto program-continuous cardiotocographic monitoring during labor with computer analysis and real-time alerts in UK	Monitoring	prevent missed diagnoses; Trigger referral for critically ill patients; standardise care; improve clinical effectiveness	Expert systems;	Software program; EHR; paper guideline	Quantitative non-randomised	Portugal, January 2001–December 2014	Secondary care or higher;
Ignatov et al., 2016	qCTG	quantitative Cardiotocogram management program and algorithm in a Bulgarian Hospital	Monitoring	standardise care; improve clinical effectiveness	Expert Systems;	Software program; EHR; paper guideline	RCT	Bulgaria, 2008–2011	Secondary care or higher;
Ignatov et al., 2012	qCTG	quantitative Cardiotocogram management program and algorithm in a Bulgarian Hospital	Monitoring	standardise care; improve clinical effectiveness	Expert Systems;	Software program; EHR; paper guideline	RCT	Bulgaria, 2008–2011	Secondary care or higher;
Nunes et al., 2017	Omniview-SisPorto	Omniview-SisPorto program-continuous cardiotocographic monitoring during labor with computer analysis and real-time alerts in UK	Monitoring	prevent missed diagnoses; Trigger referral for critically ill patients; standardise care; improve clinical effectiveness	Expert systems;	Software program; EHR	RCT	UK, August 2011–July 2014	Secondary care or higher;
Saccone et al., 2021	Computerised CTG	Antepartum cardiotocography with computer analysis interfaced to 2CTG2 system	Monitoring	prevent missed diagnoses; Trigger referral for critically ill patients; standardise care; improve clinical effectiveness	Expert systems;	Software program; EHR;	RCT	Italy, March 2019–December 2019	Secondary care or higher;
Saronga et al., 2015	QUALMAT	Combined decision-support and performance-based incentives to improve reported client satisfaction with maternal health services in primary facilities through support of WHO maternity and childbirth guidelines	Monitoring	improve patient satisfaction; Guideline adherence; Standardise care; improve safety	Expert systems; Workflow support	Desktop/ laptop	Economic evaluation	Tanzania, June 2009–March 2013	Primary care;
Saronga et al., 2017	QUALMAT	Combined decision-support and performance-based incentives to improve reported client satisfaction with maternal health services in primary facilities through support of WHO maternity and childbirth guidelines	Monitoring	improve patient satisfaction; Guideline adherence; Standardise care; improve safety	Expert systems; Workflow support	Desktop/ laptop	Economic evaluation	Tanzania, June 2009–March 2013	Primary care;
Dalaba et al., 2014	QUALMAT	Combined decision-support and performance-based incentives to improve reported client satisfaction with maternal health services in primary facilities through support of WHO maternity and childbirth guidelines	Monitoring	improve patient satisfaction; Guideline adherence; Standardise care; improve safety	Expert systems; Workflow support	Desktop/ laptop	Economic evaluation	Ghana, October 2009–April 2013	Primary care;

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Article	Name	Additional description of CDSS	Decision problem	System rational	CDSS type level 1	CDSS environment	Study type	Country, year	Level of healthcare
(Continued from previous page)									
Dalaba et al., 2015	QUALMAT	Combined decision-support and performance-based incentives to improve reported client satisfaction with maternal health services in primary facilities through support of WHO maternity and childbirth guidelines	Monitoring	improve patient satisfaction; Guideline adherence; Standardise care; improve safety	Expert systems; Workflow support	Desktop/ laptop	Economic evaluation	Ghana, October 2009–April 2013	Primary care;
Sukums et al., 2015	QUALMAT	Combined decision-support and performance-based incentives to improve reported client satisfaction with maternal health services in primary facilities through support of WHO maternity and childbirth guidelines	Monitoring	improve patient satisfaction; Guideline adherence; Standardise care; improve safety	Expert systems; Workflow support	Desktop/ laptop	Mixed methods	Ghana; Tanzania, October 2011–December 2013	Primary care;
Zakane et al., 2017	QUALMAT	Combined decision-support and performance-based incentives to improve reported client satisfaction with maternal health services in primary facilities through support of WHO maternity and childbirth guidelines	Monitoring	improve patient satisfaction; Guideline adherence; Standardise care; improve safety	Expert systems; Workflow support	Desktop/ laptop	Qualitative	Burkina Faso, June 2012–April 2014	Primary care;
Aninanya et al., 2021	QUALMAT	Combined decision-support and performance-based incentives to improve reported client satisfaction with maternal health services in primary facilities through support of WHO maternity and childbirth guidelines	Monitoring	improve patient satisfaction; Guideline adherence; Standardise care; improve safety	Expert systems; Workflow support	Desktop/ laptop	Quantitative non-randomised	Ghana, April 2012–2014	Primary care;
Mensah et al., 2015	QUALMAT	Combined decision-support and performance-based incentives to improve reported client satisfaction with maternal health services in primary facilities through support of WHO maternity and childbirth guidelines	Monitoring	improve patient satisfaction; Guideline adherence; Standardise care; improve safety	Expert systems; Workflow support	Desktop/ laptop	Quantitative non-randomised	Ghana; Tanzania, 2009–2014	Primary care;
Carlisle et al., 2021	QUIPP app	The QUIPP app is a browser based support tool to stratify women into high risk and low risk of pre-term birth	Screening	Better target scarce resources; prevent missed diagnoses; improve clinical outcomes	Expert system	app; EHR	Qualitative	UK, January–March 2019	Secondary care or higher;
Watson et al., 2021	QUIPP app	The QUIPP app is a browser based support tool to stratify women into high risk and low risk of pre-term birth	Screening	Better target scarce resources; prevent missed diagnoses; improve clinical outcomes	Expert system	app; EHR	RCT	UK, March 2018–February 2019	Secondary care or higher;
Veglia et al., 2017	Risk-stratification protocol for SGA fetuses	Risk-stratification protocol for SGA fetuses	Screening	improve safety; improve clinical effectiveness; Standardise care	Expert systems;	Paper	Quantitative non-randomised	UK, October 2014–April 2016	Secondary care or higher;
Chakravarthy et al., 2019	Saving Mothers Score	Saving Mothers Score' early obstetric warning score	Screening	Trigger referral for critically ill patients, improve clinical outcomes	Expert systems; Point of care alerts/reminders	Paper	RCT	India, 2017–2018	Secondary care or higher;

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Article	Name	Additional description of CDSS	Decision problem	System rational	CDSS type level 1	CDSS environment	Study type	Country, year	Level of healthcare
(Continued from previous page)									
Vankan et al., 2019	SIMPLE study VABC Decision Aid	Vaginal Birth After Caesarean Section (VBAC) decision aid using a prediction model for probability of success given VBAC trial	Mode of birth	Aid external information acquisition; Patient empowerment and education; standardise care; provide information on risks and benefits; improve patient satisfaction	Expert systems	Paper	Quantitative non-randomised	Netherlands, September 2012–September 2014	Secondary care or higher;
Albert et al., 2020	Sinedie	Gestational diabetes management in a Spanish hospital	Medical conditions and prescribing	improve clinical outcomes; better target scarce resources;	Medication dosing support; Point-of-care alerts/reminders	Phone app; SMS	Quantitative non-randomised	Spain, March 2020–May 2020	Secondary care or higher;
Cabellero et al., 2017	Sinedie	Gestational diabetes management in a Spanish hospital	Medical conditions and prescribing	improve clinical outcomes; better target scarce resources;	Medication dosing support; Point-of-care alerts/reminders	Phone app; SMS	RCT	Spain, No years given	Secondary care or higher;
McCarthy et al., 2013	OTDA	Obstetric Triage Decision Aid (OTDA). Algorithms were developed for triaging two potentially serious conditions in pregnancy: pre-eclampsia and vaginal bleeding >20 weeks gestation.	Peripartum management	standardise care; improve clinical effectiveness; improve safety	Workflow support; Expert system;	EHR	Quantitative non-randomised	USA, January 2016–June 2019	Secondary care or higher;
Kuppermann et al., 2020	TOLAC decision aid	Trial of labour after cesarean (TOLAC) decision aid in USA	Mode of birth	Patient empowerment and education; provide information on risks and benefits;	Expert systems; Relevant information display	Software program	RCT	USA, January 2016–June 2019	Secondary care or higher;
Eden et al., 2014	VBAC Decision Aid	Interactive DSS to reduce decisional conflict about birth methods in previous cesarean	Mode of birth	Aid external information acquisition; Patient empowerment and education; improve patient satisfaction; provide information on risks and benefits	Expert systems;	Software program; Desktop/laptop;	RCT	USA, 2005–2007	Secondary care or higher;
McCarthy et al., 2022	OTDA	Obstetric Triage Decision Aid (OTDA). Triage tool for midwives and nurses using 10 common pregnancy complaints to risk stratify acute pregnancy problems	Peripartum management	standardise care; improve clinical effectiveness; improve safety	Workflow support; Expert system;	EHR	Quantitative descriptive	Australia, August 2017–February 2018	Secondary care or higher;
Maiga et al., 2023	REC-Maternity	Reproductive Health and Maternity Care e-registry (REC-Maternity). Electronic platform with prenatal care, labour and delivery care, postnatal care modules providing enhanced decision support and case management capacity.	Multi-faceted	Standardise care; improve clinical effectiveness; improve patient satisfaction; Patient empowerment and education;	Expert system;	EHR	Quantitative non-randomised	Burkina Faso, November 2021	Primary care
Imo et al., 2024	Opioid Personalised Prescription Protocol	CDSS to decrease the morphine equivalents prescribed while still adequately controlling pain after cesarean delivery	Medical conditions and prescribing	improve safety; standardise care;	Medication dosing support; Order facilitators;	EHR	Quantitative non-randomised	United States, March 2021–June 2022	Secondary care or higher;
Nagraj et al., 2023	SMARThealth Pregnancy	A traffic light system to highlight issues of concern requiring immediate referral and management	Screening	Trigger referral; Improve safety;	Expert system;	Phone App;	Mixed methods	India, October 2019–December 2020	Primary care;

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Article	Name	Additional description of CDSS	Decision problem	System rationale	CDSS type level 1	CDSS environment	Study type	Country, year	Level of healthcare
(Continued from previous page)									
Wang et al., 2022	PIDA	Pregnancy in IBD Decision Aid (PIDA). Patient facing decision aid to support family planning for women with inflammatory bowel disease at a range of different stages	Medical conditions and prescribing	Patient empowerment and education	Expert System; Relevant Information display;	Website	Quantitative non-randomised	Australia, Canada, Denmark, the Netherlands	Secondary care or higher;
Humphries et al., 2023	DASH-TOP	Decision Analysis in Shared decision making for Thrombophylaxis during Pregnancy (DASH-TOP). A shared decision-making intervention that included three components: (1) direct choice exercise; (2) preference elicitation exercises and (3) personalised decision analysis	Screening	Patient empowerment and education; provide information on risks and benefits;	Expert Systems;	Software program;	Mixed methods	Canada, Spain, November 2019–March 2021	Secondary care or higher;
Kandahari et al., 2024	Oxytocin Decision Support Checklist	Oxytocin decision support checklist to standardize dosing and management of oxytocin by providing nursing staff administering the oxytocin-specific parameters for discontinuing or decreasing the dose of oxytocin, starting resuscitative measures, and notifying the supervising provider	Monitoring	Improve clinical effectiveness; improve safety; standardise care;	Point of care alerts/reminders; medication dosing support;	Paper; EHR;	Quantitative non-randomised	United States; October 2012–February 2017	Secondary care or higher;

Table 1: Included articles and clinical decision support systems.

five quantitative non-randomised studies.^{48–51} All other studies (n = 76) were considered to be at risk of bias.

Results of individual studies

87 papers described in Table 1 evaluated 47 unique CDSS.^{42–127} Results for all included studies are included in Supplementary 6, and vignettes describing the evidence for a selection of ten CDSS in Supplementary 7.

Results of syntheses

We describe features of the tools evaluated by decision problem, type of tool used, rationale for CDSS use, and the environment to which it was deployed. These features are non-unique; each tool may have multiple features of the same category, and no tools had only one feature per category. Features specific to implementations, such as time periods and country of deployment, are described in Table 1 and Supplementary 6.

Fig. 3 shows 47 CDSS by clinical problems and the phase of care they were used in. CDSS were most commonly deployed in antenatal care (32 CDSS; 68%) on screening problems (13; 28%), such as anaemia screening which would involve a one-off blood test,⁷³ and monitoring problems (14; 30%) in intrapartum care (21; 45%) such as interpreting a foetal heartbeat trace.⁸⁴ Six (13%) systems supported medical and prescribing decisions such as whether and how to change insulin doses in patients with diabetes. Four (9%) systems supported decision-making of pregnant women to trial Vaginal Birth After C-section (VBAC). Two (4%) supported risk management in suspected ectopic pregnancies, Four (9%) support peripartum decisions such as commencing induction of labour and 1 system (2%) grouped as preventative care advised on vaccination of eligible mothers. One CDSS (2%) grouped as mental health supported screening and management of postpartum depression and three CDSS (6%) had multiple functionalities that spanned many categories. Four systems (9%) were deployed in postpartum care.

Of the 47 CDSS, Expert Systems were the most common type (37, 79%) with only 11 Point of Care Alerts and Reminders (23%), the next most common type. CDSS were intended to Standardise Care (32, 68%), Improve Clinical Outcomes (34, 72%), trigger care pathways (14, 30%), and educate and empower patients (14, 30%). They were typically deployed through Standalone Computer Programs (17, 36%), EHRs (17, 36%) or Paper (17, 32%). However, CDSS combinations of type, rationale and environment rarely reoccurred, and 37 (79%) observed combinations of CDSS types, rationales and environment were unique to that CDSS. For example, two tools (5%) were Expert Systems implemented in Excel to Standardise Care and Improve Clinical Outcomes. These tools were the M4 and M6 (a later iteration of M4) systems designed to manage

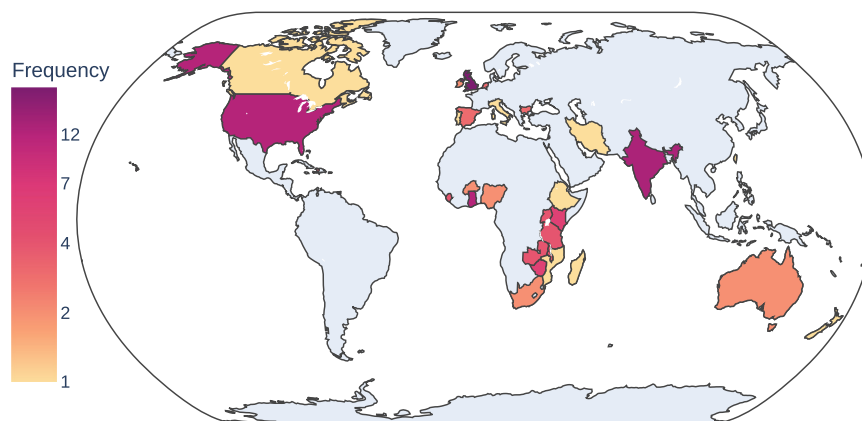


Fig. 2: Publication of included articles on maternal Clinical Decision Support Systems by country, with colour representing the frequency of publication. Grey countries had no articles identified.

pregnancy of unknown location.^{49,50} Few tools were as closely related in development, illustrating the naturally occurring variation in CDSS design.

Fig. 4 shows a forest plot meta-analysing results of studies of CDSS. 48 outcomes from 25 CDSS across 35 studies were included. Meta-analysis of all outcomes found that the Odds Ratio (OR) of successful outcomes that indicate better care for groups receiving CDSS was 1.69 (95% confidence interval 1.24–2.30). For a subgroup of RCT results, the OR was 1.25 (95% CI 0.96–1.62), and for non-randomised studies the OR was 2.92 (95% CI 1.24–2.30). Substantial statistical heterogeneity was observed, supporting the variation in CDSS described above. In the overall model there was greater heterogeneity within single CDSS results than between different CDSS (intra-cluster $I^2 = 60.83\%$, between-cluster $I^2 = 38.41\%$, total model $I^2 = 99.24\%$), suggesting that where a CDSS was evaluated for multiple outcomes or studies, there was greater variation within those results than when comparing results between CDSS. Heterogeneity remained high in the subgroup models, although between-CDSS heterogeneity was higher than within-CDSS in non-randomised studies (intra-cluster $I^2 = 74.38\%$, between-cluster $I^2 = 25.39\%$) and lower in RCTs intra-cluster $I^2 = 38.20\%$, between-cluster $I^2 = 59.45\%$. A sensitivity analysis meta-analysing results at low risk of bias found an overall OR of 1.90 (95% CI 1.08–3.33); further details are in [Supplementary 3](#).

Fig. 5 is a funnel plot showing ORs from Fig. 4 against their standard errors, and shows fewer small studies had null effect sizes than large effects. This may imply publication bias, however Egger's test for publication bias did not show evidence of missing studies ($p = 0.09$). When applying Egger's test to RCTs and non-randomised trials separately, this effect was further reduced ($p = 0.35$ for RCTs, $p = 0.68$ for non-randomised trials).

Discussion

In our systematic review of clinical decision support systems, we identified 47 CDSS deployed and evaluated across 87 unique studies. CDSS designs were most commonly Expert Systems, designed for knowledge representation and user accessibility. CDSS most frequently aimed to Improve Clinical Outcomes and to Standardise Care, and were delivered through paper, standalone computer programmes, and integrated EHR environments. Meta-analysis of available quantitative outcomes found that the OR for achieving a desired outcome when using CDSS increased by 1.69 (95% confidence interval 1.24–2.30).

We identified significant variation between tools in terms of stated objectives, measured outcomes, design, and deployment context, all of which affect decisions to utilise or develop CDSS. Trick et al. demonstrated substantial effects on their desired outcome by identifying a policy with no uptake and using a workflow alteration to increase vaccine coverage from 0% to 59% of eligible post-partum mothers.⁹⁵ The effectiveness of this relatively simple CDSS is likely driven by its contextual fit. This type of improvement is difficult to generalise due to two research challenges: identifying the active ingredients required to make improvements replicable and providing causal evidence that the CDSS resulted in the improvement. Context may be a crucial factor to understanding these active ingredients, as smaller studies in fewer centres may have better contextual fit and implementations, resulting in better outcomes than larger or randomised studies.

Numerous RCTs have investigated the causal effect of CDSS on improvements. Typically, these are cluster randomised trials, reflecting CDSS as organisational interventions with infrastructure investment and process changes that cannot be randomised to individual patients. While most trials were adequately powered to measure outcomes, many used small numbers of large

	 Antenatal Care	 Intrapartum Care	 Postpartum Care
Screening	BACIS eRegQual GAP protocol Genetic testing HP4All m4Change PANDA Risk S. SGA Fetus Bliss4Midwives Fundal height chart SMARThealth pregnancy DASH-TOP	Saving mothers	
Monitoring	Computerised CTG	Alertwatch OB ALDA Protocol Omniview-SisPorto ALD Algorithm ASMAN qCTG iDeliver MEWT MOEWS Cradle VSA QUALMAT INFANT CDSS Trial NEWS score	
Medical conditions and prescribing	Sinedie CPOE PIDA BIG CHANGE	Opioid Personalised Prescription Protocol Oxytocin checklist	
Mode of delivery	DIAMOND SIMPLE - VBAC TOLAC VBAC deci Aid		
Ectopic	M4 M6		
Peripartum management	Triage deci aid OTDA IPROB	QUIPP App	
Preventive care			dTAP vaccination
Mental Health			CHICA
Multifaceted	REC-Maternity mCDMSI ImTeCHO		

Fig. 3: Identified tools organised by clinical problem (rows) and phase of pregnancy care (columns).

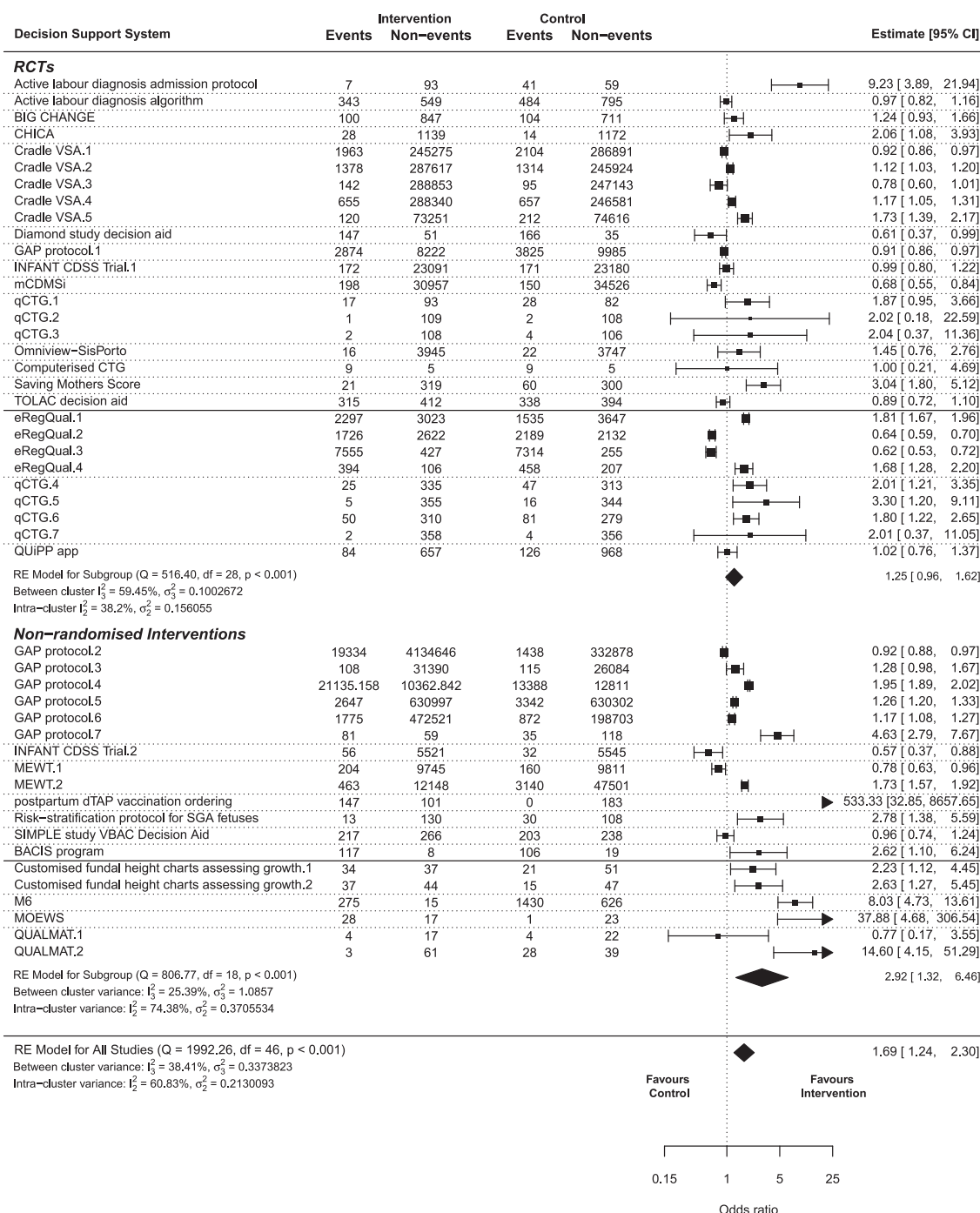


Fig. 4: Forest plot of outcomes of interventional studies with control groups and binary outcomes. All included outcomes are displayed with odds ratio and 95% confidence interval plotted. Outcomes for each Clinical Decision Support Systems (CDSS) are combined, and then all CDSS are combined together. Dotted lines separate CDSS, while solid lines separate Randomised Controlled Trials (RCTs) with clinical outcomes, RCTs with process outcomes, Non-randomised interventions with clinical outcomes, and non-randomised interventions with process outcomes. Details of outcomes analysed are provided in [Supplementary 6](#).

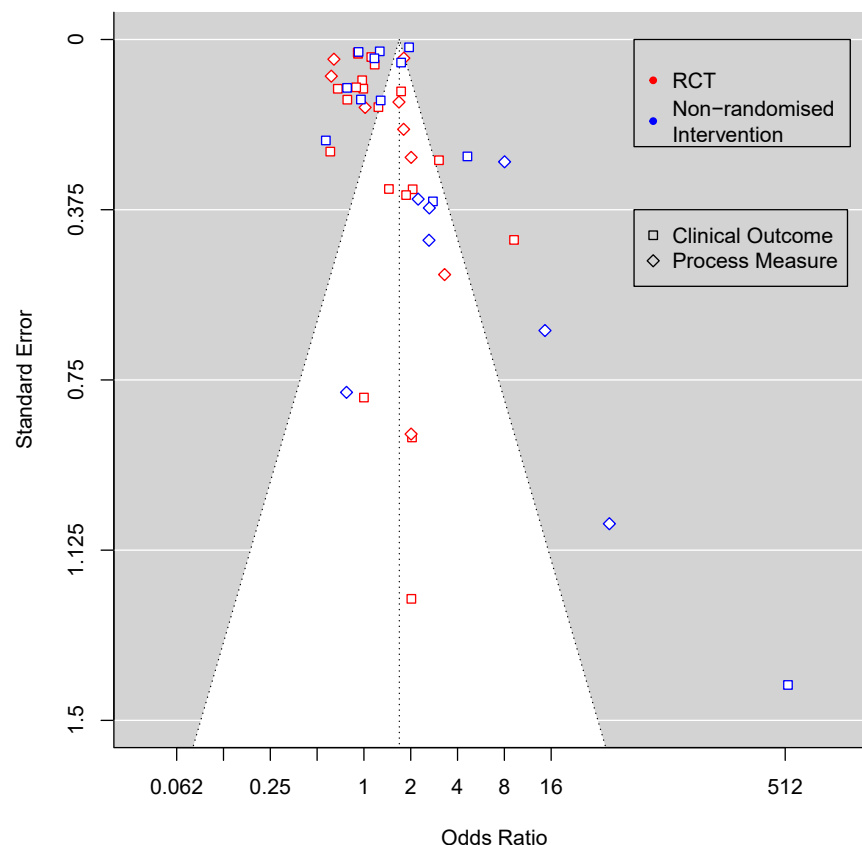


Fig. 5: Funnel plot showing ORs against standard errors for included outcomes in the meta-analysis. The white area represents the range inside the 95% pseudo-confidence intervals.

clusters; the EQUIPPT trial used 11 hospitals³⁰ and Cradle VSA used 10 countries,⁶⁷ contrasting with eRegQual which used 119 antenatal clinics.⁷³ Clusters are likely limited by the nature of the intervention and larger allocation samples with smaller cluster units may provide more generalisable evidence. No CDSS saw a replication trial and many did not have embedded economic analyses; CDSS trials must therefore achieve a high burden of evidence to answer their research question, as meta-analysis or further study of individual CDSS is unlikely. The INFANT trial achieved individual randomisation, however, their intervention had some important enabling features that reduced contamination between patients.⁸⁴

Kwan et al.'s meta-analysis of CDSS RCTs found significant increases in process outcomes (5.8% mean increase in proportion of patients receiving desired care, 95% CI 4.0, 7.6%) with no change detected in clinical outcomes (0.3% median increase in patients achieving clinical targets, 95% CI -0.7, 1.9%), smaller effects than those observed in our data and from more generalisable studies.¹⁸ Moja et al. observed an 22% higher risk of adverse clinical outcomes in controls, comparable to our

similar RCT subgroup analysis where odds of success were 25% higher in interventions.¹²⁸ No previous reviews have been undertaken of maternity care CDSS, but two recent neonatal CDSS reviews have been published, which have parallels with maternity care and share some intended outcomes.^{129,130} A review of features and functions of neonatal systems found the most common functionalities involved prescribing decisions, unlike in our maternal CDSS review where risk stratification was more prevalent.¹³⁰ A systematic review focussing on CDSS predicting neonatal sepsis found consistent reductions in neonatal mortality across multiple RCTs.¹²⁹ Single topic reviews of maternal CDSS tend to focus on patient decision aids,^{16,131} demonstrating again how maternity care CDSS differ from other specialities in that many are aimed at midwifery staff who oversee and deliver maternity care. Transferring these tools across contexts may come with additional challenges; for example, the ratio of midwives to obstetricians is over 20 times smaller in the USA than in the UK or Australia.¹³²

Reviews of CDSS often focus on generalisable CDSS as therapeutic interventions, which does not adequately

describe CDSS. CDSS representing guidelines are arguably implementation strategies, used to increase uptake of health interventions identified as effective.^{133–135} In contrast, risk stratification tools such as QUIPP have more in common with diagnostic or screening tools than therapies,³⁰ while risk alerts/point of care monitoring systems serve as behavioural interventions targeting providers.^{44,54} While disciplines have developed around evaluating the effectiveness of these distinct approaches, evaluation becomes challenging when CDSS combine different strategies, with multidisciplinary input required to identify active ingredients of the CDSS intervention.¹³⁶

Many CDSS evaluations measure process improvements of evidence-based care such as those identified by Kwan et al., which implies their use as implementation strategies.¹⁸ However, uptake of proven therapeutic interventions may not lead to improved health outcomes if the implementation strategy has unintended consequences that might prevent realisation of process benefits, such as alerts that attract attention but interrupt staff workflows in emergency situations.^{26,137} Conversely, declining CDSS use can imply its success as an implementation strategy if increases in desired care processes are sustained.

This systematic review has identified and described the broad range of evaluated CDSS tools in maternity care, offering insight into the supply and demand of decision support in the unique maternity context. As the first systematic review of maternity CDSS, we have identified a list of evaluated tools that can be used for future research and secondary analyses, and by clinicians, health services, and designers looking to utilise or develop tools for their own context. Using a snowballing methodology in addition to systematic database search identified tools that do not describe themselves as CDSS. We described the decision problems, goals, CDSS types, environments, and impact of these tools to generate insight into the key decisions involved in deploying CDSS, highlighting the evaluation challenges of identifying features of CDSS for maternity and demonstrating effectiveness.

However, this review has limitations in design. Not all CDSS are evaluated after deployment, and many developed CDSS are currently being evaluated, and therefore excluded from our review. The likely publication bias and the dominance of English-speaking countries suggests many CDSS may be absent from the published literature. The large number of tools identified through snowballing after a systematic data search suggests limitations in our search strategy. Although the strategy comprehensively identified all pre-identified CDSS, CDSS take many forms and descriptions, making truly systematic identification through traditional database searches challenging. Most CDSS that we identified were expert systems and this could be linked to our use of the Wyatt definition, as

these systems are more likely to acquire information. The breadth and richness of the data produced is challenging to synthesise into clear messages for researchers and clinicians, and other existing taxonomies describing CDSS with greater focus on context¹³⁸ and on goals¹³⁹ could also have been used. However, for the purposes of this review the Wright taxonomy adequately described how CDSS were intended to function, and we described other features of CDSS to highlight the unique requirements of maternity care.

CDSS may have important contributions to make to maternity services by improving patient safety and supporting decision making of both staff and patients, and most evaluations report positive findings. However, delivering healthcare in maternity services may generate specific requirements of CDSS that are not observed in other specialities. Identifying features that predict effectiveness of CDSS across contexts may be a limited approach in complex health services as the requirements for CDSS vary enormously; problem-focussed approaches such as Human-Centered Design¹⁴⁰ may be more promising in delivering effective CDSS that are able to positively influence healthcare decision making.

Contributors

NC conceptualised and designed the study, curated data and verified the final dataset, performed formal analysis, created visualisations, and wrote the original draft.

CO curated data and verified the final dataset, performed formal analysis, created visualisations, and reviewed and edited the manuscript.

SW curated data, performed formal analysis, created visualisations, and reviewed and edited the manuscript.

AE curated data and reviewed and edited the manuscript.

RN curated data and reviewed and edited the manuscript.

MS reviewed and edited the manuscript.

WPS reviewed and edited the manuscript and provided supervision to NC.

BT reviewed and edited the manuscript and provided supervision to NC.

JSC reviewed and edited the manuscript and provided supervision to NC.

KN conceptualised and designed the study, reviewed and edited the manuscript and provided supervision to NC.

Data sharing statement

All data reported in this paper is available in [Supplementary 6](#). Analysis code in python and R is available on request.

Editor note

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Declaration of interests

WPS is a council member Royal College of Obstetricians and Gynaecologists. MS and KN are directors of OpenClinical CIC, a not-for-profit organisation that seeks to promote the use of Clinical Decision Support technologies. MS owns stock and received royalties from Deontics Ltd., a Clinical Decision Support company whose products are not included in the reviewed papers. JSC received grant and contract funding from National Institute for Health and Care Research, Youth Endowment Fund, College of Policing, University of Birmingham, Birmingham City Council, Home Office (UK). BT received grant and contract funding from NIHR and UKRI/MRC. KN received grant and contract funding

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Appendix A. Supplementary data

Supplementary data related to this article can be found at <https://doi.org/10.1016/j.eclinm.2024.102822>.

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3.1. Impact of CDSS on maternity services

The manuscript considers in detail how maternity services might use CDSS. However, it did not discuss maternal health inequalities, a key theme of this thesis and a major challenge maternity services face. While no evidence in the review directly considered health inequalities, a key finding of the systematic review is that most CDSS aim to standardise care. Literature reported elsewhere has found that CDSS can reduce health inequalities by ensuring that all populations receive high quality care.⁽¹³⁰⁾ By improving adherence to standards of care, CDSS may reduce inequalities where the standards are appropriate but not implemented; however where standards are inappropriate due to incorrect knowledge, CDSS may worsen inequalities. For example, race was previously used in risk calculators predicting Vaginal Birth after Caesarean Section, and predictions for black and Hispanic women in the US had double the odds of adverse outcomes.^(131,132) Subsequent work uncovered that risk associated with race was largely due to chronic hypertension, and using race as a proxy for biological features has led to minoritised groups receiving different and inappropriate care to the majority racial population.⁽³²⁾

The largest impact of CDSS may therefore be due to the knowledge content they represent rather than the delivery mode of that knowledge, but CDSS that are patient-facing may generate inequalities due to their design. Douthit et al.'s review noted the effects of the inaccessibility of technology, access to care, trust of technology, and technology literacy, and d'Elia's broader review on healthcare AI in primary care, of which CDSS is considered one element, noted these factors, the algorithmic bias described above, and external effects of the wider digital determinants of

health.(133,134) The use of CDSS must therefore deliberately assess health inequalities when considering the beneficiary population, the technology and service designs, and the wider digital context to ensure broader benefits from services.

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4. Automated Analytics for Epidemiological Research

Chapter 3 presented a study into clinical decision support systems, representing an element of technical infrastructure for implementing knowledge into practice within LHS. Chapter 4 will present a study on developing data-to-knowledge infrastructure, by outlining how analysis of routinely collected health data can be automated. Although software was developed as part of this study, the key contribution is the standard rulesets for conducting analysis in open cohorts, which enables greater portability of the findings between different systems, datasets, and software architectures. Such automation allows for greater scale and consistency in conducting these analyses, and Chapter 5 will go on to present a study using large outputs of such automated data collections and analyses.

Manuscript 2: Automating incidence and prevalence analysis in open cohorts

RESEARCH

Open Access



Automating incidence and prevalence analysis in open cohorts

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Abstract

Motivation Data is increasingly used for improvement and research in public health, especially administrative data such as that collected in electronic health records. Patients enter and exit these typically open-cohort datasets non-uniformly; this can render simple questions about incidence and prevalence time-consuming and with unnecessary variation between analyses. We therefore developed methods to automate analysis of incidence and prevalence in open cohort datasets, to improve transparency, productivity and reproducibility of analyses.

Implementation We provide both a code-free set of rules for incidence and prevalence that can be applied to any open cohort, and a python Command Line Interface implementation of these rules requiring python 3.9 or later.

General features The Command Line Interface is used to calculate incidence and point prevalence time series from open cohort data. The ruleset can be used in developing other implementations or can be rearranged to form other analytical questions such as period prevalence.

Availability The command line interface is freely available from https://github.com/THINKINGGroup/analogy_publication.

Motivation

Introduction

With the growing demand for and accessibility of administrative healthcare databases, analysis of the large datasets available require scalable analysis methods and dissemination [1]. Solutions must be readily deployable, reliably reproducible, minimise additional

resource or capabilities requirements, and adhere to open science and code principles [2]. However, such data analysis solutions require domain knowledge, technical skills and significant time investment [3] and so few generalisable solutions have been deployed [4]. Our team have previously developed the 'Data Extractor for Epidemiological Research' (DExtER) [5] to automate analysis-ready extraction from healthcare data according to specific epidemiological study designs, and in this paper outline open analytics to handle analysis-ready data outputs.

Open code

Open Code refers to making research code available as a research output, for example by creating open source software or sharing electronic notebooks. By making research reproducible, replicable and transparent, this

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approach promotes productivity, innovation and trust in science [6, 7]. However, its adoption in current research can be limited by concerns about personal data privacy issues, resource constraints and intellectual property [8]. In the context of healthcare data analysis and epidemiological research, adopting open code principles can increase the impact of tools and research outputs. For example, openPrescribing [9] is a tool to improve the quality, safety, and cost-effectiveness of prescribing practices and provides open access to all code and analysis via GitHub. Open source projects allow for greater scrutiny, adaptability, and trust, and can address major challenges in healthcare research [10].

Rationale for automation

Automating health data analysis enables greater validity and attention to methods by standardising processes and analyses, and increase productivity of analytic resources [11]. Incidence and prevalence code is often generated per-analysis, which reduces standardisation of the analysis and leads to issues in reproducibility and comparability. Other work has previously noted the impact that choices in calculating incidence and prevalence can have on analytical results [12], and Ostropelets et al. showed that analysis choices in parameters such as incidence definition, age, and data source can generate 1000-fold differences in incidence rate estimates [13]. This could allow analysts to focus more time on implications and critical analysis of their findings, leading to more valuable insights and a greater understanding of population health. With the growing quantity of healthcare data increasing year on year, due to advances in healthcare technology, population growth, and an ageing population, automated analysis will be essential to using this data to its full potential.

Open cohorts, incidence, and prevalence

Open cohorts generate datasets where participants can continuously enter and exit the cohort throughout the study period of the cohort [14]; this results in non-uniform follow up periods during which events can be observed, and adds complexity to analysis. Incidence and prevalence are used extensively in epidemiology to describe the population health needs, for example using data from open cohorts, and are used by policy makers to identify and plan for disease-associated burden of disease by developing health services, research programmes or preventative policies [15, 16]. Prevalence, “*the proportion of a population who have specific characteristics in a given time period*”, informs the need for health and social care services, while incidence, “*the number of new cases of a characteristic that*

develop in a population in a specified time period”, is crucial in tracking disease causes, trends and evaluating the effectiveness of interventions [17]. Reducing unwarranted variation is urgently necessary and automated incidence and prevalence can provide efficient and reproducible methods across systems, datasets, and populations. Automated analysis can thus support a more precise understanding of disease patterns across times, places, and populations, helping to identify health inequalities and inform population health needs interventions [18]. This enables data-driven decision-making in public health, and can contribute to the overall improvement of health services and equity.

Implementation

In this paper we provide both an explicit implementation-free set of rules for incidence and prevalence calculation that can be applied to any open cohort, and a command line interface for a python implementation of these rules.

Analysis approach

We provide methods for calculating point prevalence and period incidence time series, and calculate confidence intervals using Byar’s method as described elsewhere [19]. Other types of incidence and prevalence metrics can be calculated by rearranging the rules provided; for example, period prevalence can be calculated using the denominator rules from incidence and the incidence from prevalence. Point prevalence is the proportion of a population with a characteristic such as a diagnosis at a given point in time (e.g. proportion with a diagnosis of high blood pressure). Incidence is the rate at which a population experiences an event such as receiving a diagnosis over a given period of time (e.g. the rate of heart attacks).

Data requirements

Calculating estimates from an open cohort requires that for each observation, the time at risk is calculated. Therefore, each observation must have the following information:

- **START DATE** Date on which an individual’s study participation starts.
- **END DATE** Date on which an individual’s study participation ends.
- **EVENT DATE** Date on which event occurred, or NA if not recorded.

- **PERIOD START** Date on which a point prevalence is calculated, or observation for an incidence calculation begins.
- **PERIOD END** Date on which observation for an incidence calculation ends.

Rules

Point prevalence

Definition of numerator in point prevalence for a given population P:

$$\text{Numerator}(P) = \sum I_n$$

where I_n is an indicator function defined as

$$I_n = \begin{cases} 1, & \text{if } Z_n == \text{TRUE} \\ 0, & \text{otherwise} \end{cases} \quad (1)$$

where Z_n is True if all three statements below are True:

1. **START DATE <= PERIOD START** (patient follow-up began before or on the start date for the analysis.)
2. **END DATE >= PERIOD START** (The patient follow-up end date occurred on or after the start date for the analysis.)
3. **EVENT DATE <= PERIOD START** (The event date occurred before or on the start date for the analysis.)

Period incidence

Definition of numerator in incidence rate for a given population P:

$$\text{Numerator}(P) = \sum I_n$$

where I_n is an indicator function defined as

$$I_n = \begin{cases} 1, & \text{if } Z_n == \text{TRUE} \\ 0, & \text{otherwise} \end{cases} \quad (3)$$

where Z_n is True if all statements below are True:

1. **PERIOD START <= EVENT DATE < PERIOD END** (The event date occurred on or after the start date but before the end date of the analysis.)
2. **END DATE >= PERIOD START** (The patient follow-up end date occurred on or after the start date for the analysis.)
3. **START DATE < PERIOD END** (Patient follow-up started before the end date of the analysis.)

Definition of denominator in incidence rate for a given population P:

$$\text{Denominator}(P) = \sum PT_d$$

where PT_d is total person time contributed by each patient in the period of interest.

$$PT_d = \begin{cases} (\text{END\_OBSERVATION} - \text{START\_OBSERVATION})/365.25, & \text{if } Z_d == \text{TRUE} \\ 0, & \text{otherwise} \end{cases} \quad (4)$$

Definition of denominator in point prevalence for a given population P

$$\text{Denominator}(P) = \sum I_d$$

where I_d is an indicator function defined as

$$I_d = \begin{cases} 1, & \text{if } Z_d == \text{TRUE} \\ 0, & \text{otherwise} \end{cases} \quad (2)$$

where Z_d is True if both statements below are True:

1. **START DATE <= PERIOD START** (patient follow-up began before or on the start date for the analysis.)
2. **END DATE >= PERIOD START** (patient follow-up end date occurred on or after the start date for the analysis.)

where,

- **START OBSERVATION** = maximum(**START DATE**, **PERIOD START**)
- **END OBSERVATION** = minimum(**END DATE**, **EVENT DATE**, **PERIOD END**)

and, Z_d is True if all statements below are True:

1. **START DATE < PERIOD END** (Patient follow-up occurred before the end date of the analysis.)
2. **END DATE >= PERIOD START** (The patient end date occurred on or after the start date of the analysis.)
3. **EVENT DATE >= PERIOD START** or **EVENT DATE == NA** (The event date occurred on or after the start date for the analysis.)

4. **EVENT DATE > START DATE** or **EVENT DATE == NA** (The event date occurred after patient follow up began or there was no event.)

Python implementation

These rules have been implemented into a python command line interface (CLI) available from https://github.com/THINKINGGroup/analogy_publication and used as part of our workflow for analysis of primary care records. The CLI requires python 3.9 or above and contains example data to test. We recommend using Anaconda for open source python distribution. Below we present an example output analysing incidence and prevalence of ectopic pregnancy.

Use case

Ectopic pregnancy

Ectopic pregnancy presents a key risk to maternal health, and ruptured ectopic pregnancy is a predominant cause of mortality in the first trimester [20]. UK incidence and prevalence has not been reported in the literature since 2011 [21] and no study has reported the burden of disease in key subgroups. We provide the incidence and prevalence of ectopic pregnancy in the CPRD Aurum database, derived from UK primary care data.

Study design

We extracted data for women aged 12-60 from CPRD Aurum between 2006 and 2021 [22]. 10,248,694

women were eligible for inclusion and ectopic pregnancy definitions are available in S1 & S2 Codelists. Incidence and prevalence were calculated according to Implementation.

Overall Incidence and Prevalence

Figure 1 shows the incidence of ectopic pregnancy in women aged 12-60 years rose from 38.0 (95% CI: 36.0, 40.1) per 100,000 person years in 2006 to 44.1 (95% CI: 42.0, 46.2) per 100,000 person years in 2021. In the same period, the prevalence of women who had ever had a recorded diagnosis of ectopic pregnancy rose from 839.3 (95% CI: 829.7, 848.9) per 100,000 population in 2006, to reach 1209.2 per 100,000 population in 2021 (95% CI: 1197.8, 1219.1).

Incidence and prevalence by subgroup

Between 2006-2021, ectopic pregnancy was higher in women of black ethnicity compared to white ethnicity, while no difference was observed between mixed and white ethnicity, as shown in Fig. 2 (black: 1793.5 [95% CI: 1735.0, 1853.4], mixed: 1292.8 [1215.9, 1373.3], white: 1282.4 [1269.1, 1295.8]). Women of asian, other, and missing ethnicities reported lower prevalence of ectopic pregnancy when compared to patients of white ethnicity (asian: 966.3 [95% CI: 936.1, 997.2], other: 823.6 [757.6, 893.9], missing: 862.7 [839.2, 886.7]). Additional data including deprivation and regional subgroups are reported in S3,S4 and S5 Additional Data.

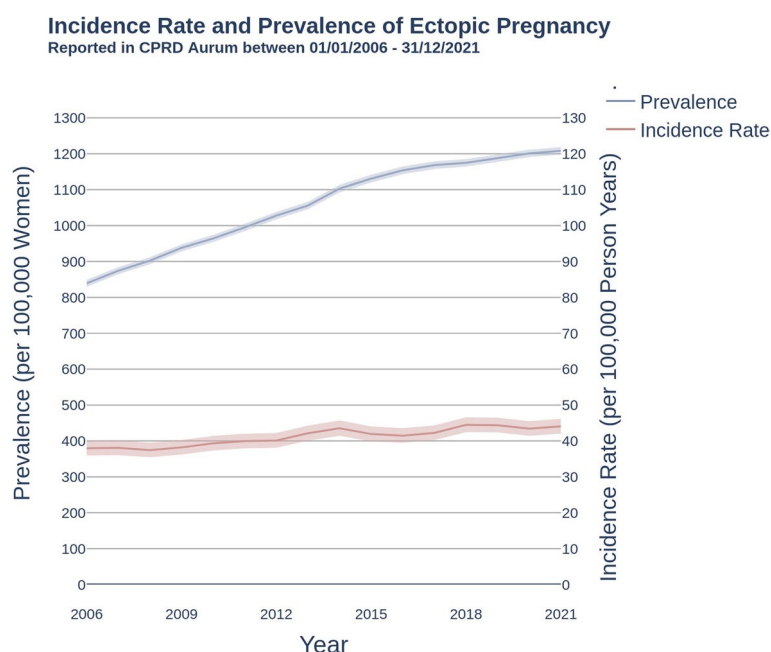


Fig. 1 Incidence rate and lifetime prevalence of ectopic pregnancy per 100,000 women. Women aged 12-60 years of age; Clinical Practice Research Datalink Aurum; UK, 2006-2021

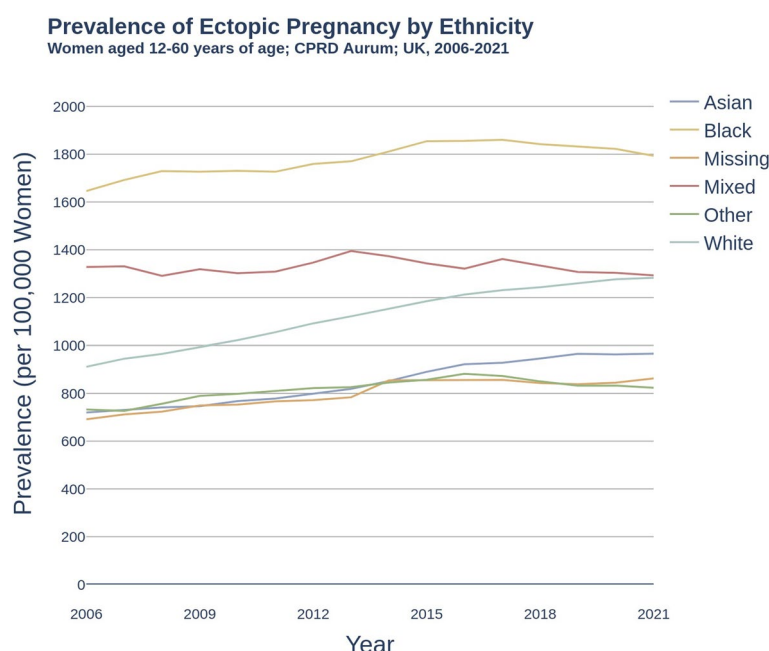


Fig. 2 Prevalence of ectopic pregnancy per 100,000 women by ethnicity. Women aged 12-60 years of age; Clinical Practice Research Datalink Aurum; UK, 2006-2021

Discussion

We have demonstrated a standardised process for calculating incidence and prevalence in an open cohort dataset. Describing the underlying rules allows other analysts to reuse the rules in their own analyses and reinterpret them for other contexts such as different data sources, and aids communication and scrutiny of the analysis undertaken. We encourage readers to apply our easy-to-use CLI on their own datasets to test their analysis for replicability, and report differences to increase transparency around the effect of analysis methods, which have been shown to create substantial differences in estimates of effect sizes [23]. No UK study of the burden of ectopic pregnancy has been undertaken since 2011. However, our analysis of ectopic pregnancy is similar in design to the automated analysis estimate from PrevalenceUK, who report an annual incidence of ectopic pregnancy per woman of 46.5 per 100,000 for the UK in 2019, 4.7% larger than our estimate of 44.4 per 100,000 [24]. Three differences in analysis may explain the magnitude of difference; we used CPRD aurum only, while PrevalenceUK use a combined CPRD Aurum-Gold database; we restricted age of women included in the study to 12-60 years while PrevalenceUK likely used a whole population denominator; and differences in implementation of incidence.

Strengths and limitations

We chose ectopic pregnancy as a use case to demonstrate the ability to rapidly identify and address gaps in research using transparent methods. However, it also reveals challenges to this automated process in specialist conditions; a more natural denominator for ectopic pregnancy might be pregnancy, rather than women of child bearing age. Biases in the source data must also be considered and studies are likely to require input from analysts or other experienced data users. For example, the 44% rise in ectopic pregnancy prevalence, concurrent with modest change in incidence, reflects better recording over time as electronic health records mature. Automated analytics in open cohorts are therefore likely to remain a specialist tool.

Applications and future developments

We have implemented standardisation of incidence and prevalence locally, using the DExtER platform to produce a complete incidence and prevalence pipeline of analysis, and are developing tools to automate open cohort analysis using propensity score matching, cox regression, and statistical process control. Our tool's automation and subgrouping features may have particular applications into inequalities policy making and research, by allowing rapid investigation of multiple conditions, in multiple contexts, affecting different groups of people.

Conclusion

Many teams use common datasets such as CPRD Gold and Aurum, and exact replication of results by other teams should be feasible. Our ruleset enables analysts to use clearly defined criteria for calculating estimates, and our CLI tool can automate these calculations, for example to support sensitivity checks of results using alternative code. However barriers still exist to achieving these open science goals.

Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s12874-024-02266-7>.

Supplementary Material 1: S1. Ectopic Pregnancy Incident Phenome. SNOMED-CT codes used to identify ectopic pregnancy events.

Supplementary Material 2: S2. Ectopic Pregnancy Prevalent Phenome. SNOMED-CT codes used to identify ectopic pregnancy history.

Supplementary Material 3: S3. Baseline Characteristics. This table summarises characteristics of eligible women on entry to the ectopic pregnancy cohort extracted from CPRD Aurum database.

Supplementary Material 4: S4. Incidence of ectopic pregnancy overall and by subgroup. Time series of incidence of ectopic pregnancy in CPRD Aurum from 2006–2021, overall and by subgroups of Index of Multiple Deprivation, region, ethnicity and age category.

Supplementary Material 5: S5. Prevalence of ectopic pregnancy overall and by subgroup. Time series of prevalence of ectopic pregnancy in CPRD Aurum from 2006–2021, overall and by subgroups of Index of Multiple Deprivation, region, ethnicity and age category.

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Authors' contributions

NC and JSC conceived the project. NC, BH, SC, IG, AA, RT, FC, KN, and JSC designed the methods. NC, BH, SC and AA created the software. NC, BH, SM, WPS, BT, JSC interpreted the results. NC, BH, IG, and AA wrote the first draft. All authors reviewed the manuscript.

Funding

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Availability of data and materials

Individual patient data are available from CPRD with valid license; all analysis results are presented in S3–5: Additional Data.

Declarations

Ethics approval and consent to participate

CPRD obtains annual research ethics approval from the UK's Health Research Authority Research Ethics Committee (East Midlands, Derby; reference no. 05/MRE04/87) to receive and supply patient data for public health research. Therefore, no additional ethics approval is required for observational studies using CPRD Aurum data for public health research, subject to individual research protocols meeting CPRD data governance requirements. The use of CPRD Aurum data for the study was approved by the CPRD Independent Scientific Advisory Committee (reference no. 22_001978).

Consent for publication

Not applicable

Competing interests

JSC, KN and KMG are co-directors of DExtER operating division which is part of the University of Birmingham. DExtER operating division supports the extraction and preparing of healthcare data to support epidemiological analyses such as those seen in this article. No other competing interests have been declared by authors.

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4.1. Using Automated Analytics to support maternal health services

Automated analytics can contribute to surveillance within LHS. This study detected an increasing rate of ectopic pregnancy among younger women, and has been the topic of further research applications. Using this approach within a LHS requires routinely collecting dimensions of health inequalities that might affect pregnancies, such as deprivation and ethnicity, but also homelessness, migrant status, and many other social factors.(1)

However, the specific implementation outlined in this study has some limitations for maternal health care not discussed within the manuscript, most importantly that maternal health care may be better considered a closed cohort with clearly defined entry and exit from the cohort based on natural progression of a pregnancy. In such cases, the rules outlined for incidence in **Implementation** need to be rearranged to use number of included pregnancies at risk, instead of time at risk.

