University of Southampton

Faculty of Environmental and Life Sciences

School of Health Sciences

Staffing and Quality of Care of Inpatient Maternity Services

by

Lesley Yvonne Turner

BSc BMid MSc RGN RM FHEA

ORCID ID https://orcid.org/0000-0003-1489-3471

Thesis for the degree of PhD in Health Sciences

October 2024

University of Southampton

<u>Abstract</u>

Faculty of Environmental and Life Sciences

School of Health Sciences

<u>Thesis for PhD in Health Sciences</u>

Staffing and Quality of Care of Inpatient Maternity Services

by

Lesley Yvonne Turner

Maternity services are reported to be under resourced and there is a national shortage of midwives. There is little empirical evidence on the relationship between staffing levels and the quality of care, so the consequences of understaffing are unclear. This thesis comprises four studies that aim to explore the association between variation in midwifery staffing levels and a range of outcomes to better understand the likely consequences of understaffing.

Secondary data from published and unpublished sources have been used. Study designs include three cross-sectional and one longitudinal study. Multiple regression techniques were used to separate staffing effects from those associated with individual characteristics, care interventions and service differences. Staffing and outcomes were measured as close to women as possible to understand relationships in greater depth.

The first study used staffing and survey data from 129 NHS trusts and found an association between more full-time equivalent midwives and women reporting a better experience of postnatal inpatient care. Fewer women reported delays in discharge in organisations with higher midwifery staff, and more women reported that staff always helped in a reasonable time, and they always had the information and explanations they needed. The second study continued to investigate postnatal care experience but delved more deeply using staffing data from 123 postnatal wards within 93 NHS trusts, including both midwives and support workers. Wards with higher support worker staffing were associated with higher rates of women reporting they always had help when they needed it and were always treated with kindness and understanding.

The next two studies accessed individual patient data from three NHS trusts over forty-six months covering 106,904 maternal admissions, of which 64,250 admissions resulted in a birth. Variation was noted in midwifery staffing and the demand for care. Understaffing by midwives was significantly associated with higher rates of postnatal readmissions and more reported harmful incidents. These findings were not replicated for understaffing by maternity support workers. Days with higher than expected admissions and discharges were associated with higher rates of harmful incidents. The relationships have not been confirmed as being causal, as evidence comes from observational studies.

The evidence presented in these four research studies highlights the potential impact of understaffing on a range of outcomes, not just those relating to labour care. This work justifies the need to combat low staffing levels and match staffing to needs in all inpatient settings. Maternity support workers contribute to women's experience of care but should not be deployed as a substitute for midwives. Further work is needed to strengthen the evidence base on multi-professional staffing and to understand the impact of setting staffing standards to guard against critical understaffing of maternity services.

Table of Contents

Table of Tables

Table of Figures

Research Thesis: Declaration of Authorship

Print name:

Lesley Yvonne Turner

Title of thesis:

Staffing and Quality of Care of Inpatient Maternity Services

I declare that this thesis and the work presented in it are my own and has been generated by me as the result of my own original research.

I confirm that:

1. This work was done wholly or mainly while in candidature for a research degree at this University;
2. Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated;
3. Where I have consulted the published work of others, this is always clearly attributed;
4. Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work;
5. I have acknowledged all main sources of help;
6. Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself;

7. Parts of this work have been published as:-

   Study 1

   Turner, L., Culliford, D., Ball, J., Kitson-Reynolds, E. and Griffiths, P. (2022) 'The association between midwifery staffing levels and the experiences of mothers on postnatal wards: cross sectional analysis of routine data', *Woman and Birth*, 35(6), pp. e583–e589.

   Study 2

   Turner, L., Ball, J., Culliford, D., Kitson-Reynolds, E. and Griffiths, P. (2022) 'Exploring the relationship between women's experience of postnatal care and reported staffing measures: an observational study', *PLoS ONE*, 17(8): e0266638.

   Study 3

   Turner, L., Saville, C., Ball, J., Culliford, D., Dall'Ora, C., Jones, J., Kitson-Reynolds, E., Meredith, P. and Griffiths, P. (2024) 'Inpatient midwifery staffing levels and postpartum readmissions – a retrospective multi-centre longitudinal study'. *BMJ Open,* 14:e077710*,*

   Study 4

   Turner, L., Ball, J., Meredith, P., Kitson-Reynolds, E. and Griffiths, P. (2024) 'The association between midwifery staffing and reported harmful incidents: a cross sectional analysis of routinely collected data'. *BMC Health Services Research*, 24(1), pp1-8

   Appendix C

   Turner, L., Griffiths, P. and Kitson-Reynolds, E. (2021) 'Midwifery and nurse staffing of inpatient maternity services – a systematic scoping review of associations with outcomes and quality of care', *Midwifery,* 103, 103118.

I worked with my supervisors to identify and develop the questions and plan the study designs. I acquired the data for the first two studies and was part of the study team acquiring the data for studies three and four. I manipulated and joined the data and performed all data analysis, taking advice from a statistician. I drafted all the papers and received advice on the drafts from co-authors, which I incorporated before submission to the journals. I addressed all peer-review comments and correspondence with the journals to achieve publication.

Signature: Date: 28th October 2024

Acknowledgements

This work is dedicated to my dad who inspired me in the time we had together and to my mum for always being there for me. Jamie and Leah have also been a great inspiration and have been on impressive learning journeys at the same time. I am immensely proud of you all, and grateful especially to Jay for your patience, endless cups of tea and practical help while I have been immersed in this PhD.

It is a privilege to have been able to contribute to this topic, and I am so grateful for the knowledge and support from my supervisors Professor Peter Griffiths, Dr Ellen Kitson-Reynolds and Professor Jane Ball. Their support and guidance has far exceeded my expectations. Their warmth and encouragement have helped me grow in my learning and feel valued at every stage. My work is a small extension to what has gone before, and I am thankful to have stood on the shoulders of giants to shine a light on midwifery staffing and the quality of care.

Wise words have also come from the health workforce research group, our fabulous midwifery team and my close friends. I am so grateful for your support, sense of fun and encouragement. Finally, I would also like to express thanks to the School of Health Sciences at the University of Southampton, the NIHR and ARC Wessex for supporting my work.

Abbreviations

AIC .... Akaike Information Criterion.

APPG .... All-Party Parliamentary Group.

BIC .... Bayesian Information Criterion.

CCG .... Clinical Commissioning Group.

CHPPD .... Care Hours Per Patient Day.

CI .... Confidence interval.

CQC .... Care Quality Commission.

ERGO............................... Ethics and Research Governance Online.

ESR.................................. Electronic Staff Record.

FTE .... Full Time Equivalent.

HPPD............................... Hours Per Patient Day.

ICC .... Intra-cluster Correlation Coefficient.

ICD .... International Classification of Diseases.

IQR .... Interquartile range.

IRR................................... Incident Rate Ratio.

MA .... Maternity Assistant.

MNSI............................... Maternity and Newborn Safety Investigations.

NICE .... National Institute for Health and Care Excellence.

NMC .... Nursing and Midwifery Council.

NNU .... Neonatal unit.

OR .... Odds Ratio.

RM .... Registered Midwife.

UV .... Univariable.

VIF .... Variance Inflation Factor.

WHO............................... World Health Organisation.

Chapter 1 Introduction

Maternity services need to provide safe, effective and person-centred care for women and families (Crowe *et al.*, 2019). The provision of high quality care depends on services having sufficient staff with the right knowledge and skills to respond to demand in a timely way (National Quality Board, 2016; House of Commons, 2023). Demand for care is variable and organisations need to meet women's needs across a range of settings to provide a seamless service (National Maternity Review, 2016). The notion of sufficient staff is not well defined in maternity settings; some inspections have noted that there are not always enough staff to keep people safe (Care Quality Commission, 2023a), and calculations from staffing tools have not been matched to outcomes to assess the adequacy of staffing (Griffiths *et al.*, 2023). There is variation in how services are staffed, and care quality has been described as a postcode lottery (Nuffield Trust, 2024; APPG Birth Trauma, 2024). It is not clear whether differences in deployed staffing can be explained by population case mix or if the variation represents under or over staffing compared to need.

Workforce is a costly investment with 45% of the NHS budget being spent on staff, amounting to 66.2 billion pounds annually (The Kings Fund, 2023). The NHS is the largest employer in Europe, employing one in every twenty five adults of working age in England (National Health Service, 2019). Many NHS trusts are in financial deficit and trusts are being asked to make savings (Kings Fund, 2022). Staffing decisions need to be based on evidence, considering both the quality of care and efficiency, as spending on staff competes with other NHS resources (Care Quality Commission, 2015). Without evidence to demarcate the benefits of employing midwives, there is a risk that organisations will reduce midwifery posts or replace some with unregistered staff (Royal College of Midwives, 2016a). The consequences of understaffing need to be understood, so that priorities can be set at government level and service planners can make informed decisions about offering posts and deploying their workforce.

1.1 Aim and research questions

The over-arching aim of this work is to understand the relationship between inpatient midwifery staffing levels and the quality of care received by women and babies. Specifically, the thesis looks at how variation in maternity staffing relates to variation in women's experience of care, postnatal readmission, and the risk of harmful incidents.

1.2 Rationale

Health care managers need to plan staffing to meet the needs of women, babies, and families in maternity services. The needs of women include individual expectations and preferences as well as clinical need (Makarova *et al.*, 2024). Under resourcing can lead to a reduction in quality and safety (Royal College of Nursing, 2023), whereas unnecessarily high staffing would be a waste of scarce resources and this money could be spent elsewhere (Saville *et al.*, 2021b). Lack of guidance contributes to variation in staffing across the country and when budgets are squeezed there is no mandate to protect women and babies from extremely low staffing levels. Rafferty *et al.* (2023) discuss the missed opportunities to secure safe staffing in nursing and midwifery in the UK and the failure to take action recommended in the Francis report over 10 years ago (Francis, 2013).

Within maternity services, the National Institute for Health and Care Excellence (2015) concluded there was a lack of evidence to set absolute staffing recommendations, except for care in labour where one-to-one care is recommended. The position statement from the Royal College of Midwives (2009) recommended an average ratio of one full-time equivalent midwife for every 28 hospital births, based on a review of staffing in maternity units at that time. This document includes further guidance such as “ensure women who have had surgical deliveries have the same level of support afforded to any patient on a surgical ward” and “ensure that the midwife coordinating the labour ward is supernumerary” (Royal College of Midwives 2009, p5). This guidance does little to reassure women that there will be sufficient staff to care for them throughout their maternity journey, as the establishment guide represents the total number of staff for the service and does not give details on how staff should be deployed. The 1:28 ratio has not been updated to reflect current need or patterns of service provision. Maternity units are instructed to make their own workforce calculation based on their service configuration and local population demographics (National Institute for Health and Care Excellence, 2015) and report this at board level every six months (NHS England, 2014). Even with reporting at this level, trusts may provide staffing they can afford rather than staffing matched to calculated need (Royal College of Midwives, 2022b).

The relationship between health care staffing levels and the quality of clinical care is complex (Leary *et al.*, 2016). Clarifying this relationship will help service planners base their decisions on robust evidence as they are responsible for planning staffing levels and have little basis to do so. It is important to first understand the strength and direction of effects related to midwifery understaffing, as the evidence in midwifery is still in its infancy compared with the numerous staffing studies in nursing (Griffiths *et al.*, 2016; Kane *et al.*, 2007).

The Safe Staffing Advisory Committee for maternity noted that there was no evidence on staffing and outcomes at an individual woman and baby level, nor on a shift level (National Institute for Health and Care Excellence, 2015), and highly aggregated data is insufficient to inform staffing decisions in ward areas. These evidence gaps will be addressed in this project using data close to mothers and babies, exploring a range of outcomes that are important to them and to service providers.

1.3 Structure of the thesis

The thesis starts by setting some context about maternity services and how the quality of care is defined in this setting. It goes on to discuss areas in maternity care where services have been considered substandard and contributing factors to this, highlighting the policy drivers and current work to improve maternity services. This chapter then discusses the maternity workforce and the documented consequences of workforce shortages. Research evidence is considered to assess how substantial the evidence base is, the quality of the evidence, and research gaps when considering the relationship between staffing and outcomes.

Key areas for study have been selected where evidence is limited. The research areas were chosen as they matter to women, families and clinicians as evidenced by rising complaints about care experience, readmissions and incidents (APPG Baby Loss and Maternity, 2022; National Maternity and Perinatal Audit, 2022). A staff and service user consultation has been undertaken (described in Appendix A) which confirmed that these are key areas thought to be impacted by understaffing and are a cause for concern.

Next in this chapter the methodology will be outlined and justified, including why routinely collected data has been used as a data source, and why multivariate regression analysis helps to explore the relationship between staffing and measures of quality. The quality of available data and the measurement of staffing exposure and outcomes will be explored, focussing on the level of observation and proximity to the individuals studied. The lessons from previous research in terms of addressing limitations and pointers for research design are discussed, and these issues have been incorporated into the study designs for each of the four studies making up this thesis.

The next four chapters comprise each of the published studies which represent a linked and coherent body of work. The studies all address areas of care quality or safety, and together make a substantial contribution to the maternity staffing literature.

Study 1: Turner, L., Culliford, D., Ball, J., Kitson-Reynolds, E. and Griffiths, P. (2022) 'The association between midwifery staffing levels and the experiences of mothers on postnatal wards: cross sectional analysis of routine data', *Woman and Birth*, 35(6), pp. e583–e589. https://doi.org/10.1016/j.wombi.2022.02.005

Study 2: Turner, L., Ball, J., Culliford, D., Kitson-Reynolds, E. and Griffiths, P. (2022) 'Exploring the relationship between women's experience of postnatal care and reported staffing measures: an observational study', *PLoS ONE*, 17(8): e0266638. https://doi.org/10.1371/journal.pone.0266638

Study 3: Turner, L., Saville, C., Ball, J., Culliford, D., Dall'Ora, C., Jones, J., Kitson-Reynolds, E., Meredith, P. and Griffiths, P. (2024) 'Inpatient midwifery staffing levels and postpartum readmissions – a retrospective multi-centre longitudinal study'. *BMJ Open,* 14:e077710 https://doi.org/10.1136/bmjopen-2023-077710

Study 4: Turner, L., Ball, J., Meredith, P., Kitson-Reynolds, E. and Griffiths, P. (2024) 'The association between midwifery staffing and reported harmful incidents: a cross sectional analysis of routinely collected data'. *BMC Health Services Research* 24(1), pp1-8 https://doi.org/10.1186/s12913-024-10812-8

The concluding chapter discusses how the studies collectively contribute to knowledge in this field. This chapter relates the overall findings to the current literature, practice, policy, and research. Advances gained from this work are identified, along with recommended next steps. This chapter includes a critical examination of the strengths and limitations of my research and remaining uncertainty. The chapter finishes with the study conclusions. Dissemination of the work to date and a glossary can be found in the appendices.

1.4 Setting and study population

This research has been undertaken in England using data generated by the National Health Service (NHS) maternity services. Maternity services are organised in NHS trusts which are large publicly funded organisations. Trusts provide maternity services in both hospital and community settings throughout antenatal, labour and postnatal periods (National Maternity and Perinatal Audit, 2019b). Hospital admissions in the antenatal period have declined as care is commonly managed in day assessment units instead, as for many women clinical outcomes are similar to inpatient settings (Dowswell *et al.*, 2009). In 2023, over 97% of births took place in hospital or in a birth centre (Office for National Statistics, 2023). In contrast, before the second world war most women had given birth at home (Davis, 2013).

The complexity of cases, interventions and inpatient workload has increased in recent years. In the financial year April 2022-March 2023, there were 547,244 births in England of which 38% were births by caesarean section, 11% by instrumental birth and 48% were spontaneous unassisted births (NHS Digital, 2023b). This compares to caesarean section rates of 12.4% in 1990-91 and 26.5% in 2014-15 (Health and Social Care Information Centre, 2015). Caesarean section rates are likely to rise further as mothers are able to request this method of birth without a clinical indication (Brown *et al.*, 2023).

The rates of induction of labour have also increased, with 33% of labours starting in this way in 2022-3 compared to 23% in 2012-13 (NHS Digital, 2023a). Increased risk factors such as rising maternal age, obesity and diabetes have contributed to rising maternal complexity (Vitner *et al.*, 2019; Sheen *et al.*, 2018) The increase in fertility treatment has meant an increase in multiple pregnancies and preterm births (Sanders *et al.*, 2022). Vulnerable babies are being cared for on postnatal wards and transitional care units, not just in neonatal units (de Rooy *et al.*, 2010). In a survey of Heads of Midwifery, 96% reported they were dealing with more complex cases than in the previous year (Royal College of Midwives, 2019). The workload of midwives now includes additional and more in-depth components such as postnatal contraceptive administration, the newborn initial physical examination, mental health screening and interaction with digital systems (Price, 2019; NHS England, 2020; Simpson *et al.*, 2012). These additional roles have come about due to shifting duties from medical staff and the extension of midwifery scope of practice to enable autonomous working and holistic care (Osborne, 2017).

The average length of postnatal stay has reduced in recent years. In 2022-3, 63.7% of women had a postnatal stay of one day or less in hospital (NHS Digital, 2023b). In the 1980's women were expected to stay in hospital for six days to recuperate following birth (Bowers *et al.*, 2016) and would therefore have a lower dependency in the latter stages of their stay. The fast pace of admissions and discharges compresses midwives' work into a shorter time frame. Reduction in length of stay following birth means that more staff time is devoted to admission and discharge processes. Distribution of postnatal ward activity has been calculated by Bowers *et al.* (2016) who found that 22.7 % of the staff input is associated with admissions, 25.1 % with discharge, with the remaining 52.2 % dedicated to caring for women in the recovery period.

As continuity of carer is not the dominant model of care (Nuffield Trust, 2023) then midwives are commonly caring for women and families that they have not met before, and some may have complex social, psychological and physical needs. In this fast-paced environment, aspects of care such as communication, breastfeeding support, provision of discharge information and translation services may be overlooked, thereby increasing the chance of poor outcomes, dissatisfaction and lack of equity in service provision (Blackman *et al.*, 2020; Lyndon *et al.*, 2022a; MBRRACE-UK, 2023b).

1.5 The maternity service workforce

The occupational groups involved in staffing maternity units include midwives, maternity support workers, medical staff, nursery nurses, nurses, clerical staff and allied health professionals (Health Education England, 2019b). Registered midwives and maternity support workers are the focus of this research.

Registered midwives

Registered midwives are autonomous practitioners who care for families during pre-pregnancy, pregnancy, labour, birth, postpartum, and the early weeks of newborn infants' lives (Nursing and Midwifery Council, 2019). They make a vital contribution to the safety and quality of maternity care (Nursing and Midwifery Council, 2019).

The midwifery workforce in England is undergoing significant challenges with vacant posts and a shortage of almost 2,500 full-time equivalent midwives (Bonar, 2019). In November 2023, there were 23,296 full-time equivalent (FTE) midwives employed in the NHS (NHS Digital, 2023d). According to the Royal College of Midwives (2017) the most common reasons for leaving the profession were that midwives were unable to give high-quality care due to workload and staffing levels. Almost 90% of midwives reported having unrealistic time pressures, and midwives have high sickness absence rates at 5.1%; 35% of which is due to anxiety, stress or depression (Launder, 2022; Taylor *et al.*, 2022).

Many midwives are approaching retirement with a reported 41% of midwives being over 50 years of age (Royal College of Midwives, 2022c). The average retirement age for midwives is 58.1 years so this is an impending problem (Taylor *et al.*, 2022). Replacing experienced staff with newly qualified midwives does not fully meet the skills gap, and it is critical to retain staff at all levels (Taylor *et al.*, 2022; Zhu *et al.*, 2024). There is evidence that trusts are finding it hard to fill vacancies as 77% of Heads of Midwifery reported that recruiting band six midwives was difficult or very difficult (Royal College of Midwives, 2022c). The Royal College of Midwives has referred to the midwifery workforce as a 'gathering storm' (Royal College of Midwives, 2017).

There is nationwide variation in the number of midwives employed per trust, with a median of 1 midwife per 28 births overall and an interquartile range of 1 midwife to 26-31 births (Turner *et al.*, 2022b). It is unknown the extent to which this variation relates to differences in service user acuity and service activity, or whether this reflects fundamental differences in how services are staffed in terms of the levels achieved and team composition.

Maternity support workers (Maternity assistants)

Maternity support workers are employees who work in maternity services but are not registered with the Nursing and Midwifery Council (Royal College of Midwives, 2024). They support midwives across the pregnancy and postnatal care pathway. A formal competency-based education programme is now available to support their education and development (Health Education England, 2019a; Health Education England, 2024). The benefits of upskilling support workers have been outlined by Griffin (2020). They can support midwives to focus on key areas as well as adding value themselves (Royal College of Midwives *et al.*, 2017). An evaluation of maternity support workers by Griffin *et al.* (2012) suggests they have a positive impact on breastfeeding, parent education and discharge procedures. According to Health Education England (2024), level four assistant practitioners in maternity will be educated to Foundation Degree level and will be expected to apply contextual knowledge and evaluate options to inform decision making. However, this role has not been fully implemented and is new for many maternity services (NHS England, 2024a).

While the proportion of support workers has grown in the NHS as a whole (Health Foundation, 2019), the figures appear relatively unchanged in maternity services, with approximately 24% of maternity staff being support workers in both 2015 and 2021 (Royal College of Midwives, 2022c). Ball *et al.* (2010) make the distinction between work that supports midwives and work that attempts to replace them. They highlight that substitution should not be done without robust research. In my published papers maternity support workers have been referred to as maternity assistants as the papers have been written for an international audience, and the title of maternity support worker is used primarily in England.

The challenges of matching workforce deployment with the demand for care are outlined below, along with policy responses to these difficulties.

Workforce planning

The NHS Long Term Plan stresses that services need enough staff with the right skills and experience to care for patients well (National Health Service, 2019). The NHS Long Term Workforce Plan (NHS England, 2023c) lists the priority areas as ‘train, retain and reform’ to enable sustainable staffing and improve care. The goal is to increase student midwife places by 13% in 2024/5 compared with 2021/2. However, it is not possible to tell whether the projected recruitment will be sufficient to fill vacancies and achieve quality standards. Not all students complete their education and go onto the professional register (McNeill *et al.*, 2024) and some have difficult experiences in the transition period after registration, leading to attrition (Watson *et al.*, 2021; Health Education England, 2018). The NHS plans to recruit both registered midwives and maternity support workers as they have different but complementary roles and work within a multidisciplinary team (NHS England, 2023c)

1.6 Workforce deployment in maternity care

Staffing of maternity services is complex and the demand for care fluctuates as labour care cannot be scheduled (Musy *et al.*, 2020). The National Institute for Health and Care Excellence (2015) guidelines on safe midwifery staffing state that organisations must be responsive by developing escalation plans to manage unexpected variations in demand. As part of escalation plans, staff are moved from other areas of the service to help cover central maternity services in times of need. For example, midwives are moved from community clinics and postnatal wards to cover staffing gaps in the labour ward. There is some concern that staff movement leads to low staffing and decreased quality of care in the contributing area (APPG Baby Loss and Maternity, 2022; Bowers *et al.*, 2016; Dunkley-Bent, 2016; Forster *et al.*, 2006). Over 50% of midwives reported being called away from a mandatory training session to work in the unit due to staffing issues (Dent *et al.*, 2024). These training sessions have safety critical content such as neonatal life support, fetal monitoring and maternity emergencies which must be completed annually by all midwives (NHS England, 2023a). A survey of 2347 UK midwives found that 88% rarely or never finished their shift on time, and 75% were not able to take their rest breaks (Dent *et al.*, 2024). Both of these factors increased the odds of work-related stress and burnout, and those working on the antenatal and postnatal wards were most at risk (Dent *et al.*, 2024).

According to an expert evaluation, understaffing has limited progress against the Government's policy commitments to improve maternity services in England (House of Commons, 2021). Staffing shortfalls have meant that plans for midwifery continuity of carer have been put on hold in many organisations (Ockenden, 2022; APPG Baby Loss and Maternity, 2022), despite evidence that this pattern of working is associated with better outcomes for mothers and babies (Sandall *et al.*, 2024). Choice of birth environment has been restricted due to the closure of birth centres (Rayment *et al.*, 2020; Campbell, 2019; Smith, 2024). Closure of labour wards has occurred when staffing levels were unable to match high demands for services (Asthana, 2017; Campbell, 2019). The Royal College of Midwives found that 40% of main obstetric units had closed at least once in the previous year, with four units closing more than ten times due to staffing pressures (Royal College of Midwives, 2019). A modelling study concluded that limiting community births for low-risk women when there are staffing shortages has a negligible effect on staff resource and has negative consequences on women's birthplace choices and staff wellbeing (Grollman *et al.*, 2022). Postnatal care has been referred to as a 'Cinderella' service with reports of unmet needs and lack of priority for funding (Goodwin *et al.*, 2018; Warwick, 2014).

Accountability in relation to safe staffing is weak in England, as there is no legislation on minimum staffing levels (Rafferty *et al.*, 2023). The regulatory body, the Care Quality Commission, conducts regular inspections of NHS trusts. They hold each organisation responsible under Regulation 18 of the Health and Social Care Act, stating that organisations must deploy sufficient numbers of suitably qualified, competent, skilled and experienced staff to meet professional standards (Care Quality Commission, 2021). As a step further, staffing ratios are mandated in some parts of the USA and Australia (Association of Women's Health Obstetric Neonatal Nurses, 2022; Australian Nursing Midwifery Foundation, 2015). For example, in Queensland Australia, a minimum of one midwife to six postnatal patients has been introduced by law (Queensland Government, 2023). This mirrors regulation in other workplace sectors in England such as in childcare settings and aviation (Department for Education, 2014; Civil Aviation Authority, 2023). However, policymakers have not erred on the side of caution when it comes to safe staffing in England (Rafferty *et al.*, 2023).

One reason cited for the lack of directives is that the evidence base on safe staffing is weak (National Institute for Health and Care Excellence, 2015). The recommendation for one-to-one care in labour is based on evidence, but no recommendations exist for other areas of maternity care. Health care managers are encouraged to use evidence-based decision support tools alongside professional judgment to set staffing levels (National Quality Board, 2018). It has been noted that the prominent staff calculation tool, Birthrate Plus, lacks empirical evidence to demonstrate that the recommended staffing numbers represent optimal or safe staffing (Griffiths *et al.*, 2023) which is a limitation of this approach.

Health services must deliver high quality care to enable women to have a positive maternity experience and achieve the best outcomes for themselves and their babies (World Health Organization, 2022). The definition of high quality care will be considered in the next section as this is central to my research.

1.7 Care quality in maternity services

The World Health Organization (2021) defines high-quality care as being effective, safe, and people-centred. Services need to be timely, equitable, integrated, and efficient to achieve these goals. Measurement of quality in maternity services has been the subject of several reports (NHS England, 2018; Renfrew *et al.*, 2014; World Health Organization, 2019; Devane *et al.*, 2019). The foundations of this work come from Donabedian's 'Structure', 'Process' and 'Outcome' model (Donabedian, 1966) and this framework has been applied by Wilson *et al.* (2010) and Lyndon *et al.* (2022b) to understand the influence of maternity staffing on outcomes.

Staffing levels and skill mix would be classified under 'Structure' and these measures represent the way in which health care is organised. 'Process' measures can be a direct way of measuring care in a contemporaneous way. Incomplete or missed care can be identified throughout the maternity and neonatal pathway. Lyndon *et al.* (2022a) has mapped missed care for labour and birth using the MISSCARE survey developed by Kalisch *et al.* (2009). Outcomes are considered to be the ultimate sign of effectiveness (Donabedian, 1966). They are often easier to measure, however, they do not present a complete picture of care.

Pittrof *et al.* (2002) propose a definition for quality in maternity services based on providing a minimum level of care to all pregnant women and their babies, and a higher level of care to those who need it. This concept is also apparent in the framework by Renfrew *et al.* (2014) when highlighting the contributions that midwives make to the care of women and babies. They identified fifty-six outcomes which could be improved by midwifery care, comprising short-, medium- and long-term measures including mortality, morbidity and psychosocial outcomes (Renfrew *et al.*, 2014). Definitions of care quality have become broader over time, and now encompass service user satisfaction as well as clinical performance (Pittrof *et al.*, 2002). There are concerns that women's experiences of care are overlooked, as childbirth has become more medicalised (Stapleton *et al.*, 2020). It is important that women receive care that is both safe and personalised (NHS England, 2021b) and are supported to make informed choices even if these fall outside of recommended guidance (Royal College of Midwives, 2022a). Some parts of the UK involve service users in reviewing the quality of services using the fifteen steps approach, which is a toolkit devised by service users, midwives, doctors and commissioners (NHS England, 2018). In a review by Izugbara *et al.* (2018), women favoured care that was integrated, co-ordinated, safe, compassionate, respectful and culturally sensitive. Sandall *et al.* (2014) report that it is important to develop indicators of quality that are important to women and their families based on their own experience. A positive experience of pregnancy, birth and motherhood are recurring themes in systematic qualitative reviews of the international literature

(Downe *et al.*, 2018; Finlayson *et al.*, 2020; Downe *et al.*, 2016). Emphasis is placed on thriving and flourishing, not simply surviving (World Health Organization *et al.*, 2018).

There is a lack of agreement on which measures are most suitable for assessing the quality of maternity care (Collins *et al.*, 2015). It is insufficient to only measure mortality, as it is a rare event in predominantly young healthy populations. The Royal College of Obstetrics and Gynaecologists identified eleven potential performance indicators which can be derived from routine health data, although their use is not widespread due to missing data and unexplained variation within the routine datasets (Knight *et al.*, 2013). The Agency for Healthcare Research and Quality has developed a number of indicators which can be used, and these are starting to encompass patient experience in addition to clinical outcomes (Quigley *et al.*, 2022). The Society for Maternal-Fetal Medicine Safety Health Policy Committees *et al.* (2016) proposes indicators that can be used internationally but note that the quality of data sources can vary considerably.

Outcome measures that are sensitive to changes in midwifery staffing have been documented, although this body of work is still in its infancy (Lyndon *et al.*, 2022b). The NICE guidance lists specific 'red flag' events to trigger a review of staffing. These are intended as early indicators of staffing insufficiency which may reduce the quality of care (National Institute for Health and Care Excellence, 2015). 'Red flag' events include delays in care, missed medication and cancelled time-critical activity.

Trends in care quality

Recent years have seen a reduction in stillbirth, maternal deaths and neonatal deaths (NHS England, 2020). However, figures for January to December 2021 saw a rise in each of these measures, partly due to the Covid-19 pandemic (MBRRACE-UK, 2023a; MBRRACE-UK, 2023b). Women with health or social risk factors, such as mental health problems, obesity, socioeconomic deprivation, language barriers, and domestic abuse are at higher risk of poor outcomes (MBRRACE-UK, 2021). Those from Black and Asian ethnic groups are disproportionately affected in terms of maternal and perinatal mortality (MBRRACE-UK, 2023a; MBRRACE-UK, 2023b), and in many cases have received substandard care (Howell *et al.*, 2017).

There have been recent investigations into poor practice and outcomes in several UK maternity services (Ockenden, 2022; Kirkup, 2022; Kirkup, 2015). The Care Quality Commission regulates health care environments and has classified 10% of maternity services as 'inadequate', 39% as 'requires improvement', 47% as 'good' and 3% as 'outstanding' (Care Quality Commission, 2023b). This rating is far worse than almost all other clinical specialities. For comparison, 75%

of NHS acute core services were rated as good or outstanding (Care Quality Commission, 2022a). Service user surveys have documented dissatisfaction with the experience of care. Areas for improvement include inpatient postnatal care, listening to parents, communication, and infant feeding support (Care Quality Commission, 2022b; Mumsnet, 2017; Harrison *et al.*, 2021). Poor quality care is also captured in adverse incidents, readmission rates, incomplete clinical care and delays in care (Australian Institute of Health and Welfare, 2023; Fischer *et al.*, 2014; National Institute for Health and Care Excellence, 2015).

This data paints a bleak picture of maternity services although there has been recent investment, as 127 million pounds was pledged in March 2022 to improve the quality of services (NHS England, 2022). A further 35 million pounds was promised in the Spring budget of 2024 to listen and act on women's experiences (Department for Health and Social Care, 2024). Investment is accompanied by several policy drivers and ongoing work to improve maternity services. The government aims to halve the 2010 rates of maternal deaths, stillbirths, neonatal deaths and brain injuries in babies by 2025 (Department of Health and Social Care, 2021). Initiatives include the Saving Babies Lives Care Bundle, Perinatal Mortality Review tool, Maternity and Newborn Safety Investigations programme (MNSI), and the Maternity Incentive scheme. Each workstream has a service user representative to ensure that women are involved in strategic planning and decision making (Department of Health and Social Care, 2021). The quality of care is not just dependent on the funding awarded to maternity services. High quality care results from a culmination of physical resources, systems, leadership, staffing, team work, training, evidence-based practice and the right culture and values (Howell *et al.*, 2017; Mosadeghrad, 2014).

1.8 Literature review: maternity staffing and care quality

The NICE guidance entitled 'Safe midwifery staffing for maternity settings' was based on the scant research evidence available at the time, with just eight research studies that examined the impact of staffing levels on maternity outcomes (Bazian, 2015; National Institute for Health and Care Excellence, 2015). A rapid appraisal of the evidence by Sandall *et al.* (2017) found no further published research to refresh this guidance.

In preparation for this research, a systematic scoping review was undertaken in 2020 and published in 2021 (Turner *et al.*, 2021), Appendix C. The aim was to identify and summarise research papers which provide data on the association between staffing levels of midwives and the quality of care and outcomes for mothers and babies. The search strategy is included in Appendix B and was conducted in Medline (Ovid), Embase (Ovid), CINAHL (EBSCO), Cochrane Library, TRIP, Web of Science and Scopus on 6th April 2020. To be eligible for inclusion, staffing levels had to be quantified and the population had to be cared for in hospital settings such as ante-natal, labour/delivery and post-natal wards and outcomes quantitatively reported.

The scoping review identified 21 separate studies that were eligible for inclusion, as agreed by two reviewers. These studies were reported in a total of 23 papers. The characteristics of the studies are outlined below in Table 1 and further details are given in Turner *et al.* (2021) presented in Appendix C. The structured searches were updated in February 2024, at which time seven new studies met the criteria for inclusion and have been added to Table 1.

The published research represents a relatively small evidence base compared to nurse staffing research where there are over 100 published studies (Ball *et al.*, 2022). Most of the worldwide midwifery studies use administrative data and have observational designs, most commonly cohort or cross-sectional studies. The focus has been mainly on outcomes on labour ward, with fewer studies considering broader outcomes such as readmission, breastfeeding rates and satisfaction with care.

Many of the studies have presented mode of birth as an outcome measure. Caesarean section rates are no longer considered an indicator of quality in England (Wilkinson, 2022). Safety can be compromised if sometimes necessary interventions such as caesarean section are not carried out in a timely way (Ockenden, 2022), and there has been an increase in women requesting caesarean section for non-medical reasons (Rai *et al.*, 2021). Although mode of birth is not a primary indicator, the available studies present some information on how high workloads can affect processes in health care and the potential for added costs and procedures. For example, Facchini (2022) found more caesarean sections were taking place when midwives had a high workload in terms of the patient to midwife ratio. A similar effect was found with epidural use which was more common at times of high midwifery workload (Kpea *et al.*, 2015).

Table 1 Studies measuring the association between staffing and quality of care

First Author	Date	Design	Population	Measurement of staffing	Outcome measures
Stillwell Mugford	1988 1988	Cohort	UK, 20 maternity units	Full-time equivalent per 1000 births	Stillbirth, neonatal mortality
Gagnon	1997	RCT	Canada, 413 women early labour	1:1 care or usual care ward and shift level*	Caesarean birth, oxytocin, pain relief, trauma, Apgar, neonatal unit admission
Hodnett	2002	RCT multicentre	Canada, 6915 women	Continuous labour support or usual care*	Caesarean birth, epidural, trauma, neonatal outcomes, satisfaction
Joyce Joyce	2002 2004	Cross sectional multicentre	UK, 540,834 births	Full-time equivalent midwives per 1000 births	Mode of birth, epidural use, stillbirth, neonatal mortality.
Tucker	2003	Cohort multicentre	UK, 1561 women with continuous fetal monitoring	Number of observed midwives vs required midwives per shift*	Appropriate fetal monitoring use, Apgar, neonatal unit admission, resuscitation
Gerova	2010	Cross-sectional multicentre	UK, 615,042 mothers giving birth	Full-time equivalent midwives to births ratio	Maternal readmission
Kashanian	2010	RCT	Iran, 100 women giving birth	Continuous labour support or usual care*	Length of labour, caesarean birth, oxytocin use, Apgar
Cerbinskaite	2011	Cohort	UK, 755 women who had emergency caesarean	Midwives:women ratio ward and shift level*	Transfer time to theatre
Clark	2014	Cohort multicentre	USA, 101,777 women with oxytocin in labour	Organisation level, proportion of 1:1 care	Caesarean birth, fetal distress, complications
Gerova	2014	Cross-sectional multicentre	UK, 261,481 women with operative birth and 214,949 unassisted birth	Full-time equivalent midwives to births ratio	Mode of birth
Knape	2014	Cohort	Germany, 999 low-risk women	1:1 care or not*	Mode of birth
Rowe	2014	Cohort multicentre	UK, 32,257 low-risk women	1:1 care or not*	Mode of birth, analgesia, interventions
Sandall	2014	Cross-sectional multicentre	UK, 656,969 births	FTE midwives and maternity support staff per 100 births	Body integrity, healthy mother, healthy baby, satisfaction
Bailey	2015	Cohort	UK, 61 women in labour	Midwives:women ratio ward and shift level*	Record keeping
Kpea	2015	Cross-sectional multicentre	France, 1835 low-risk women	Midwives on shift to annual births ratio*	Epidural analgesia when not planned it
Kim	2016	Cohort multicentre	Korea, 633, 461 admissions, 438,191 with caesarean section	Sum of nurses in hospital and proportion registered	Maternal readmission
Mercer	2016	Cohort multicentre	USA, 101,120 births	Total nursing hours per shift/births per shift*	Postpartum haemorrhage, shoulder dystocia, Apgar, fetal outcomes.

First Author	Date	Design	Population	Measurement of staffing	Outcome measures
Zbiri	2018	Cohort multicentre	France, 102,236 births	Full-time equivalent midwives per 100 births	Mode of birth
Dani	2020	Cohort multicentre	Italy, 110 midwifery led 110 obstetric led units	Organisation level typical ratios	Exclusive breastfeeding, readmission
Makfudli	2020	Cross-sectional multicentre	Indonesia, 8,266 women	Midwife to birth ratio per year, also nurse ratio	Maternal deaths, near miss events
Prapawichar	2020	Case-control multicentre	Thailand, 153 cases with haemorrhage, 1530 controls	Women to midwife ratio for the organisation, meeting 2:1 standard	Postpartum haemorrhage
Wilson	2021	Cohort multicentre	USA, low-risk women giving birth	Nursing hours per birth	Caesarean birth
Robertson	2021	Cohort	UK, 4943 women giving birth	Staffing shortfall as determined by Birthrate Plus	Delayed induction of labour
Lyndon	2022	Cross-sectional multicentre	USA, 2,691 labour nurses	Adherence to nurse staffing ratios	Missed care, exclusive breast feeding
Facchini	2022	Cohort	Italy, 11,359 births	Ratio women : midwives in labour ward*	Caesarean birth
Pokharel	2023	Cross-sectional multicentre	Nepal, 267 healthcare providers	Staff:women ratio (midwives and medical staff)	Respectful maternity care
Vanderlaan	2023	Cross-sectional multicentre	USA, 875,156 women	Midwife density per 1000 births	Caesarean birth, preterm birth
Etcheverry	2024	Cross-sectional multicentre	Argentina, Burkina Faso, Thailand, Vietnam 2,092 low-risk women	Workload as births per day and number of midwives on duty	Caesarean birth

*measurement of staffing close to women by location or time period RCT randomised controlled trial 1:1 one-to-one

The available evidence reports on quality and safety measures for mothers and babies, and a summary of the findings and directions of effects are given in Table 2 below. Statistically significant findings noted in Table 2 include a reduced incidence of perineal damage at birth, postpartum haemorrhage, maternal readmission, preterm birth and neonatal resuscitation when there were more midwifery staff. Higher staffing was also associated with higher rates of exclusive breastfeeding, respectful care and satisfaction with care. In the outcome of stillbirth and neonatal death, there were no differences observed when staffing varied. Few studies have suggested a negative impact of increasing staffing rates, and these are outweighed by studies suggesting a protective effect for many outcomes. Some studies looked at care processes in labour, such as the time taken to reach theatre for a caesarean section, the quality of documentation, delay in induction of labour and the use of appropriate fetal monitoring (Turner *et al.*, 2021; Robertson *et al.*, 2021). Many of these found improved care quality with more staff but it is unclear how these measures translate into outcomes for mothers and babies.