Two other limitations add challenges to the use of automated analytics. Routinely collected data is subject to many biases from the healthcare processes that generate the data.(2) These biases and missing data could be addressed by automated data quality assessment, but such software itself needs further validation.(3) Linkage to other datasets could enable triangulation between data, for example using primary care data to identify missing data in secondary care, but needs care in selecting the correct denominator and study designs, not sufficiently addressed in this chapter. While designing linked studies is well within the scope of good epidemiological practice

and many robust maternal studies have been published linking primary and secondary care,(4-7) this would add a significant challenge to automating the process with many more judgements needing opinionated decision making.(8)

4.2. Automatic aNAlytics for Epidemiological

Research: the Analogy team

The work of this chapter represents output from the Analogy team, a group of PhD and postdoctoral researchers interested in automation of analysis for epidemiology which I chaired and led the first projects. This chapter represents my contribution to the wider framework and the first output of the team, and in addition to the uses described above, may be used by other team members to develop time series analyses and other automation tools to mine LHS data sets for insights. Code and methods as open-source research outputs may be adopted in Dexter development as it develops its feature base.

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5. Inequalities in pre-conception long-term conditions

Chapter 4 outlined methods for automating analysis of large Electronic Health Record data, supporting the data-to-knowledge step of learning cycles with tools for surveillance and preparation for further analysis. Chapter 5 applies these methods to a cross-sectional study of 79 conditions in 3.5 million pregnancies over 20 years, demonstrating how descriptive analytics can be used to learn about group-level inequalities, and identify conditions that contribute important inequalities. Such analyses can also be used by LHS to systematically investigate current health needs, guiding priority setting and further research, taking advantage of large datasets and technical infrastructure. This chapter is based on data from a single GP record system available via CPRD Aurum, and the next chapter will then describe deployment of a platform to use data from a single maternity record system.

Manuscript 3: Ethnic and Socioeconomic variation in pre-conception long-term conditions: a cross-sectional electronic health record study of 3.4 million pregnancies in CPRD Aurum

Ethnic and Socioeconomic variation in pre-conception long-term conditions: a cross-sectional electronic health record study of 3.4 million pregnancies in CPRD Aurum

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Research in Context

Evidence before this study

Maternal mortality rates and adverse pregnancy outcomes are elevated among women from ethnic minority groups and socioeconomically deprived backgrounds in the UK. Pre-existing long term conditions are also associated with adverse pregnancy outcomes, and may be important in causing the observed health inequalities. We searched pubmed for full-length articles published before 16-01-2025 with keywords related to ethnicity or deprivation, pre-conception or pre-pregnancy, diagnosis or condition, and prevalence. We identified multiple single disease or organ-system studies, but no systematic analyses of inequalities in multiple-long term conditions.

Added value of this study

We systematically studied a large number of conditions to gain insight into both population group trends in pre-existing conditions, and to identify individual conditions that might drive inequalities. We find that ethnic minority groups tend to have lower rates of disease: women from Asian ethnic groups are 26% less likely than the general population to have pre-existing diagnoses, from black ethnic groups 5%, and from other ethnic groups 32%. This may represent lower true prevalence, or underdiagnosis of medical conditions. Women from deprived backgrounds have 8% higher rates of diagnoses, which may imply worse pre-pregnancy health status.

Implications of all available evidence

Increased prevalence of pre-existing diagnoses amongst women from more deprived backgrounds suggests that high rates of adverse pregnancy outcomes derives from worse pre-pregnancy health status. The absence of this trend among

women from ethnic minority groups with similarly elevated adverse pregnancy outcomes suggests that these adverse outcomes occur in spite of better pre-pregnancy health status, or that pre-pregnancy conditions are underdiagnosed and healthcare could better optimise health status for pregnancy.

Abstract

Background: Inequalities in pregnancy outcomes between different ethnic groups and backgrounds of deprivation have been observed in the UK and elsewhere for several decades. Pre-existing long-term health conditions increase risks of adverse outcomes and require focussed action to diagnose, prevent, and manage these conditions. We aimed to estimate differences in the prevalence of pre-conception long-term conditions between different groups to assess health needs.

Methods: This was a cross-sectional study conducted in primary care using Clinical Practice Research Datalink (CPRD) Aurum data. Diagnostic information was extracted from CPRD Aurum at the beginning of all eligible pregnancies for 79 conditions between 2000 and 2021. Age-standardised was estimated and risk ratios calculated between the overall population, and ethnic groups and Index of Multiple Deprivation quintiles. Statistical process control was used to detect conditions with elevated prevalence within groups..

Findings: In 2021, at the start of a pregnancy, women from ethnic minority groups were less likely to have been diagnosed with any one of the 79 conditions than the general population. Women from mixed ethnic groups were 4% more likely to be diagnosed, and from white ethnic groups 2% more likely to be diagnosed. Women from black groups were 5% less likely to be diagnosed, from Asian groups 26%, other ethnic

groups 32%, and women missing ethnic group information 13%. Women living in the most deprived quintile of areas were 8% more likely to have been diagnosed than the overall population, and from least deprived areas 8% less likely to have been diagnosed.

Interpretation: Pre-existing long-term conditions are a major driver of maternal morbidity and mortality, but the healthcare needs and policy priorities differ substantially between ethnic and socially disadvantaged groups. Universal health policies that narrow inequalities and targeted action are both needed to meet health needs equitably.

Funding: No specific funding was received for this study.

Keywords: maternity, health inequalities, long term conditions

Introduction

Maternity services in the UK are under increasing pressure. Despite a fall in the number of pregnancies of over 15% since 2010,(1) complexity is rising with greater maternal comorbidities,(28) and increasing caesarean section and induction of labour rates are straining maternity services.(142,143) In recent years, more safety concerns have been raised about maternity services,(23) and outcomes are deteriorating.(1) Maternal mortality rates have increased across the population, and rates are disproportionately elevated amongst mothers living in deprived areas, black and Asian mothers, and women with a preferred language other than English.(1) These disparities precede recent challenges in maternal health and are mirrored in broader women's health and infant outcome trends; life expectancy amongst women living in the most deprived areas has fallen, a UK first for such a trend,(2) and rising rates of preterm birth have been linked to rising poverty.(3) Socioeconomic deprivation and ethnicity are key social factors in describing inequality, and intersectionality between factors has an important impact on outcomes too. Stillbirths experienced by black women living in the least deprived areas occurred in 6.28 per 1000 live births, while in most deprived areas 6.97 per 1000 births.(46) By contrast, for white women in least deprived areas this was 2.55 per 1000 births, and in the most deprived areas 4.28 per 1000 births. Deprivation alone does not explain the excess stillbirth rate in Black women.

Improving maternal and child health will require targeted action for groups facing inequalities, in addition to universal population measures. In the UK, the NHS Core20PLUS5 approach to health inequalities explicitly directs attention towards

maternal inequalities and proposes continuity of care models for all women living in deprived areas or from ethnic minority backgrounds.(144) The Women's Health Strategy for England prioritised disparities throughout domains of women's health and particularly for reproductive health, noting that all Local Maternal and Neonatal Systems were required to develop equity and equality action plans and the national Maternity Disparities Taskforce which was tasked with identifying effective interventions for reducing disparities and monitoring progress towards this goal.(98,145) The National Institute for Health Research (NIHR) recently launched the NIHR Challenge Maternity Disparities Consortium with £50 million of funding to rapidly progress the reduction in inequalities.(146)

Women with long term health conditions are also at increased risk of poor maternity outcomes. Over 70% of women who died in pregnancy between 2009 and 2016 had a pre-existing comorbidity, with a 8.65 times higher odds of dying than women without comorbidities.(147,148) Primary care records show over 40% of pregnant women in England and Wales have multiple long-term conditions (MLTCs), and 24% had active MLTCs requiring treatment, but Lee et al. found that while women living in more deprived areas had an increased risk of MLTCs, women from ethnic minority backgrounds were less likely to have MLTCs.(149) Santorelli et al reviewed 21 conditions common in women of reproductive age, finding that 14 conditions had higher incidence rates among women of South Asian ethnicity than in women of White ethnicity.(137) However, these conditions imply different health needs and risks. For example, Lee et al. found that women from more deprived areas or from ethnic minority backgrounds were more likely to have cardiovascular diseases, a leading

cause of death in pregnant women.(149) Furthermore, electronic health record data may contain biases such as those resulting from differential access to healthcare for population groups, and therefore differences in diagnostic rates may not imply differences in disease rates.

Optimisation of health status prior to pregnancy, targeted towards populations with the greatest needs, may improve outcomes and is a key focus of interventions improving women's health.(1,150) This study aims to estimate prevalence of the 79 conditions studied by Lee et al. to identify pre-conception healthcare needs amongst different population groups.

Methods

Design

This is a cross-sectional prevalence study of pre-existing long-term conditions in women at the start of pregnancy in the UK population, stratified by social characteristics that are linked to health inequalities.

Data Sources and Population

Data for women, covariates, and health conditions were extracted from Clinical Practice Research Datalink (CPRD) Aurum and the associated Pregnancy Register from 2000-01-01 until 2021-12-31. CPRD Aurum is a large primary care electronic health record dataset which contains anonymised patient-level data on demographics, symptoms, diagnoses, drug prescriptions, physical measurements, and laboratory test results from 1491 GP practices using EMIS software. In March 2022, 20% of the UK population were contributing data to CPRD Aurum.(151,152) The associated pregnancy

register derived from CPRD Aurum identifies pregnancy episodes in primary care records.(153)

Women with pregnancy index dates occurring while aged 15-49 were eligible. Unique pregnancies in the Aurum pregnancy register were included if they started at least 12 months after registration to the practice, 12 months after the practice contributed good quality data, and both the pregnancy and the woman had data of acceptable quality, to ensure that coding of health conditions was accurate and up to date. Pregnancy index date was defined according to the Aurum Pregnancy Register hierarchy of pregnancy start dates.(153) Pregnancies were the unit of study, and where multiple pregnancies are identified for one woman in a single year, only the latest pregnancy was included.

Outcomes

The primary outcomes were the prevalence of 79 chronic conditions at pregnancy index date identified by the MuM-PreDiCT consortium as part of their definition of MLTC. A long term condition was considered to “have ongoing significant impact on patients, including conditions that are relapsing and remitting in nature” and the list was developed following literature review and stakeholder engagement based on condition “(i) prevalence; (ii) potential to impact on pregnancy outcomes; (iii) considered important by women; and (iv) recorded in the study datasets”.(149) This study also paid specific attention to 23 maternal conditions that are leading causes of maternal and perinatal mortality, as reported in MBRRACE report of 2024.(1) Diagnoses were identified using SNOMED-CT phenomes; Appendix 1 lists all 79 conditions and

those considered within MBRACE, and phenotype definitions are available from Lee et al. additional files 2 and 3.(149)

Comparison groups

Prevalence of conditions were described among population subgroups of ethnicity and deprivation. We used UK Office of National Statistics groupings for ethnic groups (Asian, black, missing, mixed, others, and white) identified using SNOMED-CT phenomes developed by CPRD(154) and home-address linked Index of Multiple Deprivation (IMD) quintiles to define deprivation groups. The IMD measures of deprivation for small areas of about 1800 people, and ranks areas from most to least deprived for a wide range of social metrics such as income, education, and crime.(155)

Analysis

Descriptive statistics were presented for mother's age at pregnancy index date, gravidity (number of pregnancies as recorded in the CPRD pregnancy register), ethnicity, deprivation, and region, using frequency (%) for nominal variables and mean (Standard Deviation (SD)) for continuous variables.

Annual prevalence for each of the 79 conditions was calculated as the frequency of each condition divided by the total number of pregnancies in that year, directly standardised by age. This was calculated overall and for population groups, for each year. We use 2006 as a baseline year for some comparisons as the introduction of QOF improved data quality for many conditions.(156)

Risk ratios were calculated comparing prevalence of each condition in each group to all included pregnancies prevalence for that condition. The average risk ratio for each group was then calculated as a geometric mean, which gives the likelihood of

a women from a given population group being diagnosed with any of the 79 conditions. Funnel plots were then used to identify conditions with especially higher or lower prevalence within that population group.

Analysis was performed using python, stata17, and R. All results data are available online from <https://osf.io/2p8d5/> except where fewer than 10 cases were reported, in which case results have been censored to preserve privacy.

Results

3,334,752 pregnancies among 1,996,402 women were included in this study, from a total of 9,649,405 pregnancies in the CPRD Aurum pregnancy register for the period of the study. Figure 1 outlines inclusion into the study in further detail.

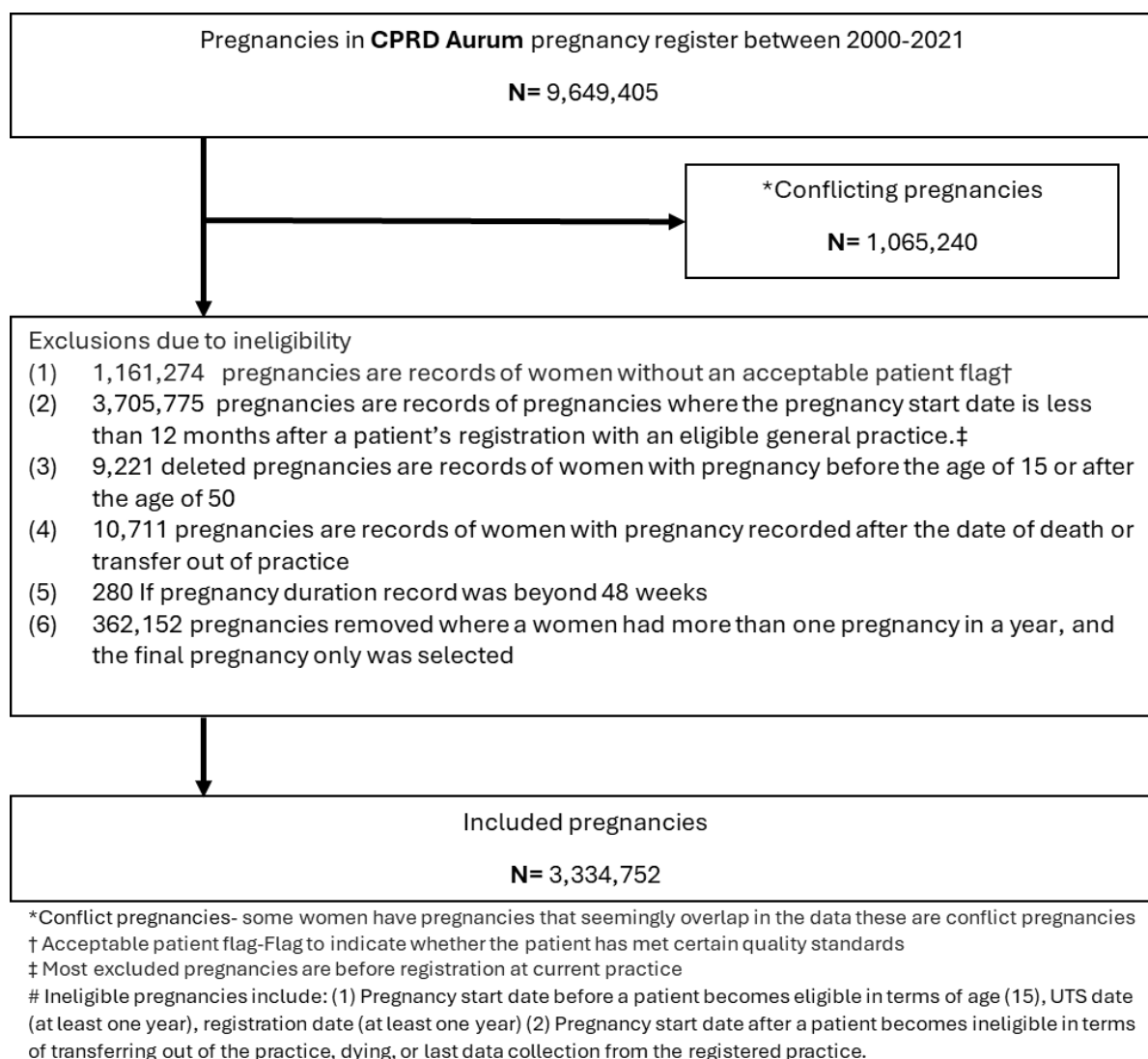


Figure 1: Inclusion of pregnancies for analysis

For 59.2% of women in this study, one pregnancy was included, and mean age at pregnancy start was 30.3 years. Women were slightly more likely to be from more deprived backgrounds, with 22.0% from most deprived areas and 17.3% from least deprived. 59.8% of women were from white ethnic groups, with 8.4% from Asian, 5.1% black, 1.6% mixed, 1.2% other, and 24.8% missing.

Table 3: Characteristics of included pregnancies and women at index date.

Pregnancies	Women

Number of included pregnancies		3334752	Number of included women		1996402
Mother's Age at start of pregnancy (years), n (%)	15-19	22737 9 (6.8)	Included pregnancies per women, n (%)	1	118129 8 (59.2)
	20-24	52779 2 (15.8)		2	497377 (24.9)
	25-29	81926 2 (24.6)		3	193931 (9.7)
	30-34	94649 3 (28.4)		4	75326 (3.8)
	35-39	58146 6 (17.4)		5	28846 (1.4)
	40-44	18895 6 (5.7)		6	11654 (0.6)
	45-49	43404 (1.3)		7	4665 (0.2)
	Mean (SD)	30.28 (6.6)		8+	3305 (0.2)

Category	Group	Pregnancies	Women
Gravidity, n (%)	1	489286 (14.7)	489286 (24.5)
	2	683029 (20.5)	482672 (24.2)

	3	635938 (19.1)	375715 (18.8)
	4	497936 (14.9)	252679 (12.7)
	5+	1028563 (30.8)	396050 (19.8)
Index of Multiple Deprivation quintile, n (%)	1 (least deprived)	562384 (16.9)	346135 (17.3)
	2	577630 (17.3)	353689 (17.7)
	3	602911 (18.1)	368846 (18.5)
	4	716726 (21.5)	429602 (21.5)
	5 (most deprived)	777476 (23.3)	438436 (22.0)
	Missing	97625 (2.9)	59694 (3.0)
Ethnicity, n (%)	ASIAN	288560 (8.7)	167869 (8.4)
	BLACK	170855 (5.1)	101448 (5.1)
	MISSING	788439 (23.6)	495033 (24.8)

	MIXED	52217 (1.6)	32327 (1.6)
	OTHER	41589 (1.3)	25076 (1.3)
	WHITE	1993092 (59.8)	1174649 (58.8)

Figure 2 shows the prevalence of 5 most common conditions and 5 conditions associated with severe maternal morbidity and mortality in 2006 and 2021. Depression was the most common condition in 2016, but anxiety became the most commonly diagnosed by 2021 and 271 women out of 1000 pregnancies had received a diagnosis of depression prior to pregnancy baseline in 2021. Prevalence of these 10 conditions increased by a median of 68% between 2006 and 2021, ranging from 15% to 270% increases. Prevalence of all conditions increased between 2006 and 2021, except for 6 conditions: spina bifida, Marfan's syndrome, Turner's syndrome, sarcoidosis, HIV, and peptic ulcer disease.

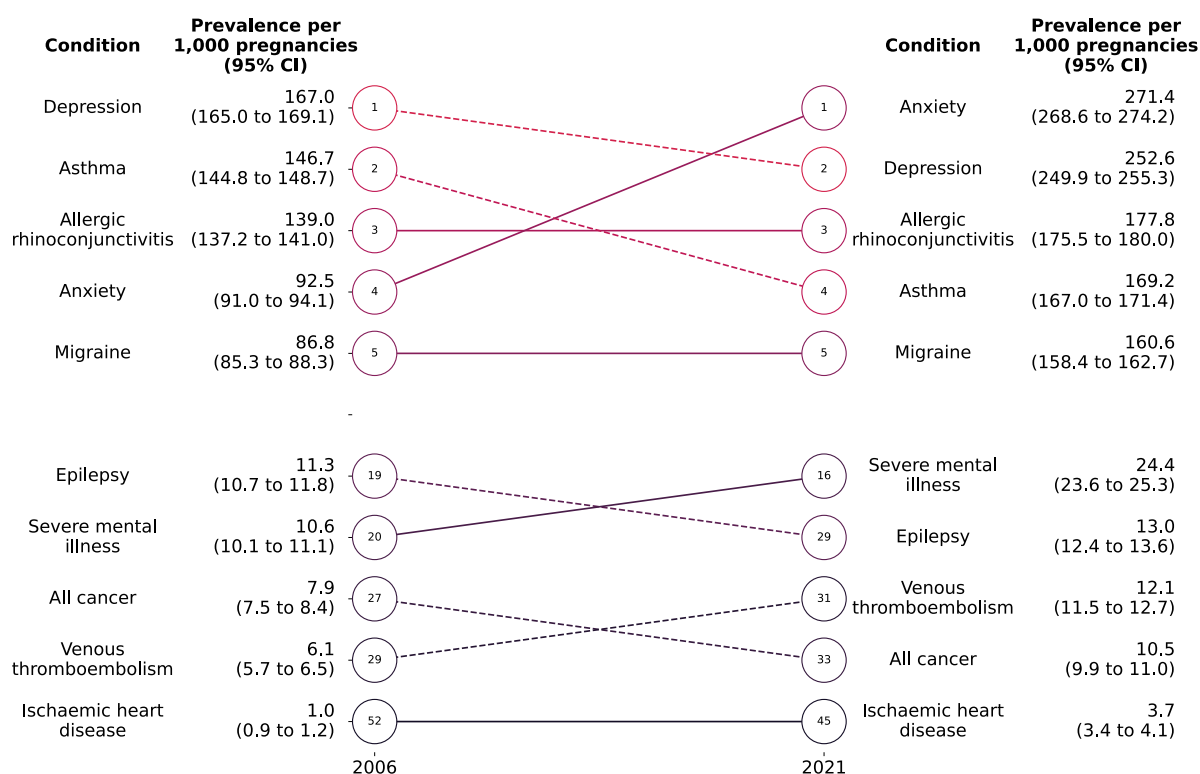


Figure 2: Change in prevalence and prevalence rank of individual conditions between 2006 and 2018 at pregnancy index, CPRD Aurum

Average risk ratios

Figure 3 shows the average rate of diagnoses of any of the 79 analysed condition between 2006 and 2021, for a) different ethnic groups and b) different deprivation quintiles, compared to all included pregnancies. In 2021, at the start of a pregnancy, women from white ethnic groups were 2% more likely to have been diagnosed with any one of the 79 conditions chosen at random than all included pregnancies, and women from mixed ethnic groups were 4% more likely to have been diagnosed. Women from black ethnic groups were 5% less likely to have been diagnosed, from Asian 26%, other 32%, and missing 19%. A clear gradient can be seen for women's deprivation, and in 2021 at the start of a pregnancy women living in the most deprived quintile of areas (IMD5) were 8% more likely to have been diagnosed

and from the least deprived quintile (IMD5) they were 8% less likely to have been diagnosed. See Appendix 2 for a discussion of properties of geometric means.

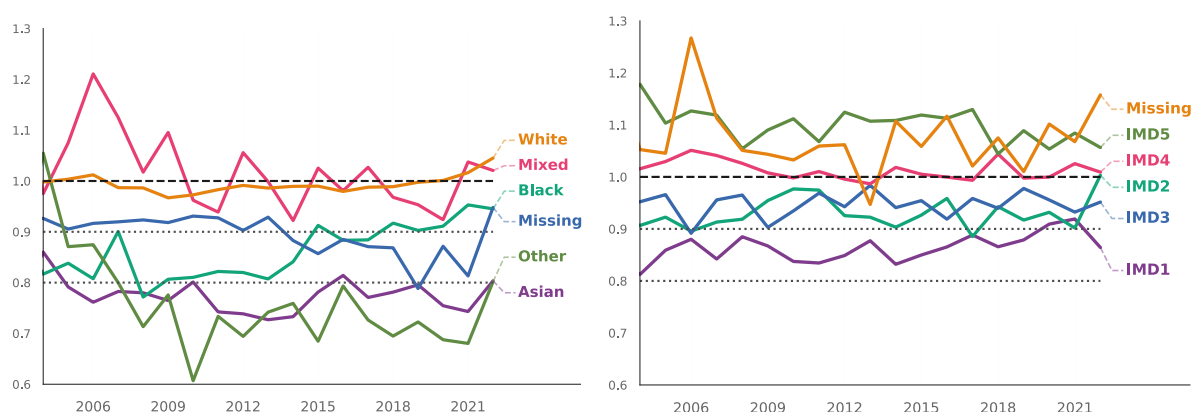


Figure 3: Average risk ratio of diagnoses over time a) by ethnic group and b) by Index of Multiple Deprivation.

Funnel plots

Figure 4 plots the prevalence of all conditions in a population group in 2021 against the ratio of that prevalence against all included pregnancies. It also plots the average rate of diagnosis for the population group for that year, and a control limit around that average. This identifies large signals for conditions that appear to be significantly higher than expected within a group, even after accounting for differential rates of diagnosis within that group.

For example, figure 4 shows that black women are more likely to have been diagnosed with fibroids and hypertension before the start of pregnancy, white women are likely to have diagnoses of depression and anxiety, Asian women are more likely to have diagnoses of Polycystic Ovarian Syndrome (PCOS), women from other ethnic backgrounds diagnoses of thyroid disorders and from mixed ethnic groups, fibroids. Common mental health conditions such as anxiety and depression were less likely to be diagnosed in women from black, Asian and other backgrounds. Women from other

ethnic backgrounds had similar prevalence of PCOS and female infertility as women from the overall population, however after accounting for the generally lower rate of diagnoses in this population group, there is a greater rate of PCOS and female infertility than would be expected. All data are available from <https://osf.io/2p8d5/>.

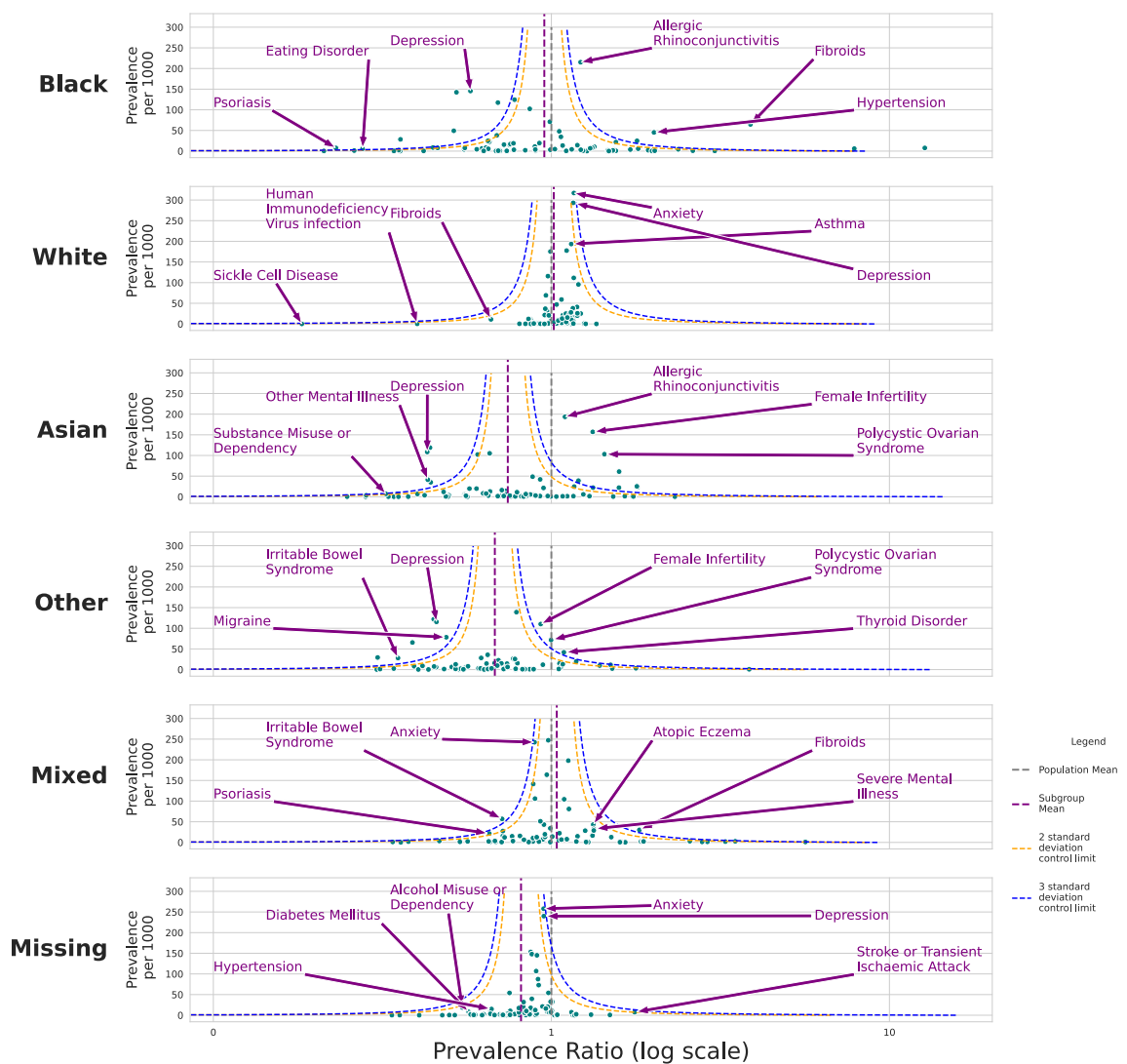


Figure 4: Funnel plots of prevalence variation by ethnicity. Each blue dot represents a condition. The X axis is the risk of diagnosis in an ethnic group compared to overall population. The Y axis is prevalence within an ethnic group.

Figure 5 shows funnel plots for conditions amongst women living in different IMD quintiles. Women in IMD1 areas (least deprived) were more likely to have diagnoses of asthma, migraine, and irritable bowel syndrome, and less likely to have

diagnoses of diabetes and hypertension. IMD5 (most deprived) women had higher rates of depression, substance misuse or dependency, and other mental illnesses such as dissociative disorders and obsessive-compulsive disorder (Lee et al. (149) for detailed definitions), while they were less likely to have irritable bowel syndrome, and eating disorders. Grouping the population by deprivation quintiles results in lower variation than for ethnicity, and this is particularly notable for IMD3&4 where signals are very weak for outlying conditions.

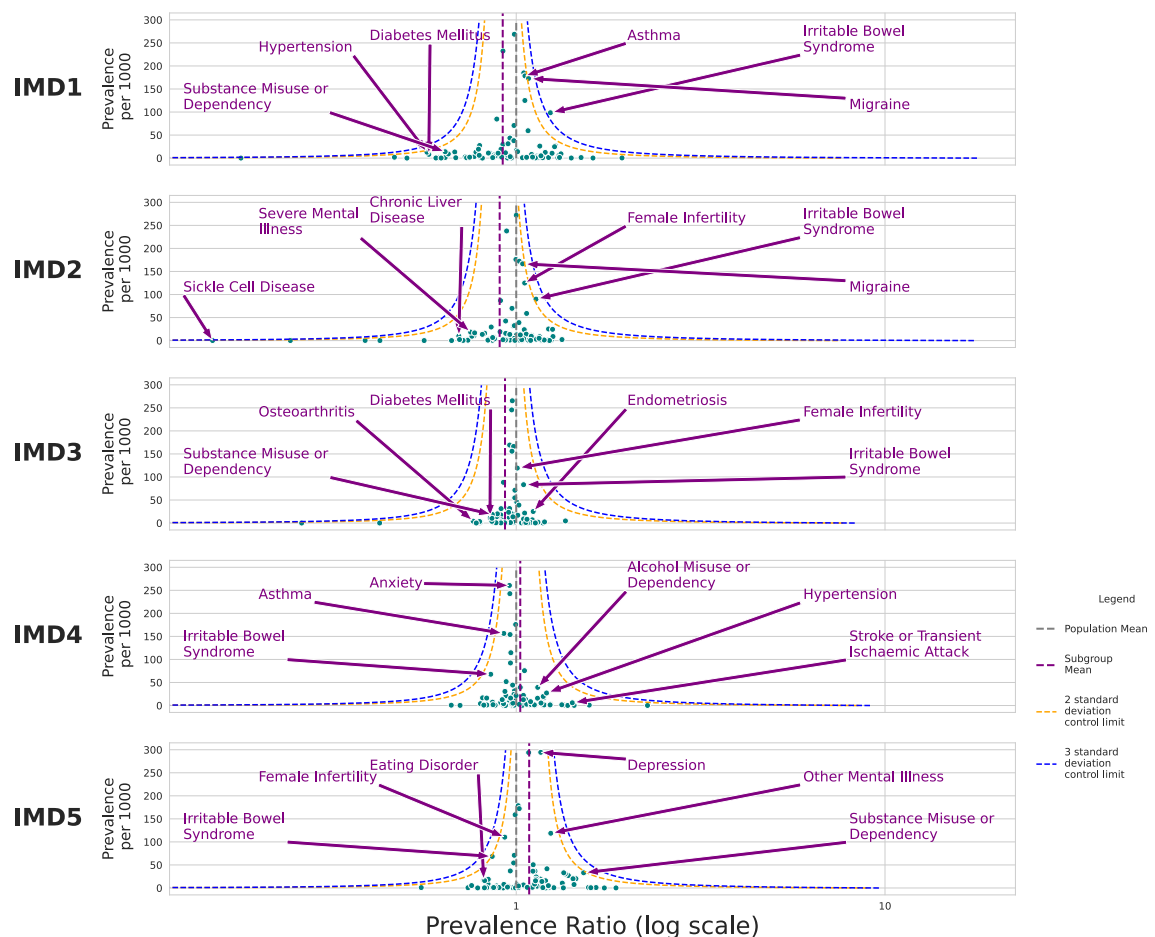


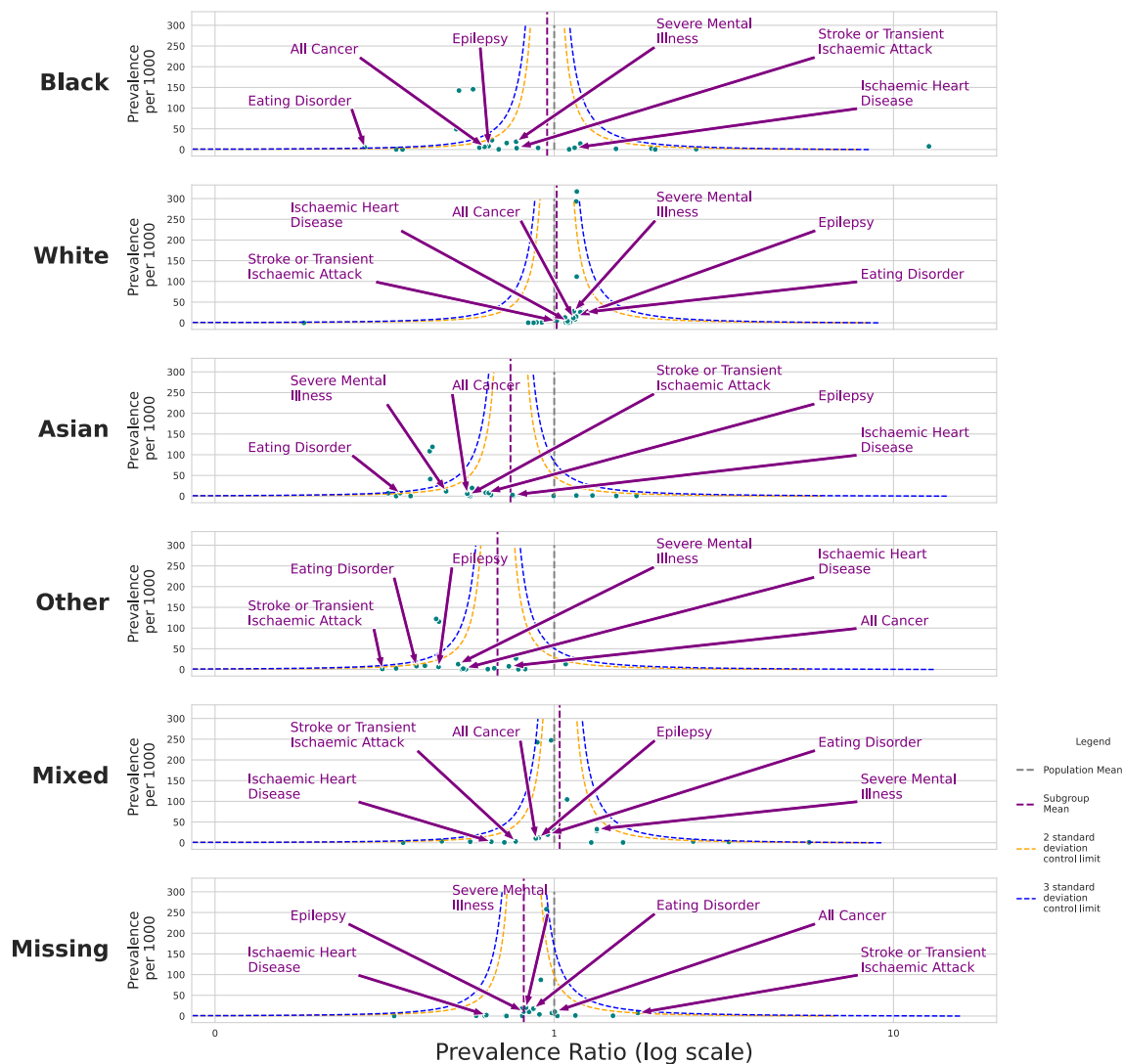
Figure 5: Funnel plots of prevalence variation by deprivation quintiles. Each blue dot represents a condition. The X axis is the risk of diagnosis in a deprivation quintile compared to overall population. The Y axis is prevalence within a deprivation quintile.

MBRRACE Conditions

Figures 6a) and 6b) show the same funnels plots as 4 and 5 but including only the 23 conditions linked to severe morbidity and mortality in the MBRRACE report of 2024. Mean and control limit lines are unchanged and for both categories, the same 6 conditions are highlighted to demonstrate differences in health needs.

Figure 6a) shows that ischaemic heart disease appears slightly elevated amongst black and white women (prevalence of 5.0 and 4.1 per 1000 pregnancies in respective groups) but reduced in Asian women (prevalence 3.3 per 1000 pregnancies, crude Risk Ratio (RR) for black and white women compared with Asian 2.16 [95% Confidence Interval 1.63, 2.86]). All cancers, in contrast, appears reduced in all non-white ethnicities. For example, the prevalence of cancer in Asian women was 5.7 cancers per 1000 and in black women 6.4 per 1000, compared to 11.7 per 1000 in white women (RR 0.57 [95% CI 0.48, 0.67] in Asian and black women compared to white).

Figure 6b) shows the same conditions across the gradients of deprivation. Women living in the least deprived quintile of areas are more likely to be diagnosed with eating disorders (RR for most deprived women compared to least deprived 0.65 [95% CI 0.58, 0.73]), cancer (RR 0.61 [95% CI 0.51, 0.72]), and ischaemic heart disease, although this was not statistically significant (RR 0.79 [95% CI 0.59, 1.05]). Women living in the most deprived quintile were more likely to be diagnosed with epilepsy (risk ratio for most deprived women compared to least deprived 1.45 [95% CI 1.24, 1.70]), severe mental illness (1.77 [95%CI 1.57, 2.00]), and stroke or transient ischaemic attack (2.2 [95% CI 1.58, 3.08]).



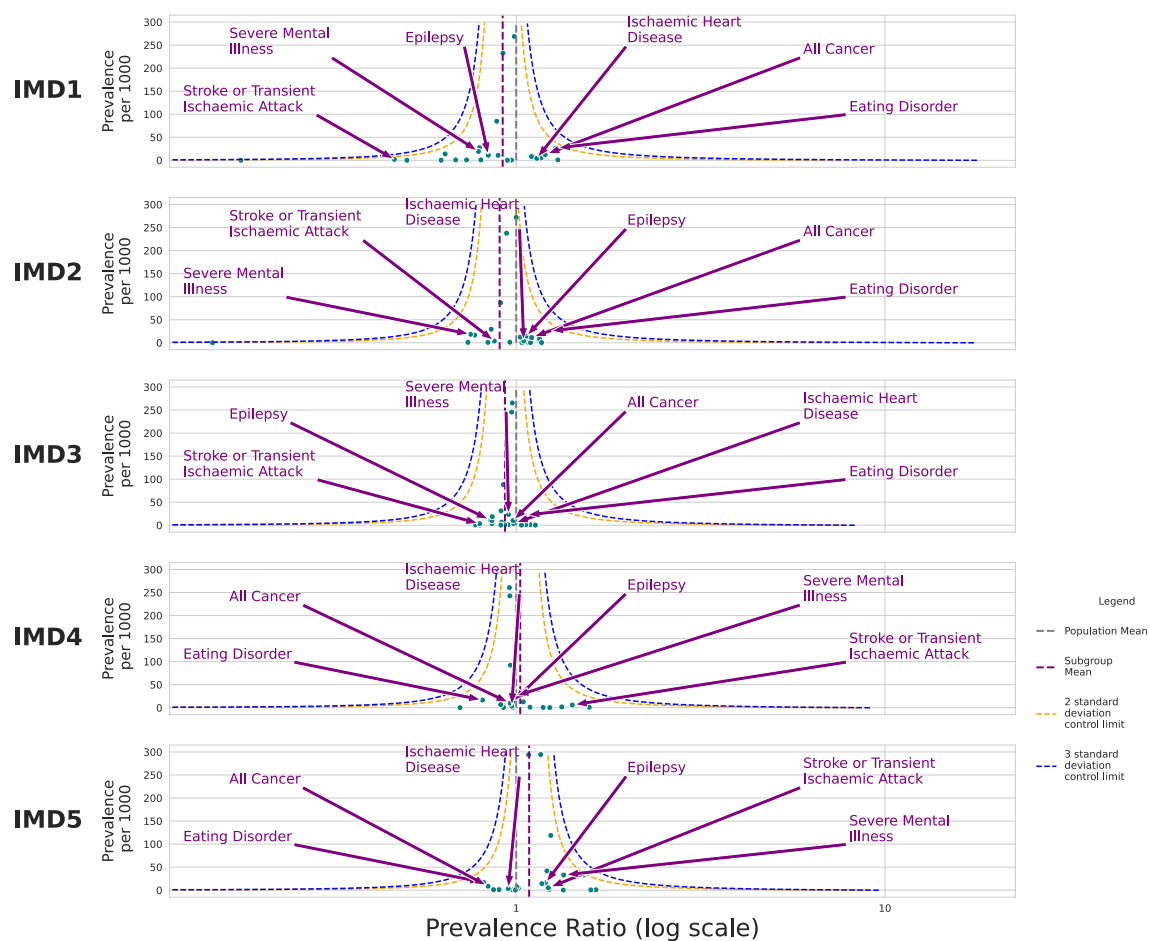


Figure 6: funnel plots displaying prevalence of MBRRACE conditions only in 2018 for a) ethnic groups and b) deprivation groups

Discussion

This study of 79 important long term health conditions in 3.4 million pregnancies found that women living in more deprived areas were more likely to have diagnoses of health conditions prior to pregnancy, while women from ethnic minority groups were less likely to have diagnoses. Prevalence increased for 73 out of 79 conditions between 2006 and 2021. Prevalence of conditions was greater in white ethnic groups and in women from more deprived areas, but many conditions did not follow these general trends. For example, ischaemic heart disease was more prevalent among black women and women from less deprived areas.

This study highlighted contrasting patterns of prevalence for women from populations that experience worse outcomes. Women from black and Asian ethnic groups were less likely to have diagnoses, while women living in more deprived areas were more likely to have diagnoses. This reinforces the different health status and experiences of women that leads to increased maternal mortality across all of these groups, driven by a range of biopsychosocial mechanisms.(157) The different drivers of mortality in different ethnic and disadvantaged groups also means that intersectional experiences will compound risks in non-linear ways, and although not investigated in this study, the effect of intersectionality is seen in increased stillbirths in women who are both from ethnic minorities and more deprived areas.(46)

This is the first systematic investigation of inequalities in long-term condition prevalence of women at pregnancy baseline in a nationally representative population. Previous work in a CPRD Aurum-derived general population identified that, similar to our results, ethnic minority groups were less likely to have diagnoses of chronic conditions, while more deprived areas were more likely to have diagnoses.(158) Lee et al.'s study of English, and Welsh primary care and Scottish secondary care datasets also found that women from ethnic minority groups were less likely to have multiple long term conditions diagnosed, but for deprivation the results were mixed; in Wales, women in more deprived areas were less likely to have multiple long term conditions, in Scotland they were more likely, and in England the signal was unclear.(149) Wang et al. found that prevalence of diagnoses in primary and secondary care showed similar differences across deprivation quintiles, and so the national differences found by Lee et al. may not be linked to care setting.

Santorelli et al looked at 21 chronic conditions in the post-partum period for White and South Asian women, using the Born in Bradford cohort. Similar to a number of the most common conditions in this study, Santorelli et al found that most conditions had a lower hazard rate in White women than South Asian. This study implies the opposite effect should be expected, but concordant with this study Santorelli et al found that cancer, mental health conditions, and neuromuscular conditions were more common in White women than South Asian women.(137)

All cancer prevalence varies substantially by population groups. Women who become pregnant with a preconception cancer diagnosis are likely to differ from most cancer population due to age-dependant incidence. Women diagnosed with childhood cancers are less likely to have a live birth(159) and current cancer care guidance often recommends avoiding pregnancy until at least 2 years after treatment is completed. Ethnic minority groups are known to have lower cancer rates in general populations(160), and this has been linked to lower true incidence due to fewer lifestyle exposures.(161) However, detection and diagnosis of cancer is also affected by lower awareness(162) and later diagnosis(163). Populations living in deprived areas are also known to have higher rates of cancer incidence, in contrast to our findings.(164) Smoking mediates 61% of the gap by deprivation, (165) but prevalent diagnoses of cancer in women of reproductive age are less likely to be highly smoke-sensitive neoplasms such as lung cancer, and more likely to be skin cancers or childhood neoplasms less sensitive to tobacco exposure.(164,166) Incidence of childhood cancers have been observed to fall with increasing material deprivation,(167) but more systematic analyses of prevalent cancer diagnoses in pregnant women is required to

understand whether the increased rate among deprived women is explained by underlying prevalence, or whether other mechanisms are at play such as previous cancer restricting future fertility options more amongst deprived women.

Mental health conditions also showed important trends in variation by population groups. Most women who initiate treatment for a mental health condition antenatally or postpartum have a preconception diagnosis of a mental health condition.⁽¹⁶⁸⁾ Low prevalence among ethnic minority groups likely underestimates healthcare needs, as ethnic inequalities in mental health care occur across the entire cascade of care, from access to services, assessment, diagnosis, treatment, and control of conditions, and result in underdiagnosis.⁽⁹⁹⁾ For example, Devonport et al investigated black communities, finding that this ethnic group of patients access mental health care at point of crisis more often than other ethnic groups, due to low confidence in services, increasing the already elevated chance of poor outcomes and being detained under the mental health act, which further damages trust between services and communities.⁽¹⁶⁹⁾ The association between mental health conditions and deprivation is well established, with most conditions increasing with deprivation except for eating disorders which have the opposite trend.^(168,170,171) Our results reiterate that more deprived areas will require more healthcare resources, but not all conditions associated with deprivation have concordant trends.

This study used a large, nationally representative sample of pregnancies from a population-based dataset. Pregnancy detection and linkage algorithms have been rigorously designed and validated,⁽¹⁵³⁾ and the analysis methods made full use of the depth and breadth of data available, aggregating data together into a single result that

is readily interpretable. They then used statistical control methods to detect special-cause variation in outlying conditions and guide attention to important signals amongst different populations.

However, despite robust methods, the underlying data has several limitations. Variation in observed prevalence of conditions may represent a true difference in prevalence, but may also represent differences in care seeking behaviours, the diagnostic care received, or primary care coding. Differences between populations in care seeking or care received are still highly relevant to policy makers, but our analysis cannot differentiate between the causes of these differences in prevalence. Data coding is undertaken by front-line clinicians and where conditions are not coded but are diagnosed, we will have misclassified a condition as absent. This variation in coding behaviour clusters within general practices; while many studies may adjust for individual practice effects, we have chosen not to do so because ethnic and deprivation characteristics also cluster strongly by practice and are likely to directly affect practice behaviour, and so adjusting for practice will mask effects due to ethnicity and deprivation.

In addition to missing diagnoses, the data may also miss pregnancies. The pregnancy register is thought to capture 96% of live births,(153) but is missing many more miscarriages and terminations. Pre-existing conditions may causally increase the likelihood of terminations and miscarriages of pregnancies that may otherwise have been brought to term, and therefore these unrecorded pregnancies may represent unmet healthcare needs. Similarly, pre-existing conditions affect fertility, for example through pregnancy prevention programmes,(172) and the reduced number of

pregnancies among women with these conditions would reduce prevalence in our results.

Finally, mother's ethnicity data was missing in 24% of pregnancies, and those with missing data tended to have fewer diagnoses and therefore may have had less contact with health services.⁽¹⁷³⁾ Although IMD is well recorded, our representations of the concepts of ethnicity and deprivation have limitations. The six ethnic groups are aggregations of self-identified ethnicity and may better correspond to the concept of race than ethnicity. Using more granular ethnic categories would produce vast amounts of data with more statistical error that would be more challenging to interpret but would better reflect healthcare needs deriving from a particular set of biopsychosocial experiences. Deprivation aggregated into five quintiles also opts for interpretability over investigating differences in the extremes of the deprivation scale. The steepest gradients in health status are observed in the most and least deprived 20% of the population and so their health experiences are likely to be particularly different. The data used to calculate the IMD has varied quality, with some data used in the 2019 IMD not updated since 2011.⁽¹⁵⁵⁾ Intersectionality between ethnicity and deprivation was not studied here but will be essential to further understanding and addressing health inequalities.

These findings have different implications for health inequalities attributable to deprivation and to ethnicity. Each condition is subject to different dynamics within each population group, and primary-care derived prevalence may reflect between-group differential prevalence, access to care, diagnosis patterns, recording of conditions, or likelihood of pregnancy as a result of conditions. However, in general, deprivation

shows trends across the gradient of deprivation with generally higher burden of disease in more deprived areas, and therefore will require more resources to prevent, diagnose and treat these conditions and optimise pre-conception and antenatal health status.

Differences between ethnic groups show more complex trends; while some ethnic minority groups appear to have reduced prevalence of diagnoses, and some of this may be due to lower prevalence of the underlying condition, much may be due to underdiagnosis. Mental health is a particularly clear example of this and developing effective interventions is enormously challenging; for example, the recently published Roshni trial investigated an intervention codeveloped with women of Pakistani, Indian, and Bangladeshi ethnicity in 2003 for post-natal depression.⁽¹⁷⁴⁾ This showed a small, short-term improvement in depression symptoms, and took 20 years to develop and evaluate.⁽¹⁷⁵⁾ A significant work component of the Roshni trial involved recruiting women who otherwise may not have presented to healthcare services. Many more such interventions, tailored to granular ethnic communities with more similar health experiences than those analysed here, would need to be developed, evaluated, and implemented to ensure true burden of disease is identified and effectively managed, and the timeline of delivering such interventions must be much shorter. The recently announced NIHR Maternal Disparities Challenge is one such initiative,⁽¹⁴⁶⁾ and such initiatives should incorporate universal, life course approaches to tackling poverty and structural inequalities which will also be required to achieve the scale needed across a diverse population with varied needs and conditions.

Conclusion

Pre-existing long term conditions are a major driver of maternal morbidity and mortality, and there is significant variation in the prevalence of long term conditions at the beginning of pregnancy between women from areas of differing deprivation levels or of different ethnic backgrounds. These differences in health status and experience are likely to cause some of the increased maternal and infant morbidity and mortality seen in some groups. Prevalence of long term conditions is higher among more deprived areas, and so more resources are required to optimise health status for pregnancy; for women ethnic minority groups, prevalence appears lower but this likely masks unmet health needs and further work is needed to better diagnose those health conditions, prevent ill-health, and offer intervention that can improve pregnancy outcomes.

Conflicts of Interest

No conflicts of interest are reported by the authors.

Contributions

NC, BT, WPS, JSC, KN conceptualised the study. NC, MS, SW, AIG, SIL, KP curated data. NC conducted formal analysis and produced visualisations. NC, NJ and RS developed methodology. NC wrote the original manuscript. All authors reviewed and edited the manuscript. BT, JSC, WPS, KN supervised NC.

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health disparities. NJ and RS were supported by a UKRI Future Leaders Fellowship.

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Ethics

CPRD has ethics approval from the Health Research Authority to support research using anonymised patient data. The study has been approved by the Independent Scientific Advisory Committee for CPRD (reference: 20_181R).

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6. Epidemiological case studies using a data platform deployed into a maternity service

This chapter describes the technical elements of the SaTH-DExtER deployment and two case studies conducted using data provided by SaTH-DExtER. Deployment of DExtER required extensive creating hardware and software resources within the hospital, data modelling of the maternity record, and new workflows to interact with the data. These are demonstrated in two locally relevant data analyses: firstly, surveillance of outcomes for induction of labour using a cohort design. This study had a specific focus on health inequalities that can be detected within the electronic health record, demonstrating the strengths and limitations of LHS infrastructure for enabling built-in monitoring of inequalities. Secondly, identification of eligible women for a clinical trial using a cross-sectional study to identify eligible women is reported here as a concept for auditing potential and actual trial participation, complementing the real-world use.

6.1. The SaTH-DExtER deployment

6.1.1. Data provenance and technical architecture

Maternity data at SaTH is stored in a hospital-level Data Warehouse (DWH), and SaTH-Dexter used data from the maternity EHR called Badgernet. Three systems in total store data about maternity care: the maternity record, the Patient Administration System (PAS), or the laboratory information system. Laboratory information, which would significantly enrich the data, was not available to SaTH-DExtER, but relevant PAS

data is populated into Badgernet data. Badgernet itself is stored as an XML document store, but an Extract, Transform, and Load (ETL) process creates a reporting solution stored in the DWH as a SQL database. The database contains 154 tables and the schema can be viewed in Appendix 6.1.

Figure 6.1 outlines data flows throughout the deployment using data from the DWH. Data from the DWH (1) undergoes ETL into a DExtER data store (2), described further in section 6.1.2. The DExtER Epidemiology Engine (3) can then execute a study design to create an analysis-ready dataset from the transformed dataset. The Epidemiology Engine is instructed by a web application hosted at the University of Birmingham (4), which provides the user interface and is discussed further in section 6.3. The DExtER Epidemiology Engine then extracts a defined study, performing a set of analyses or updating a dashboard (5) and storing the dataset locally for further analysis or investigation by the user (6).