Table 2 Maternal and neonatal outcomes in relation to staffing

Outcome measure	Favours more staff	Point estimate favours more staff (non-significant)	Point estimate favours less staff (non-significant)	Favours less staff
Maternal outcomes				
Severe maternal outcome (death or near miss)	(Makhfudli *et al.*, 2020) (nurses)			(Makhfudli *et al.*, 2020) (midwives)
Intact perineum/trauma	(Sandall *et al.*, 2014)	(Gagnon *et al.*, 1997) (Hodnett *et al.*, 2002)		
Delivery with bodily integrity	(Sandall *et al.*, 2014)			
Postpartum haemorrhage	(Prapawichar *et al.*, 2020)			
Composite healthy mother		(Sandall *et al.*, 2014)		
Lower Maternal readmission	(Gerova *et al.*, 2010) (Kim *et al.*, 2016)			
Satisfaction/preference	(Hodnett *et al.*, 2002)	(Sandall *et al.*, 2014)		
Respectful care	(Pokharel *et al.*, 2023)			
Multiple complications				(Clark *et al.*, 2014)
Endometritis			(Clark *et al.*, 2014)	
Amnionitis			(Clark *et al.*, 2014)	
Neonatal outcomes				
Apgar score		(Tucker *et al.*, 2003) (Kashanian *et al.*, 2010)		(Gagnon *et al.*, 1997)
Lower Birth asphyxia		(Clark *et al.*, 2014)	(Hodnett *et al.*, 2002)	
Lower rates Neonatal resus	(Hodnett *et al.*, 2002)			
Lower rates Neonatal resus*	(Tucker *et al.*, 2003)			
Composite healthy baby		(Sandall *et al.*, 2014)		
Exclusive breastfeeding	(Dani *et al.*, 2020) (Lyndon *et al.*, 2022b)			
Admission to Neonatal unit (NNU)	(Dani *et al.*, 2020)	(Hodnett *et al.*, 2002) (Tucker *et al.*, 2003)	(Gagnon *et al.*, 1997)	
Preterm birth	(Vanderlaan, 2023)			
Neonatal length of stay		No difference (Wilson *et al.*, 2021)	(Hodnett *et al.*, 2002)	
Lower Stillbirth		No difference (Joyce *et al.*, 2004)		
Lower Neonatal death		No difference (Joyce *et al.*, 2004) No difference (Stilwell *et al.*, 1988)		
Perinatal complications		No difference (Mercer, 2016)		

*excluding bag/mask only

Only three studies included maternity support workers (Gerova, 2014; Sandall *et al.*, 2014; Kim *et al.*, 2016) and higher staffing by support workers was not associated with improved outcomes, although the evidence base is small. The contribution of maternity support workers needs to be assessed, especially as this staff group have the potential to expand and take on more tasks previously done by midwives (Health Education England, 2019b). The trade-offs between staff groups to optimise safety, quality and efficiency have not been thoroughly evaluated.

Studies were assessed for risk of bias in the scoping review. Although methodological issues have been identified, the quality of the evidence has not been rigorously evaluated which is consistent with the scoping review methodology. Less than half of the studies in Table 1 measured the staffing exposure close to the woman, in the same time period or location (denoted with an asterisk). The rest of the studies provide broad estimates of staffing using aggregate data over the organisation or a wider time period (such as annually). One difficulty with aggregate data is that it is imprecise in representing the woman's exposure to staffing, as ward level exposure and daily variation is often not represented (Yang *et al.*, 2024). A further limitation is that some staff who are counted as full-time equivalent (FTE) midwives may not be working in patient-facing roles; they may be on sick leave or maternity leave, and their inclusion may attenuate any effects seen.

Three studies had no risk adjustment (Bailey *et al.*, 2015; Cerbinskaite *et al.*, 2011; Clark *et al.*, 2014) and many others had limited risk adjustment. It is difficult to attribute the observed effects to staffing if they may be explained by other unmeasured variables. Risk adjustment is crucial, as women's outcomes are largely dependent on their parity, age and clinical risk (Sandall *et al.*, 2014). Although the review included three randomised controlled trials (Gagnon *et al.*, 1997; Hodnett *et al.*, 2002; Kashanian *et al.*, 2010) these all had some marked limitations, such as one arm having additional interventions or having a very narrow patient population or focus. Limitations of the cross-sectional studies are that the staffing exposure was not documented as preceding the effect, and therefore associations cannot be interpreted as causal without the sequence of events being known (Cox, 2018; Shimonovich *et al.*, 2021).

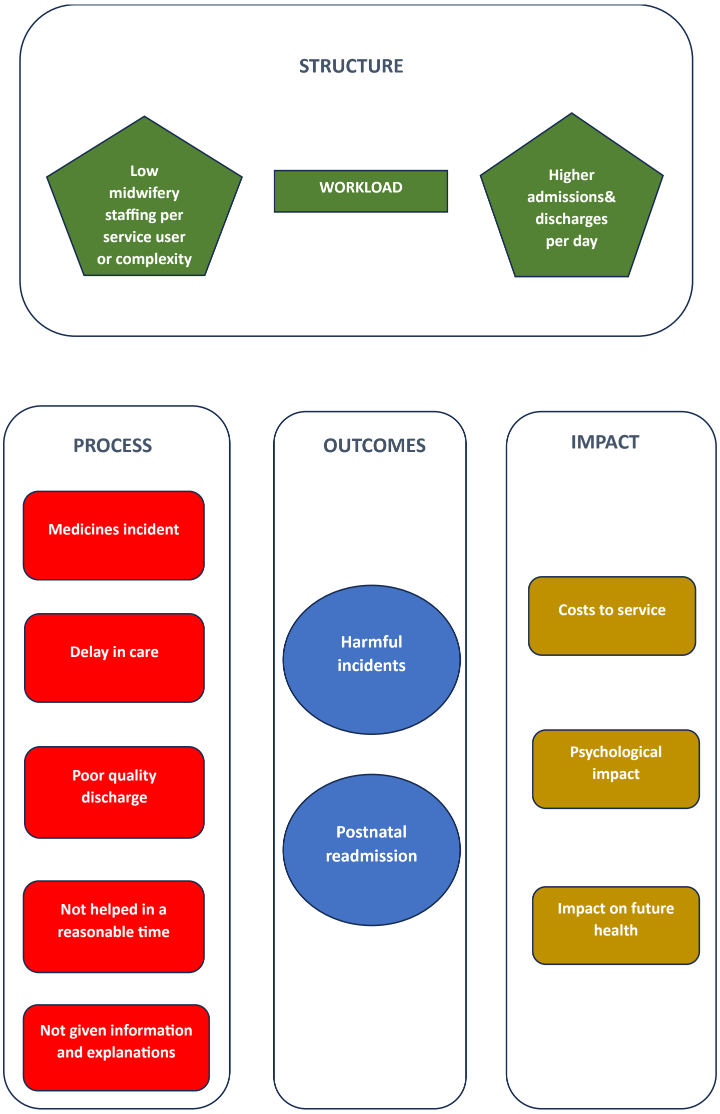
There is a need for more studies worldwide, in different settings and populations to enable study results to be applied to similar settings. Few studies have presented staffing levels or benefits in absolute terms, so it is difficult to translate findings into tangible predicted outcomes for women. There is also insufficient evidence on maternity support workers to draw conclusions on their contribution.

The scoping review demonstrated that more research is needed to understand the relationship between staffing levels, skill-mix and the quality of care for mothers and babies, using a wide range of outcome measures (Turner *et al.*, 2021). There is a reasonable amount of high-quality evidence to support the recommendation of one-to-one care in labour, based on the updated Cochrane review on continuous support in labour (Bohren *et al.*, 2017) and the positive associations found in the scoping review summarised in Tables 1 and 2 (Turner *et al.*, 2021). However, there is much more uncertainty in the areas of inpatient antenatal and postnatal care as very little research has been done in these areas. Given that midwifery staff are commonly shared within an organisation, there is potential for understaffing in these areas with unrecognised effects on quality. This may occur as managers relocate staff in response to surges in demand to ensure that one-to-one care in labour is provided (APPG Baby Loss and Maternity, 2022).

The studies undertaken as part of this PHD have responded to the evidence gaps and attempted to improve on the methodology by measuring staffing as close to women as possible, adjusting for individual and organisation characteristics, including support staff, and employing a range of designs including one longitudinal study of individual patient data.

It is hypothesised that staffing levels and workload contribute to both process and outcome measures, which may have consequences for costs and future health. Figure 1 depicts some of the variables in this research study, which aims to uncover the strength and direction of relationships between 1) staffing and care processes/experiences, and 2) staffing and outcomes. However, this work does not examine the relationships between process measures and outcomes or the cost consequences of staffing decisions, as this data was not readily available. This conceptual model will be revisited in the discussion in relation to the research findings and recommendations for future research (section 3.4).

Figure 1 Proposed conceptual model linking staffing to the quality of care and consequences



The methodological approaches and choice of measurement tools are described below.

1.9 Methodology

Overview of study designs and use of secondary data

Quantitative methods are appropriate to explore the relationships between maternity staffing and different quality measures, and to provide estimates of effect needed to inform practice. The use of large datasets means the effects of staffing can be estimated while accounting for other influencing factors using multivariable models (Bland, 2015). The precision of estimates is also improved with large sample sizes (Asiamah *et al.*, 2017).

Data has been obtained from routinely collected administrative data in the NHS for all four studies. This is classed as secondary data analysis, as data was originally collected for another purpose (Trenner *et al.*, 2019). The advantage of looking at existing datasets is that they are readily available and published online or can be made available on request following a data-sharing agreement. Investigation using routine data is quicker and less expensive than conducting a randomised trial or a prospective study (Cheng *et al.*, 2014; Jones, 2019). Routine data studies are particularly useful in areas where randomised trials are inappropriate or are difficult to complete (Hemkens *et al.*, 2016).

National health datasets hold thousands of records with real-world observations. They are not confined to specialist centres and do not have strict inclusion criteria if datasets are population-based (Sinha *et al.*, 2013; Hemkens *et al.*, 2016). Datasets can be linked, and many variables can be collected and analysed. The Goldacre (2022) review commissioned by the Secretary of State for Health and Social Care refers to the untapped potential of NHS data to answer research questions and promises improved platforms to house data in the future. A limitation of secondary analysis is that datasets are not always published in a timely way, or may have missing or incorrectly coded data (Jones, 2019). The characteristics of each study and information about the datasets are outlined in Table 3.

Table 3 Summary of data sources and measurement variables in the four studies

Study	Focus of study	Design	Staffing and quality variables	Data sources for each variable	Unit of data	Number of records
1	Experience of postnatal care	Cross-sectional	Midwives FTE	NHS Workforce statistics matched to month of survey	Trust level	129
			Experience of care	2018 CQC Maternity Survey	Individual women	17,611
2	Experience of postnatal care	Cross-sectional	Midwives FTE	NHS Workforce statistics matched to month of survey	Trust level	123
			CHPPD – Midwives and Assistants	CHPPD dataset matched to month of survey	Ward level	93
			Experience of care	2019 CQC Maternity Survey	Individual women	13,264
3	Postnatal readmissions	Longitudinal	CHPPD – Midwives and Assistants	Roster and outcome data obtained directly from maternity services 2015-2020	All inpatient maternity services (per shift)	All shifts for 46 months in 3 organisations
			Postnatal readmissions		Individual women	64,250 eligible birth admissions
4	Harmful incidents	Cross-sectional nested in longitudinal study	CHPPD – Midwives and Assistants	Roster and outcome data obtained directly from maternity services 2015-2020	All inpatient maternity services (per day)	All days for 46 months in 3 organisations
			Incident reports		Count of incidents per day	106,904 admissions

FTE Full Time Equivalent CHPPD Care Hours per Patient Day

The first study examined women's experience of inpatient postnatal care in relation to the midwifery staff employed in each organisation. This retrospective cross-sectional study examined mothers' experience of hospital postnatal care in England in February 2018. Individual responses to the Care Quality Commission Maternity Survey were accessed via the UK Dataservice. This data was joined with the nationally published full-time-equivalent staffing figures for registered midwives in the corresponding organisations. Four questions about the quality of postnatal care were used in the analysis. Staffing levels were used as independent variables in the regression analyses, adjusting for other organisational and individual covariates.

Study two is also a cross-sectional study, and this replicated methodology from the first study (using full-time-equivalent staff) but also extended the enquiry to examine ward-level staffing measured by Care Hours Per Patient Day (CHPPD). CHPPD is a nationally published dataset which contains monthly staffing levels for both midwives and support workers (NHS Improvement, 2018). This permitted a more detailed exploration of relationships between staffing and care experience, and the contribution of each of the staff groups. Both studies one and two used monthly measures of staffing which were averaged over all days of that month, and this was matched to women's survey responses relating to the same month.

Effectiveness and safety are also key components of care quality (World Health Organization, 2021) and these aspects were tackled in studies three and four. Daily staffing roster data was collected as part of a larger study (Griffiths *et al.*, 2019a), and this provided the opportunity to examine outcomes for individual women in maternity services across three NHS trusts. The trusts were purposefully selected to represent different types of services and population demographics to aid the generalisability of findings. In study three, individuals were tracked through maternity services using admission and discharge details, and their exposure to inpatient staffing was recorded during the first two 12-hour periods of their stay. This study examined relationships between staffing levels and postnatal readmissions within seven and thirty days of discharge. One advantage of this dataset is that shift-level staffing was available which is more granular than the monthly level staffing measured in studies one and two. This longitudinal study created an excellent opportunity to follow women over time to examine whether they were readmitted to hospital after their initial hospital stay giving birth. This dataset included time worked by midwives and maternity support workers and allowed for case-mix adjustment as many individual characteristics were recorded.

The last study examined daily staffing levels and reported incidents in three NHS trusts over 46 months. Study four is a cross-sectional analysis nested in the same longitudinal study as study three. Incident report data was obtained for each calendar day and incidents that were harmful to mothers or babies were the primary outcome of interest. This study matched incident counts to the staffing levels of midwives and maternity support workers in the maternity unit on the same day. This study examines some of the incidents in Table 2 and adds some new areas that have not been studied before, such as medicines incidents and incidents related to discharge.

The data relates to maternity services in 2018 (study one), 2019 (study two) and 2015-2020 (studies three and four). Service re-configurations and staff redeployment took place during the Covid pandemic (Jardine *et al.*, 2021; Stockdale, 2023), and therefore data after February 2020 was excluded.

Public and professional engagement and choice of quality measures

A consultation was undertaken with midwives and families regarding appropriate measures to use when evaluating maternity care. This anonymous survey was undertaken in April 2021 via social media (Twitter, Facebook and Netmums internet page), following ethical approval ERGO 64095. Responses were obtained from 28 members of the public and 17 midwives or midwifery managers. The adverts and questionnaires can be found in Appendix A. These were used to help incorporate the perspectives of women and midwives when evaluating the quality of care, and consider outcomes responsive to variation in staffing that are important to both groups. Measures of care experience were suggested by participants, such as a timely response when asking for help and receiving emotional support, in addition to harmful clinical consequences related to understaffing.

For this project, it was important to select quality measures that are potentially sensitive to staffing variation, those that could be measured with precision and consistency, while also contributing knowledge in key areas of quality. Circling back to the World Health Organization (2021) definition of quality, this project selected measures from each of the areas of effectiveness, safety, and person-centred care. The final choice of outcome measures were women's experience of postnatal care, maternal readmissions and harmful incidents. These are also areas where data was available in order to carry out this study, without the need to collect primary data.

Naughton *et al.* (2021) states that midwifery care is largely constrained within the biomedical model of care and that woman-centred care sometimes takes second place. Inclusion of women's experiences therefore seemed appropriate, as data on physical safety is insufficient to judge the quality of a service alone (Busse *et al.*, 2019). Readmissions are a marker of quality of care (Blume *et al.*, 2021) and postnatal readmissions have been rising in England, with latest figures showing a rate of 4.3% in women who have had a caesarean birth (National Maternity and Perinatal Audit, 2022). The complexity of cases has led to a recommendation that women who are readmitted must be reviewed by an obstetric consultant due to the seriousness of some presentations and the potential for morbidity and mortality (Ockenden, 2022). Readmissions have not been extensively studied with just one cross-sectional study in the UK reporting on this outcome in relation to staffing (Gerova *et al.*, 2010).

During this PhD (2020-2024) the Ockenden Report was published highlighting the poor experiences and outcomes for mothers and babies in one NHS trust (Ockenden, 2022). This review examined 1,592 incidents affecting 1,486 families over two decades and was the largest investigation of its kind in NHS history. Many staff had raised concerns about unsafe staffing levels and patient safety. The Care Quality Commission and numerous inquiries have also highlighted the role of understaffing in care quality and safety incidents (Care Quality Commission, 2024; Ockenden, 2022; Parkin *et al.*, 2023; House of Commons, 2021; Maternity and Newborn Safety Investigations, 2024). The Ockenden report and subsequent reflections provided additional compelling reasons to examine empirical evidence that can assess the relationship between harmful incidents and staffing levels.

Occupational groups included in the studies

The staff groups included in this project are midwives and maternity support workers, as they form most of the workforce, and workforce planning is usually undertaken for these groups together (NHS Digital, 2022b). Nurses working in maternity care and medical staff were not the focus of this research. Only a small number of registered nurses are employed in maternity services at present, with most trusts reporting there were none in a survey by the Royal College of Nursing (2019). Medical staff typically cover both obstetrics and gynaecology specialities and there is some difficulty in assessing their maternity contribution from the available data (Royal College of Obstetricians and Gynaecologists, 2022).

The studies do not include the midwifery staff arranged in Continuity of Carer teams, where midwives are assigned a caseload of families and they provide all antenatal, labour and postnatal care (Sandall *et al.*, 2024). Implementation has been paused in some areas and there is variation in how services are configured (Bradford *et al.*, 2022; Dharni *et al.*, 2021; McCourt *et al.*, 2023). Questions on staffing variability and the quality of care are more easily answered using data for inpatient services, as they record staff who are rostered in a more uniform way.

Precision in measurement of variables

Although different outcomes are used from one study to another, there is a notable refinement of the level of detail in the measurement of staffing and outcomes;
- monthly organisational level staffing in study one (a measure of those employed)
- ward level staffing in study two (a measure of those deployed)
- shift level staffing in study three (a measure of exposure to staffing at a granular level, with individual follow up of outcomes)
- daily level staffing in study four (not matched on an individual level but daily staffing exposure and incidents were captured, which is a granular level of measurement).

Quality assessment of data sources

Quality assessment for the published NHS Workforce statistics, CHPPD and Care Quality Commission Maternity survey are presented in Appendix D. A number of other routine datasets were scrutinised for relevance and quality but were set aside and full details are given in Appendix D.

For the linked roster data in studies three and four, data quality was assessed for completeness in each of the fields and decisions to exclude data were discussed with the supervisory team.

An example of this was the decision to link staffing to calendar days rather than shifts for clinical incidents in study four. The time of the incident was missing from over half of the recorded incidents for two of the organisations, and therefore linkage to shift staffing would have been imprecise. In other areas, the amount of missing data was minimal, and this is recorded in the supplementary data files and noted in the papers. Data cleaning included the removal of duplicate records after careful checking of all fields. Outliers were removed from datasets as part of the cleaning process. The rules for excluding outliers were recorded in the publications.

Triangulation of data was performed to sense-check the calculations from the individual patient data and roster data. The calculated CHPPD was compared to the published CHPPD dataset from NHS Digital (NHS Improvement, 2018). A further example of triangulation was for the readmission rates calculated for study three, which were comparable to those noted in national datasets for the same time-period. Other aspects of the data tallied with national findings such as higher rates of readmission in women who have had a caesarean section compared to a vaginal birth. Data collected after the end of February 2020 was not used in the analysis, as maternity services underwent substantial modifications due to the Covid pandemic and were not representative of usual practice (Jardine *et al.*, 2021). An example was the payment of student nurses and midwives to add to the workforce as part of the emergency NMC standards during the pandemic (NHS England, 2021a).

Selection of variables

Staffing and workload variables were chosen following a review of the literature on nursing and midwifery staffing to see which measures had been used in the past and to consider their relative merits. Workload does not have a uniform definition in the literature, but can include the number of patients to staff, complexity, patient turnover and workflow (Ivziku *et al.*, 2022). Absolute measures of workload include ratios of staff to patients, staff employed in an organisation compared to the number of births, and the number of staff per shift as described in the scoping review by Turner *et al.* (2021). Relative measures include whether staffing met an established guideline, staffing below mean levels and staffing relative to planned levels (Dall'Ora *et al.*, 2022; Lyndon *et al.*, 2022b). Absolute measures are more useful for service planners to work with, as recommendations can be considered for implementation in specific terms. However, staffing levels may vary deliberately due to the patient population and clinical need, and therefore it is useful to also consider deviation from a local norm as a way of describing understaffing. Measures used in my studies include a combination of relative staffing and absolute staffing, although there are some merits and drawbacks to each of these summary measures. As admissions and discharges represent additional workload, patient turnover was added to the regression models as a separate variable. The additional workload of assessment and discharge planning has been recognised in other fast paced clinical environments such as acute medical units (The Society for Acute Medicine, 2011). Patient turnover has been integrated into staff planning tools for inpatient areas in Western Australia, including recommendations for maternity units (Twigg *et al.*, 2009).

Independent predictor variables were selected based on clinical knowledge and previous literature on variables and their relationships with the outcomes studied (Clapp *et al.*, 2018; Girsen *et al.*, 2022; MBRRACE-UK, 2022; McLeish *et al.*, 2019). There are some occasions where variables were not available for analysis and these limitations were recognised in the papers. One deficit common across all the studies is that they were not able to account for deprivation and body mass index in the population, and rarely included medical staff. In some studies ethnicity and parity could not be included due to lack of data on these variables in the datasets. The implications of omitted variables is considered in the discussion.

Data visualisation and data analysis

Data on the distribution of variables was plotted to understand more about the range, central tendency and outliers. Where skewed, the median value was used in preference to the mean. Means are affected by outliers and skewed distributions, whereas median values are more stable in these circumstances (Walters *et al.*, 2021). Scatterplots were created to examine the relationship between variables and to observe both linear and non-linear patterns. Data characteristics and plots are included in the supplementary material in the appendices.

Decisions on data analysis were taken by myself, in conjunction with the supervisory team and a statistician. An example of this was the decision to divide postnatal experiences into a binary variable for analysis, by condensing the three possible responses of ‘yes always’, ‘yes sometimes’ and ‘no’ into two categories only. This binary variable allowed logistic regression methods to be used which are easier to interpret and analyse than ordinal data in regression analyses. In study four, the harmful incidents were grouped to produce one composite measure as the primary outcome. This composite outcome increases the power of the study to be able to detect effects if they are present in the data, reducing the chance of a type one error (Song *et al.*, 2013).

Outliers were removed before the analysis. The cut-offs were decided based on data rules or clinical knowledge about ward staffing. For example in study two, values that were more than 1.5 times the interquartile range more unusual than the first and third quartile were excluded

(Dunn, 2021). Missing data was reported for all studies, and results were interpreted recognising the limitations of incomplete data and the likely direction of bias.

The choice of regression model was informed by the data type and characteristics. Studies one to three used logistic regression models for binary dependent variables, and study four used a negative binomial model of daily count incidents (Harrell, 2015). The assumptions of models were tested and suitability was checked with a statistician. Guidance by Schreiber-Gregory (2018) was used before employing the multilevel multivariable logistic regression models. These checks included ensuring that the dependent variable is binary, observations do not come from repeated measures or matched data, there is a minimum of ten cases for each independent variable in the model, and there is an absence of multicollinearity. Predictor variables were tested for collinearity by calculating the variance inflation factor (VIF). This is an indicator of how much inflation of the standard error could be caused by collinearity. As a guide, a VIF of ten or greater is a sign of severe multi-collinearity (O'Brien, 2007).

Univariable associations between predictor variables and the dependent variable were conducted first. This insight gave early notification about the variables which are likely to account for variability in the dependent variables, other than staffing measures. Forward selection methods were used to avoid overfitting in the multivariable models. Variables were only retained where they improved model fit (Chowdhury *et al.*, 2020). The model with the least AIC and BIC scores was used to generate the regression coefficient. Where a difference of less than two on the AIC and BIC scores was noted, this was not acted upon as it is not considered to be discriminatory at this level (Burnham *et al.*, 2004). Hierarchical regression analyses were undertaken to account for clustering of participants within the same trust. The intra-cluster correlation coefficient (ICC) estimates the dependence of scores between individuals in the same group. Ignoring the clustering within higher-level units leads to a tendency to find more relationships significant than the data can support (Leyland *et al.*, 2020).

Continuous data was categorised so that comparisons could be made between high, near to mean, and low staffing. This type of analysis can suggest non-linear effects (Ho *et al.*, 2023). In studies one and two, tertiles were used in preference to quartiles or quintiles, so that the population size in each group was larger, thereby increasing the power of the analyses. Regression coefficients were transformed to odds ratios (from logistic regression in studies one to three) and incident rate ratios (from negative binomial regression in study four). Confidence intervals were presented for all results, and statistical significance was claimed where 95% confidence intervals did not contain the null effect (Bland, 2015).

The full model findings are presented in each of the papers. Some papers have included sensitivity analyses to test the planned methodology and sensitivity to the decisions undertaken, such as the grouping of variables (Delaney *et al.*, 2013). Where sensitivity analyses report similar results they are interpreted as being more robust, rather than being dependent on the research methods chosen. Secondary analyses such as analysis by subsets and exploring interaction effects have been conducted in some papers, although it has been made clear that these are exploratory analyses. A summary of all additional analyses and covariates for each study is presented in Appendix E. Conducting multiple post hoc secondary analyses needs to be done with caution as the chance of type 1 error increases with multiple analyses (Freeman, 2020). All analyses were undertaken in Stata v16.1 and coding is presented in Appendices G-J as supplementary material to the papers.

Ethics permission and Data Management Plan

Ethical permission was granted for the secondary data analysis for each of the studies (ERGO 62570, ERGO 52957). Ethics permission was also granted for the engagement consultation (ERGO 64095) with parents, midwives and midwifery managers presented in Appendix A.

The data management plan is presented in Appendix F. Data is stored in the University repository, and has not been made available along with the publications as this was not permitted by the suppliers.

Chapter 2 The Studies

Study 1

Published as Turner, L., Culliford, D., Ball, J., Kitson-Reynolds, E. and Griffiths, P. (2022) 'The association between midwifery staffing levels and the experiences of mothers on postnatal wards: cross sectional analysis of routine data', Woman and Birth, 35(6), pp. e583–e589. Supplementary material in Appendix G

Abstract

Background

Women have consistently reported lower satisfaction with postnatal care compared with antenatal and labour care. The aim of this research was to examine whether women's experience of inpatient postnatal care in England is associated with variation in midwifery staffing levels.

Methods

Analysis of data from the National Maternity Survey in 2018 including 17,611 women from 129 organisations. This was linked to hospital midwifery staffing numbers from the National Health Service (NHS) Workforce Statistics and the number of births from Hospital Episode Statistics. A two-level logistic regression model was created to examine the association between midwifery staffing levels and experiences in post-natal care.

Results

The median full time equivalent midwives per 100 births was 3.55 (interquartile range 3.26 to 3.78). Higher staffing levels were associated with less likelihood of women reporting delay in discharge (adjusted odds ratio [aOR] 0.849, 95% CI 0.753 to 0.959, p=0.008), increased chances of women reporting that staff always helped in a reasonable time aOR1.200 (95% CI 1.052, 1.369, p=0.007) and that they always had the information or explanations they needed aOR 1.150 (95% CI 1.040, 1.271, p=0.006). Women were more likely to report being treated with kindness and understanding with higher staffing, but the difference was small and not statistically significant aOR 1.059 (0.949, 1.181, p=0.306).

Conclusions

Negative experiences for women on postnatal wards were more likely to occur in trusts with fewer midwives. Low staffing could be contributing to discharge delays and lack of support and information, which may in turn have implications for longer term outcomes for maternal and infant wellbeing.

Keywords

Postnatal, Workforce, Midwife; Staffing, Patient experience, Maternity

Statement of significance (problem)

Women report negative experiences of postnatal care compared with antenatal care and birth. There is a recognised shortage of midwives in maternity services, and this may be impacting on the quality of postnatal care.

What is already known?

There is evidence that midwifery staffing levels are associated with birth outcomes but little empirical evidence on the impact of midwifery staffing levels in postnatal care.

What this paper adds?

This analysis of survey data supports previous findings that increased midwifery staffing is associated with benefits. This is the first study to examine the effects of organisational staffing on women's experience of postnatal care.

Background

The State of the World's Midwifery report estimates that 900,000 more midwives are needed internationally to provide safe care and positive birth experiences (United Nations Population Fund, 2021). Investment in midwives has been predicted to substantially reduce maternal and infant mortality (Nove *et al.*, 2021) and better workforce planning has been at the forefront of recent policy initiatives (The Institute for Fiscal Studies, 2017; Buchan *et al.*, 2019; Health Education England, 2019b).

This study focuses on inpatient postnatal care as women have consistently reported lower satisfaction with postnatal care compared with antenatal and labour care (Brown *et al.*, 2005; Scottish Government, 2019b; Care Quality Commission *et al.*, 2020). A systematic review of 53 studies on expectations and experiences of inpatient postnatal care concluded that whilst women were generally satisfied with their care, they were sometimes critical of communication, feeding support and a lack of explanations (Malouf *et al.*, 2019). In a qualitative study of ten women following caesarean section in Norway, women reported that staff had not fully taken on board their need for rest and adequate pain relief, and were more concerned with aiding breastfeeding than with their post-surgical recovery (Nilsen Mørch *et al.*, 2019). Similar concerns have been raised by researchers in Sweden, who examined feedback from 150 women. They reported that women felt insufficient attention was given to their physical and emotional needs and some felt neglected (Rudman *et al.*, 2007). In a survey of 1290 first time mothers relating to care in the first 24 hours after birth, only 41% felt they had all the emotional support they needed, 45% had all the information and advice they needed, and 56% had all their physical care needs met (Bhavnani *et al.*, 2010). Fawcett (2016) conducted a thematic analysis of women's experience on the postnatal ward. Some women reported that hospital staff seemed stressed and overworked, and this impacted on whether they felt able to ask for help (Fawcett, 2016).

An association between registered nurse staffing and outcomes for acute inpatients has been found in many cross sectional studies, large longitudinal studies and evaluations of staffing policies (Griffiths *et al.*, 2016; Kane *et al.*, 2007; McHugh *et al.*, 2021). Higher skill mix (i.e. total proportion of hours provided by registered nurses) has also been associated with improved outcomes (Twigg *et al.*, 2019). There is much less evidence of the impact of staffing in maternity services. This is especially notable in postnatal care, as a recent scoping review found a only a small number of studies, which examined outcomes such as breastfeeding and neonatal readmissions, and none looked at the woman's postnatal experience in relation to staffing levels (Turner *et al.*, 2021).

There has been an increase in caesarean section rates worldwide (Betran *et al.*, 2016) which impacts on the complexity of care on postnatal wards and length of stay (National Institute for Health and Care Excellence, 2021). The rise in maternal age and obesity also increases the risk profile for some women (Vitner *et al.*, 2019; Sheen *et al.*, 2018). Women in the UK are now offered discharge from hospital 24 hours after caesarean section if they are recovering well and do not have complications (National Institute for Health and Care Excellence, 2021), which alters the acuity case mix of women remaining in postnatal areas. It is important to know whether in-patient services are staffed appropriately for the level of demand and patient acuity, as little evidence currently exists on which to base staffing decisions (Baxter *et al.*, 2005; Forster *et al.*, 2006).

In England an annual national survey of maternity care is undertaken which asks all women about experiences of care, including postnatal care. Similarly, midwifery staffing levels are routinely reported for all National Health Service (NHS) care providers, which deliver the majority of maternity care in England.   Our research aims to examine whether the quality of postnatal care reported by women is associated with variation in midwifery staffing levels.

The following research question was addressed: Is registered midwife staffing at organisational level associated with variation in women's experience of inpatient postnatal care, controlling for other factors?

Methods

This study is a cross sectional analysis of linked routinely collected datasets in English hospital trusts. A hospital trust is an organisation which provides health services in a geographical area in England and manages one or more acute hospitals. Individual patient data on women's experiences of care has been obtained from the National Maternity Survey 2018 via the UK Data Service (Care Quality Commission *et al.*, 2020). The Maternity Survey was anonymous, confidential, and approved by the NHS Health Research Authority ethics process. Staffing and workload data was obtained from the NHS Workforce Statistics dataset (NHS Digital, 2018c) and the Hospital Episode Statistics (NHS Digital, 2018b). The size of the datasets enables detailed statistical analysis of patient and organisation level variables.   The use of secondary data is a cost effective way of analysing new questions as data has already been subject to cleaning and quality checks (UK Data Service, 2021). Ethics permission was granted for this secondary data analysis by the corresponding authors university (ERGO 62570).

Women were eligible for the annual National Maternity Survey if they had a live birth under the care of a participating hospital trust during February 2018 and were aged 16 years or over. In

2018, 97.2% of births occurred in an NHS establishment, 0.4% in a non NHS establishment and 2% occurred at home (Office for National Statistics, 2020). All eligible women were invited to participate unless they had registered to opt-out. The survey was administered by post and completed on paper but women could complete it over the phone if their first language was not English (Care Quality Commission *et al.*, 2020). Fieldwork for the survey took place between April and August 2018. Participation was voluntary and return of the questionnaire was taken as consent. The Full Time Equivalent (FTE) headcount for midwives was extracted from the NHS Workforce Statistics dataset for February 2018, which corresponds with the same time as the National Maternity survey. Records were linked by the unique hospital trust code. The number of Full Time Equivalent midwives per 100 births for each hospital trust was calculated using annual births recorded in the Hospital Episode Statistics. This data gives an indication of the midwifery staffing resource available to provide all maternity care including (but not limited to) post-natal care. Detailed data on deployment of staff to post-natal care was unavailable.

Data from 129 trusts and 17,611 women was included in this secondary analysis. The included trusts represented 98% (129/132) of those offering maternity services. Three trusts were not included in the survey as they had less than 300 births in the study period. The participating trusts varied in size, with the mean number of births per trust reported as 4844 births (range 1,122 to 15,500).

The overall response rate was 37% (range of response rates 21% to 61% between trusts). The majority of women who responded were over 30 years of age (71%). The age profile differed between trusts e.g. women aged 35 or more ranged from 17% to 57% between trusts. Data on ethnicity and parity are not available at the individual level but have been obtained at a trust level from data published online. There is variability in ethnicity of respondents between trusts, with the lowest proportion of white women in one trust as 34% and the highest 99%. Overall, 86% per cent of respondents were from a White ethnic background, with 8% Asian / Asian British, 3% Black or Black British, 2% mixed ethnicity and 1% Arab or other ethnic group (Care Quality Commission *et al.*, 2020). Younger women and women from non-white ethnicities were under-represented compared with those giving birth in the same time period (NHS Digital, 2023c).

In the survey, four closed questions asked specifically about the woman's experience of postnatal care. These relate to whether they experienced a delay in discharge, if they were able to have help within a reasonable time, if they were given the information or explanations they needed, and whether they had been treated with kindness and understanding (Table 4)

Table 4 Questions in maternity survey

Questions in Maternity Survey	Response options
On the day you left hospital, was your discharge delayed for any reason?	Yes No
If you needed attention while you were in hospital after the birth, were you able to get a member of staff to help you within a reasonable time?	Yes, always Yes, sometimes No I did not want/need this Don't know/can't remember
Thinking about the care you received in hospital after the birth of your baby, were you given the information or explanations you needed?	Yes, always Yes, sometimes No Don't know/can't remember
Thinking about the care you received in hospital after the birth of your baby, were you treated with kindness and understanding?	Yes, always Yes, sometimes No Don't know/can't remember

These four survey questions were only answered by women who had given birth in hospital, and they specifically relate to postnatal care in that setting. The responses were dichotomised into 'Yes, Always' (coded 1) and the alternative which included both 'Yes, sometimes' and 'No' (coded 0). This grouping was decided in advance of the analysis based on the implied quality standard (Care Quality Commission, 2020). A sensitivity analysis was performed by grouping all the 'Yes' responses together to examine the effects of this alternative grouping (see supplementary material). Missing values, don't know or not applicable responses were removed prior to the analysis, using pairwise deletion. Trust level midwifery staffing levels (as Full Time Equivalent per 100 births) were analysed both as a continuous variable and also divided into tertiles to explore potential non-linear relationships. Three categories were used to ensure sufficient numbers in each category, as the number of trusts is limited and to aid interpretability.

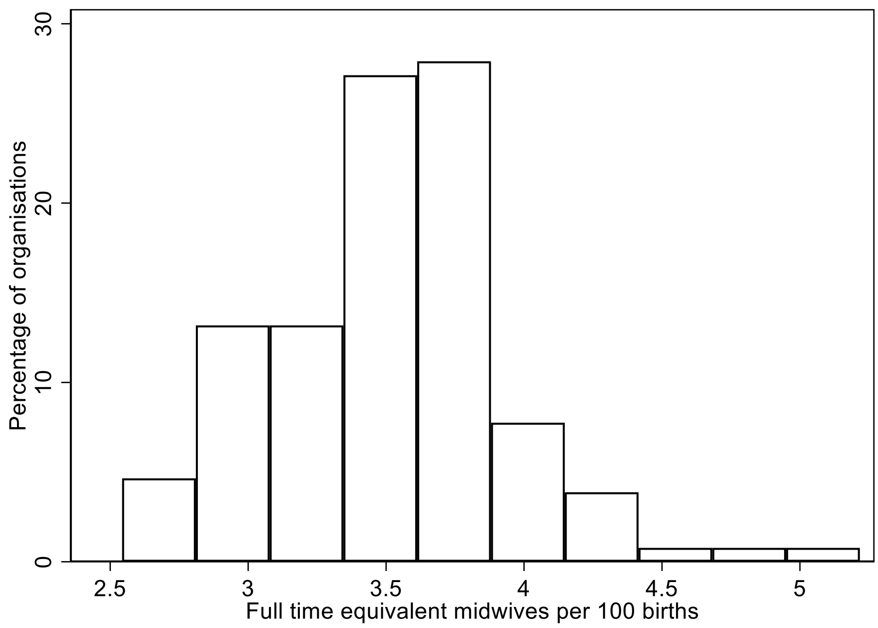
A two-level multilevel logistic regression model was created using Level-1 (mothers) nested within Level-2 (trusts). Regression coefficients and adjusted odds ratios (aOR) were calculated for individual predictors as a precursor to fitting a full model. The null model was a two-level random intercept model with no predictors to explore the extent of between-trust variation in the outcomes. Covariates were added to the multilevel models in 3 blocks: i) staffing and number of births per year (trust level data) ii) age group and type of birth (Individual level data) iii) ethnicity (percentage white) and percentage primiparous respondents (trust level data).

Akaike's Information criterion (AIC) and Bayesian information criterion (BIC) goodness of fit data were calculated in order to select models which did not to overfit or underfit the data. Models were selected based on minimising AIC and BIC scores, with lower scores indicating the best fit. Where a difference of less than 2 on the AIC scores was noted, then this was not acted upon as it is not considered to be discriminatory at this level (Burnham *et al.*, 2004). If AIC and BIC scores disagreed, then priority was given to the model lowest on AIC, and the model lower on BIC was scrutinised and compared for a sensitivity check. Interaction variables of staffing with age, mode of birth and parity were explored to see if this improved model fit using the same method for model selection. To see if results were sensitive to variation in non-responses between trusts, analyses were repeated including a variable for the trust response rate and results were scrutinised. The assumptions of the multivariable logistic regression model were examined using guidance by Schreiber-Gregory (2018). We calculated the number of women who would need to be exposed to a higher staffing level to achieve on additional positive outcome using the reciprocal of the absolute risk difference between staffing tertiles (Bender *et al.*, 2002). All data was analysed in Stata 16.1 and coding is presented in the supplementary material.

Results

For the 129 trusts studied, the median Full Time Equivalent midwives per 100 births was 3.55 (interquartile range 3.26 to 3.78). This equates to one midwife per 28 births. The distribution of staffing levels shows variation in staffing between trusts, with clustering on the left tail. (Figure 2).

Figure 2 Distribution of Full Time Equivalent midwives per 100 births in the 129 trusts



The majority of respondents reported that they did not have a delay in discharge (55%) and that staff always helped within a reasonable time (60%), they always had the information or explanations they needed (65%), and were always treated with kindness and understanding (74%). Response categories and frequencies are shown in the supplementary material. A small proportion of data was missing for each of the four questions, ranging from 466 to 603 respondents (2.6% to 3.4%).

Responses varied by age, type of birth and staffing levels. All the unadjusted rates for categorical variables are presented in Table 5.

Table 5 Patient experience outcomes by age, type of birth and staffing levels

% Yes Always as response	Delay in discharge	Staff helped in reasonable time	Information / Explanations	Treated with kindness and understanding
Responses analysed per variable	17,050	15,690	17,027	16,962
Missing responses Don't know or not applicable	561	498 1423	466 118	603 46
Overall Rate - % Yes Always	44.9%	59.6%	65.0%	74.4%
Age of mother				
16-24	48.6%	54.8%	62.0%	69.1%
25-29	46.1%	58.8%	65.3%	73.8%
30-34	44.5%	59.7%	63.8%	74.2%
35+	43.7%	61.0%	66.8%	76.0%
Type of birth				
Spontaneous birth (no instrumental intervention)	43.7%	63.2%	69.4%	79.1%
Instrumental birth	51.9%	57.0%	58.0%	69.5%
Planned caesarean	42.1%	55.0%	63.6%	70.8%
Emergency caesarean	45.2%	54.4%	57.9%	65.8%
Trust staffing levels				
low fte / 100 births fte 2.543 to 3.395	47.1%	57.3%	63.6%	73.5%
mid fte / 100 births fte 3.396 to 3.706	45.6%	59.7%	65.0%	74.0%
high fte / 100 births fte 3.707 to 5.217	41.6%	62.1%	66.8%	75.9%

fte = Full Time Equivalent

Predictor variables of age, type of birth, parity, ethnicity, and size of trust

Women in the older age bands reported a delay in discharge less frequently (adjusted odds ratio [aOR] 0.808 to 0.892 across older subgroups) and reported more frequently that they were always helped within a reasonable time (aOR 1.206 to 1.473), they always had the information or explanations they needed (aOR 1.177 to 1.339), and had always been treated with kindness and understanding (aOR 1.284 to 1.598). Some variation was also noted in women who had undergone different types of birth. Compared to those having a spontaneous birth with no instrumental intervention, those having an instrumental vaginal birth were more likely to report delay in discharge (aOR 1.406) and less likely to report that staff always helped within a reasonable time (aOR 0.769), that they were always given the information or explanations they needed (aOR 0.613) or always treated with kindness and understanding (aOR 0.604). Similar findings were reported by those who had a caesarean section (Table 6). Full models for each of the outcomes are presented in the supplementary material.