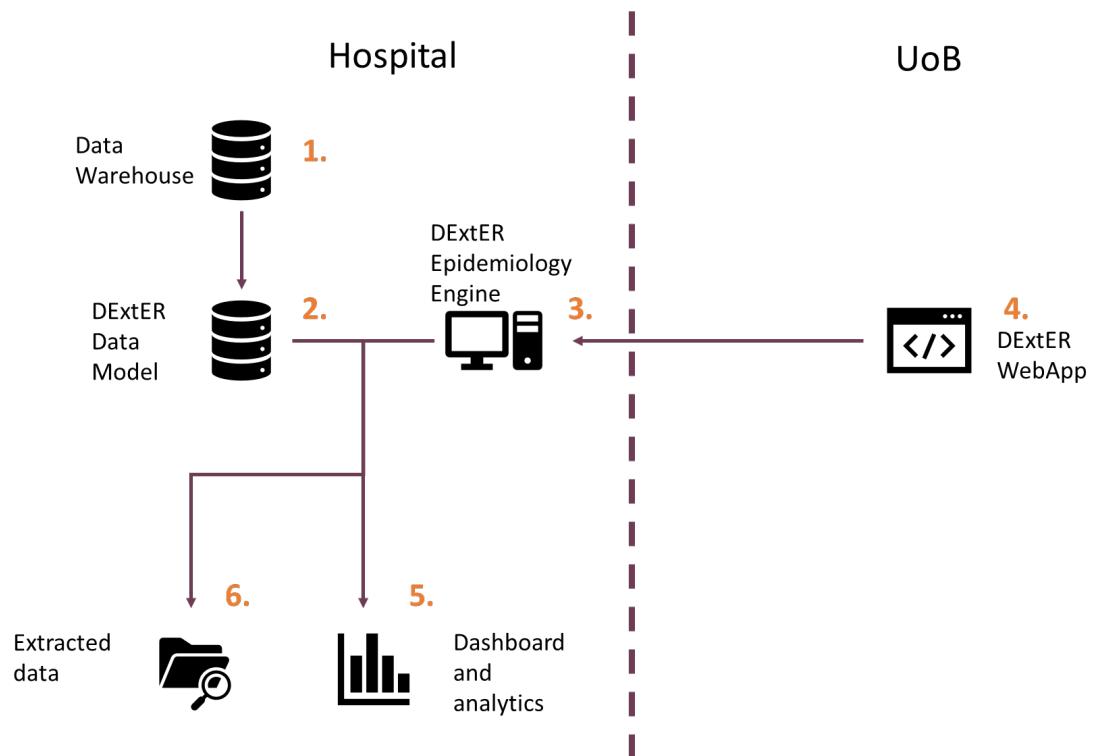


Figure 6.1: SaTH-DExtER deployment architecture.

6.1.2. Data Modelling

The DExtER data model developed for use with primary care consisted of a minimum of 5 tables.⁽¹⁾ These tables and the underlying software required some adaptation to manage maternity data; maternal health is a unique healthcare context where a single medical event often directly affects two or more patients. Analytical questions could be interested in pregnancies, mothers, or babies. Data therefore needed to be available for all three to enable processes such as matching babies on characteristics or setting index dates by trimester, while extracting outcomes and covariates across the record. A new pregnancy model was developed to enable the above linkages and the workflows described in section 6.1.3; the tables in the model are described in table 6.1, and the full model schema is in Appendix 6.2.

Table	Description
Patient	Mother or baby. Data contained includes date of birth and ethnicity.
Pregnancy	Pregnancy episode. Contains start and end points, number of fetuses
Linkage	Baby – pregnancy – mother linkage.
Medical	Any event in a patient record.
Additional	Entities with an additional associated value such as measures.

Table 6.2: DExtER Pregnancy Data Model

The two pregnancy and linkage tables were extensions to the pre-existing model, required to describe key features of the pregnancy. The pregnancy table defined the start and end of pregnancies, which defined the events and information that were related to a pregnancy. The linkage table then defined mother-baby dyads, which due to pregnancies with multiple fetuses required a many-to-one mapping for each baby to be linked to a pregnancy. Figure 6.2 describes the relationships between the different tables.

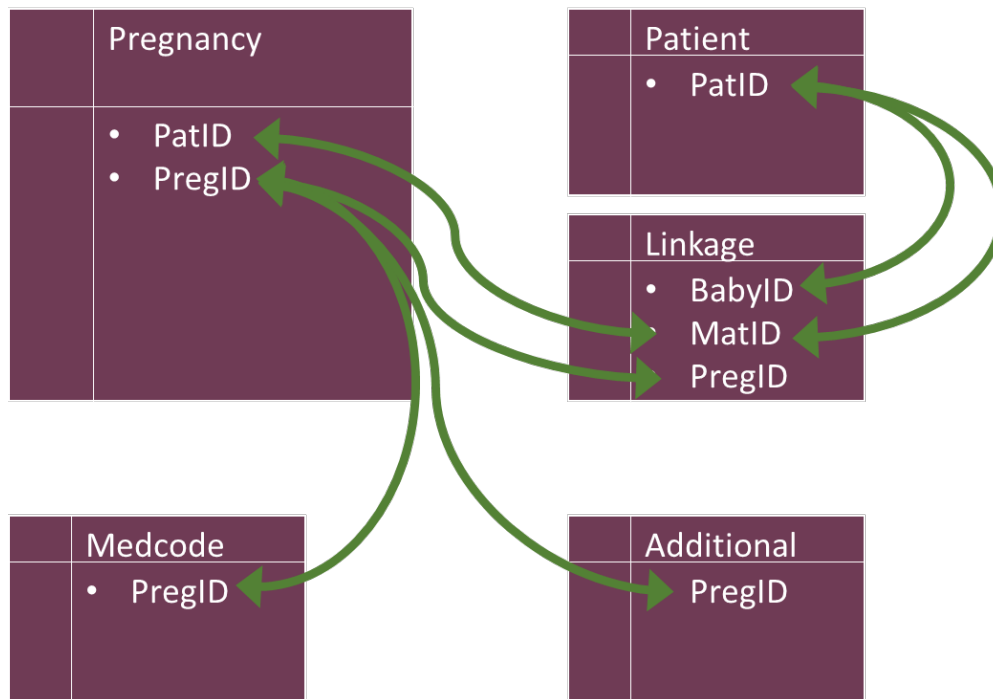


Figure 6.2: Entity relationship diagram for maternity DExtER data model

Badgernet data is reported as a database of 154 tables which needed to be remodelled into the 5 tables above. It is entered by users as a combination of structured data, such as multiple choice and checkbox option fields, semi-structured data, such as free text entered into defined fields, and unstructured data such as long form clinical notes. Long form clinical notes were not available to us, and Badgernet is not coded in a standardised terminology such as SNOMED-CT.

The data to populate the pregnancy, patient, and linkage tables were either developed as specific mappings from the source data or derived from the data in the tables as conveniences. Most source data was flexibly mapped into Medcode and Additional tables unless it was already mapped into the other 3 tables or removed to enhance privacy. Figure 6.3 describes how data was mapped into the Medcode and Additional tables, and worked examples are given in Appendix 6.3. All data was placed into the additional table, while only structured data, dynamically defined by identified

fields where values contained duplicate text strings across entries, was modelled in the Medcode table.

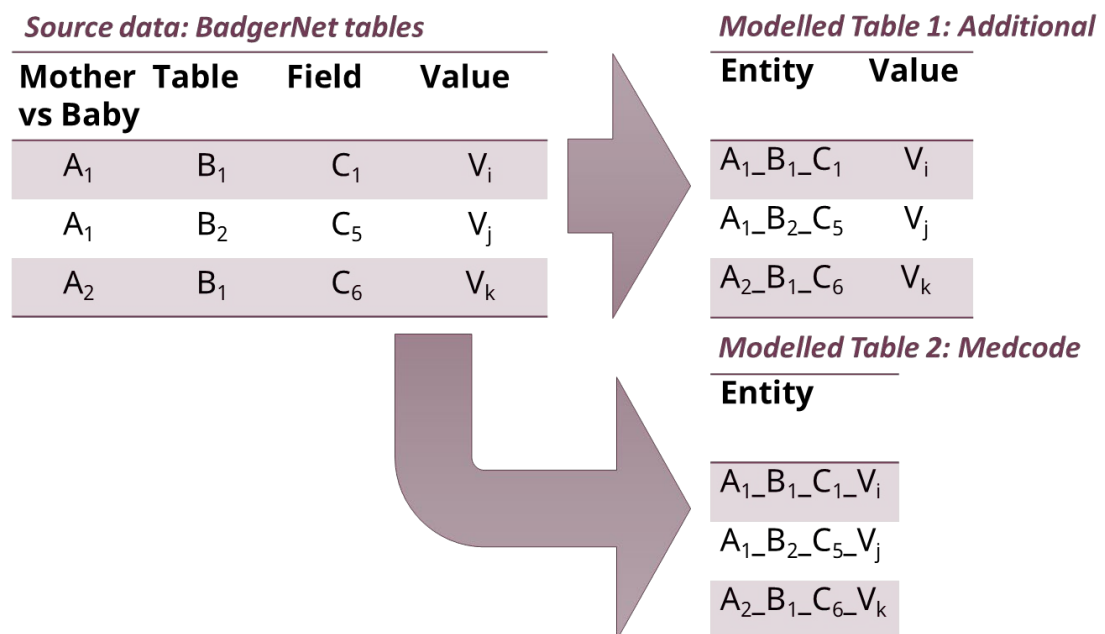


Figure 6.3: Mapping badgernet source data into Additional and Medcode data

Duplicating structured data in both additional and medcode tables provided a convenience. The medcode table enabled development of phenotypes where many medical events could be mapped to a single concept. For example, emergency caesarean sections and elective caesarean sections, themselves also possessing many descriptors, could be mapped to a single “caesarean section” phenotype. Conversely, the additional table enabled the same data to be represented in the original categories, such as mode of delivery which is recorded as a categorical variable.

6.1.3. Workflows

Phenotypes were developed using the Codebuilder utility in Dexter. Phenotypes could be developed using all medcode entities were presented to users in a searchable

and interactive list along with frequency of appearance where users could build phenotypes that corresponded to a concept. A template form to support development of phenotypes is presented in Appendix 6.4. Phenotypes developed in Dexter could then be directly used when developing study designs.

Phenotypes and additional data could be used as criteria to define eligible cases and index dates, or as outcomes and covariates. The relationship between exposures and outcomes depends on the study design selected, and after selecting a study design, users would complete a form modelled on the Population, Exposure, Comparator, Outcome structure to defining epidemiological questions. This would generate a JSON file, stored within the Birmingham Dexter servers and containing no patient identifiable information, that could then be submitted to the epidemiology engine for an extraction. Such study designs could be iteratively improved or repeated with different time periods, enabling a low-code approach to reproducible analysis that made electronic health records accessible to non-data scientists with sufficient epidemiological training.

The next section outlines two use cases from Dexter, presented as epidemiological study reports.

6.2. Outcomes of induction of labour: an electronic health record cohort study

6.2.1. Background

Induction of labour is increasingly common in UK pregnancies and rose from 28.5% of births in 2015 to 33.5% in 2018.(2,3) Rising rates are driven by increasingly

complex health needs of pregnant women, who are older and have more comorbidities than in the past,(4,5) and by new guidance and evidence suggesting improved outcomes when inducing women with hypertensive disorders of pregnancy,(6) diabetes(7), fetal macrosomia,(8), postmaturity,(9), and even for low-risk, fully term births.(10,11)

Maternal care decisions such as induction can be complicated by asymmetric risks between a pregnant woman and unborn foetus. For example, in hypertensive disorders of pregnancy, the definitive treatment is birth, but pre-term birth can increase risk of poor outcomes for babies while reducing them for mothers.(12) Decisions are made in the interests of two “patients”, which can lead to complex, value-laden decisions with risk trade-offs for families and their healthcare staff.

Inequalities in maternal outcomes between different social groups have long been recognised. Women from the most socioeconomically deprived areas are twice as likely to die during pregnancy as women from the least deprived areas, while women from Asian ethnic groups are twice as likely to die and from black ethnic groups three times as likely.(13) Increasing routine induction of labour in women from black ethnic groups was proposed in NICE guidelines in 2019, intended to reduce inequalities in outcomes due to emerging evidence that induction lowered risk of adverse outcome,(9,14) but this was found to be controversial as it was likely to negatively affect access and experiences of care without treating underlying issues.(15)

Increasing rates of induction have caused concern within SaTH and specific attention from the Patient Safety Forum and the Ockenden report, and so changes or variations in practice are closely examined. Induction of labour may be associated with

increased emergency caesarean section or blood loss in labour,(16,17) and rising rates of induction of labour have been criticised by patient groups as driven by guidance based on limited evidence.(18,19)

This analysis therefore aims to evaluate overall outcomes in induction of labour care at SaTH, and identify any inequalities experienced by different social groups.

6.2.1.1. Evaluation Objectives

1. How do outcomes of induction compare with women who labour spontaneously?
2. Which groups of women are more likely to undergo induction of labour?
3. How do reasons for induction differ between different groups of women?

6.2.2. Methods

6.2.2.1. Study Design

This was a cohort study using data from the BadgerNet EHR at SaTH. All pregnancies that laboured at SaTH between 01-01-2022 and 10-12-2024 were included. This entailed excluding elective caesarean sections.

The exposed group was defined as pregnancies where induction of labour was recorded as attempted before birth. Recording before birth was added as a requirement to ensure data quality through contemporaneous recording. Appendix 6.5 contains a phenome for identifying induction as well as other phenomes used in this study. Reasons for induction were extracted from the Induction_MainReason field in BadgerNet.

Pregnancies where labour was established and was recorded before birth were included in the comparator group.

Outcomes were emergency caesarean sections, defined as any caesarean section occurring after labour was established or induction attempted, average blood loss, baby admission to neonatal unit, or perinatal death, defined as either a stillbirth that occurred after labour established or induction commenced, or a neonatal death.

Included covariates are pregnancy risk level as assessed at the booking visit (low, intermediate, high, or unknown), gestational age at birth (as a continuous measure or grouped as less than 28 weeks, 28-31 weeks, 31-34 weeks, 34-37 weeks, 37-41 weeks, and over 41 weeks), postcode-linked IMD deciles, ethnic group (Asian, black, missing, mixed, other, or white), and parity (primiparous vs multiparous). IMD was linked to women's home address Lower Super Output Area from national data lookups.

6.2.2.2. Statistical Analysis

Characteristics of women who underwent induction compared to women in whom labour was established were described. Frequency and percentage of women were calculated for categorical variables and mean and standard deviation for continuous variables. Univariable risk ratios and 95% Confidence Intervals (95% CIs) were calculated, and a multivariable modified Poisson regression model was fitted for binary outcomes to understand which factors affect access to induction for women.

Similarly, outcomes were described using frequency and percentage of women for categorical variables and mean and standard deviation for continuous variables. Univariable risk ratios were calculated and a multivariable models predicting outcomes were fitted using modified Poisson regression for binary outcomes and ordinary least squares for blood loss, a continuous variable, to estimate differences in outcomes.

Analysis was conducted using Excel and Python.

6.2.2.3. *Ethical approval*

This study was approved as a service evaluation by SaTH Research & Innovation on 21st January 2025.

6.2.3. Results

6.2.3.1. *Study Inclusion*

Figure 6.4 outlines selection of participants for this study. Of 10,171 births at SaTH during the study period, 7,782 met our inclusion criteria. 3144 (40%) of pregnancies underwent induction of labour, and 4638 (60%) laboured spontaneously.

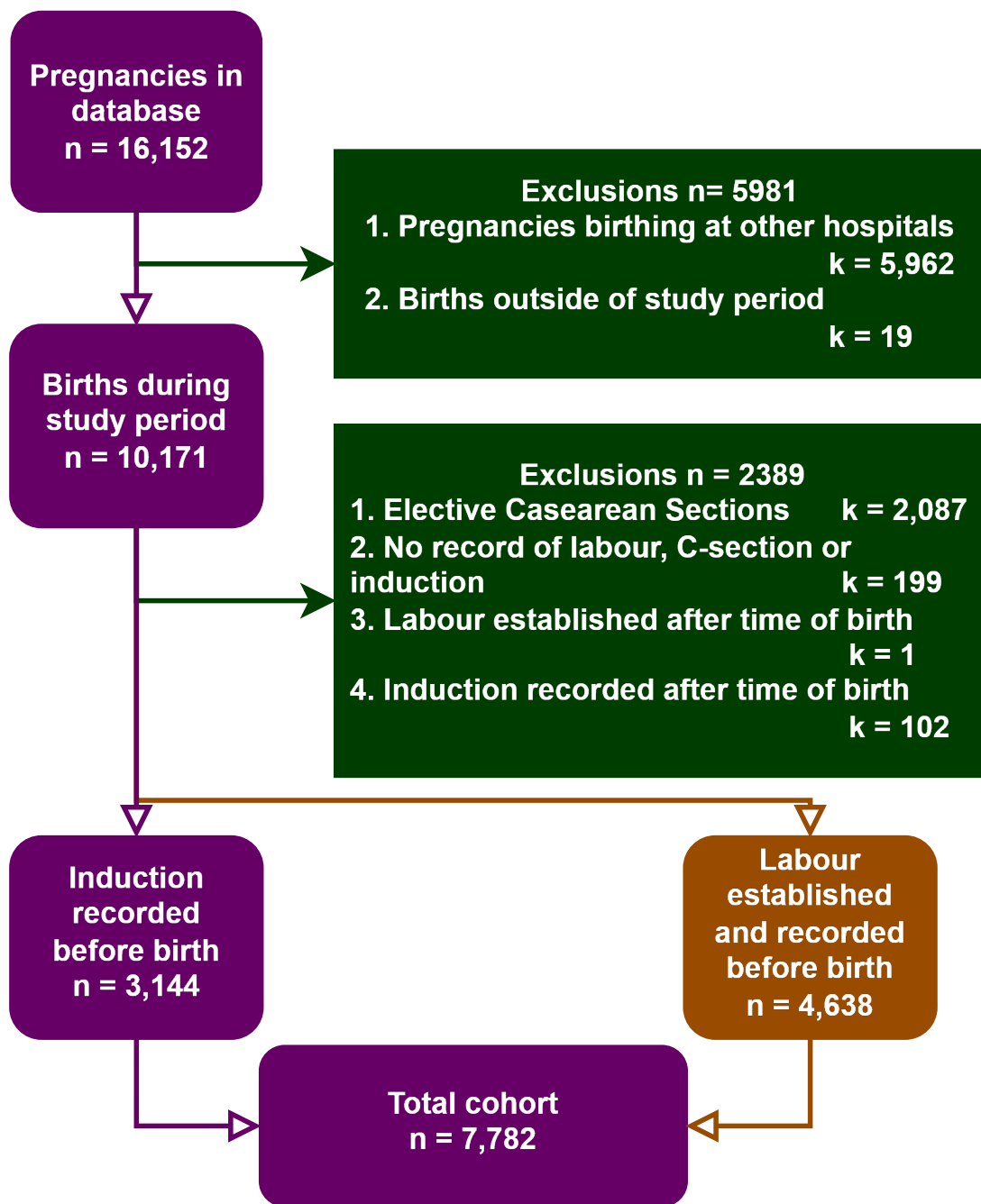


Figure 6. 4: Pregnancy selection for study inclusion

6.2.3.2. Access to Induction

Table 6.2 outlines the characteristics of the cohort, stratified by induced and spontaneous births. Most pregnancies were to mothers aged between 17-30 years (47%) or 31-40 years (49%). Pregnancies in women aged 17-30 and 41-50 were more likely to be induced than women aged 31-40. Women who underwent induction were

slightly younger on average (mean: 0.36 years younger (95% Confidence Interval (CI) 0.11, 0.62)). 6386 pregnancies (82%) ended between 37 and 41 weeks of gestation; women were more likely to labour spontaneously until 37 weeks of gestation, and there was no statistically significant difference in likelihood of induction between 37-41 weeks and over 41 weeks.

4207 pregnancies (54%) in the cohort were in multiparous women. Multiparous women had a similar unadjusted likelihood of being induced to nulliparous women, but following adjustment for factors including assessed risk, multiparous women were 7% less likely to be induced (Risk Ratio (RR) 0.93 (95%CI 0.88, 0.99)). 4315 women (55%) were assessed to be at high risk in their pregnancy, and were more likely to be induced (adjusted RR: 1.49 (95%CI 1.40, 1.58)).

Women tended to be from more deprived areas and 56% were from the more deprived half of areas. Women from the most deprived areas had a greater probability of being induced (IMD1 unadjusted RR: 1.26 (95%CI 1.10, 1.44)); no other decile of deprivation had a statistically significantly different risk of induction compared to the least deprived decile. Adjustment for factors including assessed risk attenuated this effect slightly (adjusted RR: 1.21 (95%CI 1.06, 1.38)). Women were predominantly from white ethnic groups (6258, 80%); Asian was the second largest grouping (374, 5%), then mixed (191, 2%), black (152, 2%) and then other ethnic groups (79, 1%). No ethnic group had a statistically significantly different likelihood of being induced; however, for women from black ethnic groups, the likelihood of induction appeared to be slightly lower than women from white ethnic groups and may have been significant in a larger sample (adjusted RR: 0.83 (95%CI 0.66, 1.03)).

Cohort		All	Induced	Spontaneous	Risk Ratio or Mean Difference	Adjusted Risk Ratio*
Measure		Frequency (%)	n (%) or Mean (std)	n (%) or Mean (std)	(95% CI)	(95% CI)
Overall		7782	3144 (40.4)	4638 (59.6)		
Mother's Age at Pregnancy Start	0-16	10 (0.1)	3 (0.1)	7 (0.2)	0.80 (0.31, 2.05)	0.61 (0.23, 1.64)
	17-30	3680 (47.3)	1565 (49.8)	2115 (45.6)	1.13 (1.07, 1.19)	1.11 (1.05, 1.18)
	31-40	3845 (49.4)	1448 (46.1)	2397 (51.7)	1 (Ref)	1 (Ref)
	41-50	245 (3.1)	127 (4.0)	118 (2.5)	1.38 (1.21, 1.56)	1.25 (1.10, 1.42)
	51-60	2 (0)	1 (0.0)	1 (0.0)	1.33 (0.33, 5.31)	1.60 (0.72, 3.57)
	Mean (std)	30 (0.4)	29 (5.7)	30 (5.4)	-0.36, (-0.62, - 0.11)	
Gestational age in weeks at birth	<27	119 (1.5)	26 (0.8)	93 (2.0)	0.52 (0.37, 0.73)	0.51 (0.36, 0.71)
	27-31	16 (0.2)	2 (0.1)	14 (0.3)	0.30 (0.08, 1.09)	0.29 (0.08, 1.07)
	31-34	54 (0.7)	3 (0.1)	51 (1.1)	0.13 (0.04, 0.40)	0.13 (0.04, 0.39)
	34-37	321 (4.1)	72 (2.3)	249 (5.4)	0.54 (0.44, 0.66)	0.51 (0.41, 0.62)
	37-41	6386 (82.1)	2670 (84.9)	3716 (80.1)	1 (Ref)	1 (Ref)
	>41	886 (11.4)	371 (11.8)	515 (11.1)	1.00 (0.92, 1.09)	1.07 (0.98, 1.16)
	Mean (std)	39 (0.5)	39 (2.4)	39 (3.4)	0.23, (0.1, 0.36)	
Parity	Primip	3575 (45.9)	1426 (45.4)	2149 (46.3)	1 (Ref)	1 (Ref)
	Multip	4207 (54.1)	1718 (54.6)	2489 (53.7)	1.02 (0.97, 1.08)	0.93 (0.88, 0.99)
Pregnancy risk at booking	Low	3463 (44.5)	1124 (35.8)	2339 (50.4)	1 (Ref)	1 (Ref)
	Moderate	3 (0)	2 (0.1)	1 (0.0)	2.05 (0.92, 4.58)	1.92 (0.88, 4.22)
	High	4315 (55.4)	2018 (64.2)	2297 (49.5)	1.44 (1.36, 1.53)	1.49 (1.40, 1.58)

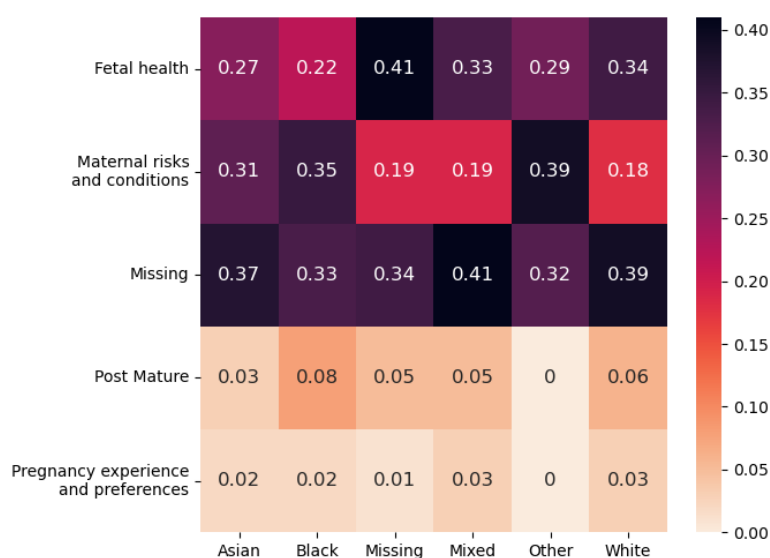
	Missing	1 (0)	0 (0.0)	1 (0.0)	0.00 (0.00, nan)	0.00 (0.00, 0.00)
Index of Multiple Deprivation decile	1 (Most Deprived)	773 (9.9)	378 (12.0)	395 (8.5)	1.26 (1.10, 1.44)	1.21 (1.06, 1.38)
	2	902 (11.6)	364 (11.6)	538 (11.6)	1.04 (0.91, 1.19)	0.98 (0.86, 1.12)
	3	552 (7.1)	209 (6.6)	343 (7.4)	0.98 (0.83, 1.14)	0.96 (0.82, 1.12)
	4	1191 (15.3)	486 (15.5)	705 (15.2)	1.05 (0.92, 1.20)	1.02 (0.89, 1.16)
	5	917 (11.8)	374 (11.9)	543 (11.7)	1.05 (0.92, 1.21)	1.02 (0.89, 1.17)
	6	963 (12.4)	385 (12.2)	578 (12.5)	1.03 (0.90, 1.18)	1.02 (0.89, 1.17)
	7	932 (12)	344 (10.9)	588 (12.7)	0.95 (0.83, 1.09)	0.94 (0.82, 1.08)
	8	589 (7.6)	234 (7.4)	355 (7.7)	1.02 (0.88, 1.19)	1.02 (0.87, 1.18)
	9	486 (6.2)	184 (5.9)	302 (6.5)	0.98 (0.83, 1.15)	0.98 (0.84, 1.15)
	10 (Least Deprived)	474 (6.1)	184 (5.9)	290 (6.3)	1 (Ref)	1 (Ref)
	Missing	3 (0)	2 (0.1)	1 (0.0)	1.72 (0.77, 3.85)	1.52 (0.78, 2.95)
Ethnicity	Asian	374 (4.8)	149 (4.7)	225 (4.9)	0.98 (0.86, 1.11)	0.99 (0.87, 1.13)
	Black	152 (2)	51 (1.6)	101 (2.2)	0.83 (0.66, 1.03)	0.83 (0.66, 1.03)
	Missing	728 (9.4)	291 (9.3)	437 (9.4)	0.98 (0.90, 1.08)	1.00 (0.91, 1.10)
	Mixed	191 (2.5)	79 (2.5)	112 (2.4)	1.02 (0.86, 1.21)	1.02 (0.86, 1.21)
	Other	79 (1)	31 (1.0)	48 (1.0)	0.97 (0.73, 1.27)	0.93 (0.71, 1.21)
	White	6258 (80.4)	2543 (80.9)	3715 (80.1)	1 (Ref)	1 (Ref)

Table 6.3: Characteristics of the cohort, stratified by induced vs spontaneous labour. *Adjusted for Mother's age, Gestational age at birth, parity, assessed risk, index of multiple deprivation, and ethnicity. std: Standard Deviation; CI: Confidence Intervals

Figure 6.5 summarises the main reason given for induction, following categorisation of semi-structured text. Fetal health refers to concerns primarily affecting the fetus and not the mother such as small for gestational age; maternal risks

and conditions concerns the pregnant women's health such as pre-eclampsia; post mature refers to pregnancies greater than 41 weeks gestation; and pregnancy experiences and preferences refers to reasons that centre a woman's plans or symptomatic relief. Many pregnancies had no reason documented (38%) but where a reason was given, Labour was most commonly induced for fetal health (34%).

However, figure 6.5a) show that for women from Asian, black, or other ethnic groups, maternal risks and conditions were more cited more often, and fetal health concerns were rarer among black women. Figure 6.5b) shows that for deprivation, a gradient can be seen for post mature pregnancies, where this was documented for 3% of inductions in the most deprived group and for 8% of inductions in the least deprived group. This trends with a gradient for the number of pregnancies ending later than 41 weeks: 6% of women from the most deprived decile had pregnancies ending after 41 weeks, while for the least deprived this was 16%.



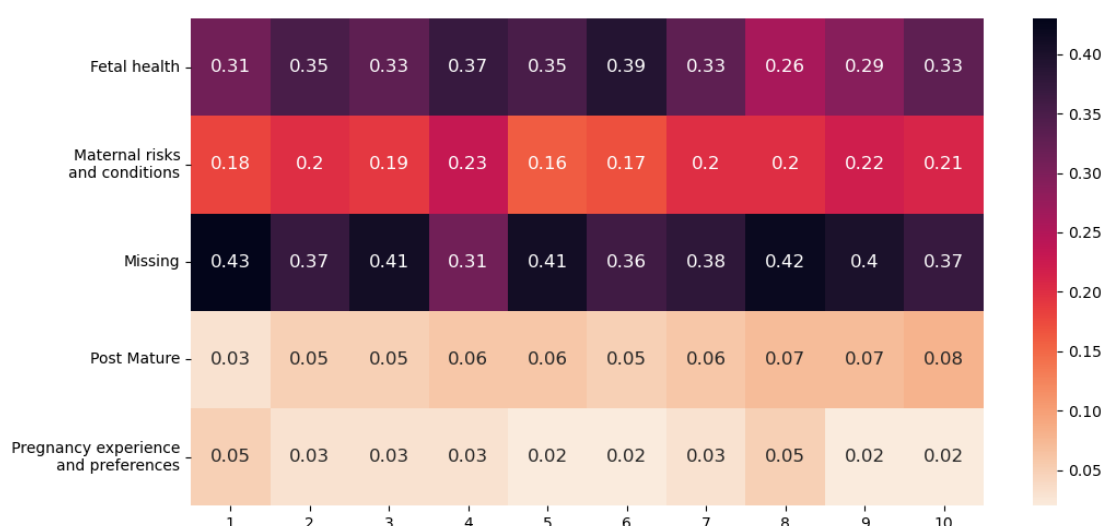


Figure 6.5 Heatmaps of reason for induction for a) ethnic groupings and b) Induction of Multiple Deprivation (IMD). IMD1 is most deprived and IMD10 is least deprived. Colour and annotation refers to proportion of inductions induced for a given reason from that population group.

6.2.3.3. Outcomes of Induction

Table 6.3 presents pregnancies outcomes stratified by induced or spontaneous labour. Women who underwent induction of labour lost an average of 59mL of blood more than women who laboured spontaneously (95%CI 39, 79). Induced pregnancies were more likely to undergo caesarean section than to birth vaginally (adjusted RR 2.07, 95%CI 1.86, 2.30), and no difference was observed for instrumental births (adjusted RR: 0.95, 95% CI 0.84, 1.07). No statistically significant differences were observed for neonatal unit admission (adjusted RR: 1.11, 95% CI: 0.88, 1.41) or perinatal deaths (adjusted RR: 1.43 95% CI 0.85, 2.42). Full model parameters are given in Appendix 6.6.

Cohort		All	Induced n (%) or Mean (std)	Spontaneous n (%) or Mean (std)	RR or Mean Difference (95% CI)	Adjusted* RR or Mean Difference (95% CI)
Measure		Frequency				
Blood Loss, ml	Mean (Std)	345	381 (480)	320 (402)	61 (41, 82)	59 (39, 79)
Mode of Birth, n (%)	NVD	5478	1980 (63.0)	3498 (75.0)	1 (Ref)	1 (Ref)
	Emergency Caesarean Section	1172	693 (22.0)	479 (10.0)	1.64 (1.54, 1.74)	2.07 (1.86, 2.30)
	Instrumental	941	362 (12.0)	579 (12.0)	1.06 (0.97, 1.16)	0.95 (0.84, 1.07)
	Missing	191	109 (3.0)	82 (1.7)		
Neonatal Unit Admission, n (%)		297	122 (4.0)	175 (4.0)	1.02 (0.89, 1.17)	1.11 (0.88, 1.41)
Stillbirth or Neonatal Death, n (%)		52	16 (1.0)	36 (1.0)	0.76 (0.51, 1.14)	1.43 (0.85, 2.42)

Table 6. 4: Outcomes of pregnancy, stratified by induced or spontaneous labour. *Modelling adjusted for maternal age, gestational age at birth, parity, assessed risk, Index of Multiple Deprivation, and ethnicity. RR: Risk Ratio. CI: Confidence Interval. std: Standard Deviation

6.2.4. Discussion

This analysis of 7782 pregnancies evaluating the induction of labour service at SaTH found that women from the most deprived deciles were 21% more likely to be induced, along with fewer women in this group carrying a pregnancy past 41 weeks. Black women may have been less likely to be induced and fetal concerns were documented less often as the indication for induction for this group. Women who were induced were more likely to have an emergency caesarean section (adjusted RR 2.07, 95%CI 1.86, 2.30) and to lose more blood (adjusted mean difference 59mL, 95%CI 39,79).

Elevated rate of induction among women from the most deprived areas after adjusting for initial risk suggests that the indication for inductions may be issues

arising during pregnancy such as small for gestational age fetuses. Watson et al. showed that rising rates of poverty were associated with increased rates of prematurity and small for gestational age births.(20) Muller et al. recommended that increasing induction of labour rates among women from more deprived backgrounds may help to narrow disparities in outcomes;(21) however, pregnant women will have to balance against the increased chance of caesarean section(17) and blood loss(16) observed here and elsewhere. Furthermore, clinical decision making based on social factors as proxies for biological and clinical features should be taken up cautiously.(22)

This study was able to provide a detailed evaluation of a local service based on routinely collected data. However it suffers several limitations, most importantly that the sample size is too small to identify important disparities, especially in rare outcomes such as perinatal deaths. Health inequalities may be observed in large sample sizes, but these can be too far removed to provide clear guidance for improvement to local services. This type of study may therefore better suited to identifying differences in processes of care, such as which groups undergo induction of labour and why.

Although this study was able to access documented indications for induction, a significant number of inductions did not have a reason documented. This study did not collect information on important diagnoses for which labour is induced that can develop after the booking appointment risk assessment, such as pre-eclampsia.(23) This study also excluded women undergoing caesarean sections, an option that may be chosen as a direct alternative to induction of labour. Spontaneous and induced labour are more natural comparisons for outcomes of blood loss and emergency caesarean,

but investigating women undergoing elective caesarean may have provided more insight into how different population groups are managed. Finally, the induction of labour cohort includes pregnancies where induction of labour failed to establish labour, which arguably could have been excluded or treated as caesarean or spontaneous labour as appropriate.

This study may provide some reassurance to the service that significant differences in the care provided to different groups of women were not detected, and can be useful for hypothesis generating to plan future research. The increased induction rate amongst women from the most deprived decile may merit further investigation to identify drivers. Further investigation of indications would require detailed phenome development to identify diagnoses and data quality for conditions; however such an investigation would not identify wider determinants of health that could be contributing and may be the most effectiveness targets for improving health among the most deprived decile of the population.

6.2.4.1. Conclusion

This study found outcomes of induction of labour were similar to those reported elsewhere in the literature, suggesting SaTH is providing induction of labour in line within broader standards of care. Small, potentially important differences were identified in access and indications for induction of labour, but further investigation would be required to understand if they are important.

6.3. Identifying eligible pregnancies for the CAPE trial: an electronic health record cross-sectional study

6.3.1. Background

Trial participation has been linked to improved outcomes for participants and organisations, and research into new interventions leads to wider social benefit.(24,25) However, increasing attention is paid to inequalities in participation,(26,27) which can reduce the generalisability of research and restrict development of research infrastructure to an “in-group” of academic centres that do not reflect wider service, the general population, or greatest health needs.(28) The NIHR’s strategy sets out inclusion as a core operating principle,(26) and recent work from the OBS-UK trial has aimed to create tools for widening participation in trials.(29)

Trial participants have been found to systematically differ from the general population in age, morbidity, and complexity;(30) often trial eligibility criteria restrict participation to people with only a single condition, excluding patients with multimorbidity but also older adults or participants from lower socioeconomic backgrounds who tend to have more comorbidities.(31) Trial structure, health beliefs, incentives, and other characteristics affect trial participation of populations from different groups.(32)

SaTH is a partner site for the “Calcium supplementation for Prevention of pre-Eclampsia in high-risk women: CAPE trial” (ISCRTN: 12033893).(33) Pre-eclampsia is a hypertensive disorder of pregnancy and in the UK, women of black and South Asian ethnic groups and from more socioeconomically deprived areas are observed to have

higher rates of pre-eclampsia.(12,34,35) Given that these women are most likely to benefit from the CAPE trial intervention, it is particularly important to ensure their participation to a) realise these benefits and b) ensure that potential effects are identified. Eligibility for this study was first assessed initially to identify eligible women for the CAPE trial at SaTH.

This cross-sectional study therefore aims to assess eligibility for CAPE by social characteristics, which can target future recruitment efforts.

6.3.2. Methods

6.3.2.1. Study Design

This was a cross-sectional study conducted on 21st October 2024 using data from the Badgernet EHR at SaTH.

All pregnancies where booking took place at SaTH, the pregnancy was in progress on 21-10-2024, and had been risk assessed for pre-eclampsia or foetal growth restriction, were assessed for eligibility for the CAPE trial in this study. All pregnancies should have a documented risk assessment for pre-eclampsia and foetal growth restriction.

The primary outcome was women who were ever eligible for the CAPE trial. To be eligible, pregnant women had to meet criteria for aspirin based on NICE or Foetal Medicine Foundation guidelines. As a secondary analysis, eligibility on the date the cross-sectional study took place is described, and required that pregnant women had undergone ultrasound scan to ensure viability and gestational age. Aspirin eligibility was identified using the pre-eclampsia risk assessment and foetal growth restriction

risk assessment. Appendix 6.7 contains phenomes for identifying outcomes and other variables from the EHR.

To compare trial eligibility amongst different ethnic and socioeconomic groups, we included covariates on ethnic group (Asian, black, missing, mixed, other, or white), postcode-linked IMD deciles, and postcode-linked rural-urban classification. We also examined parity (primiparous vs multiparous) and age at pregnancy start (continuous and grouped 0-16, 17-30, 31-40, 41-50, and 51-60).

6.3.2.2. Statistical Analysis

Characteristics of eligible women were described using frequency and percentage of women for categorical variables and mean and standard deviation for continuous variables. Univariable risk ratios were calculated for social group eligibility and multivariable modified Poisson regression fitted to estimate differences in eligibility between groups of women after accounting for age and parity.

6.3.2.3. Ethical approval

This study was approved as a service evaluation by SaTH R&I on 21st January 2025.

6.3.3. Results

Figure 6.6 describes assessment of eligibility of pregnancies for the CAPE trial based on electronic health record data. On 21st October 2024, 3,597 active pregnancies were identified that had booked at SaTH. Of these, 1161 (32%) were at increased risk of pre-eclampsia and eligible for aspirin based on midwife screening. Of these, 378 (33%)

were likely to be eligible on the date of the study, based on gestational age and key care processes.

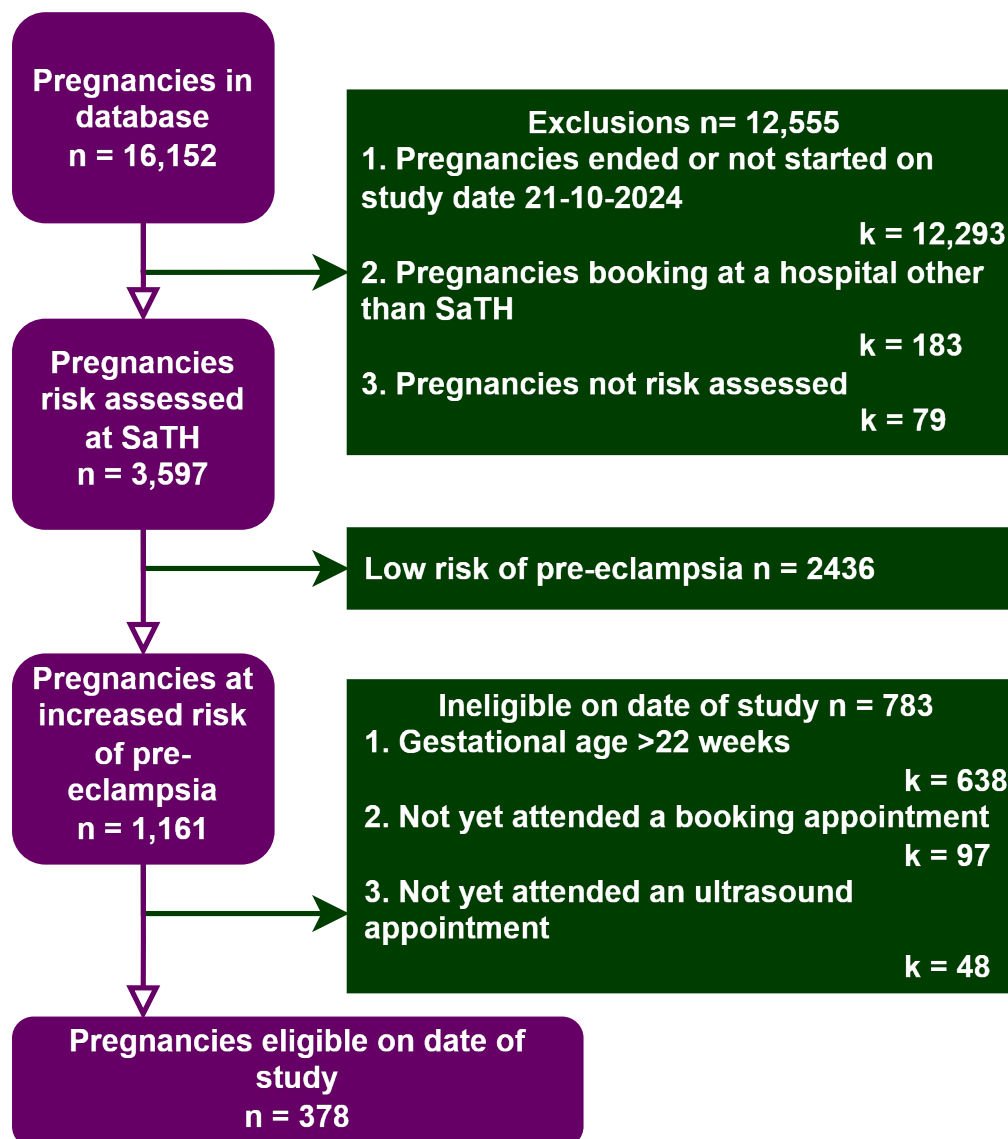


Figure 6. 6 Identification of pregnancies eligible for the CAPE Study

Table 6.4 describes characteristics of all active pregnancies on the study date where women had a booking appointment at SaTH, stratified by those that were ever eligible vs those who were ineligible. Most women were aged 17-30 (1733, 48%) or 31-40 (1749, 49%), and eligibility in these two age groups was similar, but women aged 40 and over were more likely to be eligible (adjusted RR: 3.01; 95%CI 2.72, 3.33). Among

ever-eligible, 1973 (55%) of women were multiparous, and multiparous women were more likely to be eligible (adjusted RR: 1.37; 95%CI 1.23, 1.51).

Included women were spread across the deciles of deprivation with some concentration around the central deciles 4,5,6,7. Women from more deprived areas were more likely to be eligible than women from less deprived areas (adjusted RR IMD1 vs IMD10: 1.45; 95%CI 1.12, 1.87). Most women were from white ethnic backgrounds (2936, 82%), and women from white and mixed ethnic groups had similar likelihood of being eligible (adjusted RR mixed vs white: 1.09 95%CI 0.86, 1.39), while likelihood of eligible was lower in women from Asian (adjusted RR vs white: 0.56 95%CI 0.45, 0.70), black (adjusted RR: 0.60 95%CI 0.45, 0.81), and other ethnic groups (adjusted RR: 0.60 95%CI 0.36, 1.01).

*Table 6.5: Characteristics of pregnancies ever eligible for the CAPE trial. *Adjusted for woman's age category, parity, Index of Multiple Deprivation, and Ethnicity. RR: Risk Ratio. CI: Confidence Interval.*

Cohort Measure	All Frequency	Ever Eligible n (%) or Mean (std)	Ineligible n (%) or Mean (std)	RR or Mean Difference (95% CI)	Adjusted RR (95% CI)
Overall	3597	1161 (32.3)	2436 (67.7)		
Mother's Age at Pregnancy Start, n (%)	0-16	17 (0.5)	6 (0.5)	1.16 (0.61, 2.22)	1.24 (0.63, 2.43)
	17-30	1733 (48.2)	1203 (49.4)	1.01 (0.91, 1.11)	1.01 (0.92, 1.12)
	31-40	1749 (48.6)	1217 (50.0)	1 (Ref)	1 (Ref)
	41-50	96 (2.7)	92 (7.9)	3.15 (2.90, 3.42)	3.01 (2.72, 3.33)
	51-60	2 (0.1)	1 (0.1)	1.64 (0.41, 6.58)	1.63 (0.56, 4.77)
	Mean (Std Deviation)	29 (0.8)	30 (6.1)	1.07, (0.66, 1.47)	
Parity, n (%)					
Primip	1624 (45.1)	422 (36.3)	1202 (49.3)	1 (Ref)	1 (Ref)

	Multip	1973 (54.9)	739 (63.7)	1234 (50.7)	1.44 (1.30, 1.59)	1.37 (1.23, 1.51)
Index of Multiple Deprivation decile, n (%)	1	330 (9.2)	140 (12.1)	190 (7.8)	1.55 (1.20, 2.01)	1.45 (1.12, 1.87)
	2	344 (9.6)	141 (12.1)	203 (8.3)	1.50 (1.16, 1.94)	1.47 (1.14, 1.89)
	3	257 (7.1)	89 (7.7)	168 (6.9)	1.27 (0.96, 1.68)	1.23 (0.93, 1.61)
	4	563 (15.7)	191 (16.5)	372 (15.3)	1.24 (0.97, 1.60)	1.17 (0.91, 1.50)
	5	439 (12.2)	135 (11.6)	304 (12.5)	1.13 (0.86, 1.47)	1.10 (0.84, 1.42)
	6	453 (12.6)	126 (10.9)	327 (13.4)	1.02 (0.78, 1.33)	0.98 (0.76, 1.28)
	7	459 (12.8)	142 (12.2)	317 (13.0)	1.13 (0.87, 1.47)	1.07 (0.83, 1.38)
	8	293 (8.1)	85 (7.3)	208 (8.5)	1.06 (0.80, 1.41)	1.00 (0.76, 1.32)
	9	248 (6.9)	56 (4.8)	192 (7.9)	0.83 (0.60, 1.14)	0.80 (0.58, 1.09)
	10	205 (5.7)	56 (4.8)	149 (6.1)	1 (Ref)	1 (Ref)
	Missing	6 (0.2)	0 (0.0)	6 (0.2)	0.00 (0.00, nan)	0.00 (0.00, 0.00)
Ethnicity, n (%)	Asian	281 (7.8)	57 (4.9)	224 (9.2)	0.60 (0.47, 0.76)	0.56 (0.45, 0.70)
	Black	113 (3.1)	28 (2.4)	85 (3.5)	0.73 (0.53, 1.02)	0.60 (0.45, 0.81)
	Missing	118 (3.3)	35 (3.0)	83 (3.4)	0.88 (0.66, 1.16)	0.88 (0.67, 1.16)
	Mixed	105 (2.9)	39 (3.4)	66 (2.7)	1.10 (0.85, 1.42)	1.09 (0.86, 1.39)
	Other	44 (1.2)	10 (0.9)	34 (1.4)	0.67 (0.39, 1.16)	0.60 (0.36, 1.01)
	White	2936 (81.6)	992 (85.4)	1944 (79.8)	1 (Ref)	1 (Ref)

Table 6.5 describes characteristics of women who were eligible on the day of the study, based on the time-dependent criteria for recruitment. Characteristics of eligible women are similar to table 6.4, with reduced statistical power to detect differences. There may be some difference in women of mixed ethnic groups being eligible on the study date compared to ever eligible (ever eligible adjusted RR: 1.09 [95% CI 0.86, 1.39])

vs study data eligible adjusted RR 1.37 [95% CI 0.88, 2.14]), but this is likely to be a statistical artifact of sampling.

Measure	All Frequency	Study Eligible	Ineligible	RR or Mean Difference	Adjusted RR
		n (%) or Mean (std)	n (%) or Mean (std)	(95% CI)	(95% CI)
Overall	3597	396 (11.0)	3201 (89.0)		
Mother's Age at Pregnancy Start	0-16	17 (0.5)	2 (0.5) 15 (0.5)	1.11 (0.30, 4.10)	1.06 (0.27, 4.16)
	17-30	1733 (48.2)	176 (44.4) 1557 (48.6)	0.95 (0.79, 1.16)	0.92 (0.76, 1.13)
	31-40	1749 (48.6)	186 (47.0) 1563 (48.8)	1 (Ref)	1 (Ref)
	41-50	96 (2.7)	32 (8.1) 64 (2.0)	3.13 (2.29, 4.29)	3.01 (2.20, 4.14)
	51-60	2 (0.1)	0 (0.0) 2 (0.1)	0.00 (0.00, nan)	0.00 (0.00, 0.00)
	Mean (Std Deviation)	29 (0.8)	30 (6.1) 29 (5.4)	1.02, (0.39, 1.65)	
Parity	Primip	1624 (45.1)	149 (37.6) 1475 (46.1)	1 (Ref)	1 (Ref)
	Multip	1973 (54.9)	247 (62.4) 1726 (53.9)	1.36 (1.13, 1.65)	1.26 (1.03, 1.53)
Index of Multiple Deprivation decile	1	330 (9.2)	53 (13.4) 277 (8.7)	1.50 (0.94, 2.38)	1.43 (0.89, 2.29)
	2	344 (9.6)	55 (13.9) 289 (9.0)	1.49 (0.94, 2.37)	1.50 (0.94, 2.40)
	3	257 (7.1)	29 (7.3) 228 (7.1)	1.05 (0.62, 1.77)	1.03 (0.61, 1.75)
	4	563 (15.7)	66 (16.7) 497 (15.5)	1.09 (0.69, 1.72)	1.05 (0.66, 1.66)

				1.00 (0.62, 1.61)	0.97 (0.60, 1.57)
	5	439 (12.2)	47 (11.9)	392 (12.2)	
	6	453 (12.6)	35 (8.8)	418 (13.1)	0.72 (0.43, 1.20)
	7	459 (12.8)	44 (11.1)	415 (13.0)	0.70 (0.42, 1.17)
	8	293 (8.1)	30 (7.6)	263 (8.2)	0.89 (0.55, 1.45)
	9	248 (6.9)	15 (3.8)	233 (7.3)	0.85 (0.52, 1.38)
	10	205 (5.7)	22 (5.6)	183 (5.7)	0.95 (0.57, 1.61)
					0.90 (0.54, 1.51)
					0.56 (0.30, 1.06)
					0.54 (0.29, 1.01)
					1 (Ref)
					1 (Ref)
	Missing	6 (0.2)	0 (0.0)	6 (0.2)	0.00 (0.00, nan)
					0.00 (0.00, 0.00)
Ethnicity	Asian	281 (7.8)	18 (4.5)	263 (8.2)	0.56 (0.35, 0.88)
	Black	113 (3.1)	7 (1.8)	106 (3.3)	0.51 (0.32, 0.79)
	Missing	118 (3.3)	14 (3.5)	104 (3.2)	0.54 (0.26, 1.12)
	Mixed	105 (2.9)	17 (4.3)	88 (2.7)	0.42 (0.21, 0.84)
	Other	44 (1.2)	4 (1.0)	40 (1.2)	1.04 (0.63, 1.71)
	White	2936 (81.6)	336 (84.8)	2600 (81.2)	1.02 (0.63, 1.67)
					1.41 (0.91, 2.21)
					1.37 (0.88, 2.14)
					0.79 (0.31, 2.03)
					0.70 (0.26, 1.89)
					1 (Ref)
					1 (Ref)

Table 6.6: Characteristics of pregnancies eligible on study date for the CAPE trial. *Adjusted for woman's age category, parity, Index of Multiple Deprivation, and Ethnicity. RR: Risk Ratio. CI: Confidence Interval

6.3.4. Discussion

Pregnant women eligible for the CAPE trial were more likely to be older and multiparous, to live in more disadvantaged areas, and to be from white or mixed ethnic groups. 32% of women may have been eligible for the trial. On the day of screening, 396 women potentially eligible women were identified.

National Institute of Health and Care Excellence guidance for pre-eclampsia risk factors recommends that women with 2 moderate or 1 high risk factor receive aspirin, and that age over 40 and first pregnancy are both moderate risk factors.(36) It is therefore unsurprising that older women are more likely to be eligible, but perhaps more surprising that multiparous women are more likely to be eligible even after adjusting for age. This study may have overestimated eligibility for aspirin, and in 2023 4.5% of pregnant women at SaTH were eligible according to the Maternity Services DataSet submission.(37) However this is likely to underestimate eligibility as the MSDS define aspirin eligibility by diagnostic codes and not by risk of pre-eclampsia. SaTH is in the 42nd centile of providers for eligibility, which does not suggest anomalously low recording of aspirin eligibility.

If eligibility for CAPE is taken to be a proxy for general health status, increased eligibility among women from more deprived areas and reduced eligibility from non-white ethnicities may corroborate the findings of Chapter 4 where women from more deprived areas had more diagnoses, and women from ethnic minorities had fewer diagnoses. Women from more deprived areas have been observed to have higher incidence of pre-eclampsia across the UK.(38) However, women from black and South Asian ethnic groups are known to be at 2.5- and 1.5-times greater risk of pre-eclampsia respectively than white women.(39,40) Women from ethnic minority groups served by SaTH may have lower risk of pre-eclampsia than women of ethnic minorities in other areas, and this study did not adjust for a variety of confounders to isolate the effect of ethnicity on assessed risk of preeclampsia. Conversely, women from ethnic minorities may be systematically under-screened for preeclampsia as NICE screening is known to

be to have a sensitivity of 41%,⁽⁴¹⁾ and other screening modalities have been shown to underestimate risk of preeclampsia in women from ethnic minorities.^(39,42,43) These factors may lead to women from ethnic minority groups being underrepresented in pre-eclampsia research.⁽⁴⁴⁾ While tools such as the OBS-UK dashboard for trial site selection may bring more research to underrepresented populations,⁽²⁹⁾ trial eligibility may continue to exclude those who may benefit most.