Table 6 Multilevel model for predictors of age, type of birth, parity, ethnicity, and size of trust

Question Adjusted OR 95% CI	Delay in discharge	Staff helped in reasonable time	Information / Explanations	Kindness and understanding
16-24 Reference age group				
25-29	0.892 (0.784, 1.015) p=0.083	1.206 (1.053, 1.382) p=0.007	1.177 (1.029, 1.354) p=0.017	1.284 (1.114, 1.481) p=0.001
30-34	0.829 (0.733, 0.938) p=0.003	1.327 (1.166, 1.511) p<0.001	1.139 (1.003, 1.293) p=0.045	1.384 (1.209, 1.585) p<0.001
35+	0.808 (0.713, 0.915) p=0.001	1.473 (1.291, 1.680) p<0.001	1.339 (1.177, 1.524) p<0.001	1.598 (1.392, 1.835) p<0.001
Spontaneous birth (no instrumental intervention) – Reference group				
Instrumental birth	1.406 (1.286, 1.538) P<0.001	0.769 (0.700, 0.844) p<0.001	0.613 (0.560, 0.672) p<0.001	0.604 (0.547, 0.668) p<0.001
Planned caesarean	0.950 (0.863, 1.046) P=0.298	0.673 (0.609, 0.744) p<0.001	0.743 (0.673, 0.821) p<0.001	0.603 (0.541, 0.671) p<0.001
Emergency caesarean	1.054 (0.967, 1.149) P=0.230	0.688 (0.629, 0.752) p<0.001	0.605 (0.554, 0.661) p<0.001	0.504 (0.549, 0.554) p<0.001
Trust level characteristics				
% primiparous	Not in model with best fit	0.978 (0.967, 0.990) p<0.001	0.986 (0.978, 0.995) p=0.003	0.983 (0.973, 0.992) p<0.001
% white ethnic group	Not in model with best fit	1.006 (1.001, 1.011) p=0.023	1.003 (0.999, 1.006) p=0.177	1.006 (1.001, 1.009) p=0.007
No births per trust	1.000 (1.000, 1.000) p=0.536	1.000 (1.000, 1.000) p=0.959	1.000 (1.000, 1.000) p=0.601	1.000 (1.000, 1.000) p=0.296

The case mix of each trust suggested that there may be small differences in the experience of cohorts of women in trusts with more primiparous women (aOR 0.983 to 0.986 for four outcomes) and those with fewer white women (aOR 1.003 to aOR 1.006), however the effect sizes were very small (Table 6). The size of the trust in terms of the annual number of births did not appear to be associated with variation in any of the reported experiences.

Effects of staffing variation

The association between midwifery staffing and patient experience is shown in Table 7. Full models can be found in the supplementary material.

Table 7 Outcomes by staffing levels, results from multilevel models, nested in trusts.

Question aOR, 95% CI	Delay in discharge	Staff helped in reasonable time	Information / Explanations	Treated with kindness and understanding
FTE midwives per 100 births unadjusted	0.855 (0.761, 0.961) p=0.008	1.246 (1.087, 1.427) p=0.002	1.171 (1.059, 1.295) p=0.002	1.110 (0.988, 1.247) p=0.080
FTE midwives per 100 births adjusted	0.849 (0.753, 0.959) p=0.008	1.200 (1.052, 1.369) p=0.007	1.150 (1.040, 1.271) p=0.006	1.059 (0.949, 1.181) p=0.306
Reference group low fte per 100 births 2.543 to 3.395				
mid fte per 100 births 3.396 to 3.706	0.920 (0.815, 1.037) p=0.173	1.141 (0.999, 1.303) p=0.051	1.089 (0.985, 1.203) p=0.096	1.067 (0.956, 1.189) p=0.246
high fte per 100 births 3.707 to 5.217	0.789 (0.697, 0.894) p<0.001	1.191 (1.037, 1.367) p=0.013	1.130 (1.018, 1.255) P=0.022	1.080 (0.963, 1.211) p=0.187
Absolute risk difference compared to reference group of low fte per 100 births , predicted from model				
mid fte per 100 births	-2.0% (-5.0%, -0.9%)	3.1% (0.0%, 6.2%)	1.9% (0.3%, 4.1%)	1.2% (-0.8%, 3.2%)
high fte per 100 births	-5.7% (-8.8%, -2.7%)	4.1% (0.9%, 7.3%)	2.7% (0.4%, 5.1%)	1.4% (-0.7%, 3.6%)
Number of women exposed to provide benefit for 1 woman (calculated as 1/absolute risk difference)				
Highest tertile of staffing vs Lowest tertile	18 (11 to 37)	24 (14 to 111)	37 (20 to 250)	71 (non significant)

fte = Full Time Equivalent

In the multi-level model we found that every additional Full Time Equivalent midwife per 100 births was associated with a 15% reduction in odds of reporting delay in discharge (aOR 0.849, 95% CI 0.753, 0.959, p=0.008), a 20% increased odds of women reporting that staff always helped in a reasonable time (aOR1.200, 95% CI 1.052, 1.369, p=0.007) and a 15% increased odds of women always having the information or explanations they needed (aOR 1.150, 95% CI 1.040, 1.271, p=0.006). For women being treated with kindness and understanding, the point estimate is in the direction of improved experiences with more staffing, but the relationship was not statistically significant in the adjusted model (aOR 1.059, 95% CI 0.949, 1.181 p=0.306) (Table 7).

Estimated differences related to staffing levels

Based on these models it is estimated that trusts in the highest staffing tertile would have 5.7% fewer women reporting a delay in discharge compared to trusts with staffing in the lowest tertile (95% CI 2.7%, 8.8%). For every 18 women who receive care in these trusts one fewer would experience a discharge delay in the higher staffed trust (number needed to be exposed). Trusts with the highest tertile of staffing would have 4.1% more women saying that staff always helped in a reasonable time (95% CI 0.9%, 7.3%) and 2.7% more reporting that they had always been given the information or explanations they needed (95% CI 0.4%, 5.1%). This equates to one improved outcome in a high staffed trust for every 24 women or 37 women respectively (Table 7). There appears to be a dose response effect as trusts with mid-tertile staffing had predicted effects in between the lowest and highest values (Table 7).

Sensitivity analyses

As trust response rates varied (from 21% to 61%), a variable for the trust response rate was added to the model. This led to slightly larger estimates for the effect of staffing but did not substantively alter results (see supplementary material). The model with size of organisation, staffing, age group and parity for the outcome of information and explanations had a better fit by the BIC criterion only, however the staffing coefficients were similar to the full model with six predictor coefficients (aOR 1.162 vs aOR 1.150). When alternative dichotomisation was used (‘yes sometimes’ and ‘yes always’ grouped together versus ‘no’) substantive conclusions were generally unchanged, although effect sizes tended to be larger (see supplementary material for all sensitivity analyses).

Interaction variables improved the model fit for kindness and understanding when staffing levels interacted with age group and the percentage of primiparous women. Some subgroups reported more positive experiences in trusts with higher staffing, although women aged 25-29 years and trusts with the smallest proportion of primiparous women had findings in the opposite direction. Introduction of interaction variables did not improve model fit for the other three measures (see supplementary material).

Discussion

This cross sectional secondary analysis is the first study to examine the effects of organisational staffing on women's experience of postnatal care. Midwifery staffing levels varied considerably between hospitals and were associated with variation in a number of patient reported experiences of postnatal care, after adjusting for other variables. Women in trusts with more midwifery staff were less likely to report they had experienced a delay in discharge. They were more likely to report that staff always helped them in a reasonable time and were always given the information or explanations they needed.

Higher midwifery staffing levels have been associated with reductions in postpartum haemorrhage (Prapawichar *et al.*, 2020), reduced need for neonatal resuscitation (Hodnett *et al.*, 2002), maternal readmission (Gerova *et al.*, 2010; Kim *et al.*, 2016) and increased exclusive breastfeeding rates at discharge(Dani *et al.*, 2020). This analysis of survey data supports and expands upon the previous findings that increased midwifery staffing is associated with benefits, by demonstrating differences in important experiences in post-natal care. The effect sizes observed are relatively small, but large numbers of women are affected, and the adverse experiences may have economic consequences. In the lower staffed trusts, an estimate of 5.7% more women (1 in 18) reported that their discharge had been delayed. The reason for a delay in discharge is multifactorial and may not always be related directly to staffing levels. In the 2018 Maternity Survey (Care Quality Commission *et al.*, 2020), 21% of women reported they were waiting for medicines and 10% waiting for test results. Delay in discharge contributes to bed pressures (Hendy *et al.*, 2012) and has negative consequences for the woman's experience (Malouf *et al.*, 2019). There is room for improvement as overall 45% of women in the survey reported their discharge had been delayed. In a previous survey, student midwives and postnatal women identified that the postnatal discharge process was rushed and this resulted in poor quality discharge advice (Haith-Cooper *et al.*, 2018). Both a delay in discharge and rushed discharge are unsatisfactory outcomes and have been linked to staffing pressures in postnatal wards.

A higher proportion of staff responding in a timely way and providing information may contribute to a mother's wellbeing. Psychological health has been recognised as a major public health challenge (Royal College of Obstetricians and Gynaecologists, 2017), with up to one in five women developing mental health problems during pregnancy or in the first year after birth (Royal College of Obstetricians and Gynaecologists, 2017). It is known that women value support, reassurance, and information from health professionals at this time (Finlayson *et al.*, 2020). Previous work has suggested that midwives do not have enough time to talk to women and support them on postnatal wards (Malouf *et al.*, 2019) and this study provides further evidence that this may sometimes be the case. There may be unrecognised consequences of lack of support, which may manifest in readmissions or a decline in breastfeeding rates if not addressed (Brown, 2020; Dykes, 2005). The move to a continuity of carer model in some countries may alter the pattern and experience of care for postnatal women. Such changes require staff to be available at the right time and place to provide this care, and overall staffing levels to facilitate this (McLachlan *et al.*, 2008).

The increased drive to provide personalised, respectful and compassionate care is seen in many national and international initiatives (Miller *et al.*, 2016; NHS England, 2020; Nursing and Midwifery Council, 2019; Bridges *et al.*, 2019a). In this study, three quarters of women felt they were always treated with kindness and understanding. Although the primary analysis did not find a significant association for staffing levels, our sensitivity analyses do provide evidence that that women's experience of kindness and understanding may be affected by staffing levels. Babaei *et al.* (2019) suggested that workload can be a barrier to providing compassionate care. While negative interactions with patients are relatively rare, Bridges *et al.* (2019b) found that negative interactions are more common with lower staffing levels.

The main limitations of this study are its cross-sectional design and the level at which staffing has been measured. Data from the Maternity Survey has been linked to staffing data at an organisational level, so there is not an accurate picture of how many midwives were actually deployed in the postnatal ward area. It may be proportional to the total number of midwives, although this is not certain, and there may be variations in how individual trusts deploy midwives to meet local needs. There may also be registered nurses and non-registered staff in postnatal areas which have not been accounted for, or movement within the organisation during shifts as some midwives may be relocated away from the postnatal ward to meet needs in other areas (Dykes, 2005). Confirmation of these results is needed from studies with more direct measures of postnatal ward staffing. New sources of data from electronic rosters has created the potential to undertake longitudinal studies with exposure to staffing measured at a ward or individual patient level, mirroring studies now being undertaken in general nursing (Griffiths *et al.*, 2019b) . Recall bias and cognitive halo effects may have influenced responses to the maternity survey, as data was collected some months after the postnatal stay.

We did not consider staffing by other professional groups in this analysis. It is conceivable that other staff groups, such as doctors, adult nurses, neonatal nurses and nursery nurses contribute to women's experiences in the postnatal period. Although this survey data records women's perceptions of delays in discharge, actual delays have not been empirically demonstrated. This could be the focus of future research, along with midwives' autonomy in the discharge processes.

This was a large national study including 129 trusts and over 17,000 women which aids the generalisability of findings. Although the response rate of 37% is fairly typical of similar surveys, this does raise questions about the experience and views of non-responders, especially in trusts with a lower response rate. The study respondents differed from the target population, for example, there were fewer younger mothers and women from non-white ethnic groups (NHS Digital, 2023c). The sensitivity analyses of response rate did not suggest a bias arising from variation in response rates between trusts.

This analysis of the Maternity Survey in the UK adds to the body of evidence examining staffing and outcomes in maternity care. We found that that variation in midwifery staffing at organisational level is associated with variation in women's experiences of postnatal care. Low staffing levels were linked to higher levels of adverse experiences that could have important consequences in terms of hospital resource use and maternal wellbeing. While we cannot assume the relationship is causal, nonetheless it seems plausible, and this is worthy of further exploration.

Study 2

Published as Turner, L., Ball, J., Culliford, D., Kitson-Reynolds, E. and Griffiths, P. (2022) 'Exploring the relationship between women's experience of postnatal care and reported staffing measures: an observational study', *PLoS ONE*, 17(8): e0266638
Supplementary material in Appendix H, Link to peer review and response

Abstract

Background

Women have reported dissatisfaction with care received on postnatal wards and this area has been highlighted for improvement. Studies have shown an association between midwifery staffing levels and postnatal care experiences, but so far, the influence of registered and support staff deployed in postnatal wards has not been studied.

Methods

Cross sectional secondary analysis including 13,264 women from 123 postnatal wards within 93 hospital trusts. Staffing was measured in each organisation as Full Time Equivalent staff employed per 100 births, and on postnatal wards, using Hours Per Patient Day. Women's experiences were assessed using four items from the 2019 CQC maternity survey. Multilevel logistic regression models were used to examine relationships and adjust for maternal age, parity, ethnicity, type of birth, and medical staff.

Results

Trusts with higher levels of midwifery staffing had higher rates of women reporting positive experiences of postnatal care. However, looking at staffing on postnatal wards , there was no evidence of an association between registered nurses and midwives hours per patient day and patient experience. Wards with higher levels of support worker staffing were associated with higher rates of women reporting they had help when they needed it and were treated with kindness and understanding.

Conclusion

The relationship between reported registered staffing levels on postnatal wards and women's experience is uncertain. Further work should be carried out to examine why relationships observed using whole trust staffing were not replicated closer to the patient, with reported postnatal ward staffing. It is possible that recorded staffing levels on postnatal wards do not actually reflect staff deployment if midwives are floated to cover delivery units. This study highlights the potential contribution of support workers in providing quality care on postnatal wards.

Keywords

Postnatal, Staffing, Experience, Midwife, Support worker

Background

Midwives have expressed concern about the quality of postnatal care provided in hospital, and cite increased workloads, limited staffing and busy work environments as contributing to this (McLachlan *et al.*, 2008; Morrow *et al.*, 2013). In line with this, women have reported lower satisfaction with postnatal care compared with antenatal and labour care (Care Quality Commission *et al.*, 2021; Scottish Government, 2019b). A survey of 1260 first time mothers found that less than half of them had all the help they needed with infant feeding, one in five did not have the physical care they needed, and one in seven had unmet information needs (Bhavnani *et al.*, 2010). The World Health Organization highlights that postnatal care needs to be well resourced in order to provide both a positive postnatal experience and safe care (World Health Organization, 2022).

The quality of care is affected by the availability of staff (Winter *et al.*, 2021) and it is reported that staff prioritise those with urgent medical needs and consider discharging other women to ease pressure on beds (Kokab *et al.*, 2022). Staff need to be available with the right skills, in the right place at the right time to deliver high quality care and minimise avoidable harm (National Quality Board, 2016). Staffing shortages in postnatal care have been highlighted in a number of reports (The National Federation of Women's Institutes *et al.*, 2017; Beake *et al.*, 2005; Alderdice *et al.*, 2016) and have been linked with reduced vital signs monitoring, reduced support for breastfeeding, delays in care and newborn hypothermia (Simpson *et al.*, 2017; Simpson *et al.*, 2016). Studies on satisfaction with postnatal care are now emerging, highlighting the need for individualised care, proactive information and emotional support (McLeish *et al.*, 2021; McLeish *et al.*, 2020). It had previously been suggested that dissatisfaction with postnatal care was related to a mismatch between expectations and experiences, however recent work by McLeish *et al.* (2020) has disputed this and highlights that meeting individual needs is the key issue.

Population needs and ward activity are relevant when planning staffing and skill mix. The average length of postnatal stay has reduced from 2.8 days in 2001 to 1.5 days in 2020 (Bowers *et al.*, 2016), and almost half of women are discharged within 24 hours (Harrison *et al.*, 2018). Faster patient turnover leads to a greater proportion of the midwives' day involved in admissions or discharges, which reduces the amount of time spent providing ongoing care (Bowers *et al.*, 2016). Reduced length of stay means that people staying in wards may be more acutely unwell than before (National Institute for Health Research, 2019). Increased risk factors such as rising maternal age, obesity, diabetes and rates of intervention have contributed to rising acuity in postnatal women (Sheen *et al.*, 2018; Vitner *et al.*, 2019; NHS Digital, 2019c). Both system level and individual risk factors come together to increase risk in the maternity population. Systemic racism has been noted in maternity services in both the UK and USA, and contributes to poorer outcomes for women who are black, Asian or mixed race (Birthrights, 2022; MBRRACE-UK, 2021; Russell, 2021). It is concerning that women from minority ethnic groups have a poorer experience of maternity services than white women accessing the same service (Henderson *et al.*, 2013).

From a workforce perspective, it is not clear whether the deployed workforce has kept up with demand and acuity on postnatal wards. With a national shortage of midwives, postnatal staffing may be impacted given the emphasis on one to one care in labour, increased intervention and the safety agenda as outlined in the recent Ockenden report (Ockenden, 2022). Variability can be seen across England in the number of midwives and health care support workers present on postnatal wards (NHS Improvement, 2021). The development of support workers and growth in their numbers has led to expansion of these roles on many postnatal wards (Griffin *et al.*, 2012) and it is uncertain whether this growth is based on evidence of benefit.

Although staffing is implicated in findings of postnatal dissatisfaction (Nilsen Mørch *et al.*, 2019) there have been few studies examining this relationship. One cross sectional study found that higher registered midwife workforce is associated with a better postnatal care experience, as measured by the CQC Maternity Survey in England (Turner *et al.*, 2022b). This study measured staffing at an organisational level across the whole maternity service. We found no published studies examining the impact of staffing measured on postnatal wards themselves, which is expected to provide a more accurate measurement of staffing exposure.

We set out to use staffing recorded on postnatal wards to improve estimates of exposure and to include the contribution of support workers as this is a growing workforce that has received little attention in research studies to date. Maternity support workers in England provide support to the maternity and neonatal nursing services in the form of direct patient care, and are distinct from those providing clerical or housekeeping roles (Health Education England, 2019b). Failure to control for differences in support worker staffing may distort relationships between midwife staffing and patient experiences, or may lead to an overemphasis on registered staff to address quality of care problems (Kalisch *et al.*, 2011).

Although Nursing Hours per Patient Day has been measured in many primary studies (Driscoll *et al.*, 2018; Min *et al.*, 2016), the dataset of Care Hours Per Patient Day (NHS Improvement, 2021) has not been used in published research to our knowledge. Its contribution and limitations have yet to be described, especially in a maternity setting which differs from acute medical and surgical wards in terms of patient flow, acuity and workforce.

Variation in staffing levels on postnatal wards could affect patient experience, and this has not been assessed to date. Previous studies have looked at variability in staff employed per organisation, without the ability to delve deeper to study staffing levels deployed within wards themselves. This study presents an opportunity to study patient experience in relation to staffing measures closer to the delivery of care. In this paper we seek to explore the relationship between staffing levels in midwifery services and women's experiences of postnatal care in inpatient wards. The following research questions were studied :
Is there an association between midwife staffing in the organisation and women's experience of postnatal care?

Is there an association between postnatal ward staffing levels and composition (registered nurses, midwives and support workers) and the experience of mothers receiving postnatal care?

Methods

Data Sources

This is a cross sectional analysis of linked routinely collected datasets in English hospital trusts. Anonymised individual patient data from the 2019 CQC Maternity Survey was obtained from the UK Data Service (Care Quality Commission *et al.*, 2021). This data relates to women's experience of maternity care and the survey was sent to all women who had a live birth in February 2019 under the care of an NHS trust. Case mix variables of age group, parity, and type of birth were extracted for individuals participating in the survey. Length of stay was not extracted as it could be both a measure of case mix or outcome measure and is also likely to be highly correlated with type of birth. Ethnicity and response rate per trust were obtained from data published online relating to this survey. Ethics approval was gained prior to data collection (ERGO 62570).

Staff recorded on postnatal wards

Data for staff on wards was obtained via the Care Hours Per Patient Day (CHPPD) dataset which is publicly available on the NHS England website (NHS Improvement, 2021). Hours Per Patient Day is intended to indicate the care available to patients on wards by indicating the level of staff deployed on that ward. HPPD is available for Registered staff (combined for Nurses and Midwives) and separately for Health care support staff (NHS Improvement, 2021). This is reported as a monthly figure for each staff group in the dataset. HPPD is calculated from the number of patients occupying beds at midnight each day and the actual hours worked by staff groups, totalled for the month. These totals are then divided to produce the HPPD average for that month (NHS Improvement, 2018). Hours worked by permanent, bank and agency staff are included, but those worked by supernumerary staff and students are not. Newborns were not counted in addition to mothers in this dataset, although this measure has been introduced for subsequent datasets from 2021.