This study was able to systematically describe an entire population eligible for trial recruitment, providing a powerful tool to guide trial delivery and site selection. SaTH is a site for the CAPE trial, and currently such recruitment takes place through manual note review, which is labour intensive and significantly constrains the scale of recruitment possible. DExtER-supported screening saves many hours of work, and also improves screening transparency, as manual screening may introduce non-random biases into recruitment such as recruiting from specific clinics. However, screening for eligibility was limited by data quality and the development of phenomes to describe all aspects of preeclampsia risk assessment. Using midwife assessments results in sensitive eligibility criteria with broad inclusion, but with poor specificity. Detailed phenotyping that precisely captures the clinical criteria of the Fetal Medicine Foundation may provide a more accurate assessment of women who receive aspirin, but data may remain too limited for this to be applied accurately.

6.3.4.1. Conclusion

This study provided a useful tool to a research midwife in guiding recruitment for the 396 women eligible on the day of study extraction, and a proof-of-concept audit tool to identify inequalities in trial recruitment and research participation at research-

active sites, complementing work such as the OBS-UK dashboard.⁽²⁹⁾ It outlines a clear challenge in ensuring equitable recruitment if flawed tools are used to screen and treat the risk of preeclampsia.

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7. Discussion

This thesis presents an investigation into Learning Health Systems approaches for maternal health inequalities. This chapter will outline how the thesis has met the objectives set out in Chapter 1, positioning the findings in broader research contexts and evaluating their strengths, limitations, and implications. As this thesis is presented in alternate format, each chapter contains detailed discussions of the findings; this chapter will consider the findings from a LHS lens, considering high-level, generalisable research with broad applications (Chapters 3, 4, and 5) and then describing local efforts and investigations to support the development of a LHS (Chapter 6).

7.1. Aims and Objectives

This thesis sought to answer “How can maternity services be supported to learn from data they capture?” The aim of this thesis was to improve the data-to-knowledge part of the Learning Health Systems in maternity services and its objectives were:

1. To contextualise the potential of Learning Health Systems in improving maternity services.
2. To synthesise and meta-analyse published evidence on Clinical Decision Support Systems (CDSS) use in maternity services as an element of the LHS.
3. To develop methods for routinely transforming data-to-knowledge using EHR in maternity services.
4. To systematically describe existing national health inequalities in pregnant women.
5. To demonstrate the data-to-knowledge element of LHS through case studies in maternal health inequalities.

The following section describes how each of these objectives were met.

Objective 1: Contextualise the potential of Learning Health Systems in improving maternity services.

Chapter 2 contextualized Learning Health Systems (LHS) potential in improving maternity services by describing what LHS are, identifying critical maternity service challenges, and outlining where LHS may contribute to solutions.

LHS were described as learning communities, operating under uncertainty, with a sociotechnical infrastructure that supports learning cycles. Significant pressures facing UK maternity services were identified: maternal mortality is rising after a decade of progress, increasing from 8.5 to 13.6 deaths per 100,000 pregnancies,(1) and services struggle with safety concerns,(2) workforce shortages,(3) increasing care complexity,(4) and failed implementations of resource-intensive policies.(5) No evidence identified specifically considered the role of LHS in maternity services, but the chapter outlined how introducing LHS approaches to generating knowledge from data may support maternity services in managing uncertainty, scaling up what works, and deploying the increasingly high volumes of expertise required to deliver care.

The role for data-to-knowledge approaches in maternity suggests that technologies such as Dexter, that build learning infrastructure and automate tasks in the data-to-knowledge learning cycle, may offer significant value to maternity services, which are further explored in Chapters 4,5, and 6.

Objective 2: Synthesise and meta-analyse published evidence on CDSS use in maternity services

The systematic review and meta-analysis manuscript in Chapter 3 synthesised comprehensively identified all evidence on CDSS implementations in maternity services. 87 articles evaluating 47 unique CDSS after screening 12,039 papers were identified, and the quantitative meta-analysis of 35 studies produced a pooled odds ratio of 1.69 (95% CI 1.24–2.30) for improving target outcomes, demonstrating positive effects of CDSS in maternity care. The review also characterised the significant heterogeneity in the evidence base, synthesising the existing evidence base by categorising CDSS according to study design, deployment settings, purpose and aims, and mechanism of decision support.

Objective 3: Develop methods for routinely transforming data-to-knowledge using EHR

Chapter 4 developed automated analysis methods for calculating incidence and prevalence in open cohorts, aiding discovery of new knowledge in electronic health record data. The software and transportable rules were successfully applied to ectopic pregnancy data, demonstrating the data-to-knowledge transformation by revealing that rising prevalence (50% increase) was not matched by rising incidence, indicating improved recording rather than increased disease occurrence. The methods specifically incorporated inequalities analysis between population groups, providing actionable knowledge from routine data.

Objective 4: Systematically describe existing national health inequalities in pregnant women

A systematic analysis of UK maternal health inequalities is presented in Chapter 5 as a cohort study examining 79 conditions across multiple population groups between 2006-2021. The study quantified disparities by deprivation (16% more likely to have diagnoses in the most deprived quintile compared to the least deprived quintiles) and ethnicity (26% less likely for Asian groups, 32% less likely for other ethnic groups compared to white women). This provided the first systematic national-level description of pregnancy health inequalities across multiple conditions and demographic characteristics.

Objective 5: Demonstrate the data-to-knowledge element of LHS through case studies in maternal health inequalities

Chapters 6 presented two epidemiological case studies of maternal health inequalities using EHR data. It successfully demonstrated data-to-knowledge implementation through deployment of a data platform into a maternity service and conducting rapid analysis of routinely generated data. The case studies revealed actionable inequalities: women from most deprived areas were more likely to be induced for labour (RR 1.21 [1.06, 1.38]) even after adjusting for risk assessments at the beginning of pregnancy, and ethnic minorities were less likely to be screened for clinical trials (Asian RR 0.56 [0.45, 0.70], black RR 0.60 [0.47, 0.76]) despite potentially having the greatest benefit of the intervention. This demonstrated how locally

deployed platforms can transform routine data into on-demand knowledge for service improvement.

7.2. What these studies add

7.2.1. Contribution of Chapter 3: Systematic Review of maternal CDSS

This manuscript presents the first systematic review of CDSS in maternity care, and finds similar effects to non-maternity systematic reviews,(6,7) validating CDSS effectiveness in this specific context while providing maternity-focused evidence for implementation. The review introduces the use of rigorous, established taxonomies, such as the Wright et al.'s taxonomy of decision support mechanisms,(8) paired with the development of new categories, to describe tools which future developments can build upon. While many studies have categorised tools,(6,7,9–11) standardisation and reuse across studies is limited and studies should look to both previous and new standards in development to improve transportability of knowledge.(12)

7.2.2. Contribution of Chapter 4: Automated analyses of EHR data

The article in Chapter 4 reports novel software and methods for automated epidemiological analysis. Similar software exists such as PrevalenceUK or IncidencePrevalence,(13,14) but none have explicitly considered health inequalities. The value of such an approach is demonstrated in a study of ectopic pregnancy, and the analysis represents the first published descriptive epidemiology since 2011,(15)

providing current epidemiological estimates and revealing ethnic disparities in prevalence patterns.

7.2.3. Contribution of Chapter 5: National disparities in diagnoses of health conditions among pregnant women

This study provides the first systematic epidemiological analysis of multiple pregnancy conditions across population groups, finding increasing rates of morbidity among pregnant women as suggested in section 2.2.1. Importantly, although ethnic minorities and socioeconomic deprivation status are both associated with worse maternal outcomes,(16) they showed the opposite trend for diagnoses, underlining the fundamentally different mechanisms driving outcomes for different groups. These trends have been observed in multimorbidity results observed elsewhere,(1,17) and suggests that some component of increased mortality among women from deprived backgrounds may be due to worse pre-pregnancy health status, but that this explanation does not hold for ethnic minority women.

7.2.4. Contribution of Chapter 6: Maternal Health Inequalities Case Studies

This chapter demonstrates how routinely collected data can be monitored for health inequalities. Parsons et al. recommend monitoring as one of their seven principles for health equity in LHS;(18) such data could however be used to advance other principles, such as establishing the importance of health inequalities through advocacy supported by such findings. NYU Langone Health expands on research of health inequalities within LHS with a 6-step road map; this study demonstrates steps 1 and 2 are feasible

within the SaTH-DExtER platform, but further action and research will require greater engagement of the health service.(19) However, taking such a localised approach to health inequalities supports the production of “Mode 2” knowledge, described as “socially distributed, application-oriented, trans-disciplinary, and subject to multiple accountabilities”, differing from typical scientific knowledge that attempts to describe general rules.(20) Here, applied epidemiology requested within the service creates embedded knowledge; rather than requiring translation or implementation, this type of knowledge production should be “realised knowledge” within absorptive capacity theory,(Section 2.1.2.2) (21) closer to improving performance at the time of production.(22)

7.2.5. Implications for research, policy, and practice

7.2.5.1. *Clinical Decision Support Systems*

Chapter 3 showed that on average CDSS are effective in maternity care and should be pursued as interventions. The systematic review identified all published evaluations of implemented tools, which may guide researchers in identifying gaps for development of future CDSS, and health service procurement of tools for use. Chapter 3 contributes to the development of frameworks, important in predicting factors that affect outcomes and building theory that spans across studies,(23) and ontologies that describe CDSS such as those in development by Open Digital Health.(12)

However, attention must be paid to context and variation, as significant heterogeneity between CDSS and their evaluations was present. Implementers must be aware of the variation in tools and pay attention to local complexity and unintended consequences. Simple, flexible, locally deployed tools can be highly effective

implementation strategies,(24) and hence further research and policy may focus on the pipeline to implementation for maternity services for development and deployment of selected tools appropriate to context. Implementers must also be aware of the consequences on health inequalities of deploying tools; standardisation resulting from CDSS may reduce health inequalities where standards are appropriate to all population groups, but inappropriate standardisation may broaden them.

7.2.5.2. Using Primary Care Data

Chapters 4 and 5 used data from CPRD Aurum to investigate pregnancy outcomes. Chapter 4 identified an apparent increase in ectopic pregnancy incidence among women aged 12-20 (Appendix 3.4), a signal that merits further investigation. The simple and modular package can be used in larger software architectures, as few implementations of epidemiological tools sensitive to inequalities are available in python. Chapter 5 found that women of different ethnic groups have substantially different rates of diagnosis across a range of conditions at the beginning of pregnancy. This implies different health needs for optimising health status and emphasises how different approaches will be required to manage socioeconomic and ethnic inequalities. Furthermore, researchers and policymakers will need to understand intersectional relationships between these and other sociodemographic characteristics, which are difficult to evaluate quantitatively, but will impact the development and implementation of interventions to improve health in pregnancy of women with pre-existing conditions. Chapter 5 presents a large quantity of granular, nationally representative data that can be reused by policymakers and researchers, and interprets this data through novel application of statistical process control methods,

which have been popularised within the NHS (25) and may provide researchers with a new approach to understanding health inequalities in large datasets.

7.2.5.3. *Using Secondary Care Data*

Chapter 6 presents the experiences of using secondary care data within a service to address health inequalities. Technologies used to interrogate large national datasets can also be used locally to interrogate data generated by the service, allowing an increased degree of absorptive capacity. Chapter 6 reveals the presence of unexpected inequalities in screening for trial recruitment; SaTH-DExtER enables such analyses to be repeated and re-deployed in other settings and time points, which could improve trial recruitment and accountability. This data can also be used by wider system partners, such as public health departments acting on wider determinants of health, who can form part of the learning community. Demonstration of potential value added can win over stakeholders to the value of LHS, and to learning itself as a mechanism for improving outcomes, such as envisioned through absorptive capacity theory for example.

7.3. Strengths and Limitations

7.3.1. Strengths and limitations of Chapter 3: Systematic review of maternal CDSS

This systematic review used a systematic screening method pre-registered in PROSPERO, reported according to PRISMA guidelines, with forward and backward citation tracing to maximise inclusion of eligible articles.

However, many CDSS are unlikely to receive an impact evaluation. CDSS are typically regulated as a type of medical device, which in the UK are estimated to have a lifecycle of 18 months before replacement by new models or practice.(26) Those that are evaluated may therefore be unrepresentative or have longer lifecycles, in contrast to the flexibility called for above.

The need for mechanistic understandings of how CDSS deliver value is also identified as a key knowledge gap above, but the systematic review method may be poorly suited to such understandings compared to methods such as realist synthesis that can elicit causal pathway and generate theory.(27)

7.3.2. Strengths and limitations of Chapter 4: Automated analyses of EHR data

Automation enables reproducible, transparent, and rapid insight into data. Chapter 4 outlines automated methods for analysing incidence and prevalence, which can be further used for time series analysis and statistical process control methods recommended in the NHS, while supporting specific analysis of inequalities and even intersectional groups where data is available.(25,28) However, “automation” is limited and still requires expert input to use correctly. For example, closed cohorts such as a pregnant population would typically use every eligible pregnancy as a denominator, instead of time contributed. Correctly specifying the numerator and denominator could be performed at cohort level but the analysis still requires expert input use.

The software also requires that extraction and preparation of the data has been performed, in Chapter 4’s case by DExtER.(29) This enables the code to be more modular than IncidencePrevalence for example, which requires a complex data model,

but means the software must be integrated into a broader architecture such as SaTH-Dexter.(13)

7.3.3. Strengths and limitations of Chapter 5: National disparities in diagnoses of health conditions among pregnant women

This systematic analysis of a large, nationally representative dataset of primary care data made use of several validated algorithms to prepare a pregnancy cohort for analysis.(17,29,30) It also used a novel method incorporating statistical process control to describe group-level and condition-level prevalence trends, and to identify important signals of interest. These methods can also be applied to local-level datasets to identify signals of disparities and direct policy attention by making use of the large amounts of data generated by contemporary electronic health records.

However, the results reported have multiple interpretations with differing policy implications, as for example increased burden of disease needs different solutions to reduced access to care. Increasing prevalence may be due to improved coding and recording of diagnoses over time, as observed in Chapter 4 where prevalence of ectopic pregnancy is rising faster than expected with given incidence.(31) An absence of a diagnosis is, often incorrectly, assumed to be absence of disease, a significant limitation common to many EHR studies, and in this study no ethnic group was recorded for 24% of pregnancies.(32) Many pregnancies may not be captured in primary care data, particularly miscarriages and terminations, which may be more likely in some health conditions.(30) Some conditions may also prevent women from

becoming pregnant,(33) and therefore underestimate the scale of health need in our data.

7.3.4. Strengths and limitations of Chapter 6: Maternal health inequalities case studies

The studies in Chapter 6 were entirely localised within a medium-sized maternity service. Study conception, design, data collection, extraction, and analysis were all conducted within the SaTH service by SaTH stakeholders, using validated extraction and analysis methods.(29,34) Data were collected to a high degree of completeness, including ethnic group data which were missing in less than 10%, unusual for electronic health record data in the UK.(35)

However, data from a single service over 2.5 years generates insufficient cases for detailed examination of inequalities in outcomes, many of which are rare. 10% of pregnant women were recorded as an ethnic group not classed as white; this is higher than Shropshire's 3% non-white ethnic minorities in the 2021 census, but still a low proportion of the population. This further limits options for interrogating intersectional health experiences; understanding these is crucial to developing effective interventions and working with community groups, but quantitative methods are limited and often require very large datasets.(28) However, as pointed out by Bowleg, although direct evidence cannot be generated, interpreting the results through intersectional lenses is still possible, and local data can be interpreted with local knowledge such as specific geographies managed by community midwifery teams or with values of local populations and stakeholders in mind.(36)

Furthermore, for such analysis to fulfil its potential to impact local services, it must be conducted within an LHS that works to broader principles,(18,37) such as enabling participation of broader stakeholders, especially local populations and service users, and building governance, monitoring frameworks and action plans that address inequalities. These studies did not receive input from patient and public collaborators, nor were they conducted within frameworks that ensured attention and action to the findings. This limitation will be discussed further within the next section.

7.3.5. Strengths and limitations of the overall thesis

Detailed evaluations of each chapter have been presented both within chapters and in the previous section. This section will evaluate the overall work in generating evidence towards addressing inequalities with LHS. This thesis centres the notions that informatics technologies can manage knowledge at scale, but inequalities frequently need local action. LHS can integrate these two problems through supporting complicated decision making (Chapter 3), scaling up the use of data (Chapter 4) and using this data to draw insight into the complex nature of inequalities with enormous variation across the long tail of health needs (Chapter 5). The same techniques and technologies can be localised, by deploying research infrastructure that supports systems to learn from routinely collected data and local inequalities (Chapter 6).

The research in this thesis therefore provides proofs of concept of how informatics research can be intertwined with service delivery in LHS. However, three substantial limitations exist throughout this thesis:

- SaTH-DExtER is not a Learning Health System.
- The learning community remains absent.

- Data are limited and contested.

7.3.5.1. *Overall limitation 1: SaTH-DExtER is not a Learning Health System*

Firstly, no investigation took place within LHS, which were defined in Chapter 2 as *“science, informatics, incentives, and culture are aligned for continuous improvement and innovation”*. As with much of the literature described in section 2.1.2, this thesis has focused on the science and informatics, and has not reported an investigation of systems or culture. The deployment and examples in this thesis do not constitute a LHS in themselves, and to fully evaluate the impact of LHS on maternal health inequalities would require evaluation of complete learning loops including implementation of actions to address health inequalities, and a learning community to capture and act on such findings, to investigate the broader sociotechnical system and align with principles outlined elsewhere.(18,19,22,37–39)

7.3.5.2. *Overall limitation 2: The Learning Community remains absent*

Secondly, limited engagement with community and health system stakeholders has been undertaken in the projects described. Alignment to community and system values is a key value proposition for LHS but was out of scope in these projects. Instead, this thesis has characterised and operationalised what LHS for maternal health inequalities may look like, with some of the initial capabilities demonstrated, that can then be directed and adopted into a set of practices by stakeholders. For example, Chapters 4, 5, and 6 have considered ethnic and socioeconomic deprivation as two

dimensions of inequalities, because data is readily available and broadly understood in their operationalisation.(40) However, local stakeholders may hold different understandings of health inequalities, such as based around specific geographies or institutions, and different values for what outcomes are desirable. Data may not be collected that captures what is valued,(36) and LHS can and should go beyond technical capabilities to shape data around the values of the system and the learning community.

7.3.5.3. Overall limitation 3: data are limited and contested

Finally, the data used in Chapters 4, 5, and 6 are routinely collected EHR data from primary and secondary care. Substantial biases exist in such data reflecting the complex, real-world data generating processes.(41) Many CPRD studies adjust for general practices to correct for different recording practices,(31) but for inequalities such approaches are problematic as inequalities may be caused by such practices, and because adjustment will also attenuate inequality signals due to the geographic clustering of populations experiencing inequalities into practices. Scientific conclusions drawn from such data can be challenged, and using data itself becomes a complex approach due to the presence of Flawed, Uncertain, Proximate, and Sparse (FUPS) data.(42) However, using such data is key to improving the quality of the data, and shaping the interpretation and design of data collection systems. This work is most easily done at a local scale where data retains its context, as the process of creating general, decontextualised categories such as the MSDS is non-neutral and involves stripping away selected information determined by broader social and political

antecedents that may not reflect that values and goals of LHS.(43–45) This issue is exemplified in the use of ONS categories and IMD to operationalise ethnicity and socioeconomic status, as discussed in section 7.2.2.

Wolpert and Rutter describe how a children and young people's mental health program was advised not to share FUPS data by academics, but chose to share their findings in ways that acknowledged data limitations while progressing conversations and learning across the engaged networks and communities.(42) This approach led to continued development of data collection systems and the development of new ideas and treatment approaches.

7.4. Future Plans

During my public health training and through the work of this thesis and related projects, I have developed my skills as an independent researcher with interests in maternal health inequalities and sociotechnical systems with strong quantitative and project management skills. I intend to continue developing implementation science and health services research skills to continue scaling up LHS approaches. I plan further work with qualitative and stakeholder engagement methodologies, particularly on working with patient and public contributors and developing their roles within LHS.

As part of further development of LHS approaches and addressing health inequalities, I have contributed to a range of grants and other projects that build on the work of my thesis. Chapter 4 describes automated results from a study into ectopic pregnancy, and these results led to a grant studying the incidence and prevalence of ectopic pregnancy in the UK. This epidemiology has not been studied since 2011 (46)

but our results suggested significant changes, and so I was awarded a grant as principal investigator to study these changes, identify maternal health inequalities, and potential targets for interventions (see Appendix 7.1). The results, currently under peer review, support our initial observation of an increase in the rate of ectopic pregnancy in women aged under 20. A second award on which I am a co-investigator builds on incidence and prevalence results by implementing automated Interrupted Time Series analysis, with a case study in the implementation of an Artificial Intelligence tool for screening dermatological malignancies. Once developed, such analysis pipelines can be integrated into the LHS network of resources and applied to future questions.

A further proposal is currently being developed based on the work of this thesis, to scale up the SaTH-DExtER infrastructure to incorporate 6 hospitals into a single Learning Health System network. This would provide tools at a hospital level to investigate problems, which can then be shared across hospital settings to replicate similar projects, dashboards, and learning cycles on a shared infrastructure. A quality improvement project itself can then become a 'knowledge artifact', and the network of hospitals, a 'learning community of learning communities', can build a library of knowledge artifacts together that can be implemented using the shared resources.

Chapter 6 describes the deployment and use of a data platform for using electronic health record data. This system was planned for use in two further grants: a cluster RCT of the de-implementation of proteinuria screening for pre-eclampsia, and an EHR system in Sri Lankan maternity care. The cluster RCT required data to be extracted from electronic health record systems to collect data on implementation and evaluation of the intervention, and hence the SaTH-DExtER system would need to be

deployed and implemented into new settings. By reducing the cost of data collection, this substantially increases the potential scale of the trial, making it feasible where previously the required power would have been prohibitive.

The two studies in Chapter 6 demonstrate the ability of DExtER to contribute within a maternity service to service evaluation and monitoring, and to research. The study presented in section 6.2 provided assurance on request to a patient safety forum, informing strategic priorities and using epidemiologically rigorous methods to manage large volumes of data, expanding the services capacity to learn from its own data and practice. The study in section 6.3 efficiently screened eligibility, saving dozens of hours of research midwife time in one study, and with potential to support trial planning, delivery, and equity. Further developments can incorporate audit work, quality improvement cycles, and population health management. This requires continuous development of capabilities in SaTH-DExtER, such as reusable phenomes, understanding data quality, and engaging stakeholders who can further support the use of Electronic Health Record data in improving health and narrowing inequalities.

The LHS concept was also applied to adult social care, which includes settings such as residential and nursing homes, and a proposal developed for a Care Data and Analytics Learning System (CANALS). I am a co-investigator on this proposal and lead for development, implementation and evaluation of the Learning System, bringing together a community of practice, analytical service, and an early-stage data infrastructure.

Finally, I am an early career member of the Health Outcomes for Pregnancy Equity (HOPE)-West Midlands collaboration, part of the Maternal Disparities

Consortium challenge by the National Institute of Health Research, and Chapter 5 represents an early academic outputs of the collaboration.(146) This £50 million award is mandated with reducing the long standing health inequalities, bringing together a wide array of collaborators across the breadth of maternal health and care and the long tail of health needs that drive health inequalities.

7.5. Conclusions

This thesis has investigated how the data-to-knowledge approach of Learning Health Systems may support maternity services, using a range of informatics methods. Maternity services could be supported in addressing several challenges with more knowledge, on-demand. Using an LHS approach should aim to support maternity services investigate and manage the uncertainty and scale of inequalities, coproduced with the populations they serve and facing increasingly complicated health care knowledge and needs. This thesis has presented a range of methods that can be used, outlining requirements for informatics technology to support maternity services to act as Learning Health Systems.

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2.1 Project Initiation Document

SaTH Maternity Care: Learning Health System PID

Project Rationale

The Shrewsbury and Telford Hospital NHS Trust (SaTH) maternity services are currently undergoing a period of significant review and development. With the anticipated report of the Ockenden Review and the CQC findings, the service has put together a comprehensive improvement package, and the service seeks to implement rigorous and scientific evaluation of the improvement journey. Continuous evaluation of this system from the outset provides an opportunity to create a Learning Health System, with technical, procedural and cultural orientation of the service around continuous quality improvement.

Project Objectives

1. Independent quantitative evaluation of the SaTH Maternity Service improvement and development package.
2. Continuous quality improvement of services.
3. Contribution of the service towards research and knowledge creation in maternal care.
4. Lessons learned in the service improvement journey which can be shared with other services nationally.

Project Workstreams

Figure 1 shows the elements of a Learning Health System which would achieve the objectives.

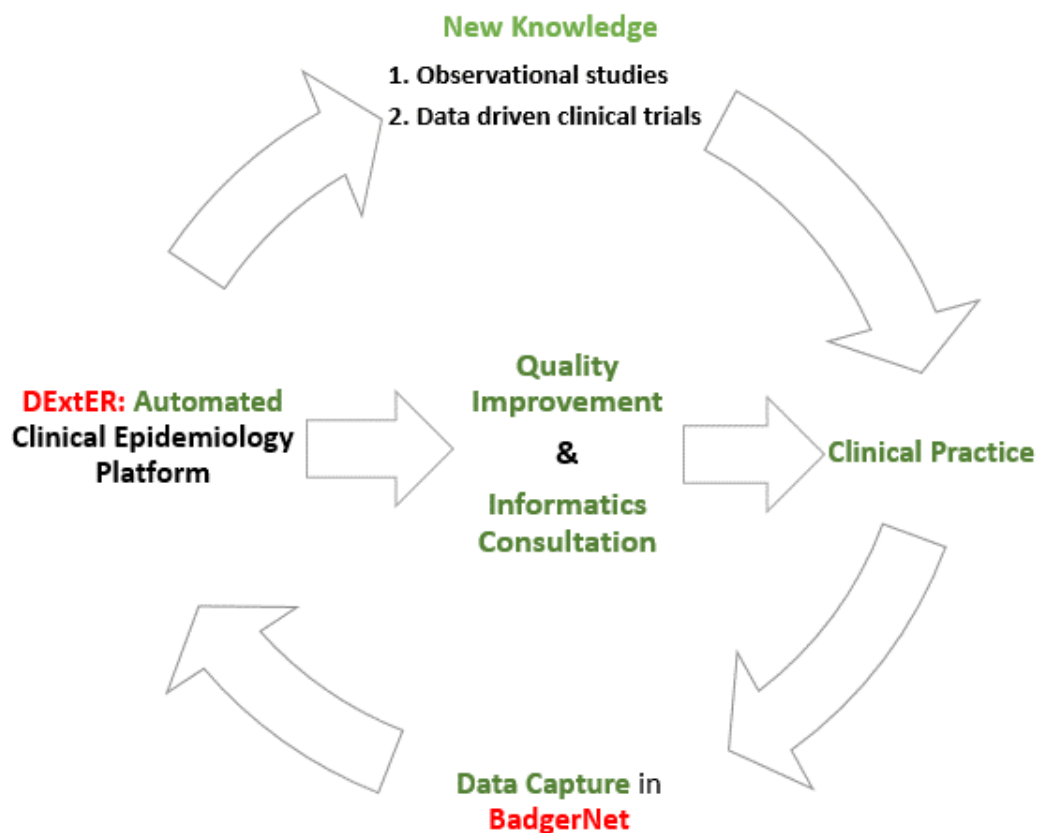


Figure 1: A Learning Health System

Data Capture requires development of a data model that would process clinical information captured in electronic health records into a structured database for analysis. Data input from the clinical setting needs to capture high quality information without additional documentation burden on practitioners.

Automated Analysis of the database using the DExtER platform will provide ongoing statistical analysis of the database without the need for continuous analyst or technical input. In addition to descriptive and aggregate statistics, DExtER can produce automated modelling studies to allow deep insight into the data.

These insights will then be used in continuous **Quality Improvement** and development of **New Knowledge**. Automated cohort studies and data driven clinical trials can be extracted to study questions of interest such as the impact of the improvement journey interventions on key outcomes such as maternal deaths and Neonatal Unit admissions. However, the system can also contribute to quality improvement under the ownership of the service and independently of academic input, supporting service development with the data required for population health management, service evaluation and data-driven decision making.

Informatics Consultation is a new technology that will enable clinicians to examine evidence within the database on questions where limited research exists, to enable rigorously analysed data to support the experience and judgement of those clinicians. Automated epidemiological tools such as DExtER could allow clinicians to specify questions where evidence or guidance is limited and request analysis of databases, just as they are currently able to request imaging or pathology investigations.

Clinical Practice and service delivery is developed in response to the insights of the learning health system, and continues to receive data-driven review as part of the learning health systems. Clinical practice also develops in response to new research, technologies and health challenges which in turn enter the learning health system and can be continually improved.

DExtER is an innovative tool created in University of Birmingham to enable observational research. In this project we will implement it as a tool that has a number of functionalities, including providing health intelligence for improvement of quality of service and individual patient care.

Independent Evaluation during the improvement journey is also required to establish a baseline of outcomes. This will enable benchmarking of the service against similar services, both regionally and nationally, and allow comparisons over the life of the Maternity Improvement Project (5 years) to assess if changes implemented are having an impact on outcomes for the service. The LHS will provide data from clinical practice to demonstrate if improvements have been made; in addition to this, the independent evaluation will utilise data from nationally collected data sets such as the Friends and Family Test, GIRFT and Staff survey.

Risks

Data quality is key to the success of the project, as only good quality data entered into medical records will lead to accurate and feasible evaluations and research. While the principles of good medical record keeping are widely known, in practice there are frequently many barriers to good documentation such as time pressures, clinical governance and staff attitudes towards record keeping. We will work with the SaTH team to help improve record keeping.

Informatics consultations are a novel technology in healthcare. Further research and development of the DExtER platform is required to implement it, and so it would be available later than other elements of the project.

Uptake of the learning system and improvements to translate findings into improved clinical practice requires receptiveness of the service continuous improvement using the LHS. Normalisation Process Theory (NPT) describes many of the difficulties in embedding new complex interventions, and the Non-adoption, Abandonment, Scale-up, Spread, Sustainability (NASSS) framework can describe the risks associated with failure of digital infrastructure projects in healthcare.

Appendices to Chapter 3 - Clinical Decision Support Systems for Maternal Health

3.1 Search Strategy

Clinical decision support systems for maternity care

The Medline (Ovid) strategy, followed by its translation to CINAHL (Ebsco), Embase (Ovid), HMIC (Ovid), the Cochrane Library and PubMed.

Medline (Ovid):

1. exp informatics/ or exp dental informatics/ or exp medical informatics/ or exp nursing informatics/ or exp public health informatics/
2. clinical informatics.mp. [mp=ti, ab, hw, tn, ot, dm, mf, dv, kf, fx, dq, nm, ox, px, rx, ui, sy]
3. exp medical informatics/ or exp medical informatics applications/ or exp decision making, computer-assisted/ or exp decision support techniques/ or exp "information storage and retrieval"/ or exp information systems/ or exp clinical laboratory information systems/ or exp databases as topic/ or exp decision support systems, clinical/ or exp geographic information systems/ or exp hospital information systems/ or exp integrated advanced information management systems/ or exp knowledge bases/ or exp management information systems/ or exp medical records systems, computerized/ or exp medlars/ or exp online systems/ or exp radiology information systems/ or exp reminder systems/ or exp medical informatics computing/ or exp pattern recognition, automated/
4. clinical decision support\$.mp. [mp=ti, ab, hw, tn, ot, dm, mf, dv, kf, fx, dq, nm, ox, px, rx, ui, sy]
5. exp Computers/ or exp Clinical Pharmacy Information Systems/ or exp Medical Order Entry Systems/ or physician order entry system.mp. or exp Medication Errors/ or exp Medication Systems, Hospital/
6. (physician order entry system\$ or computeri\$ed physician order entry system).mp. [mp=ti, ab, hw, tn, ot, dm, mf, dv, kf, fx, dq, nm, ox, px, rx, ui, sy]
7. (electronic\$ adj3 guideline\$).mp. [mp=ti, ab, hw, tn, ot, dm, mf, dv, kf, fx, dq, nm, ox, px, rx, ui, sy]
8. (electronic\$ adj3 protocol).mp. [mp=ti, ab, hw, tn, ot, dm, mf, dv, kf, fx, dq, nm, ox, px, rx, ui, sy]
9. (computer\$ adj3 guideline\$).mp. [mp=ti, ab, hw, tn, ot, dm, mf, dv, kf, fx, dq, nm, ox, px, rx, ui, sy]
10. (computer\$ adj3 protocol\$).mp. [mp=ti, ab, hw, tn, ot, dm, mf, dv, kf, fx, dq, nm, ox, px, rx, ui, sy]
11. 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10
12. maternity.mp. or exp Hospitals, Maternity/ or exp Obstetrics/ or exp Maternal Health Services/
13. exp Pregnancy Complications/ or exp Pregnancy/ or pregnancy.mp.
14. exp Pregnancy/ or exp Pregnant Woman/ or Mother/ or exp Obstetrics/ or exp Obstetric Delivery/ or Birth/ or exp Childbirth/ or Maternal Care/ or (pregnan* or gravid* or gestation* or 'pregnant wom#n' or matern* or mother* or obstetric* or (child adj3 bearing) or childbearing or parturition or childbirth or child-birth).ti,ab. or exp Pregnancy Outcome/ or exp Pregnancy Disorder/ or exp Pregnancy Complication/ or Pregnancy Outcome/
15. 12 or 13 or 14

CINAHL (Ebsco):

1. (MH "Health Informatics+") OR (MH "Informatics+") OR (MH "Medical Informatics+" OR ("MH Nursing Informatics+"))
2. TI clinical informatics OR AB clinical informatics OR MW clinical informatics OR SU clinical informatics
3. (MH "Medical Informatics+") OR (MH "Decision Making, Computer Assisted+") OR (MH "Decision Support Techniques+") OR (MH "Information Retrieval+") OR (MH "Information Storage+") OR (MH "Information Systems+") OR (MH "Health Information Systems+") OR (MH "Clinical Information Systems+") OR (MH "Nursing Information Systems+") OR (MH "Clinical Laboratory Information Systems+") OR (MH "Decision Support Systems, Clinical+") OR (MH "Geographic Information systems+") OR (MH "Hospital Information Systems+") OR (MH "Integrated Advanced Information Systems+") OR (MH "Knowledge Bases+") OR (MH "Management Information Systems+") OR (MH "Patient Record Systems+") OR (MH "Electronic Health Records+") OR (MH "Medlars+") OR (MH "Online Systems+") OR (MH "Radiology Information Systems+") OR (MH "Reminder Systems+")
4. TI clinical decision support* OR AB clinical decision support* OR MW clinical decision support* OR SU clinical decision support*

5. (MH "Computers and Computerization+") OR (MH "Clinical Pharmacy Information Systems+") OR (MH "Electronic Order Entry+") OR (MH "Medication Errors+") OR (MH "Medication Systems+")
6. TI (physician order entry system* OR computeri?ed physician order entry system) OR AB (physician order entry system* OR computeri?ed physician order entry system) OR MW (physician order entry system* OR computeri?ed physician order entry system) OR SU (physician order entry system* OR computeri?ed physician order entry system)
7. TI (electronic* N3 guideline*) OR AB (electronic* N3 guideline*) OR MW (electronic* N3 guideline*) OR SU (electronic* N3 guideline*)
8. TI (electronic* N3 protocol) OR AB (electronic* N3 protocol) OR MW (electronic* N3 protocol) OR SU (electronic* N3 protocol)
9. TI (computer* N3 guideline*) OR AB (computer* N3 guideline*) OR MW (computer* N3 guideline*) OR SU (computer* N3 guideline*)
10. TI (computer* N3 protocol*) OR AB (computer* N3 protocol*) OR MW (computer* N3 protocol*) OR SU (computer* N3 protocol*)
11. 1 OR 2 OR 3 OR 4 OR 5 OR 6 OR 7 OR 8 OR 9 OR 10
12. maternity OR (MH "Hospitals, Special+") OR (MH "Obstetrics+") OR (MH "Maternal Health Services+")
13. (MH "Pregnancy Complications+") OR (MH "Pregnancy+") OR pregnancy
14. (MH "Pregnancy+") OR (MH "Expectant Mothers+") OR (MH "Mothers+") OR (MH "Obstetrics+") OR (MH "Delivery, Obstetric+") OR (MH "Childbirth+") OR TI (pregnan* OR gravid* OR gestation* OR "pregnant wom?n" OR matern* OR mother* OR obstetric* OR (child N3 bearing) OR childbearing OR parturition OR childbirth OR child-birth) OR AB (pregnan* OR gravid* OR gestation* OR "pregnant wom?n" OR matern* OR mother* OR obstetric* OR (child N3 bearing) OR childbearing OR parturition OR childbirth OR child-birth) OR (MH "Maternal-Child Care+") OR (MH "Pregnancy Outcomes+") OR (MH "Pregnancy Complications+")
15. 12 or 13 or 14

Embase (Ovid):

1. exp information science/ OR exp dental informatics/ OR exp medical informatics/ OR exp nursing informatics/
2. clinical informatics.ab,fx,hw,kf,ot,ti,dq.
3. exp medical informatics/ OR decision support system/ OR exp clinical decision support system/ OR exp information retrieval/ OR exp information system/ OR exp medical information system/ OR exp bedside information system/ OR exp nursing information system/ OR exp pathology information system/ OR exp laboratory information system/ OR exp data base/ OR exp clinical decision support system/ OR exp geographic information system/ OR exp hospital information system/ OR exp knowledge base/ OR exp electronic medical record system/ OR exp medline/ OR exp online system/ OR exp radiology information system/ OR exp reminder system/ OR exp pattern recognition
4. clinical decision support*.ab,fx,hw,kf,ot,ti,dq
5. computer/ OR exp medical information system/ OR exp physician order entry system/ OR exp computerized provider order entry/ OR exp medication error/ OR exp hospital organization
6. (physician order entry system* OR computeri#ed physician order entry system).ab,fx,hw,kf,ot,ti,dq.
7. (electronic* adj3 guideline*).ab,fx,hw,kf,ot,ti,dq.
8. (electronic* adj3 protocol).ab,fx,hw,kf,ot,ti,dq.
9. (computer* adj3 guideline*).ab,fx,hw,kf,ot,ti,dq.
10. (computer* adj3 protocol*).ab,fx,hw,kf,ot,ti,dq.
11. 1 OR 2 OR 3 OR 4 OR 5 OR 6 OR 7 OR 8 OR 9 OR 10
12. maternity OR exp maternity ward/ OR exp obstetrics/ OR exp maternal health service
13. exp pregnancy complication/ OR exp pregnancy OR pregnancy.mp
14. exp pregnancy/ OR exp pregnant woman/ OR mother/ OR exp obstetrics/ OR exp obstetric delivery/ OR exp birth/ OR exp childbirth/ OR exp maternal care/ OR (pregnan* OR gravid* OR gestation* OR 'pregnant wom#n' OR matern* OR mother* OR obstetric* OR (child adj3 bearing) OR childbearing OR parturition OR

childbirth OR child-birth).ti,ab. OR exp pregnancy outcome/ or exp pregnancy disorder OR exp pregnancy complication/ OR pregnancy outcome

15. 15. 12 or 13 or 14

HMIC (Ovid):

1. informatics/ OR exp health informatics/ OR exp medical informatics/ OR exp nursing informatics
2. clinical informatics.ti,ab,hw,ot,sh.
3. exp medical informatics/ OR exp computer aided decision making/ OR exp decision support systems/ OR exp decision making/ OR exp decision models/ OR exp information retrieval/ OR exp information storage/ OR exp information systems/ OR exp medical information systems/ OR exp nursing information systems/ OR exp database management systems/ OR exp geographical information systems/ OR exp hospital information systems/ OR exp knowledge base/ OR exp electronic medical record/ OR exp medline/ OR exp online system/ OR exp patient appointment reminder systems/ OR exp pattern recognition
4. clinical decision support*.ti,ab,hw,ot,sh.
5. computers/ OR exp drug information systems/ OR exp computerised information systems/ OR exp medication errors/ OR exp medication systems/
6. (physician order entry system* OR computerised physician order entry system).ti,ab,hw,ot,sh.
7. (electronic* adj3 guideline*).ti,ab,hw,ot,sh.
8. (electronic* adj3 protocol).ti,ab,hw,ot,sh.
9. (computer* adj3 guideline*).ti,ab,hw,ot,sh.
10. (computer* adj3 protocol*).ti,ab,hw,ot,sh.
11. 1 OR 2 OR 3 OR 4 OR 5 OR 6 OR 7 OR 8 OR 9 OR 10
12. maternity OR exp maternity hospitals/ OR exp obstetrics/ OR exp maternity services/
13. exp pregnancy complications/ OR exp pregnancy/ OR pregnancy.mp
14. exp pregnancy/ OR exp pregnant women/ OR mothers/ OR exp obstetrics/ OR exp birth delivery/ OR exp childbirth/ OR maternal care/ OR (pregnan* OR gravid* OR gestation* OR 'pregnant wom#n' OR matern* OR mother* OR obstetric* OR (child adj3 bearing) OR childbearing OR parturition OR childbirth OR child-birth).ti,ab. OR exp pregnancy outcome/ OR exp pregnancy complications
15. 12 or 13 or 14

Cochrane Library (including CENTRAL)

The Cochrane Library does not support direct keying of MeSH terms; for each individual term, a separate search is conducted in the MeSH browser and then the desired term selected from the tree. Each MeSH term takes a line on its own so the resulting line numbering is different from the original strategy. Below is the exported search, which can also be viewed on the database at

<https://www.cochranelibrary.com/advanced-search/search-manager?search=6972602>

- #1 MeSH descriptor: [Informatics] explode all trees
- #2 MeSH descriptor: [Dental Informatics] explode all trees
- #3 MeSH descriptor: [Nursing Informatics] explode all trees
- #4 MeSH descriptor: [Public Health Informatics] explode all trees
- #5 (clinical informatics):ti,ab,kw (Word variations have been searched)
- #6 MeSH descriptor: [Medical Informatics] explode all trees
- #7 MeSH descriptor: [Medical Informatics Applications] explode all trees
- #8 MeSH descriptor: [Decision Making, Computer-Assisted] explode all trees
- #9 MeSH descriptor: [Decision Support Techniques] explode all trees
- #10 MeSH descriptor: [Information Storage and Retrieval] explode all trees
- #11 MeSH descriptor: [Information Systems] explode all trees
- #12 MeSH descriptor: [Clinical Laboratory Information Systems] explode all trees
- #13 MeSH descriptor: [Databases as Topic] explode all trees
- #14 MeSH descriptor: [Decision Support Systems, Clinical] explode all trees

- #15 MeSH descriptor: [Geographic Information Systems] explode all trees
- #16 MeSH descriptor: [Hospital Information Systems] explode all trees
- #17 MeSH descriptor: [Integrated Advanced Information Management Systems] explode all trees
- #18 MeSH descriptor: [Knowledge Bases] explode all trees
- #19 MeSH descriptor: [Management Information Systems] explode all trees
- #20 MeSH descriptor: [Medical Records Systems, Computerized] explode all trees
- #21 MeSH descriptor: [MEDLARS] explode all trees
- #22 MeSH descriptor: [Online Systems] explode all trees
- #23 MeSH descriptor: [Radiology Information Systems] explode all trees
- #24 MeSH descriptor: [Reminder Systems] explode all trees
- #25 MeSH descriptor: [Medical Informatics Computing] explode all trees
- #26 MeSH descriptor: [Pattern Recognition, Automated] explode all trees
- #27 (clinical decision support):ti,ab,kw (Word variations have been searched)
- #28 MeSH descriptor: [Computers] explode all trees
- #29 MeSH descriptor: [Clinical Pharmacy Information Systems] explode all trees
- #30 MeSH descriptor: [Medical Order Entry Systems] explode all trees
- #31 MeSH descriptor: [Medication Errors] explode all trees
- #32 MeSH descriptor: [Medication Systems, Hospital] explode all trees
- #33 ((physician order entry system*) OR (computeri?ed order entry system)):ti,ab,kw (Word variations have been searched)
- #34 (electronic* guideline*) OR (electronic* protocol) OR (computer* guideline*) OR (computer* protocol*):ti,ab,kw (Word variations have been searched)
- #35 #1 or #2 or #3 or #4 or #5 or #6 or #7 or #8 or #9 or #10 or #11 or #12 or #13 or #14 or #15 or #16 or #17 or #18 or #19 or #20 or #21 or #22 or #23 or #24 or #25 or #26 or #27 or #28 or #29 or #30 or #31 or #32 or #33 or #34
- #36 (maternity):ti,ab,kw (Word variations have been searched)
- #37 MeSH descriptor: [undefined] explode all trees
- #38 MeSH descriptor: [Obstetrics] explode all trees
- #39 MeSH descriptor: [Maternal Health Services] explode all trees
- #40 MeSH descriptor: [Pregnancy Complications] explode all trees
- #41 MeSH descriptor: [Pregnancy] explode all trees
- #42 (pregnancy):ti,ab,kw (Word variations have been searched)
- #43 MeSH descriptor: [Pregnant Women] explode all trees
- #44 MeSH descriptor: [Mothers] explode all trees
- #45 MeSH descriptor: [Obstetrics] explode all trees
- #46 MeSH descriptor: [Delivery, Obstetric] explode all trees
- #47 MeSH descriptor: [Parturition] explode all trees
- #48 MeSH descriptor: [Maternal-Child Nursing] explode all trees
- #49 MeSH descriptor: [Maternal-Child Health Services] explode all trees
- #50 MeSH descriptor: [Pregnancy Outcome] explode all trees
- #51 MeSH descriptor: [Pregnancy Complications] explode all trees
- #52 (pregnan* OR gravid* OR gestation* OR 'pregnant wom?n' OR matern* OR mother* OR obstetric* or (child NEAR/3 bearing) or childbearing or parturition or childbirth or child-birth):ti,ab,kw (Word variations have been searched)
- #53 #36 or #37 or #38 or #39 or #40 or #41 or #42 or #43 or #44 or #45 or #46 or #47 or #48 or #49 or #50 or #51 or #52

PubMed

1. (informatics[MeSH Terms]) OR (dental informatics[MeSH Terms]) OR (medical informatics[MeSH Terms]) OR (nursing informatics[MeSH Terms])

2. (clinical informatics[Title/Abstract])
3. (medical informatics[MeSH Terms]) OR (medical informatics applications[MeSH Terms]) OR (decision making, computer assisted[MeSH Terms]) OR (decision support techniques[MeSH Terms]) OR (information storage and retrieval[MeSH Terms]) OR (information systems[MeSH Terms]) OR (clinical laboratory information systems[MeSH Terms]) OR (databases as topic[MeSH Terms]) OR (decision support systems, clinical[MeSH Terms]) OR (geographic information systems[MeSH Terms]) OR (hospital information systems[MeSH Terms]) OR (integrated advanced information management systems[MeSH Terms]) OR (knowledge bases[MeSH Terms]) OR (management information systems[MeSH Terms]) OR (computerized medical record systems[MeSH Terms]) OR (medlars[MeSH Terms]) OR (online systems[MeSH Terms]) OR (radiology information systems[MeSH Terms]) OR (reminder systems[MeSH Terms]) OR (computing, medical informatics[MeSH Terms]) OR (automated pattern recognition[MeSH Terms])
4. (clinical decision support*[Title/Abstract])
5. (computers[MeSH Terms]) OR (clinical pharmacy information systems[MeSH Terms]) OR (medical order entry systems[MeSH Terms]) OR (computerized physician order entry system[MeSH Terms]) OR (medication errors[MeSH Terms]) OR (medication systems, hospital[MeSH Terms])
6. (physician order entry system* OR computeri* physician order entry system[Title/Abstract])
7. (electronic* guideline*[Title/Abstract])
8. (electronic* protocol[Title/Abstract])
9. (computer* guideline[Title/Abstract])
10. (computer* protocol* [Title/Abstract])
11. #1 OR #2 OR #3 OR #4 OR #5 OR #6 OR #7 OR #8 OR #9 OR #10
12. (maternity[Title/Abstract]) OR (hospitals[MeSH Terms]) OR (obstetrics[MeSH Terms]) OR (maternal health services[MeSH Terms])
13. (pregnancy complications[MeSH Terms]) OR (pregnancy[MeSH Terms]) OR (pregnancy)
14. (pregnancy[MeSH Terms]) OR (pregnant woman[MeSH Terms]) OR (mother[MeSH Terms]) OR (obstetrics[MeSH Terms]) OR (obstetric delivery[MeSH Terms]) OR (birth[MeSH Terms]) OR (childbirth[MeSH Terms]) OR (pregnan*[Title/Abstract] OR gravid*[Title/Abstract] OR gestation*[Title/Abstract] OR "pregnant woman"[Title/Abstract] OR "pregnant women"[Title/Abstract] OR matern*[Title/Abstract] OR mother*[Title/Abstract] OR obstetric*[Title/Abstract] OR child bearing[Title/Abstract] OR childbearing[Title/Abstract] OR parturition[Title/Abstract] OR childbirth[Title/Abstract] OR child-birth[Title/Abstract]) OR (pregnancy outcome[MeSH Terms]) OR (pregnancy complications[MeSH Terms])
15. #12 OR #13 OR #14

3.2 Extraction Form

Extract Form Fields for a Systematic Review of Clinical Decision Support Systems in Maternal Health		
Study Details	Title	
	Lead Author	
	Year	
	Full Citation	
	DOI or other RefID	
Study Background	Aims	What are the stated aims and research question? In one sentence per aim, what were they trying to achieve in this study, either from a research perspective (answer a question) or from an intervention perspective (what problem were they trying to solve?) Text copied and pasted from the paper
	Rationale	Why has a CDSS been used in this context? What is the justification for using a CDSS to solve the problems described? Text copied and pasted from the paper
	Study Type	MMAT study type - selected from the drop down menu. For further information on classifying the study type, see MMAT resources.
	Study Design	Summary of the study design in greater detail than type
Participants	Setting	Where and when is the study conducted? In particular, where does the intervention take place, and where is the outcome measured?
	Recruitment process	How were the units of intervention (such as hospital or clinician) selected or enrolled into the study? If units of intervention are different to the unit of outcome, how were unit of outcome (usually pregnant women) recruited?
	Inclusion & Exclusion Criteria	Any inclusion & exclusion criteria either for unit of intervention or for unit of outcome
	N	Numbers enrolled in the study and in each arm
Intervention	Definition	What was the whole intervention implemented in the study? E.g. describe all training, infrastructure or equipment provided, organisational change. This section is usually text copied and pasted from the paper and is broader than the CDSS description
	CSDS Description	Describe the CDSS tool in detail. This section is usually text copied and pasted from the paper
Control	Definition	How is the control arm selected/recruited/treated?
Outcome	Outcome Definition	What outcomes are relevant to assessing the impact of the CDSS ? There may be multiple outcomes. One row per outcome, each subsequent outcome goes in another row.
	Primary vs Secondary	Is this outcome described by the study as a primary outcome? Document as either primary or secondary

Follow-up	Length of follow up	When (or for how long) was the outcome assessed?
Result	Score or measure assessed, units	What is being measured and in what units. Where possible, this measure should be comparative e.g. ratios or differences
	Frequencies	For binary outcomes, please give the frequencies they occurred in each arm. E.g. in a 2-arm RCT measuring neonatal mortality, state (infants died/infants in group) intervention, (infants died/infants in group) control
	Value	Please give the summary statistic with confidence intervals. E.g. odds ratio, risk ratio etc. If you are unsure or no summary statistic is available, discuss with Co-Authors
	Factors associated with success or failure	Qualitative results or any evidence in a study that a feature is associated with success or failure of the intervention. This must be evidence and not conjecture/anecdotal.
SCREENING QUESTIONS	S1. Are there clear research questions?	
	S2. Do the collected data allow to address the research questions?	
	1.1. Is the qualitative approach appropriate to answer the research question?	
	1.2. Are the qualitative data collection methods adequate to address the research question?	

1. QUALITATIVE STUDIES	1.3. Are the findings adequately derived from the data?	
	1.4. Is the interpretation of results sufficiently substantiated by data?	
	1.5. Is there coherence between qualitative data sources, collection, analysis and interpretation ?	
2. RANDOMIZED CONTROLLED TRIALS	2.1. Is randomization appropriately performed?	
	2.2. Are the groups comparable at baseline?	
	2.3. Are there complete outcome data?	
	2.4. Are outcome assessors blinded to the intervention provided?	
	2.5 Did the participants adhere to the assigned intervention?	

3. NON-RANDOMIZED STUDIES	3.1. Are the participants representative of the target population?	
	3.2. Are measurements appropriate regarding both the outcome and intervention (or exposure)?	
	3.3. Are there complete outcome data?	
	3.4. Are the confounders accounted for in the design and analysis?	
	3.5. During the study period, is the intervention administered (or exposure occurred) as intended?	
	4.1. Is the sampling strategy relevant to address the research question?	
	4.2. Is the sample representative of the target population?	

4. QUANTITATIVE DESCRIPTIVE STUDIES	4.3. Are the measurement s appropriate?	
	4.4. Is the risk of nonresponse bias low?	
	4.5. Is the statistical analysis appropriate to answer the research question?	
	5.1. Is there an adequate rationale for using a mixed methods design to address the research question?	
	5.2. Are the different components of the study effectively integrated to answer the research question?	
	5.3. Are the outputs of the integration of qualitative and quantitative components adequately interpreted?	

5. MIXED METHODS STUDIES	5.4. Are divergences and inconsistencies between quantitative and qualitative results adequately addressed?	
	5.5. Do the different components of the study adhere to the quality criteria of each tradition of the methods involved?	
COMMENTS		

3.3 Meta-analysis Sensitivity Findings

A Systematic Review of Clinical Decision Support Systems for Maternity Care

Sensitivity Meta-analysis excluding studies assessed at increased risk of bias

Methods

All analyses are conducted identically to main analysis on a restricted group of studies. Both Randomised Controlled Trials and Non-Randomised Quantitative studies are included, assessed using the Mixed Methods Assessment Tool. The MMAT supports judgements in 5 key domains of a study and is not designed to produce a score that designates studies at low or high risk of bias. In this analysis, we included studies that were at low risk of bias in domains that we considered particularly important, while accepting low and high risk of domain bias in the other domains. The below table outlines these domains, which requirements were relaxed, and a brief justification for not requiring certain domains.

Study Design	Risk of Bias Domain	Low risk required
2. RANDOMIZED CONTROLLED TRIALS	2.1. Is randomization appropriately performed?	Yes
	2.2. Are the groups comparable at baseline?	Yes
	2.3. Are there complete outcome data?	Yes
	2.4. Are outcome assessors blinded to the intervention provided?	No – outcomes usually drawn from routinely collected data, generated by staff conducting interventions, and so frequently it is less possible or meaningful to blind outcome assessors
	2.5 Did the participants adhere to the assigned intervention?	No – adherence to interventions is often evaluated in other studies. Furthermore, in complex interventions such as in CDSS, it can be difficult to meaningfully separate adherence to CDSS use and adherence to the desired outcome (often processes of care).
3. NON-RANDOMIZED STUDIES	3.1. Are the participants representative of the target population?	Yes
	3.2. Are measurements appropriate regarding both the outcome and intervention (or exposure)?	Yes
	3.3. Are there complete outcome data?	Yes

	3.4. Are the confounders accounted for in the design and analysis?	Yes
	3.5. During the study period, is the intervention administered (or exposure occurred) as intended?	No – adherence to interventions is often evaluated in other studies. Furthermore, in complex interventions such as in CDSS, it can be difficult to meaningfully separate adherence to CDSS use and adherence to the desired outcome (often processes of care).

Results

We included 18 (62% of those included in the main meta-analysis) outcomes from 11 (50%) CDSS for RCTs, and 4 (21%) outcomes from 4 (36%) CDSS in this sensitivity.

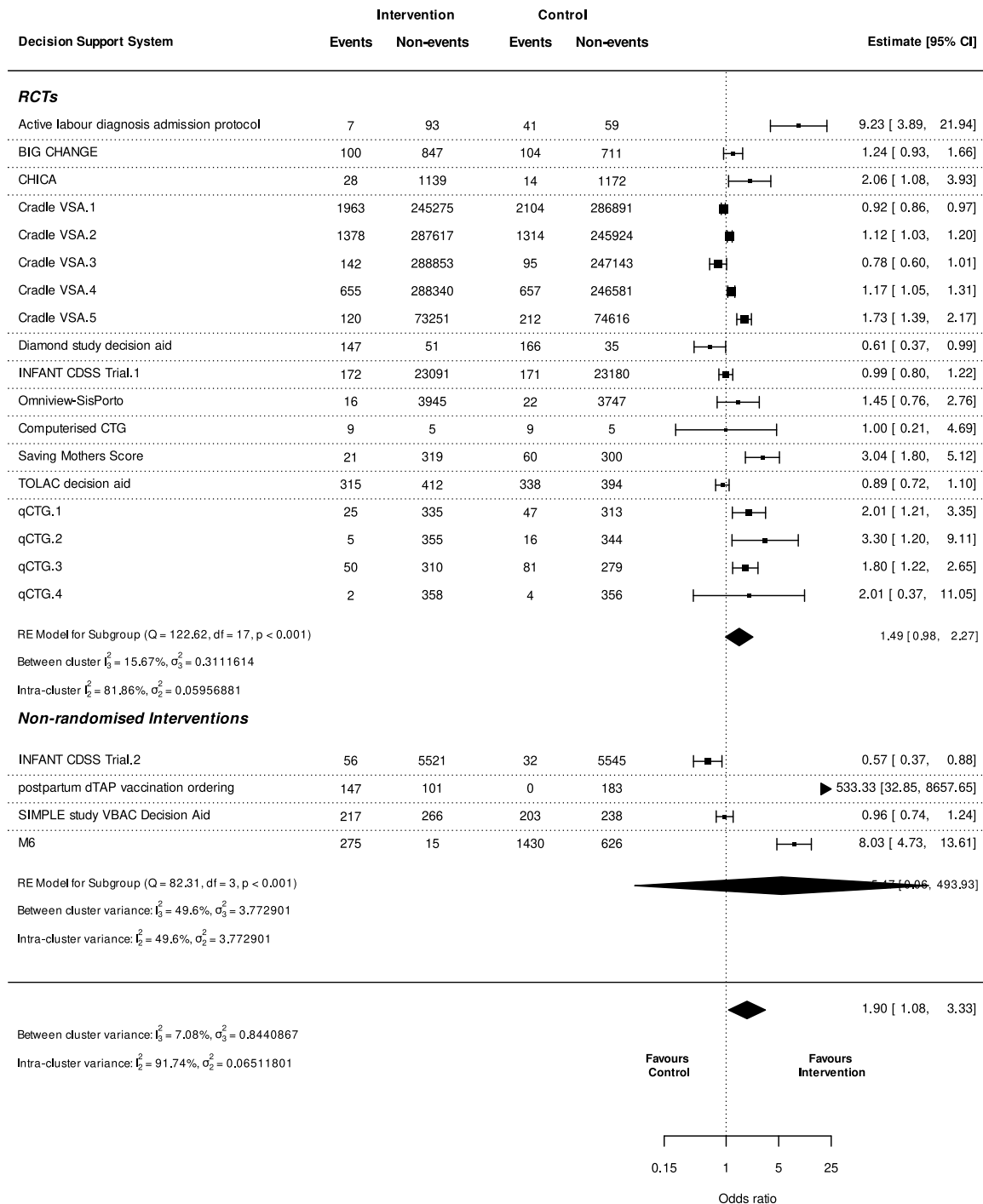


Figure 1: Subgrouped sensitivity meta-analysis forest plot.

The sensitivity analysis shows an increased effect compared to the main sensitivity analysis, due in part to the effect of a single small non-randomised interventional study with an OR of 533. The RCT subgroup however also tends towards an increased effect size. The sensitivity analysis is not statistically significantly different to the main

analysis, although the precision of the results is reduced. The confidence interval of the non-randomised group is very broad, and heterogeneity is substantial.

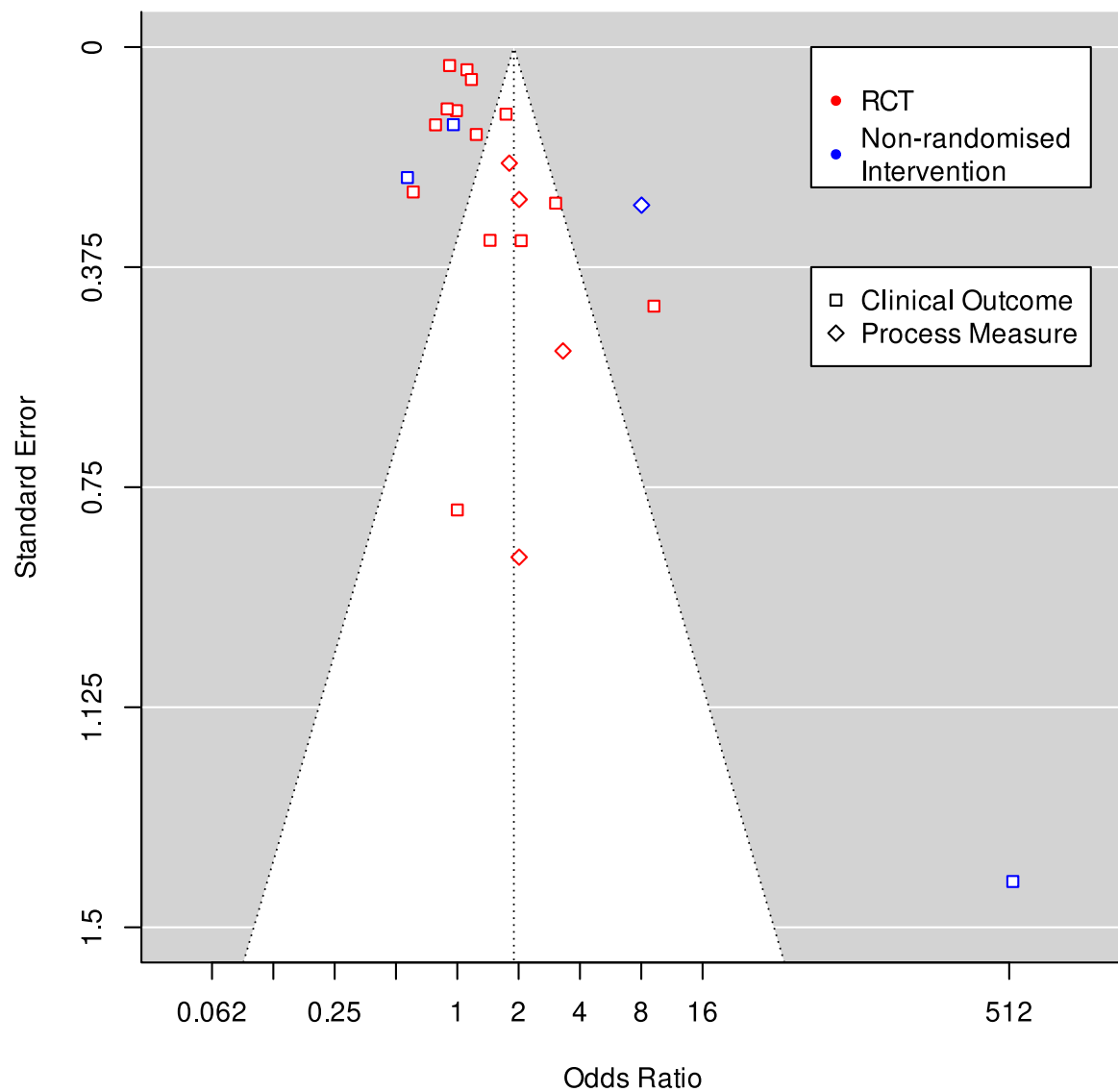


Figure 2: Sensitivity analysis funnel plot

The funnel plot shows a more centralised spread compared with the main analysis, and most results included in the sensitivity analysis have a low standard error. Egger's test $p = 0.19$.

3.4 Citation Tracing Results

Supplementary 3 – Snowballing Results

Database searches retrieved 26 reports which were included in the review, while citation tracing included 55 reports by snowballing from the original 26 reports. Citation tracing occurred in 7 rounds until saturation was reached and no new records were found; the results are presented in the table below.

Table 1: Results of successive rounds of snowballing.

Round	Date of citation tracing	New (deduplicated) records retrieved	Full text inclusion	Yield (%)
1	17/08/2022	785	14	1.7
2	21/10/2022	610	13	2.5
3	23/11/2022	352	12	3.4
4	02/12/2022	169	8	4.7
5	16/12/2022	195	6	3.1
6	05/01/2023	196	1	0.5
7	18/01/2023	35	0	0

3.5 Risk of bias assessments

Study Design, Article	MMAT Question				
Qualitative	1.1	1.2	1.3	1.4	1.5
Carlisle 2021					
Mackintosh 2014					
Klumpner 2020					
Emmett et al. 2007					
Rees et al. 2009					
Nathan 2018					
Bartlett 2021					
Abejirinde 2018					
Zakane 2017					
Usmanova 2020					

RCT	2.1	2.2	2.3	2.4	2.5
Watson 2021					
Carlisle 2021					
Brocklehurst 2017					
Montgomery 2007					
Venkateswaran 2022					
Cabellero 2017					
Ignatov 2016					
Ignatov 2012					
Nunes 2017					
Saccone 2021					
Luitjes 2018					
Eden 2014					
Kuppermann 2009					
Carlson 2019					
Chakravarthy 2019					
Vousden 2019					
Vousden 2019					
Giblin 2021					
Amoakoh 2019					
Kupperman 2020					
Cheyne 2008					
Vieira 2022					
Abasian Kasegari, 2020					
Carroll 2010					

Quantitative non-randomised	3.1	3.2	3.3	3.4	3.5
Blumenthal 2021					
Shields 2016					
Merriel 2016					
Sheikh 2007					
Wilson 2021					
Vankan 2019					
Albert 2020					
Horner 2013					
Amoakoh 2020					
Dinh 2022					
McNabb 2015					
Trick 2010					
Iliodromiti 2020					
Ravula 2022					
Hugh 2020					
Cowan 2020					
Veglia 2017					
Aninanya 2021					
Mensah 2015					
Haberman 2009					
Usmanova 2021					
Gardosi 2005					
McCarthy et al 2013					
Bobdiwala 2020					
Bobdiwala 2016					
Lopes-Pereira 2018					
Imo 2024					
Maiga 2023					
Wang 2022					
Kandahari, 2024					

Quantitative descriptive	4.1	4.2	4.3	4.4	4.5
Klumpner 2018					
Valdera Simbron 2021					
Long 2012					
Amoakoh 2019					
Abejirinde 2019					
Benski et al. 2017					
McCarthy 2022					

Mixed methods		Vos 2017	Vousden 2019	Vousden 2018	Amoakoh 2018	Relph 2022	Abejirinde 2018	Sukums 2015	Shah 2019	Nagraj 2023	Humphries 2023
	1.1										
	1.2										
	1.3										
	1.4										
	1.5										
	2.1										
	2.2										
	2.3										
	2.4										
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	3.4										
	3.5										
	4.1										
	4.2										
	4.3										
	4.4										
	4.5										
	5.1										
	5.2										
	5.3										
	5.4										
	5.5										

Economic Evaluation	Schroeder, 2021	Hollinghurst, 2010	Luitjes, 2020	Saronga, 2015	Saronga, 2017	Dalaba, 2014	Dalaba, 2015
The research question is stated.							
The economic importance of the research question is stated.							
The viewpoint(s) of the analysis are clearly stated and justified.							
The rationale for choosing alternative programmes or interventions compared is stated.				NA		NA	
The alternatives being compared are clearly described				NA		NA	
The form of economic evaluation used is stated.							
The choice of form of economic evaluation is justified in relation to the questions addressed.							
The source(s) of effectiveness estimates used are stated.							
Details of the design and results of effectiveness study are given (if based on a single study).							
Details of the methods of synthesis or meta-analysis of estimates are given (if based on a synthesis of a number of effectiveness studies).	NA	NA	NA	NA	NA	NA	NA
The primary outcome measure(s) for the economic evaluation are clearly stated.							
Methods to value benefits are stated.				NA		NA	

Details of the subjects from whom valuations were obtained were given.						
Productivity changes (if included) are reported separately.	NA	NA	NA	NA		NA
The relevance of productivity changes to the study question is discussed.	NA	NA	NA	NA		NA
Quantities of resource use are reported separately from their unit costs.						
Methods for the estimation of quantities and unit costs are described.						
Currency and price data are recorded.						
Details of currency of price adjustments for inflation or currency conversion are given.						
Details of any model used are given.	NA	NA	NA	NA		NA
The choice of model used and the key parameters on which it is based are justified.	NA	NA	NA	NA		NA
Time horizon of costs and benefits is stated.						
The discount rate(s) is stated.		NA	NA			
The choice of discount rate(s) is justified.		NA	NA			
An explanation is given if costs and benefits are 1t discounted.	NA				NA	NA
Details of statistical tests and confidence intervals are given for stochastic data.						
The approach to sensitivity analysis is given.						
The choice of variables for sensitivity analysis is justified.						
The ranges over which the variables are varied are justified.						
Relevant alternatives are compared.						
Incremental analysis is reported.	NA				NA	
Major outcomes are presented in a disaggregated as well as aggregated form.	NA					
The answer to the study question is given.						
Conclusions follow from the data reported.						
Conclusions are accompanied by the appropriate caveats.						

3.6 Results table

Appendix 3.6 is provided as a supplementary file.

3.7 Evidence summary of selected CDSS

Supplementary 6 – Vignettes of evidence for selected tools

Contents

Cradle VSA	1
QUALMAT	2
cGAP	3
QUiPP APP.....	3
DIAMOND.....	4
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iDeliver	5
Asman.....	5
Infant.....	5
eRegQual.....	6

Cradle VSA

The CRADLE vital sign alert (VSA) semi-automated device measures blood pressure and pulse to calculate the pregnant mothers' risk of hypovolaemic or septic shock, designed for use in low resource settings. The device aimed to trigger referral for critically ill patients, to improve safety, and to better target scarce resources, acting as a Point of Care alerts/reminder and Expert System. The CRADLE-VSA device was used in low and lower-middle income countries during antenatal care across all levels of care.

Six papers reported outcomes from three projects which spanned both primary and secondary or greater care settings. The CRADLE 2 study took place over 15 months (between January 2015 and April 2016) in Nigeria and South Africa. ([Nathan, 2018](#)) A feasibility study of Cradle-3 took place in Zimbabwe, Ethiopia, India from November 2015 - January 2016, and then the Cradle-3 VSA trial took place in 10 low- and middle-income country sites from April 2016-November 2017.

The qualitative evaluation of the CRADLE-2 trial (Nathan, 2018) was assessed as being of low risk of bias, while the remaining 5 out of 6 papers had high risk of bias in at least one or more MMAT components.

In the CRADLE-3 RCT there was a non-significant increase in the rate of a composite of maternal mortality or major morbidity (aOR 1.22 [95% CI 0.73-2.06]) in the intervention compared to control group (Vousden, 2019). Secondary analyses also found a non-significant increase in eclampsia (pre vs post intervention odds ratio 1.30 95% CI [0.82 2.05]) but non-significant reductions in odds of maternal death due to hypertensive disorders of pregnancy (0.84 95% CI [0.47 1.51]) ([Vousden, 2019](#)), and a statistically significant reduction in the odds of women referred for obstetric haemorrhage following intervention (0.56 [95%CI 0.42-0.74]) without any increase in bleeding-related morbidity (maternal death or emergency hysterectomy) ([Giblin, 2021](#)).

A process evaluation during the Cradle-3 trial ranked fidelity, reach and adoption of implementing sites and found no association between these rankings and maternal morbidity and mortality (aOR 0.93; [95%CI 0.07–13.01]). ([Vousden, 2019](#)).

The CRADLE-3 feasibility study found that the intervention was perceived by women to have improved capacity to make clinical decisions around treatment and referral, escalating care and making appropriate referrals. The CRADLE-2 study similarly found that most healthcare workers perceived the CRADLE device to be easy to use and accurate. The traffic lights early warning system was unanimously reported positively, giving healthcare workers confidence with decision-making and a sense of professionalism. Unanimously, pregnant women liked the CRADLE device. The traffic light early warning system gave women and their families a better understanding of the importance of vital signs in pregnancy and during the postpartum period.

QUALMAT

QUALMAT is standalone software that aims to improve patient satisfaction, guideline adherence, and safety as an Expert System and Workflow Support. It provides decision support based on WHO guidelines on "pregnancy, childbirth, postpartum and newborn care: a guide for essential practice".(ref) The software was used primarily in Antenatal and Intrapartum Care in Low- and Middle-Income Countries.

Eight studies investigated the impact of QUALMAT across 3 implementations in Tanzania (Saronga 2015, 2017), Ghana (Dalaba 2014, 2015, Aninanya 2021), Burkina Faso (Zakane 2017), and studies using both Tanzanian and Ghanaian data (Sukums 2015, Mensah 2015). Aninanya alone was assessed to have low risk of bias.

Sukums (2015) evaluated uptake by looking at QUALMAT usage data compared to client registers. For ANC, 71% of clients were managed with QUALMAT in Tanzania and 59% in Ghana, and IPC, 83% in Tanzania and 67% in Ghana. In Burkina Faso, Zakane et al found that only 24% of ANC visits were managed using QUALMAT, and that QUALMAT did not fit into the workflow and features such as the partogram were not user-friendly. Mensah et al. compared the duration of ANC visits between intervention and control sites in Ghana and Tanzania finding against expectations that adjusted differences were small (additional 0.5 minute) and not statistically significant (Ghana: 0.51min [p=0.06], Tanzania: 0.54min [p=0.26]).

Aninanya et al. Constructed general satisfaction scores and evaluated the change before and after QUALMAT intervention. QUALMAT improved the general client satisfaction of ANC in the intervention site with a difference-in-differences of 0.058 (p= 0.014). The general satisfaction of the delivery outcomes were Diff-Diff of 0.072 (p=0.017).

Saronga et al. (2015) found that QUALMAT cost 52.7 USD per CDSS contact. Saronga et al. (2017) then constructed a quality score measured by questionnaire and found an increase of 4.53% in the score in implementing sites in Tanzania compared to baseline, at a economic Incremental Cost Effectiveness Ratio (ICER) of 2469 USD per percentage point of quality score for ANC and ICER of USD 338 per percentage point of quality score for childbirth. In Ghana, Dalaba et al similarly investigated average financial cost per contact using QUALMAT, at a cost per ANC contact of 4.17 USD and per birth of 26.7 USD.

GAP

The CDSS component of GAP focuses on developing customised growth charts specific to pregnant women, delivered as part of an educational program and guideline with high-risk and low-risk pathways for managing risk of Small-for-Gestational Age (SGA). This expert system-type tool was implemented to improve safety and guideline adherence in high-income countries during antenatal care.

Our review identified 7 studies evaluating the impact of GAP in 6 implementations, all of which were assessed to have a risk of bias in at least one or more MMAT components. Initially evaluated as a paper-based customised growth charts in 1999 which showed increased odds ratio of detection of SGA of 2.23 (95% CI 1.12,4.45), 6 studies have been published since 2020 with conflicting messages on effectiveness, following greater uptake in UK hospitals from 2008. A 3-year UK-based cluster RCT of 13 sites beginning in 2016 [Vieira] showed no effect of GAP on correctly identifying SGA babies compared to standard care. Conversely, two non-randomised interventional studies both showed improvements before and after implementation; a New Zealand tertiary centre (Cowan) found increased odds ratio of detection of 4.80 (95% CI 2.82,8.18) and an Indian tertiary centre (Ravula) saw increased odds ratio of detection of 1.95 (95% CI 1.89, 2.02). In addition to this process outcome, studies also evaluated impact on stillbirths: in the same Indian study, there appeared to be a reduction in stillbirths but this was not statistically significant (Risk Ratio 0.78 [95% CI 0.60, 1.02]). Two designs took ecological approaches to review the impact of GAP on national stillbirth rates: Hugh et al found that in England, stillbirths were less likely in 2017 compared to 2018, when 94 out of 133 hospital trusts had implemented GAP (OR 0.82 [95% CI 0.78, 0.86]), but a smaller and non-statistically significant effect was noted when comparing implementers to non-implementers (OR 0.94 [95% CI 0.86, 1.02]). However, Iliodromoti compared Scottish stillbirth rates, where GAP was not implemented, with England over the same period and found a greater fall in the rate of stillbirths in Scotland of 41.0 per 100,000 (95% CI 40.9,41.1).

A process evaluation embedded into the 2016 trial (ref) noted that implementation was affected by resourcing for the GAP protocol, and that changes to practice caused healthcare staff to fear they could be held accountable for negative outcomes.

QUIPP APP

The Quantitative Innovation in Predicting Preterm birth (QUIPP) app supports identification and management of threatened preterm labour (TPTL). Its use was evaluated in a single high income country (XX), in intrapartum secondary care settings. The app was available via mobile device, webpage and some EHRs, and acted as an expert system aiming to better target scarce resources, prevent missed diagnoses and improve clinical outcomes.

3 studies evaluated QUIPP, all embedded into the EQUIPTT trial in England which was a 13-unit cluster RCT. [\(Carlisle, 2021a\)](#) and [\(Carlisle, 2021b\)](#) were assessed as low risk of bias.

The RCT did not provide evidence of a reduction in a composite outcome of inappropriate admission or discharge decisions of TPTL per woman (OR 0.97 [95% CI 0.66-1.42]) (Watson et al 2021). In a subset of participants from the EQUIPTT study investigating pregnant women's experiences with the QUIPP app [\(Carlisle, 2021\)](#), the reduction in anxiety measured on a Visual Analogue Scale for Anxiety (VASA) scores for women aware of the QUIPP app being used compared with those not aware that the app was being used fell just below the statistical significance threshold (mean difference 0.84 [95% CI 1.758, -0.078]), and odds of women experiencing high

decisional conflict about management decisions for women who were aware of the QUiPP app use showed no evidence of effect (OR 0.71 [95%CI 0.29, 1.76]).

Qualitative findings from the EQUIPTT study ([Carlisle, 2021](#)) found that clinicians appeared to find the QUiPP app an accessible and acceptable clinical that changed how they perceived TPTL risk and increased their confidence in clinical decision making. Clinicians also felt the QUiPP scores allowed them to have better conversations with women they cared for. Staff shortages, busy acute settings and hospital culture affected app implementation.

DIAMOND

The DIAMOND trial tested an unnamed computer-based decision aid aiming to reduce decisional conflict and help pregnant women who previously had a caesarean section to decide on mode of delivery. The software program acted as an expert system and aimed to aid external information acquisition, standardise care, provide information on risks and benefits and improve patient empowerment and education. The tool was used as part of ANC in secondary care settings in a high income country.

Four studies evaluated the decision aid, and two of the four studies were assessed as having low risk of bias. The individual RCT (DIAMOND) was conducted in four maternity units in the UK from May 2004 to August 2006 (Montgomery, 2007) and tested a CDSS, an information only program and usual care. The increased rate of vaginal birth was not statistically significant for women in the CDSS group compared to usual care (37% v 30%, aOR 1.42, [95CI 0.94, 2.14]), and decision analysis groups had reduced mean decisional conflict scores on a 25-point scale compared with women in the usual care group (-4.0 [95%CI -6.5, -1.5]). The embedded cost-consequence economic evaluation (Hollinghurst 2010) estimated mean total cost per mother and baby with CDSS to be similar to usual care (-4.52 [95%CI -172, 107]).

Prior to the trial the tool was piloted and women's views of the acceptability and usability of the programs investigated through semi-structured 1-1 interviews (Emmett). Overall, women found the CDSS useful, with the main contrast in women's views concerning the two decision aids related to the difficulty some users of the decision analysis program experienced correctly completing the ratings task. Healthcare practitioner views on decision aid implementation (Rees) were tested at the end of DIAMOND trial. Overall, women found the program content and the CDSS informative and useful. The main contrast in views concerning the two decision aids related to the difficulty some users of the decision analysis program experienced correctly completing the ratings task.

Bliss4Midwives

Bliss4Midwives (B4M) consists of a non-invasive monitoring device with integrated decision support. Decision support focussed on risk assessment of pre-eclampsia, gestational diabetes and anaemia and identifying women who required referral.

Three studies evaluated B4M, of which one (Abejerinde 2018b) was assessed to have low risk of bias. Abejerinde 2019 observed 7 health facilities implementing the device and found that of 708 women who may have required non-urgent referral for investigation, 335 (40%) were investigated and managed onsite using B4M, and 107 women were urgently referred for further management of 835 women who presented to care. A mixed methods realist review surveyed users and found no evidence of difference in usability ratings between the low-uptake and moderate-uptake clusters, and a linked qualitative study found time required to offer care increased, but women treated using B4M felt more listened to and expressed greater trust in

managements plans made using the device. Health workers felt B4M may have increased demand for services at the facilities using the device.

iDeliver

iDeliver is an integrated health record with clinical decision support and educational functionality, deployed in a Kenyan hospital in 2018. CDSS components brought together and described a range of intrapartum guidelines to improve guideline adherence and clinical effectiveness through Expert System, Relevant Information display, and Order Facilitator mechanisms.

Two studies evaluated iDeliver, of which Dinh et al may have been at low risk of bias. Dinh et al extracted usage data from the system, finding that 45% of babies who delivered at the hospital were recorded in iDeliver. Data entry for most variables improved over time (from X to Y%). CDSS components were not specifically evaluated. Bartlett et al conducted a qualitative evaluation alongside describing a detailed design process. Participants reported that the tool was easy to learn and use, and specific features were highlighted as helpful by different participants, but the additional burden of documentation and tech interaction was challenging in the low-resource environment and high workloads meant care recommendations from the tool were not completed in the available time.

Asman

ASMAN (Alliance for Saving Mothers and Newborns) is a provider-facing mobile device app for peripartum care including a Safe Childbirth Checklist and the embedded Safe Delivery App. The CDSS acted as a workflow support system and aimed to trigger referral and improve guideline adherence. ASMAN was evaluated throughout pregnancy, in all levels of care, in a lower middle income country.

Of 2 papers evaluating ASMAN, 1 paper had a low risk of bias (Usmanova 2021). They found that data entry completeness varied substantially at different stages of pregnancy care, being lowest during at the PNC period (40.5%), followed by admission (80.2%), discharge (82.9%), post-delivery (93.1%) and delivery (93.7%). A semi-structured interview study of 44 providers found that ASMAN improved provider's ability to take a complete history and physical exam, identify high-risk patients, manage cases confidently, facilitate provider communication, improve reporting processes, and ensure continuity of care for referral patients. Respondents also perceived improvements in peripartum outcomes and related metrics at their facilities after the introduction of ASMAN, including decreases in obstetric complications and stillbirth rates, and increases in timely referrals.

Infant

INFANT is a decision support system for identifying foetal distress on cardiotocography monitoring. It is integrated into a maternity electronic health record used in several high-income countries, acting as both expert system and high-risk state monitoring to improve safety and clinical outcomes.

Three studies evaluated outcomes of INFANT, of which Wilson et al may have been at low risk of bias. Brocklehurst et al conducted an individually RCT from 2010-2013 in UK and Ireland maternity units and found no effect on a composite neonatal outcome including stillbirth and deaths (Risk ratio 1.01 [95%CI 0.82, 1.25]), or on developmental outcomes (PARCA-R score mean difference 0.63 [95%CI -0.98, 2.25]). Schroeder et al.'s economic evaluation of the same trial found no differences in costs between interventions and controls for mothers during

admissions (22.03 [95%CI –4.79 to 48.85]) or after discharge, (–178.27 [95%CI –364.28, 7.74]). In contrast, a before-and-after Australian tertiary centre interventional study by Wilson et al. found a reduced odds ratio of a similar composite neonatal outcome of 0.57 (95%CI 0.37, 0.88).

eRegQual

eRegQual is an integrated electronic health record with clinical decision support implemented across Palestinian antenatal clinics. Bringing together a range of clinical guidelines as an expert system, it provided diagnostic support and treatment functions to users.

A cluster RCT evaluating eRegQual, with some risk of bias due to lack of blinding in the trial, evaluated guideline adherence for management of anaemia (adjusted Odds Ratio of 1.88 [95%CI 1.52,2.32]), diabetes (aOR 1.45 [95%CI 1.14,2.05]), hypertension (aOR 1.62 [95%CI 1.29, 2.05]), and abnormal foetal growth (aOR 0.59 [95%CI 0.37,0.96]). Clinics with higher patient volumes, attached laboratories and older populations appeared to have better performance.

Chapter 4 - Automated Analytics for Epidemiological Research

4.1 S1. Ectopic Pregnancy Incident Phenome. SNOMED-CT codes used to identify ectopic pregnancy events.

S1. Ectopic Pregnancy Incident Phenome. SNOMED-CT codes used to identify ectopic pregnancy events.		
Read Code	SNOMED-CT CODE	DESCRIPTION
L032.00	9899009	Ovarian pregnancy
L03y000	79290002	Cervical pregnancy
L031.00	79586000	Tubal pregnancy
L03y100	87605005	Cornual pregnancy
7E13100	176928008	Excision of ectopic ovarian pregnancy
L031200	609525000	Tubal abortion
L03y600	198626009	Mesenteric pregnancy
7E19000	271415006	Removal of products of conception from fallopian tube
584E.00	370382007	Antenatal ultrasound confirms ectopic pregnancy
7E19011	387615001	Removal of ectopic pregnancy from fallopian tube
7E19012	387616000	Fimbrial extraction of tubal pregnancy
7E13398	176929000	Ruptured tubal preg.removal op
7E13399	176929000	Tubal preg. removal op.
L03y.00	34801009	Other ectopic pregnancy
L03yz00	34801009	Other ectopic pregnancy NOS
L03z.00	34801009	Ectopic pregnancy NOS
Lyu0000	34801009	[X]Other ectopic pregnancy
L031100	198620003	Gravid fallopian tube rupture
	609525000	Miscarriage of tubal ectopic pregnancy
	31601007	Simultaneous intrauterine AND extrauterine pregnancies
	31601007	Heterotopic pregnancy
	198620003	Ruptured tubal pregnancy
	79586000	Fallopian pregnancy
	34801009	EP - Ectopic pregnancy
L511.00	173300003	Maternal care for viable fetus in abdominal pregnancy
L03y800	69532007	Mesometric pregnancy
L030000	198617006	Delivery of viable fetus in abdominal pregnancy
7E13300	176929000	Excision of ruptured ectopic tubal pregnancy
L031z00	79586000	Tubal pregnancy NOS
L03y300	31601007	Combined or heterotopic pregnancy
	31601007	Combined heterotopic pregnancy
7E13199	176928008	Ovarian preg. removal op.
L031000	79586000	Fallopian tube pregnancy
L03y200	198624007	Membranous pregnancy
L03..00	34801009	Ectopic pregnancy
	198617006	Delivery of viable foetus in abdominal pregnancy
L03y500	35656003	Intraligamentous pregnancy
L030.00	82661006	Abdominal pregnancy
	237253003	Viable fetus in abdominal pregnancy
	17433009	Ruptured ectopic pregnancy
	237254009	Unruptured tubal pregnancy
	440537001	Number of ectopic pregnancies
	237253003	Viable foetus in abdominal pregnancy
	63596003	Laparoscopic treatment of ectopic pregnancy with salpingectomy

	387617009	Aspiration of ectopic pregnancy from fallopian tube
	81130000	Removal of intraligamentous ectopic pregnancy
	276881003	Secondary abdominal pregnancy

4.2 S2. Ectopic Pregnancy Prevalent Phenome. SNOMED-CT codes used to identify ectopic pregnancy history.

pregnancy history.		
Read Code	SNOMET-CT Code	Description
L032.00	9899009	Ovarian pregnancy
L03y000	79290002	Cervical pregnancy
L031.00	79586000	Tubal pregnancy
L03y100	87605005	Cornual pregnancy
7E13100	176928008	Excision of ectopic ovarian pregnancy
L031200	609525000	Tubal abortion
L03y600	198626009	Mesenteric pregnancy
7E19000	271415006	Removal of products of conception from fallopian tube
584E.00	370382007	Antenatal ultrasound confirms ectopic pregnancy
7E19011	387615001	Removal of ectopic pregnancy from fallopian tube
7E19012	387616000	Fimbrial extraction of tubal pregnancy
7E13398	176929000	Ruptured tubal preg. removal op
7E13399	176929000	Tubal preg. removal op.
L03y.00	34801009	Other ectopic pregnancy
L03yz00	34801009	Other ectopic pregnancy NOS
L03z.00	34801009	Ectopic pregnancy NOS
Lyu0000	34801009	[X]Other ectopic pregnancy
L031100	198620003	Gravid fallopian tube rupture
	609525000	Miscarriage of tubal ectopic pregnancy
	31601007	Simultaneous intrauterine AND extrauterine pregnancies
	31601007	Heterotopic pregnancy
	198620003	Ruptured tubal pregnancy
	79586000	Fallopian pregnancy
	161763005	History of ectopic pregnancy
	34801009	EP - Ectopic pregnancy
L511.00	173300003	Maternal care for viable fetus in abdominal pregnancy
L03y800	69532007	Mesometric pregnancy
L030000	198617006	Delivery of viable fetus in abdominal pregnancy
7E13300	176929000	Excision of ruptured ectopic tubal pregnancy
1544	161763005	H/O: ectopic pregnancy
L031z00	79586000	Tubal pregnancy NOS
L03y300	31601007	Combined or heterotopic pregnancy
	31601007	Combined heterotopic pregnancy
7E13199	176928008	Ovarian preg. removal op.
L031000	79586000	Fallopian tube pregnancy
L03y200	198624007	Membranous pregnancy
L03..00	34801009	Ectopic pregnancy
	198617006	Delivery of viable foetus in abdominal pregnancy
L03y500	35656003	Intraligamentous pregnancy
L030.00	82661006	Abdominal pregnancy
	237253003	Viable fetus in abdominal pregnancy
	17433009	Ruptured ectopic pregnancy
	237254009	Unruptured tubal pregnancy
	440537001	Number of ectopic pregnancies
	237253003	Viable foetus in abdominal pregnancy

	63596003	Laparoscopic treatment of ectopic pregnancy with salpingectomy
	387617009	Aspiration of ectopic pregnancy from fallopian tube
	81130000	Removal of intraligamentous ectopic pregnancy
	276881003	Secondary abdominal pregnancy

4.3 S3. Baseline Characteristics. This table summarises characteristics of eligible women on entry to the ectopic pregnancy cohort extracted from CPRD Aurum database.

	Overall
	(n = 10248694)
Age at Baseline, mean (SD)	31.58 (13.26)
Length of Follow Up, median [IQR]	4.29 [1.60, 9.37]
Age Category, %	
0-16	1384418 (13.5)
17-30	3813892 (37.2)
31-40	2313599 (22.6)
41-50	1498164 (14.6)
51-60	1142315 (11.1)
61-70	96306 (0.9)
Health Authority, %	
East Midlands	293107 (2.9)
East of England	396571 (3.9)
London	2556598 (24.9)
Missing	6473 (0.1)
North East	279182 (2.7)
North West	1668647 (16.3)
Northern Ireland	33907 (0.3)
South East	2030076 (19.8)
South West	1172603 (11.4)
West Midlands	1444817 (14.1)
Yorkshire & The Humber	366713 (3.6)
Ethnicity, %	
Asian	924311 (9.0)
Black	473739 (4.6)
Missing	2387184 (23.3)
Mixed	189687 (1.9)
Other	167919 (1.6)
White	6105854 (59.6)

4.4 S4. Incidence of ectopic pregnancy overall and by subgroup.

Time series of incidence of ectopic pregnancy in CPRD Aurum from 2006-2021, overall and by subgroups of Index of Multiple Deprivation, region, ethnicity and age category.

S4. Incidence of ectopic pregnancy overall and by subgroup. Time series of incidence of ectopic pregnancy in CPRD Aurum from 2006-2021, overall and by subgroups of Index of Multiple Deprivation, region, ethnicity and age category.

Category	Year	Subgroup Value	Incidence	Person Years	Count	Lower	Upper
Overall	#####	OVERALL	37.97087649	3486882.9	1324	35.9529	40.0727
Overall	#####	OVERALL	38.06618445	3541200.7	1348	36.061	40.1539
Overall	#####	OVERALL	37.43867222	3600555	1348	35.4665	39.492
Overall	#####	OVERALL	38.20050588	3649166.3	1394	36.2212	40.2598
Overall	#####	OVERALL	39.33017364	3686736.8	1450	37.3316	41.4079
Overall	#####	OVERALL	39.93554719	3715987.6	1484	37.9293	42.0204
Overall	#####	OVERALL	40.12020295	3748734.8	1504	38.118	42.2003
Overall	#####	OVERALL	42.14941625	3722471.5	1569	40.0894	44.2879
Overall	#####	OVERALL	43.53287721	3700651.3	1611	41.4328	45.7118
Overall	#####	OVERALL	41.92508617	3763856.3	1578	39.8818	44.0459
Overall	#####	OVERALL	41.47661386	3857595.5	1600	39.4689	43.5599
Overall	#####	OVERALL	42.23600773	3961075.1	1673	40.2361	44.3095
Overall	#####	OVERALL	44.49018753	4054826.7	1804	42.4606	46.5917
Overall	#####	OVERALL	44.3893051	4068547.6	1806	42.3654	46.4849
Overall	#####	OVERALL	43.4328436	4068349.8	1767	41.4311	45.5063
Overall	#####	OVERALL	44.06986038	4027696	1775	42.0433	46.1689
IMD Score	#####	1	35.54267449	334808.79	119	29.4437	42.5324
IMD Score	#####	1	35.13246553	338718.04	119	29.1038	42.0416
IMD Score	#####	1	34.67085881	346111.99	120	28.7451	41.4582
IMD Score	#####	1	33.68260101	353298.13	119	27.9028	40.3066
IMD Score	#####	1	37.24433389	357101.3	133	31.1835	44.139
IMD Score	#####	1	40.97526679	358753	147	34.6188	48.1606
IMD Score	#####	1	28.41266193	358994.87	102	23.1666	34.4913
IMD Score	#####	1	33.70120901	359037.56	121	27.9639	40.2689
IMD Score	#####	1	38.46605116	358757.91	138	32.3158	45.4459
IMD Score	#####	1	34.99434113	365773.42	128	29.1945	41.6087
IMD Score	#####	1	34.93264155	375007.43	131	29.2067	41.4528
IMD Score	#####	1	33.94274935	382997.85	130	28.3587	40.3045
IMD Score	#####	1	42.38081537	389327.1	165	36.1605	49.3638
IMD Score	#####	1	37.19667552	389819.78	145	31.3884	43.7679
IMD Score	#####	1	36.46220539	381216.66	139	30.6524	43.0526
IMD Score	#####	1	40.00532746	377449.73	151	33.8786	46.9196
IMD Score	#####	2	36.96146388	270552.05	100	30.0726	44.9555
IMD Score	#####	2	28.45896674	274078.82	78	22.4948	35.5185
IMD Score	#####	2	34.06010699	278918.68	95	27.556	41.6371
IMD Score	#####	2	33.88582803	283304.28	96	27.4469	41.3808
IMD Score	#####	2	36.71256013	286005.66	105	30.0266	44.4432
IMD Score	#####	2	37.43922821	288467.48	108	30.7115	45.2023
IMD Score	#####	2	38.69826009	289418.7	112	31.8634	46.5644
IMD Score	#####	2	36.23638313	284244.7	103	29.5767	43.9476
IMD Score	#####	2	32.06787855	280654.67	90	25.7856	39.4173
IMD Score	#####	2	32.31392584	284706.97	92	26.0489	39.6306

IMD Score	#####	2	36.67255648	291771.31	107	30.0534	44.3154
IMD Score	#####	2	33.53603924	298186.67	100	27.2856	40.7892
IMD Score	#####	2	39.85182531	306134.03	122	33.094	47.5835
IMD Score	#####	2	39.40716491	307050.76	121	32.6985	47.0869
IMD Score	#####	2	32.76920306	311267.87	102	26.7188	39.7799
IMD Score	#####	2	48.64617297	312460.35	152	41.2197	57.0239
IMD Score	#####	3	33.7311683	320178.65	108	27.6698	40.7253
IMD Score	#####	3	30.2264043	324219.84	98	24.5387	36.8367
IMD Score	#####	3	33.88548633	330524.99	112	27.9007	40.7734
IMD Score	#####	3	32.29303337	337534.1	109	26.5154	38.9553
IMD Score	#####	3	29.11068559	340081.31	99	23.6592	35.4416
IMD Score	#####	3	34.15013477	342604.8	117	28.2426	40.9284
IMD Score	#####	3	34.79551972	344871.99	120	28.8485	41.6072
IMD Score	#####	3	32.19345972	344790.53	111	26.4832	38.7696
IMD Score	#####	3	33.44424633	343855.86	115	27.6112	40.1451
IMD Score	#####	3	37.47441753	349571.81	131	31.3318	44.469
IMD Score	#####	3	38.20375398	355985.96	136	32.0526	45.1911
IMD Score	#####	3	36.51913685	364192.62	133	30.5763	43.2796
IMD Score	#####	3	42.37471394	372863.87	158	36.0246	49.5216
IMD Score	#####	3	41.76122745	378341.37	158	35.503	48.8047
IMD Score	#####	3	39.81917768	374191.55	149	33.6819	46.751
IMD Score	#####	3	33.92565356	362557.5	123	28.1951	40.4784
IMD Score	#####	4	34.30130949	358586.89	123	28.5073	40.9266
IMD Score	#####	4	30.55135594	363322.66	111	25.1324	36.792
IMD Score	#####	4	29.24174487	369335.01	108	23.9871	35.305
IMD Score	#####	4	35.93764218	375650.69	135	30.1309	42.5368
IMD Score	#####	4	32.34293426	380299.45	123	26.8797	38.59
IMD Score	#####	4	34.66925357	383625.22	133	29.0274	41.0873
IMD Score	#####	4	36.75066089	386387.61	142	30.9544	43.3169
IMD Score	#####	4	41.15063687	381525.08	157	34.9651	48.1149
IMD Score	#####	4	38.86349227	378247.02	147	32.8346	45.6785
IMD Score	#####	4	41.49314314	383195.84	159	35.2939	48.4676
IMD Score	#####	4	41.02568241	389999.61	160	34.9147	47.8983
IMD Score	#####	4	46.22548125	398048.86	184	39.787	53.4089
IMD Score	#####	4	40.0530654	404463.42	162	34.1224	46.718
IMD Score	#####	4	43.31318135	401725.28	174	37.1161	50.2489
IMD Score	#####	4	41.29951088	397099.13	164	35.2202	48.1267
IMD Score	#####	4	39.62562076	396208.3	157	33.6693	46.3318
IMD Score	#####	5	31.34884427	325370.85	102	25.5607	38.0557
IMD Score	#####	5	36.37560725	329891.4	120	30.1585	43.4966
IMD Score	#####	5	42.72637394	337028.37	144	36.0325	50.3027
IMD Score	#####	5	39.82079345	344041.36	137	33.4317	47.075
IMD Score	#####	5	39.92970137	348111.79	139	33.5674	47.1469
IMD Score	#####	5	42.60500866	349724.14	149	36.0384	50.0218
IMD Score	#####	5	41.75625733	354437.9	148	35.2996	49.0518
IMD Score	#####	5	45.88350116	350888.65	161	39.0693	53.5442
IMD Score	#####	5	43.37158039	345848.59	150	36.7082	50.8946
IMD Score	#####	5	52.06380673	351491.78	183	44.7932	60.1782

IMD Score	#####	5	45.52743055	360222.39	164	38.8257	53.0535
IMD Score	#####	5	43.68663319	370822.81	162	37.2179	50.9562
IMD Score	#####	5	41.51242961	380608.9	158	35.2915	48.5139
IMD Score	#####	5	43.8278136	381036.58	167	37.4322	51.0026
IMD Score	#####	5	39.85742379	386377.2	154	33.8106	46.6734
IMD Score	#####	5	43.73484765	381846.53	167	37.3528	50.8944
IMD Score	#####	6	35.09397991	356186.45	125	29.2115	41.8132
IMD Score	#####	6	42.58401242	361638.07	154	36.1236	49.8662
IMD Score	#####	6	33.18804656	367602.23	122	27.5602	39.6269
IMD Score	#####	6	38.47643661	371656.04	143	32.4283	45.325
IMD Score	#####	6	39.99098154	375084.57	150	33.8469	46.9276
IMD Score	#####	6	40.96466808	378374.85	155	34.7691	47.9455
IMD Score	#####	6	38.94029195	382637.09	149	32.9385	45.7191
IMD Score	#####	6	44.07659571	383423.44	169	37.6813	51.246
IMD Score	#####	6	45.05306983	383991.59	173	38.5892	52.2898
IMD Score	#####	6	37.33003617	391105.97	146	31.5201	43.9003
IMD Score	#####	6	37.64010526	398511.11	150	31.8572	44.1689
IMD Score	#####	6	39.26153464	407523.55	160	33.4133	45.8387
IMD Score	#####	6	42.64188711	415084.82	177	36.5908	49.4077
IMD Score	#####	6	43.85576107	412716.59	181	37.6989	50.7313
IMD Score	#####	6	51.03080154	415435.37	212	44.392	58.3823
IMD Score	#####	6	45.44854243	415854.92	189	39.1995	52.4105
IMD Score	#####	7	39.13939118	406240.35	159	33.2918	45.7182
IMD Score	#####	7	37.40626944	414369.04	155	31.7489	43.7808
IMD Score	#####	7	38.15154737	419380.11	160	32.4687	44.5427
IMD Score	#####	7	39.21118132	420798.34	165	33.4561	45.6719
IMD Score	#####	7	43.17435423	428495.12	185	37.1766	49.8642
IMD Score	#####	7	37.68969119	435132.25	164	32.1417	43.9201
IMD Score	#####	7	41.2972561	440707.25	182	35.5149	47.7525
IMD Score	#####	7	41.89691301	443946.79	186	36.0917	48.37
IMD Score	#####	7	49.81732731	443620.75	221	43.4651	56.8366
IMD Score	#####	7	46.34171246	448839.69	208	40.2572	53.0859
IMD Score	#####	7	42.95831371	465567.62	200	37.2104	49.3425
IMD Score	#####	7	44.13159258	484913.39	214	38.4163	50.4574
IMD Score	#####	7	44.55865299	500463.96	223	38.9016	50.8069
IMD Score	#####	7	47.89168644	503218.86	241	42.0354	54.3355
IMD Score	#####	7	47.33245717	507051.64	240	41.5329	53.7151
IMD Score	#####	7	47.58500843	498056.02	237	41.7189	54.0448
IMD Score	#####	8	45.06004925	312915.77	141	37.9292	53.1418
IMD Score	#####	8	45.2939636	320130.96	145	38.2213	53.2956
IMD Score	#####	8	41.04425887	326476.84	134	34.3889	48.6116
IMD Score	#####	8	44.12258956	330896.26	146	37.2555	51.8884
IMD Score	#####	8	44.38049895	335733.04	149	37.5402	52.1063
IMD Score	#####	8	40.37409381	339326.5	137	33.8963	47.7291
IMD Score	#####	8	47.3846223	343993.46	163	40.389	55.2435
IMD Score	#####	8	43.05818293	336753.64	145	36.3347	50.6649
IMD Score	#####	8	51.22383694	331876.74	170	43.8126	59.5295
IMD Score	#####	8	45.16260759	338775.83	153	38.2895	52.913

IMD Score	#####	8	46.3124714	349797.79	162	39.4549	54.019
IMD Score	#####	8	47.43286719	362617.76	172	40.6085	55.0756
IMD Score	#####	8	52.89812869	374304.36	198	45.7859	60.8019
IMD Score	#####	8	51.01792719	372418.11	190	44.0209	58.8109
IMD Score	#####	8	48.14691718	369701.76	178	41.3331	55.7632
IMD Score	#####	8	42.48746616	362459.84	154	36.0417	49.7532
IMD Score	#####	9	40.40796751	351415.84	142	34.0349	47.6276
IMD Score	#####	9	49.03547772	356884.46	175	42.039	56.8634
IMD Score	#####	9	37.92071627	361280.1	137	31.8365	44.8288
IMD Score	#####	9	41.69256389	364573.41	152	35.3276	48.8728
IMD Score	#####	9	42.90508891	368254.68	158	36.4755	50.1415
IMD Score	#####	9	44.01442347	370333.15	163	37.5164	51.3144
IMD Score	#####	9	43.30235035	374113.64	162	36.8905	50.508
IMD Score	#####	9	46.24039421	376294.37	174	39.6245	53.6449
IMD Score	#####	9	47.60520288	378109.93	180	40.9041	55.0907
IMD Score	#####	9	47.56149907	386867.54	184	40.937	54.9525
IMD Score	#####	9	45.15720506	398607.49	180	38.8007	52.2578
IMD Score	#####	9	44.48114399	411410.28	183	38.2694	51.4137
IMD Score	#####	9	48.37621462	423761.97	205	41.98	55.4714
IMD Score	#####	9	39.01044765	433217.28	169	33.3502	45.3558
IMD Score	#####	9	41.16712242	434813	179	35.3567	47.6597
IMD Score	#####	9	49.3996465	429152.87	212	42.973	56.5161
IMD Score	#####	10	45.6611996	429248.47	196	39.4919	52.5208
IMD Score	#####	10	41.73204562	436115.69	182	35.8888	48.2553
IMD Score	#####	10	47.1188213	441437.19	208	40.9323	53.9761
IMD Score	#####	10	41.62815767	444410.73	185	35.8452	48.0784
IMD Score	#####	10	45.69998963	444201.41	203	39.629	52.4378
IMD Score	#####	10	44.61864496	446001.89	199	38.6341	51.2674
IMD Score	#####	10	48.30708107	449209.51	217	42.0929	55.1802
IMD Score	#####	10	51.91189722	437279.34	227	45.3777	59.1226
IMD Score	#####	10	51.03777238	431053.3	220	44.5157	58.2464
IMD Score	#####	10	42.41086071	438566.91	186	36.5344	48.9634
IMD Score	#####	10	45.21323165	446771.87	202	39.1926	51.8969
IMD Score	#####	10	48.39267438	454614.26	220	42.2086	55.2277
IMD Score	#####	10	49.1745387	461621.01	227	42.9849	56.0051
IMD Score	#####	10	53.20722756	462343.2	246	46.7652	60.2886
IMD Score	#####	10	52.19007828	463689.67	242	45.8209	59.1968
IMD Score	#####	10	46.83022521	463375.95	217	40.806	53.4932
Health Authority	#####	East Midlands	43.8329039	82130.082	36	30.6958	60.685
Health Authority	#####	East Midlands	42.1727465	82991.986	35	29.3706	58.6539
Health Authority	#####	East Midlands	27.0471092	85036.814	23	17.1401	40.5857
Health Authority	#####	East Midlands	38.1096524	86592.236	33	26.2287	53.5218
Health Authority	#####	East Midlands	31.66628421	88422.121	28	21.0374	45.7683

Health Authority	#####	East Midlands	27.97764548	89357.055	25	18.1007	41.3022
Health Authority	#####	East Midlands	27.71524011	90203.079	25	17.9309	40.9148
Health Authority	#####	East Midlands	26.76725042	89661.805	24	17.1452	39.8292
Health Authority	#####	East Midlands	40.36864003	89178.134	36	28.2698	55.8889
Health Authority	#####	East Midlands	27.60557529	90561.416	25	17.86	40.753
Health Authority	#####	East Midlands	24.70134278	93112.347	23	15.6535	37.0658
Health Authority	#####	East Midlands	26.07890428	95862.923	25	16.8723	38.4992
Health Authority	#####	East Midlands	30.03999929	99866.847	30	20.2639	42.8855
Health Authority	#####	East Midlands	31.13448932	93144.293	29	20.8469	44.7159
Health Authority	#####	East Midlands	18.42230916	86851.219	16	10.5232	29.9183
Health Authority	#####	East Midlands	28.64720257	83777.814	24	18.3494	42.6266
Health Authority	#####	East of England	37.67927797	148622.81	56	28.4607	48.9306
Health Authority	#####	East of England	40.98553569	151272.88	62	31.4217	52.5425
Health Authority	#####	East of England	39.49673454	154443.15	61	30.2102	50.7361
Health Authority	#####	East of England	45.00051017	157775.99	71	35.1443	56.7628
Health Authority	#####	East of England	40.05546859	159778.43	64	30.8461	51.1508
Health Authority	#####	East of England	37.86208156	161111.06	61	28.9599	48.6363
Health Authority	#####	East of England	37.50058642	162664.12	61	28.6834	48.1719
Health Authority	#####	East of England	38.50963702	163595.41	63	29.5903	49.2714
Health Authority	#####	East of England	45.76198239	163891.5	75	35.9933	57.3638
Health Authority	#####	East of England	40.275809	166352.96	67	31.2118	51.1496
Health Authority	#####	East of England	49.4343685	169922.27	84	39.4296	61.2038
Health Authority	#####	East of England	38.02816888	173555.56	66	29.4096	48.3819
Health Authority	#####	East of England	34.94977248	174536.19	61	26.7324	44.8952