Workforce data from the single month of February 2019 was used as this matches the period of the patient experience survey. Postnatal wards were identified by selecting the speciality codes of Midwifery or Obstetrics within the dataset. Entries were excluded if they were unlikely to be postnatal wards e.g. if Registered staff HPPD >=10 or if they were named exclusively as Labour Ward, Delivery Suite, Birth centre, Antenatal ward or Neonatal unit. The 10 HPPD cut off was chosen on examination of the HPPD data by ward title in the whole dataset, where it emerged that HPPD records above this level were found in critical care areas and labour wards, and this is supported by the categorisation by Twigg and Duffield (Twigg *et al.*, 2009). This process identified 93 trusts containing 123 wards, as some trusts were larger and had more than one postnatal ward serving the obstetric unit. 27 trusts were not represented as postnatal wards were not identifiable using the method above. Fifteen trusts had more than one postnatal ward, so the published February 2019 HPPD for each ward was averaged to produce one figure per trust for each staff group. The variable of skill mix was generated by calculating the percentage of registered staff on each ward.

Staff measured within trusts

Additional analyses of midwifery staffing were undertaken using a metric based on total numbers of midwives and medical staff per 100 births, at each organisation (i.e. trust), for the same trusts covered by the HPPD data. The newly obtained 2019 dataset was used to confirm or counter our previous published findings relating staffing to patient experience (Turner *et al.*, 2022b). We included Full Time Equivalent midwives and medical staff employed in Obstetric and Gynaecology (NHS Digital, 2022b) although support worker figures could not be ascertained for this speciality. The number of births per year was obtained from the Hospital Episode Statistics dataset (NHS Digital, 2019a).

Measures of care quality

Four survey questions were selected for analysis (Table 8) as they were the only questions which explored the quality of care provided by staff on the postnatal ward. These questions were answered only by women who received care in hospital after the birth due to filter questions within the survey.

Table 8 Questions in maternity survey selected for analysis in this study

Questions in Maternity Survey	Response options
On the day you left hospital, was your discharge delayed for any reason?	Yes No
If you needed attention while you were in hospital after the birth, were you able to get a member of staff to help you when you needed it?	Yes, always Yes, sometimes No I did not want/need this Don't know/can't remember
Thinking about the care you received in hospital after the birth of your baby, were you given the information or explanations you needed?	Yes, always Yes, sometimes No Don't know/can't remember
Thinking about the care you received in hospital after the birth of your baby, were you treated with kindness and understanding?	Yes, always Yes, sometimes No Don't know/can't remember

The survey ordinal responses were dichotomised into 'yes always'=1 and 'yes sometimes or no' = 0 based on an implied quality standard (Care Quality Commission, 2020). Alternative grouping was tested in the sensitivity analysis. 'Don't know/can't remember' responses represented less than 1% of the data for each question and were removed by pairwise deletion to maximise the data available for analysis. The patient experience variables were linked to staffing variables by the unique trust code for each organisation.

Data analysis strategy

We were able to link ward HPPD data to patient experience in 93 trusts with 123 wards, representing 13,264 respondents. Analysis was firstly conducted with staffing as a continuous variable. Trusts were also divided into tertiles to represent those with the highest, middle and lowest staffing for both registered and support staff. The rationale was to enable detection of non-linear effects which would not be possible if analysed as continuous variables, and it also aids interpretation of effect sizes (Gelman *et al.*, 2009).

Descriptive analysis was performed to understand the variation in staffing between postnatal wards and between trusts. Variation in women's responses between trusts were summarised. A two-level multilevel logistic regression model was created using Level-1 (mothers) nested within Level-2 (trusts). The null model was a two-level random intercept model with no predictors to explore the extent of between-trust variation in the outcomes. Covariates of mothers' age group, ethnicity, parity, type of birth and midwifery staffing measures were included in the main model as these characteristics have been shown to contribute to variability in clinical outcomes and patient experience measures (Sandall *et al.*, 2014; Turner *et al.*, 2022b; Henderson *et al.*, 2013). Additional covariates of survey response rate, number of births in each trust and obstetric/gynaecological medical staffing were added to the main model and were retained only if the model fit improved. These variables were added as it was anticipated that they could account for variation in women's satisfaction or because they may highlight bias in the self-selection of respondents.

Model fit was judged by calculating the Akaike's Information criterion (AIC) and Bayesian information criterion (BIC). If AIC and BIC scores disagreed, then priority was given to the model lowest on AIC, and the model lower on BIC was scrutinised and compared for a sensitivity check (see supplementary material S1 for details of variable selection and model fit). The primary model considered Registered staff and Support workers as independent groups in the workforce. It is also possible to conceptualise the workforce as a single entity with varying composition, and so alternative models with variables representing skill mix (percentage registered staff) and total number of staffing hours (combined HPPD for registered and support staff) were explored as secondary analyses. All Stata 16.1 coding can be found in supplementary material S9.

Results

The characteristics of respondents in the maternity survey are given in Table 9. The median response rate was 39% among trusts (IQR 33% to 42%).

Table 9 Data characteristics for respondents in Maternity Survey

	Level of data	Summary Medians presented due to skewed distributions
Response rate	Trust	Median 38.7% IQR 32.6%, 42.4%
Age group of mothers	Individual patient	16-25 years 6.6% 25-29 years 20.0% 30-34 years 37.5% 35+ years 35.9%
Parity	Individual patient	Primiparous 50.9% Multiparous 49.1%
Type of birth	Individual patient	Spontaneous birth 55.4% Instrumental birth 14.7% Planned caesarean birth13.8% Emergency caesarean birth 16.1%
Percentage white ethnicity	Trust	Median 84.7% IQR 73.5%, 91.2%

The median FTE midwives per 100 births within trusts was 3.58 (IQR 3.33 to 3.84), equivalent to one midwife for every 28 births. For the 123 postnatal wards included in the analysis, the median HPPD for registered staff on postnatal wards was 4.69 (IQR 3.75, 5.80) and for support workers it was 2.46 (IQR 1.91, 3.18) (Table 10). The median percentage of registered staff on postnatal wards was 63.6% (IQR 58.0%, 70.6%).

Table 10 Distribution of staffing deployed on postnatal wards and within trusts

	Measurement of data	Summary Medians presented due to skewed distributions
FTE midwives per 100 births	Trust	Median 3.58 IQR 3.33, 3.84
FTE obstetric/gynaecology doctors per 100 births	Trust	Median 0.92 IQR 0.83, 1.04
HPPD – Registered staff (nurses and midwives combined)	Ward	Median 4.69 IQR 3.75, 5.80
HPPD – Support staff	Ward	Median 2.46 IQR 1.91, 3.18
HPPD – Overall (Registered plus Support staff)	Ward	Median 7.27 IQR 5.68, 8.82
Percentage Registered staff in Overall HPPD	Ward	Median 63.6% IQR 58.0%, 70.6%

15 trusts were in the highest tertile for both Registered HPPD hours and Support staff HPPD hours. 21 trusts were in the lowest tertiles for both these staffing measures. Three trusts were in the lowest tertile for Registered staffing while also having the highest tertile of Support staff

HPPD. The trust measure of Registered FTE Midwives and the ward measure of Registered staffing HPPD appear to have only a weak relationship between them, Spearman's rho 0.197 (see supplementary material S2 for more detail on staffing distribution in trusts and wards.

Summary of patient experience

Responses to the four questions relating to postnatal care are given in Table 11. The majority of women answering each question responded positively, although the worst rated measure was delay in discharge with 44% of women stating they had experienced a delay. 75% of respondents reported they were always treated with kindness and understanding.

Table 11 Summary of postnatal experience measures

Question in Maternity Survey	Response categories	Frequency % answers	Statistically sig variables in UV analysis
On the day you left hospital, was your discharge delayed for any reason? n= 13,264, 450 missing	Yes No	5690 (44.4%) 7124 (55.6%)	Age group Parity Type birth
If you needed attention while you were in hospital after the birth, were you able to get a member of staff to help you when you needed it? n=13,264, 420 missing 827 not applicable as did not want/need help	Yes, always Yes, sometimes No Don't know/can't remember	7376 (61.4%) 3829 (31.9%) 762 (6.3%) 50 (0.4%)	Parity Type birth % white ethnicity
Thinking about the care you received in hospital after the birth of your baby, were you given the information or explanations you needed? n=13,264, 402 missing	Yes, always Yes, sometimes No Don't know/can't remember	8361 (65%) 3507 (27.3%) 890 (6.9%) 104 (0.8%)	Parity Type birth % white ethnicity
Thinking about the care you received in hospital after the birth of your baby, were you treated with kindness and understanding? n=13,264, 400 missing	Yes, always Yes, sometimes No Don't know/can't remember	9653 (75%) 2771 (21.5%) 405 (3.2%) 35 (0.3%)	Age group Parity Type birth % white ethnicity

Univariable analyses using the dichotomised data for patient response found that age group, parity, type of birth and ethnicity were significantly associated with differences in responses (see supplementary material S3).

Relationship between staffing and patient experience

Whole Organisation Staffing

When analysed using trust employed staffing, higher staffing levels of Registered midwives were associated with better patient experience measures in terms of delay without discharge and women always receiving the information and explanations they needed. Findings remained statistically significant after controlling for case mix factors of age, ethnicity, parity and type of birth. Table 12 includes a summary of the direction of effects, the point estimates for odds ratios and confidence intervals. Women were more likely to report they always had help when needing it and been treated with kindness and understanding in trusts with higher numbers of midwives, but these findings were not statistically significant.

Table 12 Summary of univariable and adjusted regression analysis (whole trust)

Estimated odds of a positive response (whole trust staffing).								
FTE Midwives	Discharge without delay OR(95%CI)		Help when needed it OR(95%CI)		Information / explanations OR(95%CI)		Kindness OR(95%CI)	
Continuous (linear) staffing variable model								
	Univariable	Adjusted*	Univariable	Adjusted*	Univariable	Adjusted*	Univariable	Adjusted*
Continuous FTE	OR 1.15 (1.01, 1.33)	OR 1.13 (0.99, 1.30)	OR 1.18 (0.99, 1.41)	OR 1.12 (0.94, 1.34)	OR 1.11 (0.93, 1.32)	OR 1.16 (1.00, 1.35)	OR 1.22 (1.05, 1.41)	OR 1.05 (0.88, 1.25)
Categorical staffing variable model, compared with lowest tertile of staffing								
Mid Tertile	OR 1.06 (0.94, 1.20)	OR 1.04 (0.92, 1.19)	OR 1.06 (0.90, 1.26)	OR 1.03 (0.88, 1.21)	OR 1.05 (0.92, 1.21)	OR 1.03 (0.90, 1.18)	OR 1.06 (0.90, 1.24)	OR 1.02 (0.87, 1.21)
High Tertile	OR 1.17 (1.03, 1.33)	OR 1.14 (1.01, 1.31)	OR 1.16 (0.97, 1.37)	OR 1.12 (0.95, 1.33)	OR 1.22 (1.06, 1.40)	OR 1.18 (1.03, 1.36)	OR 1.09 (0.93, 1.29)	OR 1.07 (0.91, 1.26)

* Adjusted for age, ethnicity, parity and type of birth for all models
FTE – full time equivalent , OR odds ratio. Univariable analyses and full models in supplementary material S4 and S5

Staff recorded on postnatal wards (HPPD)

The relationship between staffing measured on postnatal wards and patient experience responses are displayed in Table 13. There were no statistically significant associations between Registered staffing HPPD and women's responses, and the direction of the point estimate suggested potentially worse experience with more registered staff.

Support worker staffing was measured only on postnatal wards and there were differences in the odds of positive responses in trusts with a higher number of support worker care hours in the categorical analysis. In the adjusted models, the odds of reporting a positive experience was 24% greater for being treated with kindness and understanding (OR 1.24, 95% CI 1.03,1.49), and 28% greater for reporting having help when needing it (OR 1.28, 95% CI 1.07, 1.54) in the higher staffed trusts compared to the lowest. Results for the other two questions were in the same direction but not statistically significant.

Table 13 Summary of univariable and adjusted regression analyses (ward level)

Estimated odds of a positive response (analysed by staff recorded on postnatal wards)								
	Discharge without delay OR(95%CI)		Help when needed it OR(95%CI)		Information / explanations OR(95%CI)		Kindness OR(95%CI)	
Continuous (linear) staffing variable model								
	Univariable	Adjusted*	Univariable	Adjusted*	Univariable	Adjusted*	Univariable	Adjusted*
HPPD Registered staff	OR 1.01 (0.97, 1.04)	OR 0.98 (0.94, 1.02)	OR 1.02 (0.98, 1.07)	OR 0.98 (0.94, 1.03)	OR 1.02 (0.99, 1.06)	OR 1.00 (0.96, 1.04)	OR 1.04 (0.99, 1.08)	OR 1.00 (0.96, 1.05)
HPPD Support workers	OR 1.05 (0.99, 1.10)	OR 1.06 (1.00, 1.13)	OR 1.08 (1.00, 1.15)	OR 1.09 (1.01, 1.18)	OR 1.03 (0.97, 1.09)	OR 1.02 (0.96, 1.09)	OR 1.07 (1.00, 1.14)	OR 1.07 (1.00, 1.16)
Categorical staffing variable model, compared with lowest tertile of staffing								
Registered staff HPPD								
Midtertile	OR 0.98 (0.86, 1.23)	OR 0.91 (0.78, 1.05)	OR 0.92 (0.77, 1.10)	OR 0.77 (0.64, 0.92)	OR 0.93 (0.80, 1.08)	OR 0.87 (0.74, 1.01)	OR 0.98 (0.83, 1.15)	OR 0.83 (0.69, 1.00)
High tertile	OR 1.06 (0.93, 1.21)	OR 0.99 (0.86, 1.15)	OR 1.05 (0.88, 1.25)	OR 0.89 (0.74, 1.06)	OR 1.07 (0.93, 1.25)	OR 0.99 (0.85, 1.16)	OR 1.10 (0.93, 1.30)	OR 0.95 (0.79, 1.14)
Support worker HPPD								
Mid tertile	OR 1.02 (0.90, 1.17)	OR 1.06 (0.92, 1.23)	OR 1.02 (0.86, 1.22)	OR 1.13 (0.95, 1.34)	OR 0.91 (0.78, 1.05)	OR 0.95 (0.82, 1.10)	OR 1.06 (0.90, 1.25)	OR 1.14 (0.96, 1.36)
High tertile	OR 1.04 (0.91, 1.19)	OR 1.09 (0.93, 1.26)	OR 1.14 (0.96, 1.36)	OR 1.28 (1.07, 1.54)	OR 1.04 (0.90, 1.20)	OR 1.08 (0.93, 1.26)	OR 1.15 (0.97, 1.35)	OR 1.24 (1.03, 1.49)

* Adjusted for age, ethnicity, parity, type of birth and medical staff for all models

FTE – full time equivalent, OR odds ratio. Univariable analyses and full models in supplementary material S6 and S7

For overall number of staff (registered plus support staff HPPD) the adjusted models showed higher odds of reporting positive experiences in all four questions when the overall number of staff was higher, although this was not statistically significant. Trusts in the highest tertile for skill mix (measured as the percentage of Registered staff HPPD compared to Overall staff HPPD) had lower odds of a positive response to all questions compared to those in the lowest tertile. This was statistically significant for women reporting they always had help when needing it (OR 0.80, 95% CI 0.69, 0.94) and discharged without delay (OR 0.86, 95% CI 0.76, 0.97) (see supplementary material S8). There was no significant relationship between Obstetric and Gynaecology doctors per 100 births and patient experience. However, this variable was retained in the full models of ward staffing as it improved model fit.

Sensitivity analyses

The potential for interaction effects was explored by examining the model fit when considering tertiles of Registered staff in combination with different tertiles of health care support staff. We found no evidence of significant interaction effects and no improvement in model fit was noted when these interaction effects were added.

When outliers for HPPD were removed, this resulted in very small changes to the odds ratio estimates and there were no changes to the statistical significance of associations. Effect sizes were smaller when using an alternative dichotomy (no vs yes sometimes, yes always) but the conclusions were unchanged (all sensitivity analyses are presented in supplementary material S10 to S12).

Discussion

This cross-sectional analysis of linked datasets expands on previous research by using the CHPPD dataset to examine relationships for staff recorded on postnatal wards using multiple staff groups. We studied the postnatal care experience of women in relation to staffing levels using regression analysis, using both staff employed within organisations and those assigned to wards. When measured within the organisation, our findings suggest that patient experience is better when more midwives are employed. However, when focussing on postnatal ward staffing measured as Hours Per Patient Day, there is no evidence of a relationship between registered midwife/nurse staffing and patient experience. Higher levels of support worker hours were associated with more women reporting they have been treated with kindness and understanding and being helped when they needed it.

Despite having what appeared to be a more precise measurement of staffing on postnatal wards , we have exposed some inconsistencies compared with organisation reported staffing which is worthy of further exploration. The weak correlation between FTE midwives and ward HPPD is interesting as we expected this to be more closely related. However, this is not an unusual finding as recent research from the USA has also discovered differences in the performance of staffing measures, and called for validated measures to be used (Merkow *et al.*, 2022). The weak correlation may be due to the fact that postnatal services are not always prioritised (Bick *et al.*, 2020), or that trusts employing a large number of midwives may have additional services such as fetal medicine or midwives in specialist roles.

Nurses in the USA have highlighted surges in workload, competing demands and staffing pressures as barriers to providing support at night on postnatal wards (Grassley *et al.*, 2015).

Areas of incomplete care include emotional support, communication, monitoring, breastfeeding support, and parent education when staffing is inadequate (Simpson *et al.*, 2016). A previous study using the CQC Maternity Survey data found a relationship between trust FTE midwives and better postnatal experience (Turner *et al.*, 2022b). This finding has been replicated using the 2019 Maternity Survey data in this study. We expected the alternative method of staffing exposure (HPPD) to better reflect the staffing experienced by women. However, HPPD for registered staff may still be a crude measure of workload as patient acuity and turnover are not factored in. Workload may be variable between postnatal wards with similar staff to patient ratios.

A mismatch may occur between the documented staffing and actual staffing by midwives on postnatal wards, which could result in a measurement bias potentially contributing to dilution or reversal of estimated effects. The deployment models for staff rostered on postnatal wards are not described in the literature. There is evidence that midwives who are rostered to attend postnatal wards are sometimes redeployed during a shift to cover areas of emergent need, such as maintaining one-to-one staffing on labour ward (Dykes, 2005; Bowers *et al.*, 2016; Wray, 2006). This has recently been noted in Care Quality Commission reports as the maintenance of one-to-one care in labour resulted in short staffing in other areas because staff were moved at short notice (Care Quality Commission, 2021a; Care Quality Commission, 2021b). If these redeployments are not reflected in the roster, units that appear to be highly staffed by midwives may not be.

Our study also examined health care support workers. We found that trusts in the highest tertile for support worker staffing had more women reporting they always had help when they needed it and were always treated with kindness and understanding. Responses to the questions about discharge without delay and receiving information and explanations were also in the same direction, although not significant when compared with the lowest tertile of support worker staffing. This finding is unsurprising given the nature of the support worker role and the likelihood that they may be available to answer buzzers and contribute to a woman's experience of feeling supported. An evaluation by Griffin *et al.* (2012) reported instances where maternity support workers have facilitated timely discharges, assisted with breastfeeding and parent education. Moreover, midwives were confident in delegating these tasks to the support workers. A survey by Baxter *et al.* (2005) found that women's satisfaction with postnatal care after caesarean section improved with the introduction of nurses and nursery nurses, highlighting the fact that these roles are valued in this setting. This research on patient experience contrasts with that on clinical outcomes, as Sandall *et al.* (2014) reported poorer outcomes for mothers in trusts where the number of support workers were higher. This composite outcome included some postnatal measures such as length of stay and readmission rates. Overall, this is an

under researched area as a recent scoping review found just three studies which related maternity support worker staffing levels with patient outcomes (Turner *et al.*, 2021).
Our research highlights the importance of examining and adjusting for the contribution of different staff groups. Analysis of results for registered staffing showed differing results before and after adjustment for covariates, including support worker staffing. This study underlines the potential contribution of maternity support workers in the postnatal environment, rather than focusing solely on registered staff. Support workers may be the stable staff on postnatal wards as they are unlikely to be redeployed to care for women arriving in labour.

Limitations

Our study is limited in that it is cross sectional and we therefore cannot be certain of the precise exposure to staffing levels that each mother was exposed to. One further limitation is that the HPPD data was identified for postnatal wards in 93 trusts, and therefore 27 trusts were not represented in this study. This was because we were unable to distinguish postnatal wards from other maternity areas within the HPPD data. In some trusts the recording of staffing appeared to be planned for inpatient maternity services as a whole, and therefore dynamic staffing between areas may be intentional according to patient need.

Although we used a systematic method to identify the postnatal wards, we have not verified this labelling with individual trusts. We are aware that some wards may have variable activity, such as mixed antenatal and postnatal women, and many include transitional care for high risk babies.

It is unclear whether the inclusion of selected trusts has affected the results, or whether trusts excluded due to limited data are materially different from those included. The selection of staff for inclusion in the HPPD calculation appears to be appropriate in that temporary staff (bank and agency) are included as they fulfil a need to provide patient care. Staff additional to the numbers such as students and supernumerary staff have not been included. It is difficult to estimate how much they contribute to patient care, and this could be a potential source of omitted variable bias if large numbers of additional staff are present but not counted.

The omission of newborns from this data is unlikely to systematically alter the findings as the same methodology was applied to all trusts and relative differences in patient experiences were calculated. This may pose a source of variation if some postnatal wards have more unwell babies, accounting for a higher workload in those areas and distorting the staff hours available to mothers. In guidelines on staffing in the USA, mothers and babies are both counted in staffing decisions with recommendations of 1 nurse for 3-4 mother-newborn couplets

(Association of Women's Health Obstetric Neonatal Nurses, 2010). Most other countries have no such recommendations for staffing ratios in postnatal care.

The averaging of staffing data for postnatal wards within the same trust, and the reporting of HPPD as monthly averages are sources of imprecision in our analysis, as daily variability within these measures have not been fully accounted for. Despite some limitations in HPPD data there is keen interest in this metric as NHS Improvement are considering how patient acuity can be integrated into HPPD calculations and they are reporting exploratory work linking this measure to patient outcomes (NHS Improvement, 2021). Measuring staff workload is a precursor to determining staffing levels, however this is complex and there is no one widely accepted staffing measure (Twigg *et al.*, 2009). Clark *et al.* (2022) explains that measuring maternity staffing is problematic. Accepted models of staffing used in medical and surgical settings may not be suitable due to the high turnover in the maternity setting and the provision of unscheduled one-to-one care in labour within the service (Clark *et al.*, 2022).

Recommendations for research

Within England, registered staff are likely to be midwives as the National Health Service employs only a small number of registered nurses in maternity services at present (Royal College of Nursing, 2019). Nurses are reported to be employed in obstetric theatres, recovery and more recently on postnatal wards (Lintern, 2021b; Royal College of Nursing, 2019). Staffing by nurses or assistants may increase in future due to midwifery staffing and recruitment pressures (Lintern, 2021b). In future studies, it would be useful to be able to distinguish between nurses and midwives as this may inform staffing decisions on their deployment. In many other parts of the world, nursing professionals with midwifery training are employed in maternity settings rather than midwives so this measurement would improve external validity (United Nations Population Fund, 2021).

Although we adjusted for as many potentially confounding covariates as possible, and included details such as ethnic mix of the sample at the organisation level we were unable to adjust fully for ethnicity as this measure was not available for individuals. Racial disparities are known to influence clinical outcomes and experiences of maternity care (MBRRACE-UK, 2021; Birthrights, 2022; Henderson *et al.*, 2013). A recent investigation highlighting these issues found that ethnicity was not recorded for 1 in 10 women in Great Britain despite the knowledge that this is an important patient characteristic to report and investigate (National Maternity and Perinatal Audit, 2021). This is an important covariate to include in future research given the evidence of inequalities in this area.

Conclusion

The relationship between staffing levels and the experience of women on postnatal wards confirms previous research that patient experience is better when more registered midwives are employed in an organisation. The relationship was not seen when registered staffing was measured on postnatal wards using the Care Hours Per Patient Day dataset, which is a widely used tool for describing staffing levels. An increased number of support workers on postnatal wards was associated with improved maternal experience, highlighting the potential contribution of this sector of the workforce. Further research investigating safety outcomes in relation to postnatal staffing is recommended, as patient experience is one key measure of quality but not the full picture. Limitations of this study mean that a causal relationship cannot be implied and therefore further research is needed to guide policy on postnatal ward staffing.

Study 3

Published as Turner, L., Saville, C., Ball, J., Culliford, D., Dall'Ora, C., Jones, J., Kitson-Reynolds, E., Meredith, P. and Griffiths, P. (2024) 'Inpatient midwifery staffing levels and postpartum readmissions – a retrospective multi-centre longitudinal study', BMJ Open. 14:e077710

Supplementary material in Appendix I, Link to peer review and response

Abstract

Background

Preventing readmission to hospital after giving birth is a key priority, as rates have been rising along with associated costs. There are many contributing factors to readmission, and some are thought to be preventable. Nurse and midwife understaffing has been linked to deficits in care quality. This study explores the relationship between staffing levels and readmission rates in maternity settings.

Methods

We conducted a retrospective longitudinal study using routinely collected individual patient data in three maternity services in England from 2015-2020. Data on admissions, discharges and case-mix were extracted from hospital administration systems. Staffing and workload were calculated in Hours Per Patient day per shift in the first two 12-hour shifts of the index (birth) admission. Postpartum readmissions and staffing exposures for all birthing admissions were entered into a hierarchical multivariable logistic regression model to estimate the odds of readmission when staffing was below the mean level for the maternity service.

Results

64,250 maternal admissions resulted in a birth and 2903 mothers were readmitted within 30 days of discharge (4.5%). Absolute levels of staffing ranged between 2.3 and 4.1 individuals per midwife in the three services. Below average midwifery staffing was associated with higher rates of postpartum readmissions within 7 days of discharge (aOR 1.108, 95% CI 1.003, 1.223). The effect was smaller and not statistically significant for readmissions within 30 days of discharge (aOR 1.080, 95% CI 0.994, 1.174). Below average maternity assistant staffing was associated with lower rates of postpartum readmissions (7 days, aOR 0.957, 95% CI 0.867, 1.057; 30 days aOR 0.965, 95% CI 0.887, 1.049, both not statistically significant).

Conclusion

We found evidence that lower than expected midwifery staffing levels is associated with more postpartum readmissions. The nature of the relationship requires further investigation including examining potential mediating factors and reasons for readmission in maternity populations.

Strengths and Limitations of this study

Longitudinal design with individual level linking of staffing exposure to subsequent readmissions.

Adjustment for case mix, staff groups and organisational level variables using hierarchical multivariable modelling.

Staffing was measured in the first two 12-hour intervals of the index (birth) hospital stay and did not account for the exposure to staffing for the whole hospital stay.

Considers exposure to staffing in the whole maternity service rather than close to women at ward level.

Background

In many countries of the world the majority of mothers give birth in hospital (World Health Organization, 2023). Preventing readmission due to potentially avoidable complications is a key priority, not only because of the negative experience and burden on the women affected (Feenstra *et al.*, 2019), but because readmissions are costly (Vest *et al.*, 2010). Readmission rates are used as an indicator of the quality of care (Blume *et al.*, 2021), and in some countries providers are held financially accountable for patient outcomes during the first 30 days after discharge for many patient groups (Brown, 2020). Rates of postpartum readmission vary by country, with reported rates of 1.0% in the USA (Clapp *et al.*, 2017), 1.7% in Sweden (Ellberg *et al.*, 2005) and 3.3% in England and Wales (National Maternity and Perinatal Audit, 2022).

Reports from England and the USA suggest that readmission rates have increased in recent years (Clapp *et al.*, 2016; National Maternity and Perinatal Audit, 2022). This coincides with an increase in caesarean birth rates (Sharvit *et al.*, 2014). In England 4.3% of women having a caesarean birth are readmitted (1 in 23) compared with 2.9% of those having a vaginal birth (1 in 34) (National Maternity and Perinatal Audit, 2022). The recent trend towards shorter length of hospital stay and reduced community provision may also contribute to increased readmission rates. However, whilst some research has pointed to an association between reduced length of stay and increased readmission rates (Liu *et al.*, 2002; Wen *et al.*, 2020) this finding is not consistent in the research literature (Ford *et al.*, 2012; Pervez *et al.*, 2021). The most common reasons for readmission include wound complications, post-partum haemorrhage, hypertension, mastitis and thromboembolism (Clapp *et al.*, 2017; Szafrańska *et al.*, 2020; Clapp *et al.*, 2016; Sharvit *et al.*, 2014; Kipkore, 2022). Postpartum readmissions typically occur within the first 14-20 days after discharge (Combs *et al.*, 2022; Wen *et al.*, 2021).

Pressures on staffing within maternity services have been reported globally (United Nations Population Fund, 2021) but the consequences of this are poorly understood. In many areas of health care there is strong evidence that lower nurse staffing levels are associated with reduced quality of care and poorer patient outcomes e.g. as measured by mortality (Needleman *et al.*, 2020), adverse events (Kane *et al.*, 2007) and patient satisfaction (Aiken *et al.*, 2018). Studies in medical and surgical inpatient settings have found that higher registered nurse staffing levels are associated with reduced readmission rates (Ma *et al.*, 2015; McHugh *et al.*, 2013; Lasater *et al.*, 2021). A scoping review of midwifery and nurse staffing for inpatient maternity services (Turner *et al.*, 2021) found just two studies which measured maternal readmission in relation to staffing. These studies found that readmission rates were lower when more midwifery staff were employed (Gerova *et al.*, 2010) and the proportion of registered staff increased (Kim *et al.*, 2016). More evidence is needed on the relationship between maternity staffing levels, skill mix and readmission rates to understand whether previous findings are replicated and to understand the size of the effect if an association exists.

The aim of this study is to assess the relationship between individual patient-level exposure to staffing and postpartum readmission rates. A longitudinal design was adopted to enable women's exposure to staffing to be aligned to their outcomes, adjusting for individual risk factors.

Methods

We conducted a retrospective longitudinal study using individual patient records in multiple centres (Griffiths *et al.*, 2019a). Maternity inpatient stays from 13th April 2015- 29th February 2020 were extracted from the hospital Patient Administration System for three Acute National Health Service (NHS) trusts in England. Data after February 2020 was not studied due to service changes during the covid pandemic. NHS trusts comprise one or more hospitals operating as a group under a combined management. Two of the trusts had inpatient services all on one site (antenatal, postnatal and labour ward). The third trust had two geographical sites, comprising two maternity hospitals.

The available data included all women admitted to maternity wards, including those admitted via Day Assessment triage unit, totalling 113,002 admissions. Patient data was extracted for the date and time of admissions and discharges per maternity patient episode during the study period. The patient pseudonyms and dates were used to identify which postpartum women had been readmitted to the same maternity service for any cause within 7 days and 30 days of discharge. The primary reason for readmission was extracted from the ICD-10 code for the readmission episode. To account for variation in case mix and comorbidities we used the age band on admission, mode of birth from the Healthcare Resource Group (HRG) procedure code (NHS England, 2023b), and the Standardised Hospital Mortality Indicator (SHMI) which calculates an age specific risk score based on comorbidities for a given reason for admission ('diagnosis') (NHS Digital, 2023e; NHS Digital, 2019b).HRGs are standard groupings of clinically similar treatments which use comparable levels of healthcare resource. Admissions without a birth were excluded from the final dataset as they would not be eligible to have a postpartum readmission.

Shift-level staffing data was obtained from trust electronic roster systems which recorded all worked shifts and the grades of staff. This data comprised the time worked excluding breaks for the Registered Midwife group and Maternity Assistant Staff group and was matched to 12 hour periods, either 07.00 to 19.00 or 19.00 to 07.00 to determine the staff time available in each time period. Staffing was measured by Hours Per Patient Day (HPPD) and this variable was generated by dividing the total worked time for the Staff group by the total ward occupancy as detailed in the measure guidance document (NHS Improvement, 2021). All admitted individuals were included in the occupancy measure because they all contribute to workload, with neonates accounting for 40% of the admitted population. The HPPD was calculated for Registered Midwife (RM) and Maternity Assistant (MA) staff separately, and the staff groups were combined as a measure of Overall staffing per 12-hour period per day. Skill mix was calculated per shift using the RM worked seconds as a proportion of the total worked seconds, which encompassed RMs and MAs. Registered Nurses were included in the Registered Midwife totals as there were very few (<0.1%) and were of a similar grade to midwives. Data was cleaned to remove shifts where patient occupancy is zero seconds, and to remove shifts with RM HPPD outliers (defined as RM HPPD < 0.5 or RM HPPD > 48).

Staffing for only the index (birth) admission prior to the postpartum readmission was recorded. For the analysis, staffing was noted in the first two 12-hour periods of care in the Index admission (one interval of day shift and one of night shift). This method avoids recording staffing exposure for increased length of stay for a minority of complex cases. Longer time periods will skew the analysis as there is more opportunity to be exposed to understaffing. We defined the expected staffing as the mean HPPD for the maternity service in each trust, and this was calculated separately for both day and night shifts. Each of the two 12-hour intervals of observed staffing (HPPD) was divided by expected staffing for the same period (HPPD) and these ratios were averaged for the first two 12 hour intervals, with values below 1 indicating a reduction in staff compared with expected levels. The HPPD was converted into the number individuals cared for per midwife and individuals per maternity assistant by dividing 24 hours by the HPPD for each group. This allows service planners to see the potential differences of altering staffing levels in absolute terms using variables familiar to them. A further measure of ward activity and workload was calculated. The variable 'turnover' equalled the total number of admissions plus discharges per trust per 12 hour interval. Transfers between wards were not included in this measure. Mean turnover was calculated per trust and variables were created to represent higher than expected turnover compared to the trust mean, by day and night shifts.

Univariable analyses on the relationship between independent variables and readmissions were performed, nested in hospital trust. Multi-level logistic regression was then undertaken with the primary outcomes of postpartum readmission within 7 days and 30 days of discharge, nested in hospital trust. Readmissions within 7 days was included as this may be more sensitive to variation in care quality during index admissions (Chin *et al.*, 2016; Graham *et al.*, 2015), and longer time intervals increase the chance that readmission may be due to outpatient management (Goldfield *et al.*, 2008). The null model was the starting point and variables were added firstly based on indicators in the literature to suggest a potential effect on readmission (age, mode of birth), then staffing variables of interest (exposure to RM and MA staffing below the mean in the main analysis) and then remaining variables of SHMI risk, skill mix and turnover were added in sequence and only retained in the full model if they improved model fit using Akaike information criterion (AIC) and Bayesian information criterion (BIC) values (see supplement S1 for model fit using this forward selection process). After the model fitting, only age, mode of birth and SHMI risk remained in the full model along with the staffing variables. For ease of interpretation, we repeated the full model using absolute values of staffing expressed as the number of individuals cared for by each midwife and maternity assistant. We performed a secondary analysis comparing low and high levels of staffing compared to near mean staffing, classified as 95% to 105% of the mean, to explore non-linear relationships. As some sub-groups may have higher support needs and thus be more vulnerable to any adverse effects of low staffing, we performed a secondary analysis to explore staffing effects according to mode of birth.

All analyses were conducted in Stata (Release 16. College Station, TX: StataCorp LLC). Ethics permission was gained via the University of Southampton Ethics Committee ERGO 52957 and IRAS 128056. This study was funded by the National Institute for Health Research, Health Services & Delivery Research programme, award 128056

Patient and Public Involvement

This study had service user and clinical staff consultation when selecting the outcome measures of interest, and a lay member contributed to the project steering group.

Results

There were 64,250 maternal admissions that led to a birth between mid-April 2015 and the end of February 2020. The trusts differed in size with 5,260, 45,518 and 13,472 admissions leading to a birth in each of the trusts respectively. In the cohort, 58.1% of women had a spontaneous vaginal birth, 12.9% assisted instrumental birth, 12.3% planned caesarean birth and 16.7% emergency caesarean birth (Table 14).

Table 14 Characteristics of the study population and their exposure to staffing

Age		
<20 years	2,099	(3.27%)
20-24 years	9,862	(15.35%)
25-29 years	18,362	(28.58%)
30-34 years	20,114	(31.31%)
35-39 years	11,016	(17.15%)
40+ years	2,797	(4.35%)
Mode of Birth		
Assisted birth	7,764	(12.88%)
Emergency caesarean birth	10,041	(16.66%)
Spontaneous vaginal birth	35,040	(58.14%)
Planned caesarean birth	7,425	(12.32%)
SHMI	Mean	0.0035
	Std. Dev.	0.0319
Turnover (admissions plus discharges per day)	Mean	56.716
	Std. Dev.	25.397
Registered midwife staffing exposure (HPPD)	Mean	6.640
	Std. Dev.	2.351
Maternity assistant staffing exposure (HPPD)	Mean	2.146
	Std. Dev.	1.045
Skill mix (registered midwives as proportion of total staff)	Mean	0.757
	Std. Dev.	0.039
Readmitted within 30 days of discharge	2903	(4.52%)
Readmitted within 7 days of discharge	2043	(3.18%)

SHMI Standardised Hospital Mortality Indicator HPPD Hours Per Patient Day

Two thousand nine hundred and three women who gave birth were readmitted postnatally within 30 days of discharge (4.5%). Of those readmitted within 30 days, 70% were readmitted within the first 7 days and 89% within 14 days. Rates of readmission differed by birth method: 3.7% of women having a spontaneous vaginal birth were readmitted, and rates were 5.9% for planned caesarean birth, 6.3% for assisted birth and 6.8% for emergency caesarean birth respectively. The postpartum readmission rates following birth varied by trust and were 1.8%, 4.9% and 4.3%. The mean length of stay for postpartum readmissions was 45.4 hours (median 22.5 hrs, IQR 3 hrs to 52 hrs). Infection/sepsis was the most common primary reason for readmission (677/2903, 23.3%). Postpartum haemorrhage accounted for 316/2903 readmissions (10.9%). Some readmissions appeared to be healthy mothers accompanying their newborn, although this represented only 125/2903 (4.3%) of maternal readmissions (supplement S2).

Staffing varied by trust for those in our study cohort, with an average of 2.3, 3.6 and 4.1 individuals per midwife in the three services (this equates to 11.7, 6.9 and 5.9 HPPD respectively). More staff were available on day shifts compared with night shifts. The proportion of RM hours per trust varies from 70.7% to 77.4% between the trusts, and almost all the registered staff are classified as midwives where this data is available (supplements S3-S5).

For two of the trusts the mean overall staffing in HPPD has shown an increase during the 5-year study period, whereas in the third trust there is a stable level of overall staffing but a slight decrease in RM staff and increase in MA staffing over this period (approx. 4% change in each group). There was more ward activity in terms of admissions and discharges on day shifts compared with night shifts (supplements S6-S7).

Univariable analyses on covariates and postpartum readmission

Age and mode of birth were statistically significant predictors of postpartum readmission in univariable analyses, with older mothers and those having assisted or operative birth at higher risk (see Table 15 and supplement S8). Higher SHMI risk was associated with higher risk of readmission, but this was not statistically significant. Women exposed to below average RM staffing and overall staffing had increased odds for readmission, but this was not statistically significant. Having more admissions and discharges than expected and a more diluted skill mix than average was not associated with increased postpartum readmissions at 7 days and 30 days.

Table 15 Univariable analyses of Readmission at 7 days and at 30 days from discharge

	Readmitted within 7 days		Readmitted within 30 days	
	OR	95% CI	OR	95% CI
Age category				
<20 years	1.009	0.770 1.323	0.994	0.787 1.256
20-24 years	1.000	reference category	1.000	reference category
25-29 years	0.954	0.828 1.100	1.013	0.897 1.143
30-34 years	1.040	0.906 1.195	1.095	0.973 1.233
35-39 years	1.043	0.893 1.219	1.125	0.986 1.284
40+ years	1.476	1.193 1.827	1.454	1.208 1.750
Mode of birth				
Assisted birth	1.838	1.622 2.083	1.828	1.642 2.036
Emergency caesarean birth	1.888	1.685 2.116	2.041	1.854 2.247
Spontaneous vaginal birth	1.000	reference category		reference category
Planned caesarean birth	1.500	1.310 1.717	1.706	1.526 1.908
Registered Midwife staffing <mean	1.065	0.974 1.166	1.041	0.965 1.123
Maternity Assistant staffing <mean	0.984	0.898 1.077	0.980	0.908 1.059
Overall staffing <mean	1.054	0.964 1.154	1.041	0.964 1.123
SHMI risk	1.554	0.601 4.021	1.546	0.671 3.560
Turnover > mean	0.972	0.889 1.062	0.966	0.896 1.042
Skill mix <mean	1.017	0.928 1.113	0.979	0.907 1.057

SHMI Standardised Hospital Mortality Indicator

Relationship between staffing and postpartum readmission in multivariable models

Model fit was improved from the null model using a forward selection procedure with the addition of age category, mode of birth, RM and MA staffing and SHMI risk in that order. It was not improved with the addition of turnover and skill mix variables and therefore these variables are not shown in the full model. The variance inflation factors were below 2 for all variables which suggests that they are not collinear. Missing data is minimal for the variables studied (supplement S1).

Lower than expected midwifery staffing was associated with an 11% higher odds of postpartum readmissions within 7 days of discharge (adjusted OR 1.108, 95% CI 1.003, 1.223). The effect was smaller and not statistically significant for readmissions within 30 days of discharge (adjusted OR 1.080, 95% CI 0.994, 1.175). Lower than expected maternity assistant staffing was associated with a lower odds of readmission at 7 days (OR 0.957, 95% CI 0.866, 1.057) and at 30 days (OR 0.965, 95% CI 0.887, 1.049). These relationships were not statistically significant in the multivariable model (see Table 16 and supplement S9).