Health Authority	#####	East of England	40.59076298	169989.41	69	31.5807	51.371
Health Authority	#####	East of England	45.41043089	158553.88	72	35.5294	57.1877
Health Authority	#####	East of England	40.8572743	159090.4	65	31.5312	52.0768
Health Authority	#####	London	48.76426271	639812.81	312	43.5027	54.4868
Health Authority	#####	London	49.00709714	655007.17	321	43.7919	54.6724
Health Authority	#####	London	49.34657195	672792.43	332	44.1805	54.9507
Health Authority	#####	London	52.68595777	690886.18	364	47.4118	58.3864
Health Authority	#####	London	56.22446851	709655.44	399	50.8422	62.0214
Health Authority	#####	London	53.24275365	723103.1	385	48.0564	58.8362
Health Authority	#####	London	56.86751411	742075.69	422	51.5704	62.561
Health Authority	#####	London	54.58793145	745586.05	407	49.4127	60.1578
Health Authority	#####	London	59.20149142	741535.37	439	53.7923	65.0073
Health Authority	#####	London	58.06668037	762916.01	443	52.7846	63.7342
Health Authority	#####	London	54.87639065	799979.73	439	49.8623	60.258
Health Authority	#####	London	54.08548569	841260.82	455	49.2293	59.2911
Health Authority	#####	London	54.72270411	875322.24	479	49.9311	59.85
Health Authority	#####	London	52.89153142	894283.05	473	48.2317	57.88
Health Authority	#####	London	53.98241654	916965.25	495	49.3309	58.9543
Health Authority	#####	London	51.32745576	915689.26	470	46.7913	56.1846
Health Authority	#####	North East	34.58610431	112762.05	39	24.5911	47.2816
Health Authority	#####	North East	42.82254312	114425.71	49	31.6778	56.6149
Health Authority	#####	North East	30.06889792	116399.34	35	20.941	41.8198
Health Authority	#####	North East	41.97688543	119113.17	50	31.1536	55.3425
Health Authority	#####	North East	40.37439901	121364.04	49	29.8668	53.3782

Health Authority	#####	North East	33.53815851	122248.81	41	24.0649	45.4995
Health Authority	#####	North East	35.77513117	122990.46	44	25.9917	48.0276
Health Authority	#####	North East	38.87024175	123487.78	48	28.6575	51.5374
Health Authority	#####	North East	29.96251856	123487.62	37	21.0936	41.3006
Health Authority	#####	North East	24.96361578	124180.73	31	16.9585	35.4351
Health Authority	#####	North East	20.71988131	125483.34	26	13.5315	30.3606
Health Authority	#####	North East	27.55388197	127023.84	35	19.1895	38.3219
Health Authority	#####	North East	26.38457972	128863.15	34	18.2693	36.871
Health Authority	#####	North East	26.8481582	126638.11	34	18.5903	37.5188
Health Authority	#####	North East	30.27028702	125535.64	38	21.4184	41.5495
Health Authority	#####	North East	33.84767746	124085.32	42	24.3919	45.7534
Health Authority	#####	North West	34.35952917	666481.78	229	30.0529	39.11
Health Authority	#####	North West	34.83906988	674530.06	235	30.5266	39.5899
Health Authority	#####	North West	33.99329481	682487.54	232	29.7593	38.6606
Health Authority	#####	North West	32.04940695	686440.16	220	27.9538	36.5761
Health Authority	#####	North West	32.29156872	687485.96	222	28.183	36.8305
Health Authority	#####	North West	34.25865712	688876.97	236	30.0267	38.9198
Health Authority	#####	North West	35.32496277	687898.81	243	31.0226	40.0571
Health Authority	#####	North West	42.16607282	678270.42	286	37.4202	47.3471
Health Authority	#####	North West	39.38157864	672903.45	265	34.7822	44.4199
Health Authority	#####	North West	40.33265903	681829.58	275	35.706	45.3924
Health Authority	#####	North West	44.08263554	694150.87	306	39.2811	49.3091
Health Authority	#####	North West	40.94974359	708185.14	290	36.3717	45.9445
Health Authority	#####	North West	47.60219861	720554.95	343	42.6971	52.9162

Health Authority	#####	North West	47.77469751	728419.05	348	42.8864	53.0675
Health Authority	#####	North West	41.89062193	735248.1	308	37.3423	46.8401
Health Authority	#####	North West	50.68645534	728005.14	369	45.646	56.1314
Health Authority	#####	Northern Ireland	38.10917914	15744.238	6	13.9854	82.9476
Health Authority	#####	Northern Ireland	49.61285829	16124.852	8	21.4193	97.7571
Health Authority	#####	Northern Ireland	36.0996706	16620.65	6	13.2479	78.5738
Health Authority	#####	Northern Ireland	35.20779755	17041.679	6	12.9206	76.6326
Health Authority	#####	Northern Ireland	34.53694317	17372.701	6	12.6744	75.1724
Health Authority	#####	Northern Ireland	56.80091342	17605.351	10	27.1932	104.465
Health Authority	#####	Northern Ireland	33.58784744	17863.604	6	12.3261	73.1066
Health Authority	#####	Northern Ireland	55.03454511	18170.405	10	26.3475	101.217
Health Authority	#####	Northern Ireland	21.56201435	18551.142	4	5.87492	55.2073
Health Authority	#####	Northern Ireland	31.79773966	18869.266	6	11.6692	69.2103
Health Authority	#####	Northern Ireland	36.34386918	19260.47	7	14.6121	74.8823
Health Authority	#####	Northern Ireland	60.8710734	19713.797	12	31.4171	106.336
Health Authority	#####	Northern Ireland	34.78815917	20121.789	7	13.9866	71.6769
Health Authority	#####	Northern Ireland	48.77435394	20502.578	10	23.3505	89.7032
Health Authority	#####	Northern Ireland	23.59196574	21193.656	5	7.66025	55.0558
Health Authority	#####	Northern Ireland	45.9189906	21777.482	10	21.9835	84.4517
Health Authority	#####	South East	36.15704054	705256.84	255	31.8548	40.8782
Health Authority	#####	South East	36.24191685	717401.35	260	31.97	40.9257
Health Authority	#####	South East	32.67735299	731393.39	239	28.6654	37.0936
Health Authority	#####	South East	32.85973124	745593.44	245	28.8734	37.2425
Health Authority	#####	South East	35.77705922	751878.45	269	31.6289	40.318

Health Authority	#####	South East	43.16307942	757591.92	327	38.6109	48.1043
Health Authority	#####	South East	39.61166974	762401.59	302	35.2695	44.3408
Health Authority	#####	South East	38.65923323	760491.03	294	34.3659	43.3406
Health Authority	#####	South East	39.879602	759786.92	303	35.5151	44.6324
Health Authority	#####	South East	34.84337275	769156.31	268	30.7961	39.2746
Health Authority	#####	South East	40.80161813	781831.74	319	36.4464	45.534
Health Authority	#####	South East	38.588957	795564.39	307	34.3925	43.1562
Health Authority	#####	South East	42.51231643	811529.53	345	38.1441	47.2436
Health Authority	#####	South East	44.08663802	821110.47	362	39.6614	48.8705
Health Authority	#####	South East	41.65634579	821003.36	342	37.3579	46.3137
Health Authority	#####	South East	44.55358616	805771.28	359	40.0634	49.4093
Health Authority	#####	South West	32.12443069	429579.6	138	26.9881	37.9536
Health Authority	#####	South West	33.50453852	432777.19	145	28.2728	39.4235
Health Authority	#####	South West	35.12533161	438430.02	154	29.7964	41.132
Health Authority	#####	South West	34.33616876	442681.89	152	29.0943	40.2495
Health Authority	#####	South West	39.20713578	446347.32	175	33.6129	45.4661
Health Authority	#####	South West	36.06860457	449144.07	162	30.7279	42.0706
Health Authority	#####	South West	29.47599739	451214.59	133	24.6793	34.9326
Health Authority	#####	South West	39.56175289	437291.04	173	33.8857	45.9164
Health Authority	#####	South West	39.63230168	426419.85	169	33.8819	46.0788
Health Authority	#####	South West	43.57999949	429095.92	187	37.5571	50.2938
Health Authority	#####	South West	34.05602227	434578.06	148	28.7901	40.0062
Health Authority	#####	South West	42.51794362	444518.21	189	36.6718	49.0309
Health Authority	#####	South West	43.97632269	452516.24	199	38.078	50.5294

Health Authority	#####	South West	41.47669277	450855.62	187	35.7445	47.8665
Health Authority	#####	South West	40.83495303	450594.37	184	35.1473	47.1807
Health Authority	#####	South West	36.89448415	444510.89	164	31.4636	42.9934
Health Authority	#####	West Midlands	39.08536724	557753.49	218	34.0686	44.6328
Health Authority	#####	West Midlands	32.68421411	566022.48	185	28.1437	37.7486
Health Authority	#####	West Midlands	38.19107871	570813.94	218	33.2891	43.6116
Health Authority	#####	West Midlands	35.40442446	570550.16	202	30.6899	40.6381
Health Authority	#####	West Midlands	35.20559011	570932.06	201	30.5063	40.4237
Health Authority	#####	West Midlands	32.4656867	572912.57	186	27.9672	37.4817
Health Authority	#####	West Midlands	39.2171605	576278.34	226	34.2703	44.6774
Health Authority	#####	West Midlands	38.73013144	570615.16	221	33.7916	44.1872
Health Authority	#####	West Midlands	40.38794306	569476.88	230	35.3364	45.9589
Health Authority	#####	West Midlands	38.1031522	582628.96	222	33.2552	43.459
Health Authority	#####	West Midlands	34.80541713	597608.12	208	30.2356	39.8707
Health Authority	#####	West Midlands	34.92214392	609928.19	213	30.3893	39.9404
Health Authority	#####	West Midlands	42.251432	622464.11	263	37.2987	47.6787
Health Authority	#####	West Midlands	38.89507447	622186.75	242	34.1484	44.1169
Health Authority	#####	West Midlands	42.1567716	621489.72	262	37.206	47.5828
Health Authority	#####	West Midlands	35.99596309	625070.09	225	31.4457	41.0196
Health Authority	#####	Yorkshire & The Humber	27.30109934	124537.11	34	18.9039	38.1517
Health Authority	#####	Yorkshire & The Humber	37.91195412	126609.14	48	27.951	50.2669
Health Authority	#####	Yorkshire & The Humber	37.11360278	129332.63	48	27.3624	49.2083
Health Authority	#####	Yorkshire & The Humber	38.04463342	131424.58	50	28.2353	50.1582
Health Authority	#####	Yorkshire & The Humber	27.91705239	132535.48	37	19.6536	38.4811

Health Authority	#####	Yorkshire & The Humber	38.29098027	133190.64	51	28.508	50.3466
Health Authority	#####	Yorkshire & The Humber	30.49420672	134451.77	41	21.8808	41.3699
Health Authority	#####	Yorkshire & The Humber	31.90730484	134765.38	43	23.0891	42.98
Health Authority	#####	Yorkshire & The Humber	39.26530504	134979.21	53	29.4104	51.361
Health Authority	#####	Yorkshire & The Humber	39.18655005	137802.38	54	29.4362	51.1309
Health Authority	#####	Yorkshire & The Humber	28.33095165	141188.34	40	20.2377	38.5797
Health Authority	#####	Yorkshire & The Humber	55.87226585	144973.54	81	44.3692	69.445
Health Authority	#####	Yorkshire & The Humber	28.9347387	148610.29	43	20.9381	38.9759
Health Authority	#####	Yorkshire & The Humber	36.7789022	141385.41	52	27.4663	48.2316
Health Authority	#####	Yorkshire & The Humber	33.65974057	130719.96	44	24.4548	45.1877
Health Authority	#####	Yorkshire & The Humber	37.64191604	119547.58	45	27.4537	50.369
Ethnicity	#####	ASIAN	41.55819652	151594.64	63	31.9328	53.1719
Ethnicity	#####	ASIAN	50.6283104	169865.44	86	40.4949	62.5263
Ethnicity	#####	ASIAN	46.17187934	192758.02	89	37.0788	56.8191
Ethnicity	#####	ASIAN	48.31077231	213202.97	103	39.4319	58.5914
Ethnicity	#####	ASIAN	48.9966058	232669.18	114	40.4154	58.8604
Ethnicity	#####	ASIAN	52.30512567	250453.47	131	43.7316	62.0678
Ethnicity	#####	ASIAN	55.02315949	268977.65	148	46.5151	64.6366
Ethnicity	#####	ASIAN	48.94128289	284013.81	139	41.1431	57.7873
Ethnicity	#####	ASIAN	57.92292513	291767.03	169	49.5186	67.3446
Ethnicity	#####	ASIAN	56.0291663	303413.4	170	47.9226	65.1139
Ethnicity	#####	ASIAN	45.32441817	319915.86	145	38.247	53.3315
Ethnicity	#####	ASIAN	52.87655629	338524.32	179	45.4135	61.2159
Ethnicity	#####	ASIAN	49.04258998	356832.7	175	42.0451	56.8716
Ethnicity	#####	ASIAN	44.21235819	368675.2	163	37.6851	51.5451
Ethnicity	#####	ASIAN	49.36963587	384851.94	190	42.5986	56.9109
Ethnicity	#####	ASIAN	42.15449385	393789.57	166	35.9853	49.0777
Ethnicity	#####	BLACK	107.9523131	94486.164	102	88.0202	131.048
Ethnicity	#####	BLACK	89.59990226	106026.9	95	72.4898	109.532
Ethnicity	#####	BLACK	85.30673918	118396.27	101	69.4822	103.656
Ethnicity	#####	BLACK	90.84348909	127692.15	116	75.0644	108.959
Ethnicity	#####	BLACK	88.16097644	134980.36	119	73.0328	105.499
Ethnicity	#####	BLACK	86.31168407	141348.19	122	71.6755	103.057
Ethnicity	#####	BLACK	89.58108888	148468.84	133	75.0033	106.164
Ethnicity	#####	BLACK	74.30703467	153417.51	114	61.293	89.2662
Ethnicity	#####	BLACK	80.44068693	156637.15	126	67.0082	95.7756
Ethnicity	#####	BLACK	73.96621949	162236.22	120	61.3243	88.4461

Ethnicity	#####	BLACK	67.11427532	169859.54	114	55.36	80.6254
Ethnicity	#####	BLACK	60.80083866	177629.13	108	49.8751	73.4079
Ethnicity	#####	BLACK	65.55306167	184583.29	121	54.3933	78.3281
Ethnicity	#####	BLACK	67.33333451	187128.71	126	56.0896	80.1695
Ethnicity	#####	BLACK	56.5927689	192604.11	109	46.4676	68.2683
Ethnicity	#####	BLACK	67.7196929	196397.82	133	56.6995	80.256
Ethnicity	#####	MISSING	35.97817969	1303567.9	469	32.7953	39.3866
Ethnicity	#####	MISSING	34.11980327	1213371.6	414	30.9118	37.5702
Ethnicity	#####	MISSING	31.43588327	1084747.6	341	28.1874	34.956
Ethnicity	#####	MISSING	26.10701606	980579.32	256	23.0065	29.5088
Ethnicity	#####	MISSING	27.12030159	907069.56	246	23.8367	30.7297
Ethnicity	#####	MISSING	25.5957864	847795.79	217	22.3032	29.2375
Ethnicity	#####	MISSING	26.69092936	801770.51	214	23.2343	30.5168
Ethnicity	#####	MISSING	30.76206547	715166.54	220	26.831	35.1069
Ethnicity	#####	MISSING	26.92374379	657412.29	177	23.1031	31.1956
Ethnicity	#####	MISSING	30.32806888	652860.56	198	26.2504	34.8595
Ethnicity	#####	MISSING	32.26171801	654025.93	211	28.0551	36.9211
Ethnicity	#####	MISSING	33.74351969	657904.1	222	29.4502	38.4866
Ethnicity	#####	MISSING	37.38096842	655413.73	245	32.8462	42.3668
Ethnicity	#####	MISSING	39.73013604	631762.25	251	34.9665	44.9616
Ethnicity	#####	MISSING	35.09898241	604006.11	212	30.5328	40.1553
Ethnicity	#####	MISSING	36.39108551	571568.55	208	31.6131	41.6872
Ethnicity	#####	MIXED	72.25801456	24910.732	18	42.8028	114.205
Ethnicity	#####	MIXED	76.10312571	28908.142	22	47.6769	115.226
Ethnicity	#####	MIXED	85.57297249	33889.205	29	57.2977	122.902
Ethnicity	#####	MIXED	68.31170957	38060.825	26	44.6122	100.096
Ethnicity	#####	MIXED	62.43251828	41644.964	26	40.7727	91.4817
Ethnicity	#####	MIXED	73.25864742	45045.877	33	50.4197	102.886
Ethnicity	#####	MIXED	86.78380146	48396.128	42	62.5395	117.309
Ethnicity	#####	MIXED	64.80844088	50919.293	33	44.6039	91.0181
Ethnicity	#####	MIXED	60.11284643	53233.214	32	41.11	84.8642
Ethnicity	#####	MIXED	31.80347486	56597.589	18	18.8391	50.2658
Ethnicity	#####	MIXED	80.67700668	60736.016	49	59.6805	106.662
Ethnicity	#####	MIXED	65.91592094	65234.619	43	47.6989	88.7905
Ethnicity	#####	MIXED	54.14411313	70183.068	38	38.3108	74.3191
Ethnicity	#####	MIXED	58.32698005	73722.315	43	42.2073	78.568
Ethnicity	#####	MIXED	62.69156119	78160.44	49	46.3759	82.8834
Ethnicity	#####	MIXED	67.6986835	81242.348	55	50.9966	88.1208
Ethnicity	#####	OTHER	47.27118198	16923.63	8	20.4083	93.1431
Ethnicity	#####	OTHER	56.26676529	19549.729	11	28.05	100.683
Ethnicity	#####	OTHER	85.09093978	23504.265	20	51.9541	131.422
Ethnicity	#####	OTHER	55.63620688	26960.86	15	31.1165	91.7687
Ethnicity	#####	OTHER	63.02161519	30148.386	19	37.9257	98.421
Ethnicity	#####	OTHER	42.543293	32907.655	14	23.2394	71.3846
Ethnicity	#####	OTHER	56.08767761	35658.456	20	34.2455	86.6271
Ethnicity	#####	OTHER	57.96550742	37953.605	22	36.3141	87.7645
Ethnicity	#####	OTHER	54.80801802	40140.112	22	34.336	82.9838
Ethnicity	#####	OTHER	42.00000844	42857.134	18	24.8792	66.3816

Ethnicity	#####	OTHER	47.26989915	46541.246	22	29.6135	71.5704
Ethnicity	#####	OTHER	50.44532752	51540.948	26	32.9442	73.917
Ethnicity	#####	OTHER	35.22915747	56771.156	20	21.5099	54.4112
Ethnicity	#####	OTHER	45.95689702	60926.655	28	30.5313	66.423
Ethnicity	#####	OTHER	68.17872197	66002.997	45	49.7254	91.2306
Ethnicity	#####	OTHER	45.8049652	69861.422	32	31.3252	64.6651
Ethnicity	#####	WHITE	35.03218622	1895399.8	664	32.4179	37.8012
Ethnicity	#####	WHITE	35.93748807	2003478.9	720	33.36	38.6612
Ethnicity	#####	WHITE	35.76651766	2147259.6	768	33.2813	38.3881
Ethnicity	#####	WHITE	38.80371044	2262670.2	878	36.2791	41.4577
Ethnicity	#####	WHITE	39.56885511	2340224.4	926	37.061	42.2018
Ethnicity	#####	WHITE	40.31792924	2398436.7	967	37.8165	42.9414
Ethnicity	#####	WHITE	38.72477002	2445463.2	947	36.2973	41.2719
Ethnicity	#####	WHITE	41.95887522	2481000.7	1041	39.4484	44.5872
Ethnicity	#####	WHITE	43.37464259	2501461.5	1085	40.8318	46.0344
Ethnicity	#####	WHITE	41.40003772	2545891.4	1054	38.9381	43.9769
Ethnicity	#####	WHITE	40.62893219	2606516.9	1059	38.2184	43.1516
Ethnicity	#####	WHITE	41.00751883	2670242	1095	38.6143	43.5102
Ethnicity	#####	WHITE	44.12234135	2731042.7	1205	41.666	46.6857
Ethnicity	#####	WHITE	43.51257608	2746332.5	1195	41.0802	46.0514
Ethnicity	#####	WHITE	42.36663701	2742724.2	1162	39.9654	44.8745
Ethnicity	#####	WHITE	43.5017024	2714836.3	1181	41.0557	46.0553
Age	#####	0-16	20.78552434	418560.53	87	16.6479	25.6392
Age	#####	0-16	22.70518603	453640.85	103	18.5323	27.5369
Age	#####	0-16	29.34798718	487256.58	143	24.7348	34.5717
Age	#####	0-16	26.28866991	517333.13	136	22.056	31.0968
Age	#####	0-16	27.86511618	545484.9	152	23.6111	32.664
Age	#####	0-16	29.863928	572597.15	171	25.5553	34.6909
Age	#####	0-16	34.81635212	600292.64	209	30.2557	39.8703
Age	#####	0-16	37.72631492	617606.04	233	33.0371	42.8944
Age	#####	0-16	33.76160353	639780.04	216	29.4088	38.577
Age	#####	0-16	36.73720875	675064.9	248	32.3067	41.6056
Age	#####	0-16	36.78966668	714874.65	263	32.4772	41.5154
Age	#####	0-16	48.35639617	756880.22	366	43.5285	53.5734
Age	#####	0-16	45.77477852	797382.34	365	41.1986	50.7203
Age	#####	0-16	45.83526915	824692.44	378	41.3304	50.6971
Age	#####	0-16	42.83155985	842836.45	361	38.5265	47.486
Age	#####	0-16	47.53470247	862527.75	410	43.0442	52.3663
Age	#####	17-30	86.5261578	899150.06	778	80.5521	92.826
Age	#####	17-30	88.10810701	926134.98	816	82.1656	94.3668
Age	#####	17-30	85.51254912	954245.91	816	79.7451	91.5868
Age	#####	17-30	81.80087723	980429.58	802	76.2367	87.6638
Age	#####	17-30	87.504545	1006804.8	881	81.821	93.4789
Age	#####	17-30	87.64601743	1026857.8	900	82.0127	93.5644
Age	#####	17-30	84.66249936	1051232.8	890	79.1909	90.4125
Age	#####	17-30	84.80841855	1054140.6	894	79.3395	90.555
Age	#####	17-30	91.42619307	1051121.1	961	85.7364	97.3943
Age	#####	17-30	79.85467349	1071947.3	856	74.594	85.3884

Age	#####	17-30	76.11935688	1106157.5	842	71.064	81.4394
Age	#####	17-30	71.37673887	1147432.6	819	66.5714	76.4373
Age	#####	17-30	78.91356742	1186107.8	936	73.9384	84.1355
Age	#####	17-30	77.3824866	1196653.2	926	72.478	82.5315
Age	#####	17-30	73.37631684	1210199.7	888	68.6289	78.3656
Age	#####	17-30	71.38608414	1193509.9	852	66.6725	76.345
Age	#####	31-40	49.27552361	886850.04	437	44.7632	54.1195
Age	#####	31-40	44.92740798	908131.62	408	40.6731	49.5057
Age	#####	31-40	40.50260564	933273.29	378	36.5219	44.7988
Age	#####	31-40	45.79630261	956409.09	438	41.6072	50.2928
Age	#####	31-40	41.09351995	975822.95	401	37.1693	45.3193
Age	#####	31-40	40.02895465	994280.27	398	36.1924	44.1615
Age	#####	31-40	38.02681691	1015073.1	386	34.3273	42.0163
Age	#####	31-40	41.2968859	1017025.8	420	37.4413	45.4418
Age	#####	31-40	40.5482272	1018540.2	413	36.7313	44.654
Age	#####	31-40	43.65808122	1042189.6	455	39.7381	47.8601
Age	#####	31-40	44.41703498	1071660.9	476	40.5159	48.5924
Age	#####	31-40	41.74998261	1104192.1	461	38.0253	45.7409
Age	#####	31-40	41.52232156	1134329.6	471	37.8565	45.4472
Age	#####	31-40	42.43847261	1142831	485	38.745	46.389
Age	#####	31-40	42.75766563	1145993.3	490	39.0551	46.7167
Age	#####	31-40	42.58561698	1141230.4	486	38.8831	46.5456
Age	#####	41-50	2.917622068	685489.74	20	1.78142	4.50625
Age	#####	41-50	2.876405407	695312.28	20	1.75625	4.44259
Age	#####	41-50	1.555755921	707051.78	11	0.77557	2.78385
Age	#####	41-50	2.505407782	718445.92	18	1.48411	3.95983
Age	#####	41-50	1.514035646	726535.07	11	0.75477	2.70919
Age	#####	41-50	2.042020432	734566.6	15	1.14207	3.36819
Age	#####	41-50	2.553381133	744111.4	19	1.5366	3.98762
Age	#####	41-50	2.820615926	744518.24	21	1.74534	4.31181
Age	#####	41-50	2.687639028	744147.55	20	1.641	4.15104
Age	#####	41-50	2.511726667	756451.74	19	1.51153	3.92257
Age	#####	41-50	2.387173659	754029.77	18	1.41407	3.77296
Age	#####	41-50	3.689293062	731847.53	27	2.43069	5.36793
Age	#####	41-50	4.522679766	707545.12	32	3.09298	6.38489
Age	#####	41-50	2.534672129	670698.19	17	1.4757	4.05847
Age	#####	41-50	4.428569393	632258.36	28	2.9421	6.40076
Age	#####	41-50	4.543771018	594220.08	27	2.99367	6.6112
Age	#####	51-60	0.339837833	588515.99	2	0.04116	1.22761
Age	#####	51-60	0	549478.18	0		0.67134
Age	#####	51-60	0	509817.34	0		0.72357
Age	#####	51-60	0	467537.89	0		0.789
Age	#####	51-60	1.181193405	423300.7	5	0.38353	2.75651
Age	#####	51-60	0	379048.62	0		0.97319
Age	#####	51-60	0	329786.02	0		1.11857
Age	#####	51-60	0.355683199	281149.07	1	0.00901	1.98174
Age	#####	51-60	0.418445691	238979.64	1	0.01059	2.33143
Age	#####	51-60	0	209395.33	0		1.76168

Age	#####	51-60	0.496929573	201235.76	1	0.01258	2.76871
Age	#####	51-60	0	210538.65	0		1.75212
Age	#####	51-60	0	218807.93	0		1.6859
Age	#####	51-60	0	222816.08	0		1.65557
Age	#####	51-60	0	226402.09	0		1.62935
Age	#####	51-60	0	225844.12	0		1.63337
Age	#####	61-70	0	8316.5397	0		44.3559
Age	#####	61-70	11.76081657	8502.811	1	0.29776	65.5271
Age	#####	61-70	0	8910.1339	0		41.4009
Age	#####	61-70	0	9010.7205	0		40.9388
Age	#####	61-70	0	8788.3644	0		41.9746
Age	#####	61-70	0	8637.1671	0		42.7094
Age	#####	61-70	0	8238.7432	0		44.7748
Age	#####	61-70	0	8031.663	0		45.9292
Age	#####	61-70	0	8082.7973	0		45.6386
Age	#####	61-70	0	8807.4192	0		41.8838
Age	#####	61-70	0	9636.9098	0		38.2787
Age	#####	61-70	0	10184.014	0		36.2223
Age	#####	61-70	0	10653.833	0		34.6249
Age	#####	61-70	0	10856.726	0		33.9778
Age	#####	61-70	0	10659.806	0		34.6055
Age	#####	61-70	0	10363.726	0		35.5941

4.5 S5. Prevalence of ectopic pregnancy overall and by subgroup.

Time series of prevalence of ectopic pregnancy in CPRD Aurum from 2006-2021, overall and by subgroups of Index of Multiple Deprivation, region, ethnicity and age category.

S5. Prevalence of ectopic pregnancy overall and by subgroup. Time series of prevalence of ectopic pregnancy in CPRD Aurum from 2006-2021, overall and by subgroups of Index of Multiple Deprivation, region, ethnicity and age category.

Category	Year	Subgroup Value	Prevalence	Denominator	Count	Lower	Upper
Overall	01/01/2006	OVERALL	839.2587216	3494989	29332	829.6814	848.919
Overall	01/01/2007	OVERALL	874.2718743	3550383	31040	864.5726	884.0528
Overall	01/01/2008	OVERALL	902.1799981	3608260	32553	892.4058	912.0345
Overall	01/01/2009	OVERALL	937.9523568	3661380	34342	928.0581	947.9258
Overall	01/01/2010	OVERALL	964.2620966	3713928	35812	954.3008	974.3015
Overall	01/01/2011	OVERALL	994.8855434	3745657	37265	984.8097	1005.039
Overall	01/01/2012	OVERALL	1027.860778	3778430	38837	1017.663	1038.135
Overall	01/01/2013	OVERALL	1056.041624	3808562	40220	1045.746	1066.414
Overall	01/01/2014	OVERALL	1103.068967	3742921	41287	1092.454	1113.761
Overall	01/01/2015	OVERALL	1130.862693	3768362	42615	1120.151	1141.651
Overall	01/01/2016	OVERALL	1153.92045	3861878	44563	1143.231	1164.685
Overall	01/01/2017	OVERALL	1168.352392	3958138	46245	1157.728	1179.05
Overall	01/01/2018	OVERALL	1174.901069	4064938	47759	1164.387	1185.486
Overall	01/01/2019	OVERALL	1188.280704	4136733	49156	1177.799	1198.832
Overall	01/01/2020	OVERALL	1200.942809	4128090	49576	1190.394	1211.562
Overall	01/01/2021	OVERALL	1208.392934	4120514	49792	1197.802	1219.054
IMD Score	01/01/2006	1	814.9949547	335953	2738	784.7506	846.1064
IMD Score	01/01/2007	1	857.0511669	339653	2911	826.197	888.7628
IMD Score	01/01/2008	1	876.2531346	345334	3026	845.3075	908.042
IMD Score	01/01/2009	1	905.950486	354324	3210	874.8785	937.8442
IMD Score	01/01/2010	1	926.2709461	359614	3331	895.0794	958.272
IMD Score	01/01/2011	1	955.1414769	362250	3460	923.578	987.5085
IMD Score	01/01/2012	1	990.2213921	364060	3605	958.1581	1023.084
IMD Score	01/01/2013	1	1020.329923	365176	3726	987.8282	1053.629
IMD Score	01/01/2014	1	1057.933534	361932	3829	1024.687	1091.984
IMD Score	01/01/2015	1	1096.540964	365969	4013	1062.874	1131.003
IMD Score	01/01/2016	1	1119.478554	375264	4201	1085.879	1153.853
IMD Score	01/01/2017	1	1135.054894	384651	4366	1101.633	1169.233
IMD Score	01/01/2018	1	1149.354985	392394	4510	1116.053	1183.398

IMD Score	01/01/2019	1	1170.110215	397313	4649	1136.714	1204.239
IMD Score	01/01/2020	1	1184.071101	389757	4615	1150.153	1218.736
IMD Score	01/01/2021	1	1169.499576	385293	4506	1135.599	1204.155
IMD Score	01/01/2006	2	809.4989062	271526	2198	776.0074	844.064
IMD Score	01/01/2007	2	835.0366872	275437	2300	801.2554	869.8762
IMD Score	01/01/2008	2	853.5970206	279523	2386	819.6866	888.55
IMD Score	01/01/2009	2	894.7775357	284540	2546	860.3552	930.2239
IMD Score	01/01/2010	2	943.9689715	288251	2721	908.8302	980.1183
IMD Score	01/01/2011	2	965.9309813	290704	2808	930.5309	1002.333
IMD Score	01/01/2012	2	992.9615445	292962	2909	957.2023	1029.715
IMD Score	01/01/2013	2	1020.825383	293488	2996	984.5956	1058.047
IMD Score	01/01/2014	2	1083.305489	284315	3080	1045.381	1122.254
IMD Score	01/01/2015	2	1104.733821	284865	3147	1066.47	1144.02
IMD Score	01/01/2016	2	1117.089138	292367	3266	1079.103	1156.071
IMD Score	01/01/2017	2	1143.448013	298833	3417	1105.427	1182.443
IMD Score	01/01/2018	2	1153.57074	305833	3528	1115.816	1192.277
IMD Score	01/01/2019	2	1149.458272	313626	3605	1112.239	1187.606
IMD Score	01/01/2020	2	1169.079103	313238	3662	1131.518	1207.57
IMD Score	01/01/2021	2	1167.3809	319690	3732	1130.225	1205.447
IMD Score	01/01/2006	3	849.7011235	320701	2725	818.0944	882.2161
IMD Score	01/01/2007	3	888.6991141	325532	2893	856.6071	921.6858
IMD Score	01/01/2008	3	918.1092583	330135	3031	885.7119	951.3887
IMD Score	01/01/2009	3	944.3901862	337890	3191	911.9044	977.7377
IMD Score	01/01/2010	3	961.6280153	343584	3304	929.1149	994.9884

IMD Score	01/01/2011	3	991.5108585	345029	3421	958.5608	1025.305
IMD Score	01/01/2012	3	1021.091252	348059	3554	987.7939	1055.225
IMD Score	01/01/2013	3	1043.438422	349230	3644	1009.832	1077.878
IMD Score	01/01/2014	3	1073.905393	347796	3735	1039.738	1108.91
IMD Score	01/01/2015	3	1098.83824	349642	3842	1064.364	1134.145
IMD Score	01/01/2016	3	1118.364696	357218	3995	1083.951	1153.593
IMD Score	01/01/2017	3	1132.107616	363923	4120	1097.8	1167.215
IMD Score	01/01/2018	3	1131.367968	372823	4218	1097.48	1166.036
IMD Score	01/01/2019	3	1153.779605	381442	4401	1119.941	1188.381
IMD Score	01/01/2020	3	1181.729168	385029	4550	1147.639	1216.575
IMD Score	01/01/2021	3	1185.748418	371664	4407	1150.996	1221.284
IMD Score	01/01/2006	4	858.1662604	361818	3105	828.244	888.8933
IMD Score	01/01/2007	4	892.4328615	364061	3249	862.0072	923.6583
IMD Score	01/01/2008	4	917.5628016	369457	3390	886.9323	948.9812
IMD Score	01/01/2009	4	954.0391823	376190	3589	923.0792	985.7729
IMD Score	01/01/2010	4	986.8661836	382524	3775	955.6335	1018.86
IMD Score	01/01/2011	4	1010.012068	386134	3900	978.5592	1042.219
IMD Score	01/01/2012	4	1051.806749	389235	4094	1019.832	1084.529
IMD Score	01/01/2013	4	1078.673722	391592	4224	1046.387	1111.704
IMD Score	01/01/2014	4	1126.734819	382965	4315	1093.364	1160.865
IMD Score	01/01/2015	4	1145.234009	383939	4397	1111.631	1179.595
IMD Score	01/01/2016	4	1168.524268	391006	4569	1134.885	1202.908
IMD Score	01/01/2017	4	1178.693675	398492	4697	1145.223	1212.894
IMD Score	01/01/2018	4	1197.414667	406292	4865	1164.001	1231.544

IMD Score	01/01/2019	4	1200.463882	412174	4948	1167.245	1234.388
IMD Score	01/01/2020	4	1221.682065	402969	4923	1187.791	1256.295
IMD Score	01/01/2021	4	1220.457715	403701	4927	1186.614	1255.021
IMD Score	01/01/2006	5	819.086024	325851	2669	788.3032	850.7629
IMD Score	01/01/2007	5	853.2402599	331208	2826	822.0689	885.291
IMD Score	01/01/2008	5	880.4178415	336204	2960	848.9835	912.7184
IMD Score	01/01/2009	5	916.7107766	343838	3152	884.9843	949.2841
IMD Score	01/01/2010	5	934.4330461	351122	3281	902.7298	966.9654
IMD Score	01/01/2011	5	963.4632506	352686	3398	931.338	996.4139
IMD Score	01/01/2012	5	996.5610636	355924	3547	964.0319	1029.908
IMD Score	01/01/2013	5	1020.04632	360964	3682	987.3616	1053.537
IMD Score	01/01/2014	5	1083.435369	350367	3796	1049.241	1118.461
IMD Score	01/01/2015	5	1086.903987	351733	3823	1052.72	1121.915
IMD Score	01/01/2016	5	1110.220963	360739	4005	1076.1	1145.148
IMD Score	01/01/2017	5	1123.753564	369654	4154	1089.837	1158.457
IMD Score	01/01/2018	5	1128.672905	381510	4306	1095.21	1162.898
IMD Score	01/01/2019	5	1139.728302	385355	4392	1106.268	1173.944
IMD Score	01/01/2020	5	1158.957891	388021	4497	1125.33	1193.336
IMD Score	01/01/2021	5	1168.642362	393448	4598	1135.105	1202.919
IMD Score	01/01/2006	6	896.7218933	357859	3209	865.9617	928.2957
IMD Score	01/01/2007	6	935.7167298	362396	3391	904.4848	967.752
IMD Score	01/01/2008	6	971.0188228	368170	3575	939.4467	1003.382
IMD Score	01/01/2009	6	997.8790724	373893	3731	966.1137	1030.423
IMD Score	01/01/2010	6	1026.877613	376968	3871	994.781	1059.746

IMD Score	01/01/2011	6	1062.47868	381090	4049	1030.002	1095.719
IMD Score	01/01/2012	6	1093.436518	384293	4202	1060.623	1127.007
IMD Score	01/01/2013	6	1109.803781	389258	4320	1076.953	1143.401
IMD Score	01/01/2014	6	1151.756629	388016	4469	1118.233	1186.029
IMD Score	01/01/2015	6	1194.368965	390834	4668	1160.349	1229.133
IMD Score	01/01/2016	6	1222.218616	400583	4896	1188.22	1256.943
IMD Score	01/01/2017	6	1244.629708	406868	5064	1210.583	1279.391
IMD Score	01/01/2018	6	1261.067241	417900	5270	1227.247	1295.583
IMD Score	01/01/2019	6	1270.196046	420565	5342	1236.36	1304.723
IMD Score	01/01/2020	6	1277.47091	416213	5317	1243.362	1312.279
IMD Score	01/01/2021	6	1284.597597	422934	5433	1250.664	1319.219
IMD Score	01/01/2006	7	763.018918	406543	3102	736.4015	790.3526
IMD Score	01/01/2007	7	792.4749751	415786	3295	765.6448	820.0054
IMD Score	01/01/2008	7	819.0531924	423782	3471	792.0294	846.7638
IMD Score	01/01/2009	7	864.5165256	423011	3657	836.7216	892.9995
IMD Score	01/01/2010	7	888.1811091	430768	3826	860.2581	916.7796
IMD Score	01/01/2011	7	926.6954028	438008	4059	898.4036	955.6515
IMD Score	01/01/2012	7	952.791763	445113	4241	924.3295	981.9076
IMD Score	01/01/2013	7	989.2002296	449454	4446	960.3346	1018.713
IMD Score	01/01/2014	7	1013.709275	450425	4566	984.5169	1043.547
IMD Score	01/01/2015	7	1057.694857	452588	4787	1027.942	1088.09
IMD Score	01/01/2016	7	1078.648782	464470	5010	1048.985	1108.939
IMD Score	01/01/2017	7	1079.71067	483185	5217	1050.609	1109.414
IMD Score	01/01/2018	7	1077.093662	501442	5401	1048.558	1106.209

IMD Score	01/01/2019	7	1083.640189	513270	5562	1055.347	1112.5
IMD Score	01/01/2020	7	1091.320449	513598	5605	1062.935	1120.272
IMD Score	01/01/2021	7	1112.711242	510375	5679	1083.957	1142.035
IMD Score	01/01/2006	8	831.2942795	312645	2599	799.6387	863.8817
IMD Score	01/01/2007	8	866.5315875	319319	2767	834.5421	899.4333
IMD Score	01/01/2008	8	892.7724012	326623	2916	860.6595	925.7769
IMD Score	01/01/2009	8	924.6478321	331802	3068	892.2154	957.9579
IMD Score	01/01/2010	8	959.8132063	336628	3231	927.0001	993.4912
IMD Score	01/01/2011	8	987.1009833	341809	3374	954.0717	1020.982
IMD Score	01/01/2012	8	1020.724503	345147	3523	987.2942	1054.998
IMD Score	01/01/2013	8	1057.482568	349793	3699	1023.676	1092.121
IMD Score	01/01/2014	8	1113.837402	335417	3736	1078.404	1150.138
IMD Score	01/01/2015	8	1143.795192	338697	3874	1108.058	1180.392
IMD Score	01/01/2016	8	1168.802494	348733	4076	1133.193	1205.246
IMD Score	01/01/2017	8	1188.98954	359549	4275	1153.612	1225.176
IMD Score	01/01/2018	8	1185.611896	373225	4425	1150.933	1221.07
IMD Score	01/01/2019	8	1204.991737	384235	4630	1170.53	1240.211
IMD Score	01/01/2020	8	1197.985674	378886	4539	1163.385	1233.354
IMD Score	01/01/2021	8	1211.51588	370445	4488	1176.328	1247.489
IMD Score	01/01/2006	9	863.7615109	351949	3040	833.3267	895.0237
IMD Score	01/01/2007	9	894.9907318	358216	3206	864.2757	926.5186
IMD Score	01/01/2008	9	931.721469	363306	3385	900.5955	963.6487
IMD Score	01/01/2009	9	968.0415187	366100	3544	936.43	1000.448
IMD Score	01/01/2010	9	977.2470341	370633	3622	945.6776	1009.602

IMD Score	01/01/2011	9	1017.365749	374300	3808	985.3065	1050.202
IMD Score	01/01/2012	9	1042.08098	377130	3930	1009.753	1075.181
IMD Score	01/01/2013	9	1072.815623	381333	4091	1040.19	1106.204
IMD Score	01/01/2014	9	1108.305752	382205	4236	1075.179	1142.194
IMD Score	01/01/2015	9	1130.728338	386565	4371	1097.453	1164.756
IMD Score	01/01/2016	9	1156.34242	397979	4602	1123.172	1190.244
IMD Score	01/01/2017	9	1172.533399	409967	4807	1139.619	1206.158
IMD Score	01/01/2018	9	1169.893021	423543	4955	1137.543	1202.93
IMD Score	01/01/2019	9	1195.001218	435146	5200	1162.739	1227.931
IMD Score	01/01/2020	9	1200.953904	443231	5323	1168.906	1233.658
IMD Score	01/01/2021	9	1214.047484	439851	5340	1181.701	1247.055
IMD Score	01/01/2006	10	875.8531757	428839	3756	848.0644	904.3206
IMD Score	01/01/2007	10	915.405124	436965	4000	887.2543	944.2219
IMD Score	01/01/2008	10	947.4045041	443422	4201	918.9698	976.4953
IMD Score	01/01/2009	10	990.7571112	446830	4427	961.7845	1020.381
IMD Score	01/01/2010	10	1025.17758	450361	4617	995.8173	1055.184
IMD Score	01/01/2011	10	1055.170268	449880	4747	1025.365	1085.622
IMD Score	01/01/2012	10	1100.421471	452463	4979	1070.065	1131.42
IMD Score	01/01/2013	10	1131.801938	453878	5137	1101.061	1163.184
IMD Score	01/01/2014	10	1209.984384	434799	5261	1177.507	1243.131
IMD Score	01/01/2015	10	1238.985277	438504	5433	1206.256	1272.377
IMD Score	01/01/2016	10	1264.695643	448092	5667	1231.98	1298.06
IMD Score	01/01/2017	10	1279.993001	457190	5852	1247.406	1313.216
IMD Score	01/01/2018	10	1294.091516	463723	6001	1261.554	1327.255

IMD Score	01/01/2019	10	1315.161081	466939	6141	1282.471	1348.474
IMD Score	01/01/2020	10	1330.473199	469908	6252	1297.696	1363.869
IMD Score	01/01/2021	10	1342.950405	474850	6377	1310.189	1376.324
Health Authority	01/01/2006	East Midlands	806.8899706	82787	668	746.8521	870.4694
Health Authority	01/01/2007	East Midlands	847.7192316	84226	714	786.6705	912.2475
Health Authority	01/01/2008	East Midlands	878.1494378	85293	749	816.3773	943.3566
Health Authority	01/01/2009	East Midlands	901.1059027	87892	792	839.4328	966.1113
Health Authority	01/01/2010	East Midlands	913.1959618	89247	815	851.5682	978.1049
Health Authority	01/01/2011	East Midlands	953.2405777	90848	866	890.8009	1018.903
Health Authority	01/01/2012	East Midlands	974.4054707	91543	892	911.5009	1040.507
Health Authority	01/01/2013	East Midlands	979.0634385	92231	903	916.2379	1045.062
Health Authority	01/01/2014	East Midlands	999.2971976	91064	910	935.4164	1066.392
Health Authority	01/01/2015	East Midlands	1046.586812	91249	955	981.2526	1115.127
Health Authority	01/01/2016	East Midlands	1070.48801	93789	1004	1005.287	1138.808
Health Authority	01/01/2017	East Midlands	1065.761755	96363	1027	1001.568	1132.99
Health Authority	01/01/2018	East Midlands	1084.585676	99946	1084	1020.973	1151.124
Health Authority	01/01/2019	East Midlands	1107.998575	103881	1151	1044.904	1173.907
Health Authority	01/01/2020	East Midlands	1072.52707	87457	938	1004.979	1143.421
Health Authority	01/01/2021	East Midlands	1053.789265	89107	939	987.4564	1123.406
Health Authority	01/01/2006	East of England	960.1151869	148628	1427	910.9403	1011.255
Health Authority	01/01/2007	East of England	996.9734734	151659	1512	947.3483	1048.524
Health Authority	01/01/2008	East of England	1019.195939	154043	1570	969.3988	1070.888
Health Authority	01/01/2009	East of England	1059.715004	157967	1674	1009.553	1111.725
Health Authority	01/01/2010	East of England	1110.419519	160660	1784	1059.484	1163.171

Health Authority	01/01/2011	East of England	1134.834927	162050	1839	1083.555	1187.915
Health Authority	01/01/2012	East of England	1174.688307	163703	1923	1122.766	1228.392
Health Authority	01/01/2013	East of England	1203.792672	165477	1992	1151.504	1257.844
Health Authority	01/01/2014	East of England	1233.70845	165193	2038	1180.722	1288.46
Health Authority	01/01/2015	East of England	1280.914494	166912	2138	1227.188	1336.387
Health Authority	01/01/2016	East of England	1286.11688	169969	2186	1232.762	1341.187
Health Authority	01/01/2017	East of England	1324.895048	174127	2307	1271.377	1380.087
Health Authority	01/01/2018	East of England	1318.199494	177439	2339	1265.314	1372.728
Health Authority	01/01/2019	East of England	1325.570428	178112	2361	1272.635	1380.142
Health Authority	01/01/2020	East of England	1350.341202	165884	2240	1294.994	1407.446
Health Authority	01/01/2021	East of England	1351.359721	161467	2182	1295.247	1409.278
Health Authority	01/01/2006	London	875.6742255	641106	5614	852.916	898.8859
Health Authority	01/01/2007	London	910.5799182	652661	5943	887.5747	934.0305
Health Authority	01/01/2008	London	943.8104911	669520	6319	920.6816	967.3735
Health Authority	01/01/2009	London	979.2897386	687437	6732	956.0347	1002.968
Health Authority	01/01/2010	London	1005.374038	708592	7124	982.1619	1028.996
Health Authority	01/01/2011	London	1035.907406	724196	7502	1012.597	1059.619
Health Authority	01/01/2012	London	1065.996365	739965	7888	1042.6	1089.785
Health Authority	01/01/2013	London	1095.730588	759402	8321	1072.312	1119.531
Health Authority	01/01/2014	London	1140.276071	755168	8611	1116.318	1164.619
Health Authority	01/01/2015	London	1173.058135	756399	8873	1148.776	1197.725
Health Authority	01/01/2016	London	1179.068874	791472	9332	1155.267	1203.238
Health Authority	01/01/2017	London	1179.386439	828736	9774	1156.12	1203.004
Health Authority	01/01/2018	London	1172.265395	869513	10193	1149.617	1195.248

Health Authority	01/01/2019	London	1177.755869	900696	10608	1155.449	1200.385
Health Authority	01/01/2020	London	1179.481594	918200	10830	1157.371	1201.908
Health Authority	01/01/2021	London	1174.713403	931972	10948	1152.811	1196.928
Health Authority	01/01/2006	North East	832.2855979	112942	940	779.9231	887.2388
Health Authority	01/01/2007	North East	854.4621427	114575	979	801.769	909.7086
Health Authority	01/01/2008	North East	883.7548847	116435	1029	830.5751	939.4465
Health Authority	01/01/2009	North East	893.7562941	119160	1065	840.8776	949.089
Health Authority	01/01/2010	North East	921.507593	121757	1122	868.3692	977.047
Health Authority	01/01/2011	North East	949.6998819	123618	1174	896.1446	1005.619
Health Authority	01/01/2012	North East	985.5951478	123986	1222	931.1026	1042.445
Health Authority	01/01/2013	North East	1011.830013	125021	1265	956.8327	1069.164
Health Authority	01/01/2014	North East	1043.599258	125048	1305	987.7392	1101.795
Health Authority	01/01/2015	North East	1118.926851	125388	1403	1061.136	1179.046
Health Authority	01/01/2016	North East	1163.442337	126693	1474	1104.799	1224.39
Health Authority	01/01/2017	North East	1208.499336	128010	1547	1149.021	1270.258
Health Authority	01/01/2018	North East	1206.565567	129707	1565	1147.521	1267.861
Health Authority	01/01/2019	North East	1229.021352	131324	1614	1169.786	1290.479
Health Authority	01/01/2020	North East	1228.968313	126773	1558	1168.694	1291.545
Health Authority	01/01/2021	North East	1227.756747	127061	1560	1167.58	1290.231
Health Authority	01/01/2006	North West	765.0584357	667400	5106	744.216	786.3366
Health Authority	01/01/2007	North West	800.0295268	677350	5419	778.8689	821.6194
Health Authority	01/01/2008	North West	826.1895525	685678	5665	804.8137	847.9895
Health Authority	01/01/2009	North West	864.024302	691300	5973	842.2498	886.2193
Health Authority	01/01/2010	North West	892.1714548	694037	6192	870.0863	914.6754

Health Authority	01/01/2011	North West	929.4771924	696413	6473	906.9705	952.4013
Health Authority	01/01/2012	North West	969.6418791	697474	6763	946.6685	993.0319
Health Authority	01/01/2013	North West	1004.509072	695265	6984	981.0869	1028.349
Health Authority	01/01/2014	North West	1048.783217	679168	7123	1024.567	1073.427
Health Authority	01/01/2015	North West	1074.204595	683017	7337	1049.764	1099.071
Health Authority	01/01/2016	North West	1107.048154	696537	7711	1082.475	1132.038
Health Authority	01/01/2017	North West	1130.048505	710235	8026	1105.459	1155.047
Health Authority	01/01/2018	North West	1146.501567	723767	8298	1121.965	1171.44
Health Authority	01/01/2019	North West	1169.744704	736400	8614	1145.171	1194.713
Health Authority	01/01/2020	North West	1199.201251	742661	8906	1174.423	1224.37
Health Authority	01/01/2021	North West	1210.553363	745279	9022	1185.701	1235.795
Health Authority	01/01/2006	Northern Ireland	848.0520309	15683	133	710.0461	1005.044
Health Authority	01/01/2007	Northern Ireland	884.7352025	16050	142	745.1955	1042.811
Health Authority	01/01/2008	Northern Ireland	921.5472293	16494	152	780.8603	1080.255
Health Authority	01/01/2009	Northern Ireland	970.8737864	16995	165	828.376	1130.843
Health Authority	01/01/2010	Northern Ireland	992.0862484	17438	173	849.7485	1151.442
Health Authority	01/01/2011	Northern Ireland	1016.891701	17701	180	873.7504	1176.79
Health Authority	01/01/2012	Northern Ireland	1067.754919	17888	191	921.6832	1230.397
Health Authority	01/01/2013	Northern Ireland	1070.663812	18213	195	925.6488	1231.949
Health Authority	01/01/2014	Northern Ireland	1095.993953	18522	203	950.3965	1257.583
Health Authority	01/01/2015	Northern Ireland	1047.286576	18906	198	906.4774	1203.767
Health Authority	01/01/2016	Northern Ireland	1090.625811	19255	210	948.0908	1248.538
Health Authority	01/01/2017	Northern Ireland	1085.633117	19712	214	945.0363	1241.247
Health Authority	01/01/2018	Northern Ireland	1102.174561	20142	222	961.9421	1257.098

Health Authority	01/01/2019	Northern Ireland	1107.15505	20503	227	967.7962	1260.943
Health Authority	01/01/2020	Northern Ireland	1109.682336	20997	233	971.755	1261.695
Health Authority	01/01/2021	Northern Ireland	1094.655505	21742	238	959.9853	1242.926
Health Authority	01/01/2006	South East	850.013361	707283	6012	828.6611	871.7766
Health Authority	01/01/2007	South East	881.6287444	718443	6334	860.0491	903.613
Health Authority	01/01/2008	South East	907.3767916	731890	6641	885.6832	929.4674
Health Authority	01/01/2009	South East	941.4026003	748139	7043	919.5435	963.6501
Health Authority	01/01/2010	South East	968.8924139	759011	7354	946.8731	991.2945
Health Authority	01/01/2011	South East	1003.700187	763475	7663	981.3519	1026.429
Health Authority	01/01/2012	South East	1037.010502	770484	7990	1014.395	1060.003
Health Authority	01/01/2013	South East	1063.177871	775129	8241	1040.346	1086.385
Health Authority	01/01/2014	South East	1112.439536	766154	8523	1088.946	1136.312
Health Authority	01/01/2015	South East	1131.018588	774081	8755	1107.45	1154.963
Health Authority	01/01/2016	South East	1152.024213	786355	9059	1128.422	1175.996
Health Authority	01/01/2017	South East	1165.859546	798724	9312	1142.299	1189.784
Health Authority	01/01/2018	South East	1175.158837	814358	9570	1151.731	1198.943
Health Authority	01/01/2019	South East	1188.411692	830941	9875	1165.086	1212.086
Health Authority	01/01/2020	South East	1204.405257	835184	10059	1180.982	1228.176
Health Authority	01/01/2021	South East	1209.556698	825013	9979	1185.94	1233.526
Health Authority	01/01/2006	South West	900.0985459	432286	3891	872.0364	928.8339
Health Authority	01/01/2007	South West	939.6939859	435993	4097	911.1377	968.9176
Health Authority	01/01/2008	South West	966.0912874	439710	4248	937.2554	995.5888
Health Authority	01/01/2009	South West	999.5193323	445214	4450	970.3656	1029.326
Health Authority	01/01/2010	South West	1013.408516	450460	4565	984.2217	1043.241

Health Authority	01/01/2011	South West	1039.221224	453224	4710	1009.752	1069.332
Health Authority	01/01/2012	South West	1062.219473	455838	4842	1032.509	1092.568
Health Authority	01/01/2013	South West	1085.89345	457043	4963	1055.89	1116.533
Health Authority	01/01/2014	South West	1161.073094	431239	5007	1129.133	1193.688
Health Authority	01/01/2015	South West	1187.530241	434010	5154	1155.328	1220.402
Health Authority	01/01/2016	South West	1231.282111	437349	5385	1198.613	1264.616
Health Authority	01/01/2017	South West	1237.366306	445139	5508	1204.902	1270.484
Health Authority	01/01/2018	South West	1251.662347	456433	5713	1219.414	1284.548
Health Authority	01/01/2019	South West	1258.852158	457798	5763	1226.558	1291.781
Health Authority	01/01/2020	South West	1262.041965	454660	5738	1229.596	1295.127
Health Authority	01/01/2021	South West	1259.206514	457828	5765	1226.909	1292.139
Health Authority	01/01/2006	West Midlands	793.2678077	557441	4422	770.0574	817.0001
Health Authority	01/01/2007	West Midlands	832.2903299	568071	4728	808.7337	856.359
Health Authority	01/01/2008	West Midlands	859.7403049	575290	4946	835.9452	884.0409
Health Authority	01/01/2009	West Midlands	902.5705041	573584	5177	878.1499	927.4981
Health Authority	01/01/2010	West Midlands	926.9864118	578002	5358	902.3296	952.1463
Health Authority	01/01/2011	West Midlands	952.578711	577905	5505	927.5795	978.081
Health Authority	01/01/2012	West Midlands	986.7662496	581090	5734	961.3889	1012.644
Health Authority	01/01/2013	West Midlands	1016.018731	582568	5919	990.298	1042.238
Health Authority	01/01/2014	West Midlands	1057.650115	574292	6074	1031.217	1084.589
Health Authority	01/01/2015	West Midlands	1079.128005	579820	6257	1052.553	1106.204
Health Authority	01/01/2016	West Midlands	1105.524782	598087	6612	1079.036	1132.499
Health Authority	01/01/2017	West Midlands	1125.609958	611313	6881	1099.17	1152.526
Health Authority	01/01/2018	West Midlands	1134.718805	623855	7079	1108.438	1161.466

Health Authority	01/01/2019	West Midlands	1150.090126	624125	7178	1123.636	1177.01
Health Authority	01/01/2020	West Midlands	1169.227079	633752	7410	1142.755	1196.158
Health Authority	01/01/2021	West Midlands	1188.054858	634735	7541	1161.39	1215.178
Health Authority	01/01/2006	Yorkshire & The Humber	873.3868712	125145	1093	822.3695	926.7405
Health Authority	01/01/2007	Yorkshire & The Humber	900.8867367	127208	1146	849.4763	954.5951
Health Authority	01/01/2008	Yorkshire & The Humber	932.284289	129896	1211	880.509	986.3093
Health Authority	01/01/2009	Yorkshire & The Humber	948.8896935	132576	1258	897.1721	1002.811
Health Authority	01/01/2010	Yorkshire & The Humber	978.3096485	133700	1308	926.0036	1032.801
Health Authority	01/01/2011	Yorkshire & The Humber	991.9359011	135291	1342	939.5683	1046.462
Health Authority	01/01/2012	Yorkshire & The Humber	1021.566402	135674	1386	968.486	1076.799
Health Authority	01/01/2013	Yorkshire & The Humber	1040.099431	137583	1431	986.9014	1095.42
Health Authority	01/01/2014	Yorkshire & The Humber	1090.696142	136610	1490	1036.012	1147.518
Health Authority	01/01/2015	Yorkshire & The Humber	1116.331598	138131	1542	1061.302	1173.475
Health Authority	01/01/2016	Yorkshire & The Humber	1118.408998	141898	1587	1064.054	1174.821
Health Authority	01/01/2017	Yorkshire & The Humber	1132.914398	145289	1646	1078.838	1188.999
Health Authority	01/01/2018	Yorkshire & The Humber	1134.057219	149287	1693	1080.674	1189.395
Health Authority	01/01/2019	Yorkshire & The Humber	1154.077523	152936	1765	1100.859	1209.204
Health Authority	01/01/2020	Yorkshire & The Humber	1168.301399	142429	1664	1112.835	1225.817
Health Authority	01/01/2021	Yorkshire & The Humber	1277.706794	126007	1610	1216.05	1341.68
Ethnicity	01/01/2006	ASIAN	719.8182664	146148	1052	676.9722	764.6653
Ethnicity	01/01/2007	ASIAN	731.5847279	161157	1179	690.4157	774.5673
Ethnicity	01/01/2008	ASIAN	741.388013	184249	1366	702.5884	781.7728
Ethnicity	01/01/2009	ASIAN	746.4644992	205770	1536	709.5964	784.7513
Ethnicity	01/01/2010	ASIAN	767.6712353	226399	1738	732.0003	804.6309
Ethnicity	01/01/2011	ASIAN	778.4268055	246009	1915	743.9489	814.0903
Ethnicity	01/01/2012	ASIAN	798.9893127	263583	2106	765.2259	833.8588
Ethnicity	01/01/2013	ASIAN	819.1705721	282725	2316	786.1446	853.2274
Ethnicity	01/01/2014	ASIAN	851.6439618	294137	2505	818.6165	885.662
Ethnicity	01/01/2015	ASIAN	890.4123212	301658	2686	857.0539	924.7364

Ethnicity	01/01/2016	ASIAN	922.0131834	316156	2915	888.8429	956.1047
Ethnicity	01/01/2017	ASIAN	928.1346618	334111	3101	895.7521	961.3888
Ethnicity	01/01/2018	ASIAN	945.6706811	352977	3338	913.859	978.3071
Ethnicity	01/01/2019	ASIAN	965.8481328	367242	3547	934.3214	998.1674
Ethnicity	01/01/2020	ASIAN	963.212103	382055	3680	932.3402	994.8458
Ethnicity	01/01/2021	ASIAN	966.2995529	399876	3864	936.0692	997.2576
Ethnicity	01/01/2006	BLACK	1645.703928	90478	1489	1563.166	1731.469
Ethnicity	01/01/2007	BLACK	1692.057388	101415	1716	1612.937	1774.055
Ethnicity	01/01/2008	BLACK	1729.270145	114557	1981	1653.95	1807.136
Ethnicity	01/01/2009	BLACK	1726.915959	125368	2165	1654.931	1801.226
Ethnicity	01/01/2010	BLACK	1730.194125	134089	2320	1660.499	1802.063
Ethnicity	01/01/2011	BLACK	1726.637108	140736	2430	1658.661	1796.683
Ethnicity	01/01/2012	BLACK	1759.149541	147685	2598	1692.149	1828.123
Ethnicity	01/01/2013	BLACK	1770.266511	154553	2736	1704.548	1837.869
Ethnicity	01/01/2014	BLACK	1811.457231	158712	2875	1745.841	1878.909
Ethnicity	01/01/2015	BLACK	1854.369292	161834	3001	1788.611	1921.927
Ethnicity	01/01/2016	BLACK	1855.536205	169385	3143	1791.227	1921.565
Ethnicity	01/01/2017	BLACK	1860.326023	177227	3297	1797.361	1924.933
Ethnicity	01/01/2018	BLACK	1842.00131	184799	3404	1780.636	1904.942
Ethnicity	01/01/2019	BLACK	1831.117331	188628	3454	1770.554	1893.224
Ethnicity	01/01/2020	BLACK	1822.126934	193565	3527	1762.483	1883.275
Ethnicity	01/01/2021	BLACK	1793.493607	198328	3557	1735.033	1853.422
Ethnicity	01/01/2006	MISSING	691.46329	1350614	9339	677.5097	705.6319
Ethnicity	01/01/2007	MISSING	711.6396502	1281688	9121	697.1092	726.3968
Ethnicity	01/01/2008	MISSING	723.6068967	1156429	8368	708.1851	739.2799
Ethnicity	01/01/2009	MISSING	749.2307439	1031191	7726	732.6162	766.127
Ethnicity	01/01/2010	MISSING	753.1023847	951929	7169	735.769	770.741
Ethnicity	01/01/2011	MISSING	766.6074673	882329	6764	748.4458	785.0985
Ethnicity	01/01/2012	MISSING	771.7449314	830067	6406	752.9607	790.8793
Ethnicity	01/01/2013	MISSING	783.6696387	788470	6179	764.2501	803.4578
Ethnicity	01/01/2014	MISSING	854.3932469	672407	5745	832.4411	876.7778
Ethnicity	01/01/2015	MISSING	855.5285787	659826	5645	833.3547	878.1431
Ethnicity	01/01/2016	MISSING	857.6383748	661934	5677	835.4721	880.2438
Ethnicity	01/01/2017	MISSING	856.4858128	662708	5676	834.3474	879.0629
Ethnicity	01/01/2018	MISSING	843.1852133	668062	5633	821.3081	865.4975
Ethnicity	01/01/2019	MISSING	838.3222536	653448	5478	816.2678	860.8217
Ethnicity	01/01/2020	MISSING	845.1353823	628775	5314	822.5635	868.1697
Ethnicity	01/01/2021	MISSING	862.6887132	592566	5112	839.2002	886.6679
Ethnicity	01/01/2006	MIXED	1327.565	23577	313	1184.546	1483.092
Ethnicity	01/01/2007	MIXED	1330.622805	27055	360	1196.701	1475.431
Ethnicity	01/01/2008	MIXED	1290.724864	32075	414	1169.369	1421.252
Ethnicity	01/01/2009	MIXED	1318.477757	36709	484	1203.615	1441.346
Ethnicity	01/01/2010	MIXED	1301.961556	40631	529	1193.361	1417.789
Ethnicity	01/01/2011	MIXED	1308.343519	44178	578	1203.841	1419.489
Ethnicity	01/01/2012	MIXED	1346.355808	47610	641	1244.131	1454.74
Ethnicity	01/01/2013	MIXED	1394.614854	50695	707	1293.695	1501.316
Ethnicity	01/01/2014	MIXED	1372.903032	53172	730	1275.102	1476.215
Ethnicity	01/01/2015	MIXED	1343.077227	55693	748	1248.538	1442.877

Ethnicity	01/01/2016	MIXED	1320.928673	59655	788	1230.297	1416.47
Ethnicity	01/01/2017	MIXED	1361.043832	63995	871	1272.144	1454.518
Ethnicity	01/01/2018	MIXED	1334.013705	68590	915	1248.965	1423.329
Ethnicity	01/01/2019	MIXED	1306.96639	73223	957	1225.462	1392.467
Ethnicity	01/01/2020	MIXED	1303.552667	77097	1005	1224.195	1386.704
Ethnicity	01/01/2021	MIXED	1292.785935	81452	1053	1215.871	1373.291
Ethnicity	01/01/2006	OTHER	732.6695472	15969	117	605.9269	878.092
Ethnicity	01/01/2007	OTHER	726.7922035	18162	132	608.0922	861.8885
Ethnicity	01/01/2008	OTHER	756.3949757	21814	165	645.3769	881.0247
Ethnicity	01/01/2009	OTHER	789.5559725	25584	202	684.4173	906.2728
Ethnicity	01/01/2010	OTHER	798.273263	29188	233	699.0524	907.6269
Ethnicity	01/01/2011	OTHER	809.5149138	32118	260	714.0949	914.133
Ethnicity	01/01/2012	OTHER	822.0989393	34789	286	729.5698	923.112
Ethnicity	01/01/2013	OTHER	826.1590289	37402	309	736.5988	923.6047
Ethnicity	01/01/2014	OTHER	845.5169984	39739	336	757.5144	940.9358
Ethnicity	01/01/2015	OTHER	857.0612323	42004	360	770.8014	950.3331
Ethnicity	01/01/2016	OTHER	881.7874428	45249	399	797.3756	972.7029
Ethnicity	01/01/2017	OTHER	872.9388943	49488	432	792.5504	959.2701
Ethnicity	01/01/2018	OTHER	850.2348614	54926	467	774.8589	930.962
Ethnicity	01/01/2019	OTHER	832.268478	59476	495	760.5547	908.9219
Ethnicity	01/01/2020	OTHER	832.6290419	63894	532	763.3689	906.4849
Ethnicity	01/01/2021	OTHER	823.6357636	69691	574	757.6245	893.8582
Ethnicity	01/01/2006	WHITE	911.142954	1868203	17022	897.5061	924.9352
Ethnicity	01/01/2007	WHITE	945.0733487	1960906	18532	931.515	958.7796
Ethnicity	01/01/2008	WHITE	965.1113601	2099136	20259	951.8668	978.4941
Ethnicity	01/01/2009	WHITE	993.8044259	2236758	22229	980.7824	1006.956
Ethnicity	01/01/2010	WHITE	1021.70441	2331692	23823	1008.771	1034.762
Ethnicity	01/01/2011	WHITE	1054.790531	2400287	25318	1041.837	1067.865
Ethnicity	01/01/2012	WHITE	1091.784889	2454696	26800	1078.752	1104.936
Ethnicity	01/01/2013	WHITE	1121.289509	2494717	27973	1108.187	1134.508
Ethnicity	01/01/2014	WHITE	1152.429108	2524754	29096	1139.225	1165.748
Ethnicity	01/01/2015	WHITE	1184.565746	2547347	30175	1171.238	1198.008
Ethnicity	01/01/2016	WHITE	1212.531601	2609499	31641	1199.208	1225.967
Ethnicity	01/01/2017	WHITE	1230.730519	2670609	32868	1217.461	1244.109
Ethnicity	01/01/2018	WHITE	1242.952145	2735584	34002	1229.775	1256.235
Ethnicity	01/01/2019	WHITE	1260.414296	2794716	35225	1247.286	1273.647
Ethnicity	01/01/2020	WHITE	1276.384409	2782704	35518	1263.144	1289.729
Ethnicity	01/01/2021	WHITE	1282.371956	2778601	35632	1269.091	1295.757
Age	01/01/2006	0-16	37.56798312	401938	151	31.81455	44.06098
Age	01/01/2007	0-16	51.14669054	437956	224	44.66729	58.30168
Age	01/01/2008	0-16	66.65862531	472557	315	59.49964	74.44162
Age	01/01/2009	0-16	85.08460861	504204	429	77.22253	93.53001
Age	01/01/2010	0-16	98.32823275	533926	525	90.09589	107.1106
Age	01/01/2011	0-16	112.9367839	561376	634	104.3156	122.0804
Age	01/01/2012	0-16	128.9141955	587988	758	119.8989	138.4277
Age	01/01/2013	0-16	148.5951593	616440	916	139.1268	158.5383
Age	01/01/2014	0-16	171.3703083	626713	1074	161.2732	181.934
Age	01/01/2015	0-16	187.2138839	658605	1233	176.9086	197.9628

Age	01/01/2016	0-16	201.8060711	697204	1407	191.3978	212.6332
Age	01/01/2017	0-16	216.1759729	738750	1597	205.7023	227.0447
Age	01/01/2018	0-16	240.2137851	780971	1876	229.4655	251.3355
Age	01/01/2019	0-16	260.9700448	816952	2132	250.0088	272.2882
Age	01/01/2020	0-16	281.1286707	837339	2354	269.8855	292.7199
Age	01/01/2021	0-16	294.9479183	853371	2517	283.5366	306.7006
Age	01/01/2006	17-30	633.5428403	896072	5677	617.1685	650.2416
Age	01/01/2007	17-30	693.0066868	924955	6410	676.1442	710.1834
Age	01/01/2008	17-30	742.1974251	952442	7069	724.9954	759.7046
Age	01/01/2009	17-30	800.8839878	978294	7835	783.2473	818.8176
Age	01/01/2010	17-30	838.5005916	1010852	8476	820.7437	856.5448
Age	01/01/2011	17-30	886.7360199	1033453	9164	868.6727	905.0804
Age	01/01/2012	17-30	934.4723626	1056104	9869	916.1257	953.094
Age	01/01/2013	17-30	975.1181534	1080587	10537	956.5874	993.9177
Age	01/01/2014	17-30	1035.319756	1068269	11060	1016.114	1054.798
Age	01/01/2015	17-30	1082.472743	1077071	11659	1062.912	1102.303
Age	01/01/2016	17-30	1107.346672	1108325	12273	1087.841	1127.114
Age	01/01/2017	17-30	1123.465076	1145741	12872	1104.14	1143.044
Age	01/01/2018	17-30	1126.730932	1188305	13389	1107.726	1145.98
Age	01/01/2019	17-30	1136.995765	1218826	13858	1118.143	1156.086
Age	01/01/2020	17-30	1158.70271	1225940	14205	1139.725	1177.917
Age	01/01/2021	17-30	1162.533744	1235405	14362	1143.598	1181.705
Age	01/01/2006	31-40	1382.19681	889526	12295	1357.872	1406.848
Age	01/01/2007	31-40	1425.712966	909580	12968	1401.279	1450.466
Age	01/01/2008	31-40	1451.395597	933722	13552	1427.061	1476.041
Age	01/01/2009	31-40	1482.614597	957700	14199	1458.327	1507.205
Age	01/01/2010	31-40	1505.907596	982464	14795	1481.739	1530.372
Age	01/01/2011	31-40	1530.67147	999300	15296	1506.509	1555.124
Age	01/01/2012	31-40	1551.627852	1020670	15837	1527.555	1575.985
Age	01/01/2013	31-40	1568.501275	1041185	16331	1544.536	1592.745
Age	01/01/2014	31-40	1615.541843	1029376	16630	1591.08	1640.286
Age	01/01/2015	31-40	1638.092029	1044691	17113	1613.64	1662.822
Age	01/01/2016	31-40	1660.717259	1074897	17851	1636.444	1685.261
Age	01/01/2017	31-40	1680.343672	1104774	18564	1656.258	1704.692
Age	01/01/2018	31-40	1682.245288	1138954	19160	1658.509	1706.237
Age	01/01/2019	31-40	1692.060609	1163729	19691	1668.508	1715.862
Age	01/01/2020	31-40	1699.131526	1166184	19815	1675.555	1722.957
Age	01/01/2021	31-40	1706.031686	1167153	19912	1682.417	1729.895
Age	01/01/2006	41-50	1110.783732	688973	7653	1086.035	1135.954
Age	01/01/2007	41-50	1135.64714	697840	7925	1110.78	1160.93
Age	01/01/2008	41-50	1155.54515	709016	8193	1130.657	1180.843
Age	01/01/2009	41-50	1180.800852	720782	8511	1155.846	1206.158
Age	01/01/2010	41-50	1197.591698	731802	8764	1172.648	1222.932
Age	01/01/2011	41-50	1218.011295	738581	8996	1192.97	1243.446
Age	01/01/2012	41-50	1248.016371	748628	9343	1222.837	1273.584
Age	01/01/2013	41-50	1264.367209	757454	9577	1239.17	1289.948
Age	01/01/2014	41-50	1305.717606	751311	9810	1280.006	1331.816
Age	01/01/2015	41-50	1319.070779	757882	9997	1293.339	1345.186

Age	01/01/2016	41-50	1339.608698	774032	10369	1313.947	1365.646
Age	01/01/2017	41-50	1380.0833	751259	10368	1353.645	1406.908
Age	01/01/2018	41-50	1411.473052	729309	10294	1384.337	1439.008
Age	01/01/2019	41-50	1458.017456	701089	10222	1429.888	1486.561
Age	01/01/2020	41-50	1495.150597	660803	9880	1465.812	1524.928
Age	01/01/2021	41-50	1545.315171	622915	9626	1514.597	1576.5
Age	01/01/2006	51-60	574.4959843	610100	3505	555.6325	593.8366
Age	01/01/2007	51-60	603.3211526	571669	3449	583.3524	623.7991
Age	01/01/2008	51-60	631.8188485	531798	3360	610.634	653.5511
Age	01/01/2009	51-60	671.4359856	491335	3299	648.7174	694.7471
Age	01/01/2010	51-60	715.6758114	446012	3192	691.0613	740.9431
Age	01/01/2011	51-60	770.4183119	404196	3114	743.5941	797.9629
Age	01/01/2012	51-60	832.7022858	356550	2969	803.0162	863.2051
Age	01/01/2013	51-60	915.4991947	304861	2791	881.8463	950.1076
Age	01/01/2014	51-60	1017.534927	259254	2638	979.0721	1057.121
Age	01/01/2015	51-60	1138.720089	221828	2526	1094.742	1184.012
Age	01/01/2016	51-60	1299.461839	198082	2574	1249.741	1350.653
Age	01/01/2017	51-60	1323.836767	207654	2749	1274.807	1374.269
Age	01/01/2018	51-60	1350.373542	216977	2930	1301.916	1400.173
Age	01/01/2019	51-60	1392.886331	225144	3136	1344.558	1442.508
Age	01/01/2020	51-60	1406.09307	227012	3192	1357.733	1455.736
Age	01/01/2021	51-60	1402.122014	231007	3239	1354.246	1451.258
Age	01/01/2006	61-70	608.5918854	8380	51	453.1029	800.2024
Age	01/01/2007	61-70	763.449839	8383	64	587.92	974.924
Age	01/01/2008	61-70	733.5243553	8725	64	564.8749	936.7092
Age	01/01/2009	61-70	761.1693326	9065	69	592.2092	963.3226
Age	01/01/2010	61-70	676.2849414	8872	60	516.0478	870.5278
Age	01/01/2011	61-70	697.0631928	8751	61	533.1691	895.422
Age	01/01/2012	61-70	718.4923439	8490	61	549.5598	922.9491
Age	01/01/2013	61-70	846.2974487	8035	68	657.1535	1072.9
Age	01/01/2014	61-70	937.7344336	7998	75	737.5596	1175.474
Age	01/01/2015	61-70	1050.090525	8285	87	841.0547	1295.297
Age	01/01/2016	61-70	953.0948811	9338	89	765.3918	1172.878
Age	01/01/2017	61-70	953.815261	9960	95	771.674	1166.001
Age	01/01/2018	61-70	1055.459605	10422	110	867.4423	1272.125
Age	01/01/2019	61-70	1064.313654	10993	117	880.2007	1275.562
Age	01/01/2020	61-70	1202.36774	10812	130	1004.56	1427.724
Age	01/01/2021	61-70	1275.438432	10663	136	1070.082	1508.711

Chapter 5 - Inequalities in pre-conception long-term conditions

5.1 Included Conditions

Condition name	Organ System	Conditions related to Mortality in MBRRACE 2024 Report
Hypertension	Cardiovascular	
Heart Failure	Cardiovascular	Yes
Atrial Fibrillation	Cardiovascular	Yes
Valvular Disease	Cardiovascular	Yes
Cardiomyopathy	Cardiovascular	Yes
Congenital Heart Disease	Cardiovascular	Yes
Psoriasis	Skin	
Profound Deafness	Ear, Nose and Throat	
Cataracts	Eye	
Severe Blindness	Eye	
Retinal Detachment	Eye	
Irritable Bowel Syndrome	Gastrointestinal	
Coeliac Disease	Gastrointestinal	
Peptic Ulcer Disease	Gastrointestinal	
Cholelithiasis	Gastrointestinal	
Polycystic Ovarian Syndrome	Endocrine	
Endometriosis	Gynaecological	
Fibroids	Gynaecological	
Female Infertility	Gynaecological	
Primary Thrombocytopenia	Haematology	
Haemophilia	Haematology	
Sickle Cell Disease	Haematology	Yes
Pernicious Anaemia	Haematology	Yes
Systemic Lupus Erythematosus	Rheumatology	Yes
Ehler's Danlos Syndrome Type 3	Musculoskeletal	
Scoliosis	Musculoskeletal	
Vertebrae Disorder	Musculoskeletal	
Chronic Back Pain	Musculoskeletal	
Osteoporosis	Musculoskeletal	
Osteoarthritis	Musculoskeletal	
Epilepsy	Neurology	Yes
Multiple Sclerosis	Neurology	
Migraine	Neurology	
Spina Bifida	Neurology	
Benign Intracranial Hypertension	Neurology	
Peripheral Neuropathy	Neurology	
Chronic Obstructive Pulmonary Disorder	Respiratory	
Obstructive Sleep Apnoea	Respiratory	
Interstitial Lung Disease	Respiratory	
Pulmonary Hypertension	Respiratory	Yes
Bronchiectasis	Respiratory	
Cystic Fibrosis	Respiratory	Yes
Sarcoidosis	Respiratory	
Urolithiasis	Renal	

Adrenal Benign Tumour	Endocrine	
Pituitary Disorder	Endocrine	
Hyperparathyroidism	Endocrine	
Human Immunodeficiency Virus infection	Infection	
Turner Syndrome	Development	
Marfan Syndrome	Development	
Solid Organ Transplant	Haematology	Yes
Ischaemic Heart Disease	Cardiovascular	Yes
Stroke or Transient Ischaemic Attack	Cardiovascular	Yes
All Cancer	Oncology	Yes
Autoimmune Skin Condition	Skin	
Inflammatory Eye Disease	Eye	
Inflammatory Bowel Disease	Gastrointestinal	
Chronic Liver Disease	Gastrointestinal	
Venous Thromboembolism	Haematology	Yes
Neurodevelopmental Disorder	Development	
Spondyloarthritis	Musculoskeletal	
Inflammatory Arthritis	Rheumatology	
Somatoform Disorder	Neurology	
Diabetes Mellitus	Endocrine	
Thyroid Disorder	Endocrine	
Diabetic Retinopathy	Eye	
Other Skin Conditions	Skin	
Eating Disorder	Mental Health	Yes
Other Mental Illness	Mental Health	Yes
Other Chronic Headaches	Neurology	
Asthma	Respiratory	
Depression	Mental Health	Yes
Anxiety	Mental Health	Yes
Atopic Eczema	Skin	
Allergic Rhinoconjunctivitis	Ear, Nose and Throat	
Alcohol Misuse or Dependency	Mental Health	Yes
Substance Misuse or Dependency	Mental Health	Yes
Severe Mental Illness	Mental Health	Yes
Chronic Kidney Disease	Renal	

5.2 Properties of Geometric Means

Appendix 2 - Properties of Geometric Means

Mean prevalence ratios of 79 diagnoses is less than 1 for all ethnic groups in 2018

In primary care data for 2018, we observe that all ethnic groups have geometric means of less than 1 for the ratio of ethnic group diagnosis prevalence against overall population diagnosis prevalence. This makes our interpretation that all ethnic groups have a lower risk of diagnoses than the overall population counterintuitive, however it remains correct and we can interpret the results as meaning that learning information about a person (in this case, their ethnic group) reduces the probability that they have any diagnosis. This is a form of Simpson's paradox and the below explanation and simulation provide further detail on why this should be the case.

Geometric means of ratios for population strata can all be less than 1

We consider a small example with two conditions and two groups of women. Let N denote a 2 by 2 matrix with elements the counts of women with diseases.

$$N = \begin{pmatrix} N_{1,1} & N_{1,2} \\ N_{2,1} & N_{2,2} \end{pmatrix} \quad (1)$$

For example, the rows could denote black and white women, respectively, and the column hypertension and depression, respectively. $N_{1,1}$ would be the number of black women diagnosed with hypertension and $N_{2,2}$ would be the number of white women diagnosed with depression.

Now define D to be a vector with two elements representing the populations of the groups, respectively.

$$D = (D_1 \quad D_2) \quad (2)$$

By dividing N by D we get a matrix R representing proportions of conditions in each group. For example, the first entry represents the proportion of black women with hypertension.

$$R = \begin{pmatrix} \frac{N_{1,1}}{D_1} & \frac{N_{1,2}}{D_1} \\ \frac{N_{2,1}}{D_2} & \frac{N_{2,2}}{D_2} \end{pmatrix} \quad (3)$$

In a similar fashion, we create a diagonal matrix, S , with diagonals the reciprocal of the proportions of women with the two diseases in the whole population.

$$S = \begin{pmatrix} \frac{D_1+D_2}{(N_{1,1}+N_{2,1})} & 0 \\ 0 & \frac{D_1+D_2}{(N_{1,2}+N_{2,2})} \end{pmatrix} \quad (4)$$

Multiplying the matrix R and S together yields a matrix X representing the ratios of the groups with a disease in their population with respect to the ratio of all women with a disease in the whole population. For example, the first entry represents the ratio of the proportion of black women with hypertension with respect to the proportion of women with hypertension in the whole population.

$$X = \begin{pmatrix} \frac{N_{1,1}}{D_1} \frac{D_1+D_2}{(N_{1,1}+N_{2,1})} & \frac{N_{1,2}}{D_1} \frac{D_1+D_2}{(N_{1,2}+N_{2,2})} \\ \frac{N_{2,1}}{D_2} \frac{D_1+D_2}{(N_{2,1}+N_{2,1})} & \frac{N_{2,2}}{D_2} \frac{D_1+D_2}{(N_{1,2}+N_{2,2})} \end{pmatrix} \quad (5)$$

We now define two statistics G_1 and G_2 which are the geometric means of prevalence of conditions in a population:

$$G_1^2 = \frac{N_{1,1}N_{1,2}}{D_1^2} \frac{(D_1 + D_2)^2}{(N_{1,1} + N_{2,1})(N_{1,2} + N_{2,2})} \quad (6)$$

$$G_2^2 = \frac{N_{2,1}N_{2,2}}{D_2^2} \frac{(D_1 + D_2)^2}{(N_{1,1} + N_{2,1})(N_{2,2} + N_{2,2})} \quad (7)$$

In the case where the group sizes are the same, these simplify to

$$G_1^2 = \frac{4N_{1,1}N_{1,2}}{(N_{1,1} + N_{2,1})(N_{1,2} + N_{2,2})} \quad (8)$$

$$G_2^2 = \frac{4N_{2,1}N_{2,2}}{(N_{1,1} + N_{2,1})(N_{2,2} + N_{2,2})} \quad (9)$$

These two terms represent the geometric means of diagnoses for the grouped populations.

Simulated example

In the example below, we calculate geometric means for two populations groups for the prevalence of 2 conditions. This represents a simplified model of our 79 conditions and 6 population groups when grouping either by ethnicity or deprivation.

```
d <- seq(5, 10000, 1) #generate a series of hypothetical population sizes
g1 <- numeric(length(d)) #prepare an empty vector
g2 <- numeric(length(d)) #prepare an empty vector

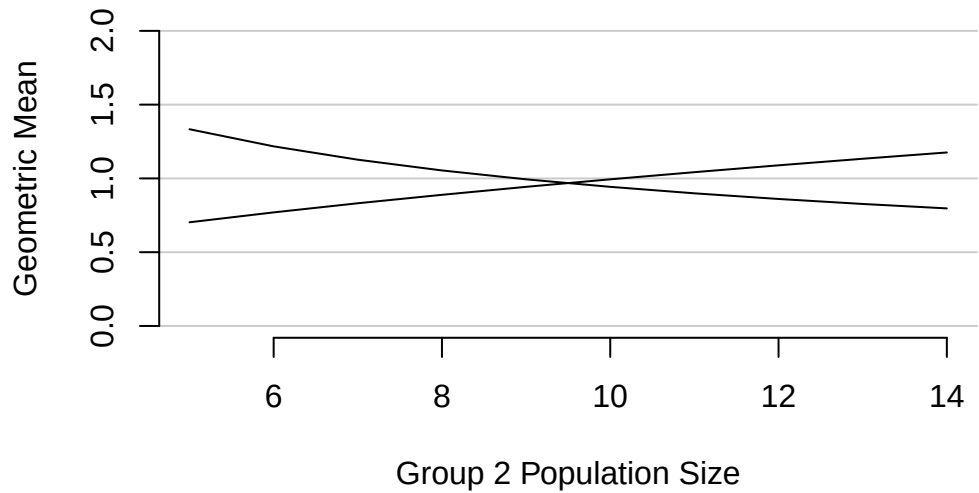
gmean <- function(x) exp(mean(log(x))) #helper function later

#for each population, vary the size of the population for 1 group
for(i in 1:length(d)){
  #these matrices represent 2 population groups and 2 conditions in our data
  N <- matrix(c(5, 10, 5, 4), 2, 2)
  #number of people with diagnoses of two conditions in two groups
  D <- matrix(c(20, 20, d[i], d[i]), 2, 2)
  #group 1 is fixed at 20 people
  R <- N/D #calculate prevalence
  rho <- colSums(N)/colSums(D)
```

```
#calculate risk ratio for a group compared to the overall population
X <- R/rho

g <- apply(X, 1, gmean)
g1[i] <- g[1] #geometric mean of risk ratios for group 1
g2[i] <- g[2] #geometric mean of risk ratios for group 2
}
```

Plot the data for geometric means of risk ratios for group 1 and group 2 when the size of group 2 increases from 5 to 14. Note that when group 2 contains 9 or 10 people, both geometric means are below 1, similar to the results observed in our real-world data.



Chapter 6 - Epidemiological case studies using a data platform deployed into a maternity service

6.1 Badgernet Data Dictionary

Appendix 6.1 is provided as a supplementary file.

6.2 Dexter pregnancy data model

Table	Unit	Description
Practice	Not in use for this dataset	
Patient	Mother or baby	
Pregnancy	Pregnancy episode	A single pregnancy episode may be linked to multiple babies, but only one mother Linkage from baby -> pregnancy - > mother.
Linkage	Baby	Optional if famnum implemented in patient
Medical	Any recorded instance of a diagnostic code applied to a baby or mother	Diagnostic labels
Therapy	Any recorded instance of a procedure or medication for a patient	Therapies including medications and procedures
Measurement	Any recorded instance of a quantitative patient measure	Measures include any variable with a quantitative measure, such as weights, many
Consult	Any recorded instance of an episode of care. The durations are non-exclusive,	Episodes of care can include hospital stays, clinic appointments, referrals or any other
Additional	Any recorded instance of a categorical patient measure	Fields with 2 or more fixed options will be recorded here e.g. ethnicity

Field	DataType	Description
pracid	String	Id for practice
startDate	Date	First date of data collection from practice
collectionDate	Date	Last date of data collection from practice
standardDate1	Date	Date1 since which data collection is up to a standard
standardDate2	Date	Date2 since which data collection is up to a standard
region	String	Country
subRegion	String	Region within country

Field	DataType	Description
patid	String	The unique patient identifier
sex	String	Sex of the patient
dob	Date	date of birth. Anonymisation could standardise to mid month provided durations can be calculated
regDate	Date	Date of first registration/observed care of the patient in the system
xferdate	Date/Time	Date at which the patient exits the record system to enter another system
deathDate	Date	Date of death
regstat	String	Specifies patient's registration status - Temp, Dead, permanent
patflag	String	defines usability status of patient data
famnum	String	Linkage between parent and baby
ethnicity	String	Ethnicity

Field	DataType	Description
pregid	String	Unique identifier of the pregnancy episode
patid	String	The ID of the pregnant person
parity	Int	Number of previous pregnancies carried past 24 weeks
Gravidity	Int	Number of previous confirmed pregnancies
LMP	date	Date of last menstrual period
preg_end	date	Date on which last child of this pregnancy was delivered
n_fetus	int	Number of fetuses identified in pregnancy
booking_appt	date	Date of booking appointment

Field	dtype	Description
babyid	string	Unique identifier for each baby
matid	string	Identifier of person who gave birth to baby. This is identical to patid in other tables
pregid	string	Identifier of pregnancy during which baby gestated
FamNum	string	Linkage between parent and baby

Field	DataType	Description
patid	String	The unique patient identifier
medcode	String	The diagnostic code. DExtER will handle a wide variety of codes, including Read codes, SNOMED-CT etc.
eventdate	datetime	The date on which the diagnosis was made
consid	String	The episode of care linked to this diagnosis
constype	String	The type of episode of care linked to this diagnosis
staffid	String	Unique identifier for staff associated to episode of care
enddate	date	
ahdid	String	

Field	DataType	Description
patid	string	The unique patient identifier
drugcode	string	The therapeutic agent code. DExtER will handle a wide variety of codes, including Read codes, SNOMED-CT etc.
consid	string	The episode of care linked to this diagnosis
prscdate	datetime	The date of prescription or procedure
staffid	string	Unique identifier for staff associated to episode of care
bnfcode	string	
dosage	string	
qty	double/string	
numdays	int	
numpacks	double	
packtype	int	
issueseq	int	

Field	DataType	Description
patid	string	The unique patient identifier
linkid	string	linkid to medical table (adid)
entitycode	string	code to represent the entity recorded
medcode	string	any related medical code
consid	string	The episode of care linked to this diagnosis
constype	string	The type of episode of care linked to this diagnosis
staffid	string	Unique identifier for staff associated to episode of care
eventdate	datetime	The date on which the measurement was taken
value	double	
units	string	
lowrange	string/double	
highrange	string/double	
data1		
data2		
data3		
data4		

Qualifier

Field	Dtype	Description
patid	String	The unique patient identifier
eventdate	datetime	The start date of the episode of care
sysdate	date	The date of recording of the episode of care
consid	String	The unique episode of care identifier
constype	String	The type of episode of care
duration	String	The duration of episode of care. This time difference can range between seconds to years
staffid	String	The unique identifier of staff member associated with the episode of care.

Field	DataType	Description
patid	string	The unique patient identifier
linkid	string	
entitycode	string	
medcode	string	
consid	string	
constype	string	
staffid	string	
eventdate	datetime	The date on which the measurement or observation was taken
data1	string	
data2	string	
data3	string	
data4	string	
data5	string	
data6	string	
data7		
data8		

Field	DataType	Description
		Lookup match for entity codes, primarily for Additional table. The naming convention should follow either a simple EntityCode or EntityCode_DataX to indicate the
Entity code	String	DataX column which contains the values being mapped
		Description returned for lookups. This is likely to be a
description	String	dictionary mapping a Key (code or category) to a
		Description

6.3 Medcode worked examples Badger-Dexter

UKMat_Baby_DIG E_BabyDeliveryDetails ModeOfDelivery tails (10)	Normal, spontaneous vertex vaginal birth, occipito-anterior : 0 Cephalic vaginal birth, with abnormal presentation of the head at delivery : 1 Low forceps - no rotation, forceps NOS : 2 Mid cavity forceps - no rotation : a Rotational forceps (incl Kiellands) : b Ventouse - no rotation or unspecified : c Ventouse with rotation : d Breech birth, spontaneous, assisted or partial : 5 Breech extraction, NOS : 6 Elective (planned) caesarean section : 7 Emergency and unspecified caesarean section : 8 Other and unspecified method of birth : 9
UKMat_Baby_DIG E_BabyNonRegisterableBirthDetails ModeOfDelivery rableBirthDetails (10)	Normal, spontaneous vertex vaginal birth, occipito-anterior : 0 Cephalic vaginal birth, with abnormal presentation of the head at delivery : 1 Low forceps - no rotation, forceps NOS : 2 Mid cavity forceps - no rotation : a Rotational forceps (incl Kiellands) : b Ventouse - no rotation or unspecified : c Ventouse with rotation : d Breech delivery, spontaneous, assisted or partial : 5 Breech extraction, NOS : 6 Elective (planned) caesarean section : 7 Emergency and unspecified caesarean section : 8 Other and unspecified method of delivery : 9

MatID or PatID (not PregID)	T:UKMat_Baby_DIGE_BabyDeliveryDetails F:ModeOfDelivery V: Normal, spontaneous vertex vaginal delivery, occipito-anterior	RecordDate	Repeat for 0-9

MatID or PatID (not PregID)	T:UKMat_Baby_DIGE_BabyNonRegiserableBirthDetails F:ModeOfDelivery V: Normal, spontaneous vertex vaginal delivery, occipito-anterior	RecordDate	Repeat for 0-9

	Notes
Field	Name of field into which a value is entered
Table	Name of the table or entity in which the field exists. Table contains other relevant data e.g. date, staff member may be available
Type	Data type of stored variable
Description	Description of Field. Typically no details available
Coding	Possible values that Field can contain.
Choices	Possible values that Field can contain.

It is unclear if any significant differences exist in coding vs choices or how this is represented in the data available from badgernet, but there is no need to preserve the distinction for Dexter data.

With choices, examples suggest that multiple choices are possible; each of these should be made available as a medcode. In many instances, choices are mutually exclusive, and while this is not significant it is possible that coding may have some meaning such as always mutually exclusive choices.

Field	DataType	Description
patid	String	The unique patient identifier
medcode	String	The diagnostic code. DExtER will handle a wide variety of codes, including Read codes, SNOMED-CT etc or internally generated codes.
eventdate	datetime	The date on which the diagnosis was made
consid	String	The episode of care linked to this diagnosis
constype	String	The type of episode of care linked to this diagnosis
staffid	String	Unique identifier for staff associated to episode of care
enddate	date	
ahdid	String	ID for a lookup dictionary if the data is encoded.

6.4 Phenotype Coding Checklist

Coding Checklist

Phenome Background

Name as appears in Dexter	
Developer	
Definition	
Concept type (include any relevant)	☐ Prevalent (include history of) ☐ Incident (new cases only) ☐ Diagnosis ☐ Procedure ☐ Prescription ☐ Observed ☐ Reported ☐ Attempted ☐ Planned ☐ Implied by Referral
Hashtags (projects or other details)	

Search terms

List codebuilder search terms for including codes (add rows as needed) Unified Medical Language System Metathesaurus https://uts.nlm.nih.gov/uts/umls/home

List search terms excluded or filtered out (add rows as needed)

Date of first completion	

Review comments

Reviewer	Date	Comments

Change Log

Developer	Date	Changes made

Example projects and studies using this code

Date	Project	Usage

6.5 Induction of Labour phenotypes

Phenome	Code
Bloodloss	M_BloodLoss_BloodLossTotal_11
Bloodloss	M_DerivedFields_TotalBloodLoss_12
Postcode	M_PatInd_Postcode_5
Modeofdelivery	B_DeliveryDetails_ModeOfDeliveryDisplay_6
Modeofdelivery	B_NonRegiserableBirthDetails_ModeOfDeliveryDisplay_7
labour_established	M_LabourAndDelivery_DateTimeLabourEstablished_8
perindeath	B_PatInd_DateAndTimeOfDeath_9
nnu	B_DerivedFields_AdmittedToNNU_10
ethnicity	M_DerivedFields_EthnicCategory_11
language	M_Registration_MothersDetails_PrimaryLanguage_10
birth_site	M_PatInd_CareLocationIDatDelivery_11
bookingrisk	M_RiskAssessment_Risk_12
inductionreason	M_Induction_MainReasonDisplay_13
inductionreason	M_InductionOfLabourBooking_MainReason_14
gestageatbirth	M_PatInd_GestationAtDeliveryDays_17
c_section	B_InstrumentalOrOperativeDelivery_CaesareanSectionDeliveryMethod_CEPH_FO RCEPS
c_section	M_DerivedFields_ReasonForConsultantReview_CATEGORY_1_CAESAREAN_SECTI ON
c_section	M_CriticalIncident_Mother_TypeDetails_CAESAREAN_SECTION_IN_2ND_STAGE
c_section	M_DerivedFields_AllCriticalIncidents_TRANSFER_IN_LABOUR_CATEGORY_1_CAES AREAN_SECTION
c_section	M_DerivedFields_AntenatalAssessmentLeaflets_CSECTION
c_section	M_DerivedFields_AllCriticalIncidents_CATEGORY_1_CAESAREAN_SECTION
c_section	M_LabourAndDelivery_OperativeCSDetailsc_STRAIGHTFORWARD_LSCS.
c_section	M_DerivedFields_AllCriticalIncidents_PPH_>=_1000_MLS_CATEGORY_1_CAESARE AN_SECTION
c_section	B_InstrumentalOrOperativeDelivery_CaesareanSectionDeliveryMethod_BREECH
c_section	B_DeliveryDetails_ModeOfDeliveryDisplay_ELECTIVE_(PLANNED)_CAESAREAN_SE CTION
c_section	M_TelephoneCall_ReasonPostnatalMother_LSCSWOUND
c_section	M_DerivedFields_AllCriticalIncidents_CAESAREAN_SECTION_IN_2ND_STAGE_CAT EGORY_1_CAESAREAN_SECTION
c_section	B_DeliveryDetails_ModeOfDeliveryDisplay_EMERGENCY_AND_UNSPECIFIED_CAE SAREAN_SECTION
c_section	M_CriticalIncident_Mother_TypeDetails_CATEGORY_1_CAESAREAN_SECTION
c_section	M_DerivedFields_AllCriticalIncidents_CAESAREAN_SECTION_IN_2ND_STAGE_PPH _>=_1000_MLS
c_section	M_DerivedFields_ReasonForConsultantReview_CAESAREAN_SECTION_IN_2ND_ST AGE
c_section	B_InstrumentalOrOperativeDelivery_CaesareanSectionDeliveryMethod_CEPH_ON EBLADE
c_section	B_RiskAssessment_LabourAndDeliveryRisks_CAESAREAN_SECTION
c_section	M_DerivedFields_AllCriticalIncidents_CAESAREAN_SECTION_IN_2ND_STAGE_PPH _>_500MLS

c_section	M_DerivedFields_AllCriticalIncidents_CATEGORY_1_CAESAREAN_SECTION_CATEGORY_1_CAESAREAN_SECTION
c_section	M_LabourAndDelivery_OperativeCSDetailsc_ROUTINE_C-SECTION
c_section	M_LabourAndDelivery_SecondStageOutcome_CSECTION
c_section	M_DerivedFields_AllCriticalIncidents_PPH_>_500MLS_CATEGORY_1_CAESAREAN_SECTION
c_section	M_AntenatalAssessment_FormsAndInformationLeafletsGiven_CSECTION
c_section	M_DerivedFields_AllCriticalIncidents_CATEGORY_1_CAESAREAN_SECTION_PPH_>=_1000_MLS
c_section	B_InstrumentalOrOperativeDelivery_CaesareanSectionDeliveryMethod_BREECH_MSV
c_section	M_LabourAndDelivery_OperativeCSDetailsc_STRAIGHTFORWARD_LSCS
c_section	M_LabourAndDelivery_OperativeCSDetailsc_C-SECTION_PERFORMED_BY_DR_ILESANMI
c_section	M_DerivedFields_AllCriticalIncidents_CAESAREAN_SECTION_IN_2ND_STAGE
c_section	M_DerivedFields_AllCriticalIncidents_CATEGORY_1_CAESAREAN_SECTION_PPH_>_500MLS
c_section	B_InstrumentalOrOperativeDelivery_CaesareanSectionDeliveryMethod_CEPHALIC
c_section	M_DerivedFields_AllCriticalIncidents_CAESAREAN_SECTION_IN_2ND_STAGE_TRANSFER_IN_LABOUR
c_section	M_AnaestheticGiven_IndicationDisplay_LSCS
c_section	M_LabourAndDelivery_OperativeCSDetailsc_BLUNT_DISSECTION_TO_SHEATH
elective_csection	B_DeliveryDetails_ModeOfDeliveryDisplay_ELECTIVE_(PLANNED)_CAESAREAN_SECTION
emergency_csection	M_DerivedFields_AllCriticalIncidents_CATEGORY_1_CAESAREAN_SECTION_CATEGORY_1_CAESAREAN_SECTION
emergency_csection	M_DerivedFields_ReasonForConsultantReview_CATEGORY_1_CAESAREAN_SECTION
emergency_csection	M_DerivedFields_AllCriticalIncidents_PPH_>_500MLS_CATEGORY_1_CAESAREAN_SECTION
emergency_csection	M_DerivedFields_AllCriticalIncidents_CATEGORY_1_CAESAREAN_SECTION_PPH_>=_1000_MLS
emergency_csection	M_DerivedFields_AllCriticalIncidents_TRANSFER_IN_LABOUR_CATEGORY_1_CAESAREAN_SECTION
emergency_csection	M_DerivedFields_AllCriticalIncidents_CATEGORY_1_CAESAREAN_SECTION
emergency_csection	M_DerivedFields_AllCriticalIncidents_PPH_>=_1000_MLS_CATEGORY_1_CAESAREAN_SECTION
emergency_csection	M_DerivedFields_AllCriticalIncidents_CAESAREAN_SECTION_IN_2ND_STAGE_CATEGORY_1_CAESAREAN_SECTION
emergency_csection	M_DerivedFields_AllCriticalIncidents_CATEGORY_1_CAESAREAN_SECTION_PPH_>_500MLS
emergency_csection	M_PreOpChecklist_ReasonForCS_EMERGENCY_C-SECTION
emergency_csection	B_DeliveryDetails_ModeOfDeliveryDisplay_EMERGENCY_AND_UNSPECIFIED_CAESAREAN_SECTION
emergency_csection	M_CriticalIncident_Mother_TypeDetails_CATEGORY_1_CAESAREAN_SECTION
neonatal_death	B_FinalOutcome_CausesOfDeath_EXTREMEPREMATURITY
neonatal_death	B_CriticalIncident_TypeDetails_NEONATAL_DEATH

neonatal_death	B_FinalOutcome_CausesOfDeath_OTHRESP
neonatal_death	B_FinalOutcome_MainCausesOfDeath_EXTREMEPREMATURITY
neonatal_death	B_DerivedFields_AllCriticalIncidents_NEONATAL_DEATH_NEONATAL_DEATH
neonatal_death	B_FinalOutcome_CausesOfDeath_OTHSPECIFICFETALCONDITION
neonatal_death	B_FinalOutcome_MainCausesOfDeath_CHROMOSOMALDISORDERS
neonatal_death	B_FinalOutcome_CausesOfDeath_URINARYTRACT
neonatal_death	B_DerivedFields_AllCriticalIncidents_NEONATAL_DEATH_NEONATAL_DEATH_NEO NATAL_DEATH
neonatal_death	B_FinalOutcome_CausesOfDeath_CNS
neonatal_death	B_FinalOutcome_MainCausesOfDeath_FETICIDE
neonatal_death	B_FinalOutcome_MainCausesOfDeath_GIT
neonatal_death	B_FinalOutcome_CausesOfDeath_PREMATURITY
neonatal_death	B_DerivedFields_AllCriticalIncidents_NEONATAL_DEATH
neonatal_death	B_FinalOutcome_CausesOfDeath_CVS
neonatal_death	B_FinalOutcome_MainCausesOfDeath_CNS
neonatal_death	B_FinalOutcome_CausesOfDeath_OTHMAJORCONGENITALANOMALY
neonatal_death	B_FinalOutcome_CausesOfDeath_GIT
neonatal_death	B_FinalOutcome_MainCausesOfDeath_CVS
neonatal_death	M_DerivedFields_ReasonForConsultantReview_NEONATAL_DEATH
neonatal_death	B_FinalOutcome_MainCausesOfDeath_MULTIPLEANOMALIES
neonatal_death	B_FinalOutcome_CausesOfDeath_U
neonatal_death	B_FinalOutcome_MainCausesOfDeath_OTHMAJORCONGENITALANOMALY
neonatal_death	B_FinalOutcome_CausesOfDeath_FETICIDE
neonatal_death	B_DerivedFields_AllCriticalIncidents_STILLBIRTH_>37_WEEKS_NEONATAL_DEATH _NEONATAL_DEATH
neonatal_death	B_FinalOutcome_CausesOfDeath_MULTIPLEANOMALIES
neonatal_death	B_FinalOutcome_MainCausesOfDeath_U
neonatal_death	B_DerivedFields_AllCriticalIncidents_STILLBIRTH_>37_WEEKS_SHOULDER_DYSTO CIA_NEONATAL_DEATH
neonatal_death	
neonatal_death	B_DerivedFields_AllCriticalIncidents_BBA_NEONATAL_DEATH_NEONATAL_DEATH
neonatal_death	B_DerivedFields_AllCriticalIncidents_BBA_NEONATAL_DEATH
neonatal_death	B_FinalOutcome_CausesOfDeath_CHROMOSOMALDISORDERS
neonatal_death	B_FinalOutcome_CausesOfDeath_OTHNEUROLOGICALDISORDER
neonatal_death	B_FinalOutcome_CausesOfDeath_OTHINFECTION
neonatal_death	B_FinalOutcome_MainCausesOfDeath_URINARYTRACT
neonatal_death	B_FinalOutcome_MainCausesOfDeath_PREMATURITY
stillbirth	B_DerivedFields_AllCriticalIncidents_STILLBIRTH_>37_WEEKS_STILLBIRTH_NEON ATAL_DEATH
stillbirth	M_DerivedFields_ReasonForConsultantReview_STILLBIRTH
stillbirth	
stillbirth	B_DerivedFields_AllCriticalIncidents_STILLBIRTH_>37_WEEKS_NEONATAL_DEATH
stillbirth	M_PatInd_ReasonForClosing_BIRTHING_AT_ANOTHER_HOSPITAL_- _OUTCOME_MISCARRIAGE/STILLBIRTH/NND
stillbirth	B_CriticalIncident_Type_STILLBIRTH
stillbirth	B_DerivedFields_AllCriticalIncidents_STILLBIRTH_NEONATAL_DEATH
stillbirth	B_DeliveryDetails_FetalProblemsInLabour_STILLBIRTH_BEFORE_LABOUR
stillbirth	B_CriticalIncident_TypeDetails_STILLBIRTH

stillbirth	B_DerivedFields_AllCriticalIncidents_STILLBIRTH
stillbirth	M_Admission_ReasonOtherDisplay_INTRAUTERINE_FETAL_DEATH
stillbirth	B_CriticalIncident_Type_STILLBIRTHFROM37
stillbirth	M_CriticalIncident_Mother_TypeDetails_INTRA_UTERINE_DEATH
stillbirth	M_Induction_MainReasonDisplay_INTRAUTERINE_FETAL_DEATH
stillbirth	M_Admission_ReasonMainDisplay_INTRAUTERINE_FETAL_DEATH
stillbirth	M_DerivedFields_ReasonForConsultantReview_INTRA_UTERINE_DEATH
stillbirth	M_Admission_ReasonOtherStore_MANAGEMENT_OF_INTRAUTERINE_DEATH
stillbirth	M_Admission_ReasonMainStore_MANAGEMENT_OF_INTRAUTERINE_DEATH
stillbirth	B_DeliveryDetails_FetalProblemsInLabour_STILLBIRTH_-_INTRAPARTUM
stillbirth	B_CriticalIncident_TypeDetails_STILLBIRTH_>37_WEEKS
stillbirth	B_DerivedFields_AllCriticalIncidents_STILLBIRTH_STILLBIRTH
stillbirth	M_DerivedFields_OutcomeDisplay_ANTEPARTUM_STILLBIRTH
stillbirth	M_DerivedFields_AllCriticalIncidents_INTRA_UTERINE_DEATH
induction	M_DerivedFields_InductionMethodsDisplay_OXYTOCIN
induction	M_Induction_MainReasonDisplay_MATERNAL_REQUEST
induction	M_Induction_WardForInductionofLabour_INDUCION_SUITE
induction	M_LabourAndDelivery_Malpresentation_FAILEDINDUCTION
induction	M_Induction_OtherReason_GROWTHLIQUORCONCERNS
induction	M_AntenatalAssessment_ReasonDisplay_INDUCION_OF_LABOUR
induction	M_Induction_MainReasonDisplay_PET
induction	M_Induction_OtherReason_PIH
induction	M_Induction_MainReasonDisplay_STATIC_GROWTH
induction	M_Induction_MainReasonDisplay_HYPERTENSIVE_DISORDER
induction	M_Induction_MainReasonDisplay_MATERNAL_AGE_=_40_AT_CONCEPTION
induction	M_Induction_MainReasonDisplay_RECURRENT_REDUCED_FETAL_MOVEMENTS
induction	M_Induction_InductionMethod_OXYTOCIN
induction	M_Induction_OtherReason_01G
induction	M_Induction_WardForInductionofLabour_LAVENDER_antenatal_ward
induction	M_Induction_OtherReason_01E
induction	M_Induction_MainReasonDisplay_PIH/PET_(NOT_DEFINED)
induction	M_Induction_ProstaglandinTypesGiven_Stored_MISOPROSTOL_VAGINAL
induction	M_Induction_MainReasonDisplay_PIH
induction	M_Induction_OtherReason_BMI
induction	M_Induction_OtherReason_MATERNALREQUEST
induction	M_Induction_OtherReason_MATERNALAGE
induction	M_Induction_OtherReason_01C
induction	M_Induction_InductionMethod_OSMOTICCERVICALDILATOR
induction	M_Induction_MainReasonDisplay_PAST Obstetric History
induction	M_Induction_OtherReason_01A
induction	M_Induction_OtherReason_SROM
induction	M_LabourAndDelivery_CSMainIndicationDisplay_FAILED_INDUCION
induction	M_PreOpChecklist_ReasonForCS_FAILED_INDUCION
induction	M_Induction_MainReasonDisplay_BMI
induction	M_Induction_ProstaglandinTypesGiven_Stored_PROSTIN
induction	M_LabourAndDelivery_CSOtherMaternalReasons_FAILEDINDUCTION
induction	M_Induction_MainReasonDisplay_OLIGOHYDRAMNIOS

induction	M_Induction_OtherReason_POLYHYDRAMNIOS
induction	M_Induction_MainReasonDisplay_DIABETES
induction	M_Induction_MainReasonDisplay_OBSTETRIC_CHOLESTASIS
induction	M_Induction_MainReasonDisplay_GROWTH_AND_LIQUOR_CONCERNS
induction	M_Induction_MainReasonDisplay_PROLONGED_ROM
induction	M_Induction_MainReasonDisplay_OTHER_MATERNAL_REASON
induction	M_Induction_OtherReason_STATICGROWTH
induction	M_Induction_OtherReason_PRETERMPROM
induction	M_Induction_OtherReason_PROLONGEDROM
induction	M_Induction_InductionMethod_PROSTOGLANDINS
induction	M_Induction_MainReasonDisplay_FETAL_GROWTH_RESTRICTION
induction	M_Induction_MainReasonDisplay_OTHER_FETAL_REASON
induction	M_Induction_MainReasonDisplay_POLYHYDRAMNIOS
induction	M_Induction_OtherReason_BI-POLA
induction	M_DerivedFields_InductionMethodsDisplay_PROSTAGLANDIN
induction	M_Induction_OtherReason_REDUCEDLIQUORVOLUME
induction	M_Induction_MainReasonDisplay_MULTIPLE_PREGNANCY
induction	M_Induction_OtherReason_RECURRENTRFM
induction	M_Induction_MainReasonDisplay_TOP_FOR_FETAL_ABNORMALITY
induction	M_Induction_OtherReason_REDUCEDFETALMOVEMENTS
induction	M_Induction_OtherReason_IVF
induction	M_Induction_MainReasonDisplay_SMALL_FOR_GESTATIONAL_AGE
induction	M_Induction_MainReasonDisplay_SINGLE_EPISODE_OF_REDUCED_FETAL_MOVE MENTS
induction	M_DerivedFields_InductionMethodsDisplay_PROSTIN
induction	M_Induction_InductionMethod_ARM
induction	M_Induction_MainReasonDisplay_POST_DATES
induction	M_Induction_MainReasonDisplay_ANTEPARTUM_HAEMORRHAGE
induction	M_RuptureOfMembranes_ReasonForArm_INDUCTION
induction	M_Induction_MainReasonDisplay_SUBOPTIMAL_FETAL_GROWTH
induction	M_Induction_WardForInductionofLabour_DELIVERY_SUITE
induction	M_RiskAssessment_Intrapartum_Display_MORE_THAN_1_CYCLE_OF_INDUCTION
induction	M_Induction_OtherReason_SUBOPTIMALGROWTH
induction	M_DerivedFields_InductionMethodsDisplay_MECHANICAL
induction	M_Induction_MainReasonDisplay_LARGE_FOR_GESTATIONAL_AGE
induction	M_Induction_MainReasonDisplay_REDUCED_LIQUOR_VOLUME
induction	M_Induction_OtherReason_SOCIALINDICATION
induction	M_Induction_OtherReason_ABNORMALDOPPLERS
induction	M_Induction_MainReasonDisplay_INTRAUTERINE_FETAL_DEATH
induction	M_Induction_MainReasonDisplay_PRE-TERM_PROM
induction	M_FAU_MainReason_INDUCTION_OF_LABOUR
induction	M_Induction_MainReasonDisplay_SROM
induction	M_Induction_OtherReason_MUSCULOSKELETALPAIN
induction	M_Induction_OtherReason_SMALLGESTAGE
induction	M_Induction_InductionMethod_CERVICALBALLOON
induction	M_Induction_OtherReason_99
induction	M_Induction_MainReasonDisplay_CONGENITAL_FETAL_ANOMALY

induction	M_Induction_MainReasonDisplay_REDUCED_LV
induction	M_Induction_OtherReason_PET
induction	M_Induction_ProstaglandinTypesGiven_Stored_MIFEPRISTONE_ORAL
induction	M_Induction_WardForInductionofLabour_WARD_1
induction	M_Induction_MainReasonDisplay_IN_VITRO_FERTILISATION
induction	M_Induction_OtherReason_02C
induction	M_Induction_OtherReason_02B
induction	M_Induction_OtherReason_02A
augmentationDRAFT	M_Induction_PlannedInductionDetails_AUGMENT_
augmentationDRAFT	M_RiskAssessment_CurrentPregnancyRiskFactors_Display_AUGMENTATION_OF_LABOUR
augmentationDRAFT	M_LabourAndDelivery_Malpresentation_FAILED_AUGMENT
augmentationDRAFT	M_Appointment_AdditionalDetails_DELIVERY_SUITE_INFORMED_AND_PATIENT_ADDED_TO_THE_AUGMENTATION_LIST
augmentationDRAFT	M_LabourAndDelivery_CSMainIndicationDisplay_FAILED_AUGMENT
augmentationDRAFT	M_Appointment_ReasonDisplay_AUGMENTATION
augmentationDRAFT	M_RuptureOfMembranes_ReasonForArm_AUGMENTATION
augmentationDRAFT	M_RiskAssessment_CurrentPregnancyRiskFactors_Stored_AUGMENTATIONLABOUR
Breech	M_LabourAndDelivery_OperativeCSDetailsc_BREECH_TWIN_1__STANDARD_PREP_AND_DRAPE
Breech	M_LabourAndDelivery_CSMainIndicationDisplay_BREECH
Breech	M_LabourAndDelivery_OperativeCSDetailsc_LIVE_MALE_-_CORD_CLAMPED_AND_CUT.__TWIN_2_FOOTLING_BREECH
Breech	M_LabourAndDelivery_OperativeCSDetailsc_BREECH_LO
Breech	M_LabourAndDelivery_OperativeCSDetailsc_LSL_FRANK_BREECH
Breech	B_DeliveryDetails_ModeOfDeliveryDisplay_BREECH_EXTRACTION
Breech	M_LabourAndDelivery_OperativeCSDetailsc_AS_ABOVE_FETUS_IN_BREECH_PRESENTATION
Breech	M_LabourAndDelivery_OperativeCSDetailsc_TRANSVERSE_UTERINE_INCISION_BREECH_DELIVERY_MSV_PLA
Breech	B_DeliveryDetails_ModeOfDeliveryDisplay_BREECH_BIRTH
Breech	M_LabourAndDelivery_OperativeCSDetailsc_THEN_SECOND_LEG__IDENTIFIED_THEN_BABY_DELIVERED_BREECH.
Breech	B_RiskAssessment_LabourAndDeliveryRisks_BREECH_BIRTH
Breech	M_LabourAndDelivery_OperativeCSDetailsc_DISCUSSED_MOD_OPTIONS_BREECH_VAGINAL_DELIVERY_VS_LSCS
Breech	B_DerivedFields_PresentationImmediatelyBeforeDelivery_BREECH_-_FRANK_(EXTENDED_LEGS)
Breech	M_LabourAndDelivery_OperativeCSDetailsc_FETUS_DELIVERED_IN_BREECH_PRESENTATION
Breech	M_LabourAndDelivery_OperativeCSDetailsc_EXTENDED_BREECH
Breech	M_LabourAndDelivery_OperativeCSDetailsc_BREECH_BABY_DELIVERED_VIA_MSV
Breech	B_InstrumentalOrOperativeDelivery_CaesareanSectionDeliveryMethod_BREECH_MSV
Breech	M_LabourAndDelivery_OperativeCSDetailsc_CLEAR_LIQUOR_TWIN_1_FEMALE_DELIVERED_BREECH_1619

Breech	M_LabourAndDelivery_OperativeCSDetailsc_ROUTINE_BREECH_EXTRACTION_EASY_DELIVERY
Breech	M_LabourAndDelivery_OperativeCSDetailsc_LSCS_DELIVERED_BREECH
Breech	M_Admission_ReasonOtherStore_ECV
Breech	M_InductionOfLabourBooking_PlannedInductionDetails_PREVIOUSLY_ELCS_FOR_BREECH._NOW_CEPHALIC.
Breech	M_LabourAndDelivery_PostOpSuggestedVBACComments_AS_THIS_WAS_FOR_BREECH.
Breech	M_LabourAndDelivery_OperativeCSDetailsc_STRAIGHTFORWARD_BREECH
Breech	M_LabourAndDelivery_OperativeCSDetailsc_CUT_THROUGH_AND_DELIVERED_THE_BABY_AS_BREECH._EASY_DELIVERY
Breech	M_LabourAndDelivery_OperativeCSDetailsc_CS_FOR_BREECH(OPERATION_BY_KWAME_ADU-KORANTENG
Breech	M_LabourAndDelivery_OperativeCSDetailsc_ROUTINE_BREECH_EXTRACTION
Breech	M_AntiD_Indication_ECV
Breech	M_LabourAndDelivery_OperativeCSDetailsc_STRAIGHTFORWARD_PROCEDURE._BABY_DELIVERED_AS_BREECH
Breech	B_DerivedFields_PresentationImmediatelyBeforeDelivery_BREECH_UNSPECIFIED
Breech	M_LabourAndDelivery_OperativeCSDetailsc_DELIVERED_WITH_BREECH_EXTRACTION
Breech	B_InstrumentalOrOperativeDelivery_CaesareanSectionDeliveryMethod_BREECH
Breech	B_DerivedFields_PresentationImmediatelyBeforeDelivery_BREECH_“COMPLETE”(FLEXED_LEGS)
Breech	M_FAU_MainReason_ECV
Breech	M_LabourAndDelivery_OperativeCSDetailsc_RST._BREECH_DELIVERED
Breech	B_InstrumentalOrOperativeDelivery_CaesareanSectionDeliveryMethod_BREECH_FORCEPSTOACH
Breech	M_AntenatalAssessment_ReasonDisplay_ECV
Breech	M_LabourAndDelivery_PostOpSuggestedVBACComments_DELIVERED_AS_BREECH
Breech	M_LabourAndDelivery_OperativeCSDetailsc_BABY_1_DELIVERED_EASILY_WITH_BREECH_EXTRACTION
Breech	M_LabourAndDelivery_OperativeCSDetailsc_BREECH
Breech	M_LabourAndDelivery_Malpresentation_BREECH
Breech	B_RiskAssessment_MaternalRisks_BREECH_PRESENTATION_ON_OR_AFTER_36/40
Breech	M_LabourAndDelivery_OperativeCSDetailsc_UNCOMPLICATED_C/S_FOR_BREECH._NO_EXTENSIONS
Breech	M_Appointment_AdditionalDetails_PRE-OP_PACK_PARTIALLY_COMPLETED_AT_UNSUCCESSFUL_ECV_APPOINTMENT.
Breech	M_InductionOfLabourBooking_PlannedInductionDetails_ELIZABETH_WOULD_LIKE_REPEAT_ECV
Breech	M_LabourAndDelivery_OperativeCSDetailsc_STRAIGHTFORWARD_ELCS_FOR_BREECH._BABY_DELIVERED_BREECH
Breech	M_LabourAndDelivery_OperativeCSDetailsc_EBL_525_MLS__OPERATION_AS_ABOVE._TWIN_1_DELIVERED_BREECH

Breech	B_CriticalIncident_Details_CAT_2_EMCS_DUE_TO_BREECH_SROM_AND_CONTRACTING
Breech	M_LabourAndDelivery_OperativeCSDetailsc_ELCS_FOR_BREECH
Breech	M_LabourAndDelivery_PostOpSuggestedVBACComments_C/S_WAS_DONE_FOR_BREECH._IF_CEPHALIC_NEXT_TIME
Breech	M_LabourAndDelivery_CSOtherMaternalReasons_DECLINED_ECV
Breech	M_LabourAndDelivery_OperativeCSDetailsc_GRABBED_RT FOOT_AND_DELIVERED_BREECH_GENTLY
Breech	M_Appointment_AdditionalDetails_?_BREECH
Breech	M_LabourAndDelivery_OperativeCSDetailsc_CLEAR LIQUOR_DROPPED_DRAPES_BABY_DELIVERED_BREECH_WITH_EASE
Breech	M_PreOpChecklist_ReasonForCS_BREECH
Breech	M_Appointment_ReasonDisplay_ECV
Breech	M_LabourAndDelivery_OperativeCSDetailsc_BREECH-_LEFT_SACROPOSTERIOR
Breech	B_DerivedFields_PresentationImmediatelyBeforeDelivery_BREECH_-_FOOTLING
Breech	M_LabourAndDelivery_OperativeCSDetailsc_LSCS_A_BREECH_PALPATED
Breech	M_LabourAndDelivery_OperativeCSDetailsc_EASY_BREECH_DELIVERY_OF_A_LIVE_FEMALE
Breech	B_DetailedENB_ReasonBabyUnderObservationDisplay_BREECH.
Breech	B_DeliveryDetails_ReasonSkinContactNotEstablishedNotes_FAILED_ECV
Breech	M_LabourAndDelivery_OperativeCSDetailsc FOOT_DELIVERED_FIRST_THEN_BREECH
Breech	M_Admission_ReasonMainStore_ECV
Breech	M_LabourAndDelivery_OperativeCSDetailsc_CAT_4_CS_FOR_BREECH__PATIENT_IDENTIFIED
Breech	M_LabourAndDelivery_OperativeCSDetailsc_FRANK_BREECH
Breech	M_LabourAndDelivery_OperativeCSDetailsc_DELIVERED_AS_BREECH
Breech	M_LabourAndDelivery_OperativeCSDetailsc_ROUTINE_JOEL_COHEN_ENTRY._STRAIGHT_FORWARD_BREECH_DELIVERY
Breech	M_LabourAndDelivery_MaternalProblemsSecondStage_FLEXED_BREECH
Breech	M_LabourAndDelivery_OperativeCSDetailsc_UNCOMPLICATED_BREECH_DELIVERY
Breech	M_LabourAndDelivery_OperativeCSDetailsc_ROUTINE_C_SECTION_BABY_FRANK_BREECH
Breech	B_NonRegisableBirthDetails_ModeOfDeliveryDisplay_BREECH_DELIVERY
Breech	M_LabourAndDelivery_OperativeCSDetailsc_BREECH_EXTRACTION
Breech	M_LabourAndDelivery_OperativeCSDetailsc_THE_LOWER_UTERINE_SEGMENT_-_DEHISCENCE._ BOTH_BABIES_BREECH
Breech	M_LabourAndDelivery_OperativeCSDetailsc_C/S_AT_36+6_FOR_STATIC_GROWTH_AND_BREECH
Breech	M_InternalTransfer_TransferReason_MALPRESENTATION/BREECH_PRESENTATION
Breech	M_LabourAndDelivery_OperativeCSDetailsc_UNCOMPLICATED_CAT_3_CS_EXTENDED_BREECH
Breech	M_AnaestheticGiven_IndicationDisplay_ABNORMAL_PRESENTATION_BREECH_ETC

Breach	M_FAU_OtherReasons_Display_ECV

6.6 Induction of labour model parameters

		Stillbirth or				
		Caesarean	Neonatal	Neonatal Unit		
Regression Coefficients, RR (95% Confidence Intervals)		Section, RR (95%CI)	Instrumental, RR (95%CI)	Death, RR (95%CI)	Admission, RR (95%CI)	Blood Loss, Mean Diff (95%CI)
Mother's Age at Pregnancy Start	0-16	0.00 (0.00, 0.00)	0.45 (0.07, 2.87)	0.00 (0.00, 0.00)	0.00 (0.00, 0.00)	-108.79 (-375.16, 157.59)
	17-30	0.76 (0.68, 0.85)	0.78 (0.70, 0.88)	1.23 (0.72, 2.11)	1.12 (0.88, 1.42)	-29.81 (-50.01, - 9.62)
	31-40	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)
	41-50	1.30 (1.01, 1.68)	1.27 (0.85, 1.88)	1.79 (0.79, 4.06)	1.39 (0.78, 2.47)	25.31 (-30.66, 81.28)
	51-60	0.00 (0.00, 0.00)	0.00 (0.00, 0.00)	0.00 (0.00, 0.00)	0.00 (0.00, 0.00)	292.82 (-301.62, 887.26)
	<27	0.06 (0.01, 0.46)	0.00 (0.00, 0.00)	355.03 (153.75, 819.80)	0.25 (0.04, 1.81)	-20.89 (-98.72, 56.95)
Gestational age in weeks	27-31	1.07 (0.36, 3.16)	0.83 (0.22, 3.07)	144.64 (34.95, 598.66)	0.00 (0.00, 0.00)	-176.47 (-386.81, 33.87)
	31-34	0.83 (0.35, 1.95)	1.28 (0.73, 2.25)	63.50 (16.47, 244.75)	5.23 (2.83, 9.66)	-11.30 (-126.29, 103.68)
	34-37	0.98 (0.73, 1.32)	0.87 (0.64, 1.19)	6.65 (1.39, 31.75)	3.80 (2.74, 5.27)	-55.91 (-104.24, - 7.58)
	37-41	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)
	>41	1.35 (1.18, 1.54)	0.97 (0.82, 1.15)	0.00 (0.00, 0.00)	1.25 (0.87, 1.78)	49.18 (18.78, 79.58)
	Parity	Nullip	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)
Multip		0.31 (0.27, 0.35)	0.18 (0.15, 0.21)	0.93 (0.55, 1.57)	0.89 (0.70, 1.12)	-152.20 (-172.77, 131.62)
Pregnancy risk at booking	Low	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)
	High	1.24 (1.12, 1.37)	0.95 (0.84, 1.07)	1.40 (0.81, 2.43)	1.16 (0.90, 1.48)	25.41 (4.90, 45.92)
	Missing	1.91 (0.26, 13.78)	0.00 (0.00, 0.00)	0.00 (0.00, 0.00)	0.00 (0.00, 0.00)	-326.88 (- 1166.78, 513.01)
	Moderate	2.86 (1.88, 4.34)	0.10 (0.03, 0.31)	0.00 (0.00, 0.00)	0.00 (0.00, 0.00)	-270.58 (-755.20, 214.05)
	Index of Multiple Deprivation	1	1.07 (0.84, 1.38)	0.66 (0.48, 0.90)	1.49 (0.42, 5.32)	1.21 (0.67, 2.16)
2		1.04 (0.82, 1.33)	0.83 (0.63, 1.08)	1.47 (0.42, 5.17)	1.16 (0.65, 2.07)	3.65 (-44.33, 51.64)
3		0.95 (0.71, 1.25)	0.77 (0.57, 1.04)	1.79 (0.48, 6.64)	1.01 (0.53, 1.91)	-16.53 (-69.28, 36.23)
4		1.03 (0.81, 1.29)	0.82 (0.64, 1.05)	1.48 (0.42, 5.24)	1.04 (0.59, 1.81)	-14.67 (-60.39, 31.05)
5		0.94 (0.74, 1.19)	0.84 (0.65, 1.08)	1.40 (0.35, 5.54)	0.99 (0.55, 1.80)	2.73 (-44.85, 50.31)
6		1.02 (0.81, 1.29)	0.79 (0.61, 1.02)	1.22 (0.32, 4.64)	1.07 (0.60, 1.90)	-21.36 (-68.59, 25.87)

decile		0.91 (0.71, 1.16)	0.94 (0.73, 1.21)	1.98 (0.51, 7.64)	1.29 (0.73, 2.28)	-8.57 (-55.98, 38.84)
7		0.87 (0.66, 1.15)	0.97 (0.73, 1.27)	0.42 (0.05, 3.85)	1.24 (0.67, 2.29)	-19.92 (-71.76, 31.91)
8		0.91 (0.69, 1.20)	0.80 (0.59, 1.07)	1.11 (0.19, 6.45)	1.24 (0.66, 2.35)	-0.76 (-55.08, 53.56)
9		1.00 (Ref)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)
10		0.00 (0.00, 0.00)	1.86 (0.42, 8.32)	0.00 (0.00, 0.00)	0.00 (0.00, 0.00)	274.29 (-211.41, 759.99)
Missing		1.22 (0.99, 1.51)	1.36 (1.08, 1.72)	1.32 (0.61, 2.84)	1.31 (0.82, 2.09)	90.52 (45.37, 135.66)
Ethnicity	Asian	1.60 (1.20, 2.13)	0.55 (0.29, 1.03)	0.39 (0.05, 2.83)	1.57 (0.80, 3.08)	181.09 (111.48, 250.69)
	Black	0.95 (0.80, 1.12)	0.93 (0.77, 1.13)	0.82 (0.30, 2.25)	0.63 (0.38, 1.04)	-74.19 (-107.25, -41.14)
	Missing	1.58 (1.25, 2.00)	0.82 (0.55, 1.23)	1.30 (0.57, 2.98)	1.17 (0.62, 2.19)	44.42 (-17.36, 106.19)
	Mixed	0.91 (0.55, 1.50)	1.09 (0.63, 1.87)	0.00 (0.00, 0.00)	1.98 (0.92, 4.25)	27.10 (-68.03, 122.22)
	Other	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)
	White					

6.7 CAPE Study phenotypes

Phenome	Code
Pre-eclampsia risk assessment	M_PreeclampsiaRiskAssessment_PreEclampsiaRiskLevel_1
FGR_risk_assessment	M_PreeclampsiaRiskAssessment_FgrRiskLevel_2
Dating_scan	M_CurrentPregnancyDetails_EDD_Scan_3
First_scan	M_UltrasoundScan_DateTime_Performed_4
First_scan	M_UltrasoundScan_DateNoteTime_5
Postcode	M_PatInd_Postcode_6
Ethnicity	M_DerivedFields_EthnicCategory_9
booking_location	M_PatInd_CareLocationIDAtBooking_10
c_section	B_InstrumentalOrOperativeDelivery_CaesareanSectionDeliveryMethod_CEPH_FORCEPS
c_section	M_DerivedFields_ReasonForConsultantReview_CATEGORY_1_CAESAREAN_SECTION
c_section	M_CriticalIncident_Mother_TypeDetails_CAESAREAN_SECTION_IN_2ND_STAGE
c_section	M_DerivedFields_AntenatalAssessmentLeaflets_CSECTION
c_section	M_DerivedFields_AllCriticalIncidents_CATEGORY_1_CAESAREAN_SECTION
c_section	M_LabourAndDelivery_OperativeCSDetailsc_STRAIGHTFORWARD_LSCS.
c_section	B_InstrumentalOrOperativeDelivery_CaesareanSectionDeliveryMethod_BRECH
c_section	B_DeliveryDetails_ModeOfDeliveryDisplay_ELECTIVE_(PLANNED)_CAESAREAN_SECTION
c_section	M_TelephoneCall_ReasonPostnatalMother_LSCSWOUND
c_section	M_CriticalIncident_Mother_TypeDetails_CATEGORY_1_CAESAREAN_SECTION
c_section	M_DerivedFields_ReasonForConsultantReview_CAESAREAN_SECTION_IN_2ND_STAGE
c_section	B_InstrumentalOrOperativeDelivery_CaesareanSectionDeliveryMethod_CEPH_ONEBLADE
c_section	B_RiskAssessment_LabourAndDeliveryRisks_CAESAREAN_SECTION
c_section	M_LabourAndDelivery_OperativeCSDetailsc_ROUTINE_C-SECTION
c_section	M_LabourAndDelivery_SecondStageOutcome_CSECTION
c_section	M_DerivedFields_AllCriticalIncidents_PPH_>_500MLS_CATEGORY_1_CAESAREAN_SECTION
c_section	M_AntenatalAssessment_FormsAndInformationLeafletsGiven_CSECTION
c_section	B_InstrumentalOrOperativeDelivery_CaesareanSectionDeliveryMethod_BRECH_MS
c_section	M_LabourAndDelivery_OperativeCSDetailsc_STRAIGHTFORWARD_LSCS
c_section	M_LabourAndDelivery_OperativeCSDetailsc_C-SECTION_PERFORMED_BY_DR_ILESANMI
c_section	M_DerivedFields_AllCriticalIncidents_CAESAREAN_SECTION_IN_2ND_STAGE
c_section	M_DerivedFields_AllCriticalIncidents_CATEGORY_1_CAESAREAN_SECTION_PPH_>_500MLS
c_section	B_InstrumentalOrOperativeDelivery_CaesareanSectionDeliveryMethod_CEPHALIC
c_section	M_AnaestheticGiven_IndicationDisplay_LSCS

c_section	M_LabourAndDelivery_OperativeCSDetailsc_BLUNT_DISSECTION_TO_SHEATH
elective_csection	B_DeliveryDetails_ModeOfDeliveryDisplay_ELECTIVE_(PLANNED)_CAESAREAN_SECTION
emergency_csection	M_DerivedFields_ReasonForConsultantReview_CATEGORY_1_CAESAREAN_SECTION
emergency_csection	M_DerivedFields_AllCriticalIncidents_PPH_>_500MLS_CATEGORY_1_CAESAREAN_SECTION
emergency_csection	M_DerivedFields_AllCriticalIncidents_CATEGORY_1_CAESAREAN_SECTION
emergency_csection	M_DerivedFields_AllCriticalIncidents_CATEGORY_1_CAESAREAN_SECTION_PPH_>_500MLS
emergency_csection	M_PreOpChecklist_ReasonForCS_EMERGENCY_C-SECTION
emergency_csection	M_CriticalIncident_Mother_TypeDetails_CATEGORY_1_CAESAREAN_SECTION
neonatal_death	B_FinalOutcome_CausesOfDeath_EXTREMEPREMATURITY
neonatal_death	B_CriticalIncident_TypeDetails_NEONATAL_DEATH
neonatal_death	B_FinalOutcome_CausesOfDeath_OTHRESP
neonatal_death	B_FinalOutcome_MainCausesOfDeath_EXTREMEPREMATURITY
neonatal_death	B_DerivedFields_AllCriticalIncidents_NEONATAL_DEATH_NEONATAL_DEATH
neonatal_death	B_FinalOutcome_CausesOfDeath_OTHSPECIFICFETALCONDITION
neonatal_death	B_FinalOutcome_MainCausesOfDeath_CHROMOSOMALDISORDERS
neonatal_death	B_FinalOutcome_CausesOfDeath_URINARYTRACT
neonatal_death	B_FinalOutcome_CausesOfDeath_CNS
neonatal_death	B_FinalOutcome_MainCausesOfDeath_FETICIDE
neonatal_death	B_FinalOutcome_MainCausesOfDeath_GIT
neonatal_death	B_FinalOutcome_CausesOfDeath_PREMATURITY
neonatal_death	B_DerivedFields_AllCriticalIncidents_NEONATAL_DEATH
neonatal_death	B_FinalOutcome_CausesOfDeath_CVS
neonatal_death	B_FinalOutcome_MainCausesOfDeath_CNS
neonatal_death	B_FinalOutcome_CausesOfDeath_OTHMAJORCONGENITALANOMALY
neonatal_death	B_FinalOutcome_CausesOfDeath_GIT
neonatal_death	B_FinalOutcome_MainCausesOfDeath_CVS
neonatal_death	M_DerivedFields_ReasonForConsultantReview_NEONATAL_DEATH
neonatal_death	B_FinalOutcome_MainCausesOfDeath_MULTIPLEANOMALIES
neonatal_death	B_FinalOutcome_CausesOfDeath_U
neonatal_death	B_FinalOutcome_MainCausesOfDeath_OTHMAJORCONGENITALANOMALY
neonatal_death	B_FinalOutcome_CausesOfDeath_FETICIDE
neonatal_death	B_FinalOutcome_CausesOfDeath_MULTIPLEANOMALIES
neonatal_death	B_FinalOutcome_MainCausesOfDeath_U
neonatal_death	B_DerivedFields_AllCriticalIncidents_BBA_NEONATAL_DEATH_NEONATAL_DEATH
neonatal_death	B_DerivedFields_AllCriticalIncidents_BBA_NEONATAL_DEATH
neonatal_death	B_FinalOutcome_CausesOfDeath_CHROMOSOMALDISORDERS
neonatal_death	B_FinalOutcome_CausesOfDeath_OTHNEUROLOGICALDISORDER
neonatal_death	B_FinalOutcome_CausesOfDeath_OTHINFECTION
neonatal_death	B_FinalOutcome_MainCausesOfDeath_URINARYTRACT
neonatal_death	B_FinalOutcome_MainCausesOfDeath_PREMATURITY

stillbirth	M_DerivedFields_ReasonForConsultantReview_STILLBIRTH
stillbirth	B_DerivedFields_AllCriticalIncidents_STILLBIRTH_>37_WEEKS_NEONATAL_DEATH
stillbirth	B_CriticalIncident_Type_STILLBIRTH
stillbirth	B_DerivedFields_AllCriticalIncidents_STILLBIRTH_NEONATAL_DEATH
stillbirth	B_DeliveryDetails_FetalProblemsInLabour_STILLBIRTH_BEFORE_LABOUR
stillbirth	B_CriticalIncident_TypeDetails_STILLBIRTH
stillbirth	B_DerivedFields_AllCriticalIncidents_STILLBIRTH
stillbirth	M_Admission_ReasonOtherDisplay_INTRAUTERINE_FETAL_DEATH
stillbirth	B_CriticalIncident_Type_STILLBIRTHFROM37
stillbirth	M_CriticalIncident_Mother_TypeDetails_INTRA_UTERINE_DEATH
stillbirth	M_Induction_MainReasonDisplay_INTRAUTERINE_FETAL_DEATH
stillbirth	M_Admission_ReasonMainDisplay_INTRAUTERINE_FETAL_DEATH
stillbirth	M_DerivedFields_ReasonForConsultantReview_INTRA_UTERINE_DEATH
stillbirth	M_Admission_ReasonOtherStore_MANAGEMENT_OF_INTRAUTERINE_DEATH
stillbirth	M_Admission_ReasonMainStore_MANAGEMENT_OF_INTRAUTERINE_DEATH
stillbirth	B_DeliveryDetails_FetalProblemsInLabour_STILLBIRTH_-_INTRAPARTUM
stillbirth	B_CriticalIncident_TypeDetails_STILLBIRTH_>37_WEEKS
stillbirth	B_DerivedFields_AllCriticalIncidents_STILLBIRTH_STILLBIRTH
stillbirth	M_DerivedFields_OutcomeDisplay_ANTEPARTUM_STILLBIRTH
stillbirth	M_DerivedFields_AllCriticalIncidents_INTRA_UTERINE_DEATH
induction	M_DerivedFields_InductionMethodsDisplay_OXYTOCIN
induction	M_Induction_MainReasonDisplay_MATERNAL_REQUEST
induction	M_Induction_WardForInductionofLabour_INDUCATION_SUITE
induction	M_LabourAndDelivery_Malpresentation_FAILEDINDUCTION
induction	M_Induction_OtherReason_GROWTHLIQUORCONCERNS
induction	M_AntenatalAssessment_ReasonDisplay_INDUCATION_OF_LABOUR
induction	M_Induction_MainReasonDisplay_PET
induction	M_Induction_OtherReason_PIH
induction	M_Induction_MainReasonDisplay_STATIC_GROWTH
induction	M_Induction_MainReasonDisplay_HYPERTENSIVE_DISORDER
induction	M_Induction_MainReasonDisplay_MATERNAL_AGE_=_40_AT_CONCEPTION
induction	M_Induction_MainReasonDisplay_RECURRENT_REDUCED_FETAL_MOVEMENTS
induction	M_Induction_InductionMethod_OXYTOCIN
induction	M_Induction_OtherReason_01G
induction	M_Induction_WardForInductionofLabour_LAVENDER_ANTENATAL_WARD
induction	M_Induction_OtherReason_01E
induction	M_Induction_MainReasonDisplay_PIH/PET_(NOT_DEFINED)
induction	M_Induction_ProstaglandinTypesGiven_Stored_MISOPROSTOL_VAGINAL
induction	M_Induction_MainReasonDisplay_PIH
induction	M_Induction_OtherReason_BMI
induction	M_Induction_OtherReason_MATERNALREQUEST
induction	M_Induction_OtherReason_MATERNALAGE
induction	M_Induction_OtherReason_01C
induction	M_Induction_InductionMethod_OSMOTICCERVICALDILATOR

induction	M_Induction_MainReasonDisplay_PAST_OBSTETRIC_HISTORY
induction	M_Induction_OtherReason_01A
induction	M_Induction_OtherReason_SROM
induction	M_LabourAndDelivery_CSMainIndicationDisplay_FAILED_INDUCATION
induction	M_PreOpChecklist_ReasonForCS_FAILED_INDUCATION
induction	M_Induction_MainReasonDisplay_BMI
induction	M_Induction_ProstaglandinTypesGiven_Stored_PROSTIN
induction	M_LabourAndDelivery_CSOtherMaternalReasons_FAILEDINDUCATION
induction	M_Induction_MainReasonDisplay_OLIGOHYDRAMNIOS
induction	M_Induction_OtherReason_POLYHYDRAMNIOS
induction	M_Induction_MainReasonDisplay_DIABETES
induction	M_Induction_MainReasonDisplay_OBSTETRIC_CHOLESTASIS
induction	M_Induction_MainReasonDisplay_GROWTH_AND_LIQUOR_CONCERNS
induction	M_Induction_MainReasonDisplay_PROLONGED_ROM
induction	M_Induction_MainReasonDisplay_OTHER_MATERNAL_REASON
induction	M_Induction_OtherReason_STATICGROWTH
induction	M_Induction_OtherReason_PRETERMPROM
induction	M_Induction_OtherReason_PROLONGEDROM
induction	M_Induction_InductionMethod_PROSTOGLANDINS
induction	M_Induction_MainReasonDisplay_FETAL_GROWTH_RESTRICTION
induction	M_Induction_MainReasonDisplay_OTHER_FETAL_REASON
induction	M_Induction_MainReasonDisplay_POLYHYDRAMNIOS
induction	M_Induction_OtherReason_BI-POLA
induction	M_DerivedFields_InductionMethodsDisplay_PROSTAGLANDIN
induction	M_Induction_OtherReason_REDUCEDLIQUORVOLUME
induction	M_Induction_MainReasonDisplay_MULTIPLE_PREGNANCY
induction	M_Induction_OtherReason_RECURRENTRFM
induction	M_Induction_MainReasonDisplay_TOP_FOR_FETAL_ABNORMALITY
induction	M_Induction_OtherReason_REDUCEDFETALMOVEMENTS
induction	M_Induction_OtherReason_IVF
induction	M_Induction_MainReasonDisplay_SMALL_FOR_GESTATIONAL_AGE
induction	M_Induction_MainReasonDisplay_SINGLE_EPISODE_OF_REDUCED_FETAL_MO VEMENTS
induction	M_DerivedFields_InductionMethodsDisplay_PROSTIN
induction	M_Induction_InductionMethod_ARM
induction	M_Induction_MainReasonDisplay_POST_DATES
induction	M_Induction_MainReasonDisplay_ANTEPARTUM_HAEMORRHAGE
induction	M_RuptureOfMembranes_ReasonForArm_INDUCATION
induction	M_Induction_MainReasonDisplay_SUBOPTIMAL_FETAL_GROWTH
induction	M_Induction_WardForInductionofLabour_DELIVERY_SUITE
induction	M_RiskAssessment_Intrapartum_Display_MORE_THAN_1_CYCLE_OF_INDUCTI ON
induction	M_Induction_OtherReason_SUBOPTIMALGROWTH
induction	M_DerivedFields_InductionMethodsDisplay_MECHANICAL
induction	M_Induction_MainReasonDisplay_LARGE_FOR_GESTATIONAL_AGE
induction	M_Induction_MainReasonDisplay_REDUCED_LIQUOR_VOLUME
induction	M_Induction_OtherReason_SOCIALINDICATION
induction	M_Induction_OtherReason_ABNORMALDOPPLERS

induction	M_Induction_MainReasonDisplay_INTRAUTERINE_FETAL_DEATH
induction	M_Induction_MainReasonDisplay_PRE-TERM_PROM
induction	M_FAU_MainReason_INDUCION_OF_LABOUR
induction	M_Induction_MainReasonDisplay_SROM
induction	M_Induction_OtherReason_MUSCULOSKELETALPAIN
induction	M_Induction_OtherReason_SMALLGESTAGE
induction	M_Induction_InductionMethod_CERVICALBALLOON
induction	M_Induction_OtherReason_99
induction	M_Induction_MainReasonDisplay_CONGENITAL_FETAL_ANOMALY
induction	M_Induction_MainReasonDisplay_REDUCED_LV
induction	M_Induction_OtherReason_PET
induction	M_Induction_ProstaglandinTypesGiven_Stored_MIFEPRISTONE_ORAL
induction	M_Induction_WardForInductionofLabour_WARD_1
induction	M_Induction_MainReasonDisplay_IN_VITRO_FERTILISATION
induction	M_Induction_OtherReason_02C
induction	M_Induction_OtherReason_02B
induction	M_Induction_OtherReason_02A
augmentationDRAFT	M_Induction_PlannedInductionDetails_AUGMENT_
augmentationDRAFT	M_RiskAssessment_CurrentPregnancyRiskFactors_Display_AUGMENTATION_OF_LABOUR
augmentationDRAFT	M_LabourAndDelivery_Malpresentation_FAILED_AUGMENT
augmentationDRAFT	M_LabourAndDelivery_CSMMainIndicationDisplay_FAILED_AUGMENT
augmentationDRAFT	M_Appointment_ReasonDisplay_AUGMENTATION
augmentationDRAFT	M_RuptureOfMembranes_ReasonForArm_AUGMENTATION
augmentationDRAFT	M_RiskAssessment_CurrentPregnancyRiskFactors_Stored_AUGMENTATIONLABOUR
Breech	M_LabourAndDelivery_OperativeCSDetailsc_BREECH_TWIN_1_STANDARD_PREP_AND_DRAPE
Breech	M_LabourAndDelivery_CSMMainIndicationDisplay_BREECH
Breech	M_LabourAndDelivery_OperativeCSDetailsc_BREECH_LO
Breech	M_LabourAndDelivery_OperativeCSDetailsc_LSL_FRANK_BREECH
Breech	B_DeliveryDetails_ModeOfDeliveryDisplay_BREECH_EXTRACTION
Breech	M_LabourAndDelivery_OperativeCSDetailsc_AS_ABOVE_FETUS_IN_BREECH_Presentation
Breech	B_DeliveryDetails_ModeOfDeliveryDisplay_BREECH_BIRTH
Breech	B_RiskAssessment_LabourAndDeliveryRisks_BREECH_BIRTH
Breech	M_LabourAndDelivery_OperativeCSDetailsc_FETUS_DELIVERED_IN_BREECH_Presentation
Breech	M_LabourAndDelivery_OperativeCSDetailsc_EXTENDED_BREECH
Breech	M_LabourAndDelivery_OperativeCSDetailsc_BREECH_BABY_DELIVERED_VIA_CMSV
Breech	B_InstrumentalOrOperativeDelivery_CaesareanSectionDeliveryMethod_BREECH_CMSV
Breech	M_LabourAndDelivery_OperativeCSDetailsc_ROUTINE_BREECH_EXTRACTION_EASY_DELIVERY
Breech	M_LabourAndDelivery_OperativeCSDetailsc_LSCS_DELIVERED_BREECH
Breech	M_Admission_ReasonOtherStore_ECV

Breech	M_LabourAndDelivery_PostOpSuggestedVBACComments_AS_THIS_WAS_FOR_BREECH.
Breech	M_LabourAndDelivery_OperativeCSDetailsc_STRAIGHTFORWARD_BREECH
Breech	M_LabourAndDelivery_OperativeCSDetailsc_ROUTINE_BREECH_EXTRACTION
Breech	M_AntiD_Indication_ECV
Breech	B_DerivedFields_PresentationImmediatelyBeforeDelivery_BREECH_UNSPECIFIED
Breech	M_LabourAndDelivery_OperativeCSDetailsc_DELIVERED_WITH_BREECH_EXTRACTION
Breech	B_InstrumentalOrOperativeDelivery_CaesareanSectionDeliveryMethod_BREECH
Breech	M_FAU_MainReason_ECV
Breech	M_LabourAndDelivery_OperativeCSDetailsc_RST._BREECH_DELIVERED
Breech	M_AntenatalAssessment_ReasonDisplay_ECV
Breech	M_LabourAndDelivery_PostOpSuggestedVBACComments_DELIVERED_AS_BREECH
Breech	M_LabourAndDelivery_OperativeCSDetailsc_BREECH
Breech	M_LabourAndDelivery_Malpresentation_BREECH
Breech	B_RiskAssessment_MaternalRisks_BREECH_PRESENTATION_ON_OR_AFTER_36/40
Breech	B_CriticalIncident_Details_CAT_2_EMCS_DUE_TO_BREECH_SROM_AND_CONTRACTING
Breech	M_LabourAndDelivery_OperativeCSDetailsc_ELCS_FOR_BREECH
Breech	M_LabourAndDelivery_CSOtherMaternalReasons_DECLINED_ECV
Breech	M_Appointment_AdditionalDetails_?_BREECH
Breech	M_PreOpChecklist_ReasonForCS_BREECH
Breech	M_Appointment_ReasonDisplay_ECV
Breech	M_LabourAndDelivery_OperativeCSDetailsc_BREECH-_LEFT_SACROPOSTERIOR
Breech	B_DerivedFields_PresentationImmediatelyBeforeDelivery_BREECH_-_FOOTLING
Breech	M_LabourAndDelivery_OperativeCSDetailsc_LSCS_A_BREECH_PALPATED
Breech	M_LabourAndDelivery_OperativeCSDetailsc_EASY_BREECH_DELIVERY_OF_A_LIVE_FEMALE
Breech	B_DetailedENB_ReasonBabyUnderObservationDisplay_BREECH.
Breech	B_DeliveryDetails_ReasonSkinContactNotEstablishedNotes_FAILED_ECV
Breech	M_LabourAndDelivery_OperativeCSDetailsc FOOT_DELIVERED_FIRST_THEN_BREECH
Breech	M_Admission_ReasonMainStore_ECV
Breech	M_LabourAndDelivery_OperativeCSDetailsc_CAT_4_CS_FOR_BREECH__PATIENT_IDENTIFIED
Breech	M_LabourAndDelivery_OperativeCSDetailsc_FRANK_BREECH
Breech	M_LabourAndDelivery_OperativeCSDetailsc_DELIVERED_AS_BREECH
Breech	M_LabourAndDelivery_MaternalProblemsSecondStage_FLEXED_BREECH
Breech	M_LabourAndDelivery_OperativeCSDetailsc_UNCOMPLICATED_BREECH_DELIVERY

Breech	M_LabourAndDelivery_OperativeCSDetailsc_ROUTINE_C_SECTION_BABY_FRA NK_BREECH
Breech	B_NonRegiserableBirthDetails_ModeOfDeliveryDisplay_BREECH_DELIVERY
Breech	M_LabourAndDelivery_OperativeCSDetailsc_BREECH_EXTRACTION
Breech	M_InternalTransfer_TransferReason_MALPRESENTATION/BREECH_PRESENTATI ON
Breech	M_LabourAndDelivery_OperativeCSDetailsc_UNCOMPLICATED_CAT_3_CS_EXT ENDED_BREECH
Breech	M_AnaestheticGiven_IndicationDisplay_ABNORMAL_PRESENTATION_BREECH_ ETC
Breech	M_FAU_OtherReasons_Display_ECV

Chapter 7 - Discussion

7.1 Gender Equality Funding Application Ectopic Pregnancy

Gender Equality Theme Funding Application

Network-wide Call – August 2023

This is an open research project call across all members of the Gender Equality research network. Applicants that are not currently involved in the network as a Theme or Workstream Lead need to clearly set out how their proposed project will contribute to the aims of the network.

This scheme can support pilot projects, research activities, research bid development, or engagement and impact in areas of strategic interest to the Gender theme. We are particularly interested in projects that address one of our emerging cross-work-stream topics:

- Respectful maternity care, including knowledge and experiences of Gender-Based Violence in reproductive and maternal health
- Understanding gendered experiences throughout the life course, especially in relation to education, work, and equality of opportunity
- Understanding contexts of miscarriage and changing attitudes
- Interdisciplinary explorations of issues related to postpartum haemorrhage
- Addressing challenges to fertility care and reproductive rights
- Traditional knowledge in maternal care and histories of women's care

This scheme will support small projects of **<£10,000** (though project value can exceed this if additional funds are being sourced from elsewhere) and all funds must be spent by 30th June 2024. We have a limited budget and are seeking to fund as many applications as possible, therefore we will prioritise high quality projects that:

- Offer value for money, especially proposals that include match funding or are co-funded, for example through an institutional Impact Accelerator Account (IAA)
- Clearly identify a source of follow-on funding that will be applied for
- Clearly bring together 2 or more of our work streams (detailed below) or address one of the focus areas above
- Are highly novel or are likely to lead to tangible impact for affected groups

The deadline for applications is **Friday, 6th October 2023** and outcomes will be communicated within three weeks of this date.

Proposals must:

- Be led by a UoB researcher (PGRs cannot lead projects)
- Be interdisciplinary in nature, clearly identifying 2 or more disciplinary areas that are being brought together
- Clearly justify costings
- Lead to tangible outputs e.g., external funding bids, publications, shared resources, etc
- Clearly link to an existing workstream or topic of interest
- Where appropriate, be carried out with input from or collaboration with relevant partners, stakeholders, or publics (e.g., charities, NGO's, patients) which can be costed

- Be for projects that will take place between October 2023 and June 2024, with **all funds spent by end of June 2024**
- If successful, complete an end of project report and contribute to other reporting and dissemination activities, where requested
- Be submitted to [Leah Fitzsimmons](#) () by 6th October
- If you are unsure if your project would be suitable or have any other queries, please contact Leah to discuss

You can also choose to complete this form online:

<https://forms.office.com/e/hALHH2YjZX>

Section 1: Project description

Project title	Investigating trends in the UK incidence and prevalence of ectopic pregnancy
Lead applicant <i>Name, role, department, affiliation</i>	Dr Neil Cockburn; Clinical Research Fellow; Institute of Applied Health Research; University of Birmingham
Co-applicants / collaborators	Joht Chandan, IAHR Rowland Seymour, School of Mathematics Krishnarajah Nirantharakumar, IAHR Krishna Gokhale, IAHR
Aims and objectives of project <i>Max 200 words.</i>	Aims: 1. To describe and explain trends in the UK incidence of ectopic pregnancy. 2. To improve the methods commonly used to describe incidence of ectopic pregnancy Objectives: • To develop methods inferring the frequency of ectopic pregnancy (numerator) • To develop methods inferring the frequency of conception including miscarriages (denominator) • To describe the incidence and prevalence of ectopic pregnancy over a 15 year period • To explain changes in the trends of ectopic pregnancies • To model the potential impacts on fertility of changes in trends of ectopic pregnancies Outputs: Undertaking the above will allow us to apply for grant funding to understand the causes of these changes and identify/evaluate suitable interventions to support affected patients.

Description of project activities and timing

Max 500 words.

Ectopic pregnancies have been understudied and underreported in the UK, with the last report on epidemiology of ectopic pregnancy dating back to 2011. However, our preliminary data shows that substantial changes have occurred in the epidemiology of ectopic pregnancies, with rising per-pregnancy rates of ectopics in 12-20 and 40+ year old women and falling rates in 25-34 year olds. This data is subject to weaknesses in collection and analysis; for example, conceptions itself is impossible to collect data on and is inferred from pregnancy reporting and activity, livebirths, miscarriages, and other events during pregnancy. 1 third of pregnancies may end in miscarriage, however these pregnancies are excluded from national estimates of conception rates, making it difficult to assess changes in events such as miscarriages, of which ectopic pregnancy is a cause. We therefore propose the following activities to investigate causes of ectopic pregnancy:

- We will create a model to estimate the frequency of conceptions over time from four data sources: live birth registrations, miscarriages, primary care pregnancy data and abortions. Each of these will have different underlying data generating processes that need to be combined into a joint distribution generating time series data that can accurately reflect the denominator within which ectopic pregnancies can occur. [Months 1-2]
- We will estimate the frequencies of ectopic pregnancies using our newly validated automated incidence and prevalence technology platform DExtER [Months 1-2]
- We will describe the incidence and prevalence of ectopic pregnancy overall and by markers of inequality; age cohorts, ethnicity, deprivation, and region. [Months 3-4]
- We will generate an explanatory model for ectopic pregnancies by adjusting for key confounders and known causes of ectopic pregnancy such as Pelvic Inflammatory Disease and assisted reproductive technologies. [Months 3-5]
- We will use the above modelling to generate hypotheses for potential causes of ectopic pregnancies and targets for future interventions which can be investigated in a future grant funded project [Months 6]

	Data sources: CPRD Aurum; CPRD Gold Open access ONS data sources in England and Wales: Birth and stillbirth registrations; Abortion notifications. Clinical codes for outcomes and exposures: Ectopic pregnancy not otherwise specified Ruptured ectopic pregnancy PID Smoking Bmi Infertility Statistical analyses: Conception time series modelling ARIMA analysis Change point analysis
Outputs and deliverables arising directly from your project <i>Max 250 words.</i>	• Methods for estimating total conceptions from varied sources • Up to date description of the epidemiology of ectopic pregnancy • Pilot data for subsequent grants further exploring causes of ectopic pregnancy
Partners/collaborators <i>Please make it clear if there are any overseas collaborators/ partners</i>	Will Parry-Smith, Professor of Obstetrics and Gynaecology, Keele University
How does this project link with (an) existing Gender workstream(s) or topic of interest? <i>Max 200 words</i>	• Understanding contexts of miscarriage and changing attitudes • Addressing challenges to fertility care and reproductive rights Ectopic pregnancies are an important cause of early pregnancy loss and complications. While a relatively small proportion of pregnancies end in an ectopic pregnancy (2011 estimated 1 in 90 pregnancies, compared to 1 in 3 total end in miscarriage), ectopic pregnancies are not viable, and can result in death or severe morbidity. Ectopic pregnancies require abdominal surgery to treat and frequently require removal of an ovary and Fallopian tube, with an impact on future fertility. Women experiencing two ectopic pregnancies may have emergency removal of both ovaries, resulting in infertility. Pregnancies ending in miscarriage, despite accounting for 1 in 3 pregnancies, are not included in official statistics on fertility.

	Assisted reproductive technologies such as IVF can result in ectopic pregnancies, as well as tubal ligation and copper Intra-Uterine Devices. Ectopic pregnancies are therefore closely bound with fertility control and timing.
Date report available	10/07/2024
Plans for follow-on activities (e.g., external funding applications) <i>Including funding applications</i>	Our goal will be to apply for a NIHR research for patient benefit grant to unpick the mechanisms further explaining these trends and identifying/evaluate appropriate interventions which would support this application.
Funds requested <i>Including itemised list of costs and justification (note: you do not need to set up a Worktribe project). Please note we fund directly incurred costs but cannot support staff buy-out. Note: casual staff set up takes 4-6 weeks and overseas payments require time for contracting.</i>	Primary costs: Grade 6 RA between 1st November 2023- 1st June 2024= £6,500 The RA will be responsible for supporting clinical code generation, data extraction, data preparation and data analysis. Data costs: £3,500 In kind costs: JSC will provide primary supervision in kind and will support NC with oversight and report writing RS will support with modelling conceptions to estimate denominator population KN and KG will provide in kind support for data extraction WPS will provide in kind support to assist with report writing and dissemination
Staff requiring financial access to account if successful (UoB staff only)	Name: Yuangen li Email Address:

Section 2: ODA Compliance

<i>Some research can be classed as Official Development Assistance. This is research where the outputs primarily benefit Low and Middle Income Countries (LMICs). In your opinion would this project have met this criteria?</i>	No
As part of this project, will you be working with overseas countries?	No
If you answered yes to the above question, please list the country or countries	

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Date Approved	Click or tap to enter a date.

IAS-IGI ID Assigned	
Account Code to be Assigned	Choose an item.