Table 16 7-day and 30-day readmissions in the full multivariable models

Staffing relative to the mean per service, supplement S9				
Variable	OR readmission 7 days	95% CI	OR readmission 30 days	95% CI
<20 years	1.066	0.810 1.402	1.065	0.840 1.350
20-24 years	1.000	reference category	1.000	reference category
25-29 years	0.914	0.790 1.057	0.969	0.856 1.098
30-34 years	0.983	0.853 1.133	1.024	0.906 1.156
35-39 years	0.983	0.837 1.153	1.046	0.913 1.198
40+ years	1.368	1.099 1.703	1.318	1.089 1.594
Assisted birth	1.873	1.648 2.128	1.850	1.657 2.065
Emergency caesarean birth	1.912	1.701 2.148	2.077	1.883 2.291
Spontaneous vaginal birth	1.000	reference category	1.000	reference category
Planned caesarean birth	1.518	1.321 1.745	1.707	1.522 1.915
Exposed to staffing below mean Registered midwives (HPPD)	1.108	1.003 1.223	1.080	0.994 1.174
Exposed to staffing below mean Maternity assistants (HPPD)	0.957	0.866 1.057	0.965	0.887 1.049
SHMI risk	0.687	0.108 4.360	0.8868	0.242 3.248

SHMI Standardised Hospital Mortality Indicator HPPD Hours Per Patient Day

In models using absolute staffing levels (rather than relative), an increase of one individual (mother or baby) per midwife was associated with a 6% increase in the odds of readmission at 7 days, aOR 1.063 (95% CI 0.960, 1.177). There was no association with maternity assistant staffing (aOR 0.998, 95% CI 0.978, 1.018). Neither relationship was statistically significant (supplement S10)

Staffing was examined in categories to capture higher than average staffing as well as lower than average levels for readmissions within 7 and 30 days (Table 17, supplement S11). When grouped as three categories, higher midwifery staffing (105% of mean or more) was associated with reduced odds of readmission compared with the category containing the mean. The category of lower than mean midwifery staffing (95% of mean or lower) was associated with increased odds of readmission. None of the relationships in the categorical analyses were statistically significant.

Table 17 Multivariable analysis with staffing in categories above and below mean levels

Variable	**OR readmission 7 days**	95% CI		**OR readmission 30 days**	95% CI	
<20 years	1.068	0.812	1.404	1.066	0.841	1.351
20-24 years	1.000	reference category		1.000	reference category	
25-29 years	0.914	0.790	1.057	0.970	0.856	1.099
30-34 years	0.984	0.854	1.134	1.025	0.908	1.158
35-39 years	0.984	0.838	1.154	1.046	0.913	1.199
40+ years	1.370	1.101	1.706	1.319	1.090	1.595
Assisted birth	1.873	1.648	2.127	1.850	1.657	2.065
Emergency caesarean birth	1.911	1.701	2.147	2.076	1.882	2.290
Spontaneous vaginal birth	1.000	reference category		1.000	reference category	
Planned caesarean birth	1.518	1.321	1.744	1.705	1.520	1.913
Midwifery staffing						
Low, 95% of mean or less	1.056	0.943	1.182	1.002	0.911	1.102
Near to mean 95%-105%	1.000	reference category		1.000	reference category	
High 105% of mean or more	0.973	0.862	1.098	0.957	0.865	1.060
Maternity assistant staffing						
Low, 95% of mean or less	0.924	0.816	1.046	0.968	0.871	1.076
Near to mean 95%-105%	1.000	reference category		1.000	reference category	
High 105% of mean or more	0.935	0.825	1.059	0.968	0.870	1.077
SHMI risk	0.693	0.111	4.335	0.889	0.243	3.247

SHMI Standardised Hospital Mortality Indicator See supplements S11 and S12

In the secondary analysis by mode of birth, exposure to midwifery understaffing was associated with an increased odds of readmission after emergency and planned caesarean births, and assisted births. The estimated effects were stronger in these groups than in the whole cohort (OR 1.113-1.315) although the result was only statistically significant for the assisted birth group. For spontaneous vaginal births there was no association between understaffing and readmissions (supplement S13).

Discussion

In this longitudinal study we analysed individual patient stays and concurrent staff rosters, and we found an association between midwifery staffing below the mean level and higher rates of postpartum readmission. This effect was stronger and statistically significant for readmissions within 7 days of discharge, with an increase in odds of 11% for understaffing compared with the organisation mean staffing levels. We estimate that if a midwife's workload is increased by one additional person, the odds of readmission within 7 days increases by 6.3%, although confidence intervals are wide and cross the null effect in this analysis of absolute staffing data. The direction of findings is in line with that of Gerova *et al.* (2010) who found that increased number of full-time-equivalent midwives in a service was associated with reduced postpartum readmissions. These findings are also seen in the nursing literature, in medical, surgical and paediatric settings (Ma *et al.*, 2015; Tubbs-Cooley *et al.*, 2013).

The mean 30-day readmission rate in this study was 4.5% which is higher than rates reported in USA (Clapp *et al.*, 2017) and Sweden (Ellberg *et al.*, 2005) where reports are between 1-2%. This difference may reflect service variability such as community provision and the threshold for readmission (Fischer *et al.*, 2014). The readmission rate following birth is much lower than with medical and surgical patients (NHS Digital, 2022a). This is likely to be because obstetric patients are healthier and younger than other patient populations and because the index case is often undergoing a normal physiological process rather than management of a disease or condition (Brown, 2020). The readmission median length of stay was 22.5 hours, which represents a sizeable provision within services each year when multiplied by the rate of readmission.

We found wide variation in the number of individuals cared for by each midwife, from 2.3 per midwife in one organisation to 4.1 per midwife in another. It is important to remember that this figure spans the inpatient maternity service where some women will receive one-to-one care in labour (Care Quality Commission, 2022b) and others will be on wards including neonates with fewer staff per person than in the birthing environment. One of the trusts had a smaller service than the others, while also having higher rates of staffing and lower readmission rates. Smaller services require more staff to ensure services are available and to manage unscheduled demand (Vaughan *et al.*, 2020; Edwards, 2020). Smaller services may also be treating fewer complex cases which could account for lower readmission rates (Fischer *et al.*, 2014). These variations were controlled for in our hierarchical analysis and also in the case-mix adjustment, so we can be confident our analysis has taken account of these factors.

Risk factors associated with maternal postpartum readmission include age, ethnicity, parity, body mass index and mode of birth (Sharvit *et al.*, 2014; Szafrańska *et al.*, 2020). Individual characteristics were noted to account for most of the inter-hospital variance in postpartum readmission rates in the study by Clapp *et al.* (2018) and we saw further evidence of this as age and mode of birth were statistically significant predictors of readmission in all of our analyses. Staffing is a modifiable factor that has also been associated with rates of readmission (Gerova *et al.*, 2010; Kim *et al.*, 2016). Having more people to care for can affect the quality of care, as some aspects can be missed or incomplete as staff prioritise and ration their time (Simpson *et al.*, 2016). Some activities such as medicines administration are commonly prioritised, whereas patient teaching and discharge preparation may be seen as less urgent, and therefore more likely to be incomplete or missed (Tubbs-Cooley *et al.*, 2013). This has been found in a number of studies including those in Malaysia (Nahasaram *et al.*, 2021), Australia (Albsoul, 2019), USA (Tubbs-Cooley *et al.*, 2013) and South Korea (Lee *et al.*, 2021), although not all of these studies are in maternity populations. Our secondary analysis suggested that women with more complex modes of birth are particularly vulnerable to the effects of understaffing.

The mechanisms for an association between staffing and readmissions need further study. Weiss *et al.* (2011) found a sequential pathway from high registered nurse staffing, to improved discharge teaching quality and readiness, to decreased odds of readmission for medical-surgical patients. However, this type of study has not been replicated in the maternity population as far as we are aware. Proposed mechanisms include reduced staff time for recognising deterioration (Jeffs *et al.*, 2014), time for education (Tubbs-Cooley *et al.*, 2013), coordination of care (McHugh *et al.*, 2013), hand hygiene compliance (Blume *et al.*, 2021; Rae *et al.*, 2021), discharge planning (Simpson *et al.*, 2016) and medicines optimisation (Combs *et al.*, 2022). We found that infection or sepsis was listed as the primary diagnosis in 23% of the postpartum readmissions. Although this was the most common identifiable reason for readmission it was not as high as that reported in the literature, where infection has been implicated in 62% of all postpartum admissions (Sharvit *et al.*, 2014) and 82% of readmissions following caesarean birth (Kipkore, 2022). Nevertheless, this is still a sizeable figure so mediating pathways from staffing linked to infection and then readmission may be worthy of exploring.

We found a statistically significant association between midwifery staffing below the mean level and higher rates of postpartum readmissions within 7 days of discharge. We went on to look at staffing levels in categories below and above the mean levels. This categorical analysis of midwifery staffing found fewer readmissions when services were staffed above mean levels and more readmissions when staffed below mean levels, although these were not statistically significant. Service planners should consider setting staffing above mean levels if these findings are confirmed, as it is possible that mean levels in themselves represent suboptimal understaffing.

There was no clear relationship between maternity assistant staffing levels and readmission rates in our study. It may be that maternity assistants perform fewer sensitive activities which could be related to the risk of readmission, although there is very little published evidence on assistants in maternity services to compare our findings to.

Strengths and Limitations

There is limited evidence to determine optimal staffing levels in maternity services. Our research adds to the body of evidence by highlighting the association between staffing levels of midwives and rates of postpartum readmissions. Our analysis has taken account of case mix and between-hospital differences when estimating effects, but unfortunately, we were unable to adjust for other important factors such as ethnicity, parity, deprivation and body mass index from the available data. A strength of our approach is the longitudinal and granular design, so we have been able to measure the individual's exposure to staffing per shift, rather than estimating via monthly or annual data. Our approach has an advantage over sequential panel studies as the longitudinal design allows direct individual-level linking of staffing exposure to readmission despite the time lag between these variables.

The amount of missing data is minimal, and therefore we believe this does not materially affect the conclusions drawn. A limitation of our study is that we have been unable to extract information on the staffing close to each woman at the ward level, as two of the trusts only had staffing data available as a whole service. We measured staffing in the first 24 hours of the admission including birth and will not have captured the hours before discharge for all women. Some of the protective mechanism of adequate staffing could be related to the period prior to discharge, with the handover of care and provision of discharge information. Also we have been unable to account for post-discharge care in the community, which is likely to have a bearing on readmission rates if women have differing opportunities to seek early intervention elsewhere (Szafrańska *et al.*, 2020). A further limitation is that our study did not include the rosters of medical staff due to differences in roster configurations. If this staff group is included in future models this may modify the estimates seen for midwives and maternity assistants.

Areas for future research

Any measurable reduction in hospital readmission rates would offer significant financial benefits to hospitals (Brown, 2020). The cost of increasing staffing could be offset by the potential savings in the future. Cost-effectiveness studies are needed to investigate the consequences of different staffing configurations in relation to the quality of care and related costs and savings. In future research, the components of services that help to reduce readmissions could be explored so resources are applied in areas known to be effective. This may mean targeting increased attention towards at-risk populations that account for a high proportion of readmissions (Sharvit *et al.*, 2014; Wen *et al.*, 2021). The provision of additional staff alone may not be fully effective in reducing readmissions unless they are focusing activity on areas of need or critical activities. A more thorough investigation of reasons for readmission would need to be included in this future work.

Conclusion

Low midwifery staffing in maternity units is associated with increased rates of readmissions within seven days after discharge but there was no adverse effect from lower assistant staffing. This is an important finding especially as readmission rates have increased in some countries in recent years, they are costly to services and distressing for families. Limiting the number of individuals cared for per midwife may have benefits beyond the inpatient stay and result in cost savings if readmissions can be reduced.

Study 4

Published as Turner, L., Ball, J., Meredith, P., Kitson-Reynolds, E. and Griffiths, P. (2024) 'The association between midwifery staffing and reported harmful incidents: a cross-sectional analysis of routinely collected data', *BMC Health Serv Res*, 24(1), 391

Supplementary material in Appendix J, Link to peer review and response

Abstract

Background

Independent inquiries have identified that appropriate staffing in maternity units is key to enabling quality care and minimising harm, but optimal staffing levels can be difficult to achieve when there is a shortage of midwives. The services provided and how they are staffed (total staffing, skill-mix and deployment) have been changing, and the effects of workforce changes on care quality and outcomes have not been assessed. This study aims to explore the association between daily midwifery staffing levels and the rate of reported harmful incidents affecting mothers and babies.

Methods

We conducted a cross-sectional analysis of daily reports of clinical incidents in maternity inpatient areas matched with inpatient staffing levels for three maternity services in England, using data from April 2015 to February 2020. Incidents resulting in harm to mothers or babies was the primary outcome measure.

Staffing levels were calculated from daily staffing rosters, quantified in Hours Per Patient Day (HPPD) for midwives and maternity assistants. Understaffing was defined as staffing below the mean for the service. A negative binomial hierarchical model was used to assess the relationship between exposure to low staffing and reported incidents involving harm.

Results

The sample covered 106,904 maternal admissions over 46 months. The rate of harmful incidents in each of the three services ranged from 2.1 to 3.0 per 100 admissions across the study period. Understaffing by registered midwives was associated with an 11% increase in harmful incidents (adjusted IRR 1.110, 95% CI 1.002,1.229). Understaffing by maternity assistants was not associated with an increase in harmful incidents (adjusted IRR 0.919, 95% 0.813,1.039). Analysis of specific types of incidents showed no statistically significant

associations, but most of the point estimates were in the direction of increased incidents when services were understaffed.

Conclusion

When there is understaffing by registered midwives, more harmful incidents are reported but understaffing by maternity assistants is not associated with higher risk of harms. Adequate registered midwife staffing levels are crucial for maintaining safety. Changes in the profile of maternity service workforces need to be carefully scrutinised to prevent mothers and babies being put at risk of avoidable harm.

Background

Most women in the United Kingdom give birth in hospital, and maternity units also provide antenatal and postnatal inpatient care and specialist services such as day assessment and induction of labour (Department of Health, 2013). Predicting the demand for care is challenging, as labour by its nature is unscheduled, and there is great variation in the number of women admitted for labour care on any given day (Creswell *et al.*, 2023). This poses difficulty in planning the staffing of maternity units, as the goal is to minimise both understaffing and overstaffing of services, as staff resources need to be deployed in a purposeful and efficient way. In some services staffing is planned and reported across a whole maternity unit, and midwives are then deployed on the shift to where they are most needed as part of an escalation process (Wilson *et al.*, 2010). Across England, staffing levels and composition varies (NHS Digital, 2022b), although the National Institute for Health and Care Excellence recommends that an evidence-based tool is used along with other information and professional judgement to help plan staffing levels and skill mix (National Institute for Health and Care Excellence, 2015). This must be tailored to the expected demand and acuity of those using the service.

Appropriate staffing of maternity units has been highlighted as a priority, being key to the quality of care provided and affecting the wellbeing of women and babies and their future health (Public Health England, 2016). However there is a global shortage of midwives (United Nations Population Fund, 2021) and the education of future midwives takes three years or more in many countries (World Health Organization Europe, 2009). Additional midwifery workload has become apparent in recent years as midwives now have a wider scope of practice and have taken on some work previously assigned to medical staff (Gu *et al.*, 2020; Nursing and Midwifery Council, 2019). With high vacancy rates, targets have been set to increase the number of midwives in training and reduce the number of staff leaving the profession (NHS England, 2023c). Shortages of midwives have led to changes in services and how they are staffed: reduction of parent education and postnatal care provision from the National Health Service, delegating more activities to maternity care assistants, recruitment of midwives from other countries, closure of birth centres, suspension of continuity of care teams and, in extreme circumstances, the temporary closure of labour wards to new admissions (APPG Baby Loss and Maternity, 2022). These changes have been in response to the context rather than being introduced as evidence-based policies and the consequences of service changes are unclear (Lamont *et al.*, 2023).

Birth and the surrounding antenatal and postnatal periods of care are generally safe, and most women and babies do not have underlying conditions which put them at risk of complications (Aoyama *et al.*, 2017). However, adverse events do occur and there have been a number of investigations into poor maternity outcomes (Kirkup, 2022; Ockenden, 2022), sparking public concern and media attention. The legal costs and recompense related to maternity cases far exceed those from all other medical specialities (NHS Resolution, 2023). The personal cost to families is immeasurable and distress is increased where events could have been avoided (Ockenden, 2022). Women over 40 years, those with medical comorbidity, those from most deprived socio-economic groups, and black and Asian mothers have increased risk of adverse events, including mortality (MBRRACE-UK, 2022).

Staffing is one factor that can be modified, albeit creatively due to the supply issues already described. There is good reason to hypothesise that low staffing levels are linked with maternity adverse events, as several studies in nursing show that low staffing is associated with avoidable harm (Griffiths *et al.*, 2016), but far less research relates to maternity care (Turner *et al.*, 2021). Health workers have reported that poor staffing levels prevent them from ensuring service user safety (De Bienassis *et al.*, 2022) and the Francis report into the Mid Staffordshire trust concluded that many incidents occurred due to short staffing (Francis, 2013). Psychological research has demonstrated that time pressure is associated with increased mistakes (Saptari *et al.*, 2015), which lends further support to this hypothesis.

Maternity service providers in England are expected to note 'red flag' events that can highlight where deficiencies in staffing levels are potentially impacting on the quality of care, allowing shift by shift modifications to be made (National Institute for Health and Care Excellence, 2015). Although 'red flags' are used in NHS services, we do not have evidence on which indicators are most meaningful or sensitive to staffing input (Simpson, 2020). There are only a small number of research studies in midwifery which examine the association between staffing levels and adverse events (Turner *et al.*, 2021). These studies have examined the association between midwifery staffing and perineal trauma, post-partum haemorrhage, birth asphyxia, and admissions to the neonatal unit, with mixed findings (Sandall *et al.*, 2014; Prapawichar *et al.*, 2020; Clark *et al.*, 2014; Tucker *et al.*, 2003; Dani *et al.*, 2020; Hodnett *et al.*, 2002). The measurement of staffing levels in these studies tended to be aggregated over large populations or time periods. Not all studies had appropriate risk-adjustment, so the impacts of other covariates were not always accounted for when producing an estimate of staffing effects (Turner *et al.*, 2021). None of the studies factored in the additional workload which comes from multiple admissions and discharges during a shift, as this activity was not captured alongside the service user census. The problem remains that we are unsure how staffing levels and skill mix influence adverse events for mothers and babies, so optimal and hazardous levels are currently unknown. Staffing interventions should be based on high quality evidence to help predict the effects of changes in staffing and skill mix (Lamont *et al.*, 2023) and avoid adverse events if some of these can be prevented.

The aim of this study is to explore the association between daily midwifery staffing levels and the rate of adverse incidents while controlling for other covariates. This study is urgently needed due to the lack of research evidence in this area and the pace at which policy decisions are being implemented to tackle workforce supply and demand.

Methods

We conducted a cross-sectional analysis nested within a retrospective longitudinal study (Griffiths *et al.*, 2019a) in three maternity centres in England. The three centres were selected purposefully to represent different types of services and population demographics to aid the generalisability of findings. Maternity service A is smaller and located within a rural hospital with a local neonatal unit. Maternity services B and C are located within different cities, and both have neonatal intensive care units and fetal medicine facilities. These larger services care for women with more complex pregnancies and serve larger populations.

Ethics permission was gained via the University Ethics Committee ERGO 52957 and IRAS 128056. Routine data was extracted for 13th April 2015- 29th February 2020 from incident reporting systems. Incidents were included in the settings of maternity theatres, maternity triage, day assessment units, labour wards, antenatal and postnatal areas. We excluded incidents in neonatal units, community, and freestanding birth centres to retain focus on midwifery staffing and to closely match incidents to rosters for inpatient areas. The incident reports were linked to calendar days as opposed to individual service users. Incidents consist of clinical events along with events involving staff members and equipment. The incident description was recorded by each organisation in two columns and specific incidents were coded if they were recorded in either column, although the data was not supplied in a uniform way across the three organisations. Service user harm classification was extracted from the data. The primary outcome was incidents associated with any harm to mothers or babies. Secondary outcomes were incidents classified as moderate or higher harm, medicines incidents, stillbirth or neonatal death, delay, haemorrhage, third- or fourth-degree tear and incidents relating to discharge.

Staffing data was obtained from electronic rosters for the corresponding time-period. Daily staffing data was obtained from roster systems for 24-hour periods from 07.00 to 07.00. Recorded staffing included permanent, bank and agency staff and all shifts worked, excluding absences. This was matched to the number of incidents occurring on the corresponding calendar day which encompassed most of these working hours. A more precise matching to the exact shift was not possible as the time of the incident was missing in a number of records. Staffing was measured by Hours Per Patient Day (HPPD). The HPPD was calculated for

Registered Midwives (RM) and this data included Registered Nurses although there were few (<0.1%) and they were of a similar grade to midwives. HPPD for Maternity Assistants (MA) were calculated separately. HPPD was calculated by dividing the total worked seconds for the staff group by the ward occupancy, which included both mothers and neonates. Ward occupancy for each 24-hour period was calculated by aggregating the durations of each admitted service user's stay as recorded to the second in the patient administration systems. Data was cleaned to remove shifts where service user occupancy is zero seconds, and to remove shifts with RM HPPD outliers (defined as RM HPPD < 0.5 or RM HPPD > 48). For staffing variables, we examined staffing levels as low relative to the service mean ("understaffing") or at/above the mean as a binary variable.

We used a negative binomial model (Cameron *et al.*, 2013) to assess the association between staffing levels and the daily number of incidents, with ward occupancy per day as an offset to account for the varying number of people exposed. The negative binomial model was chosen as it performed better than the Poisson model on the likelihood ratio chi-squared test, and because the incident events were over-dispersed as the variance exceeded the mean. Univariable analyses nested in ward were performed before multivariable analyses.

Model fitting was performed by examining the empty model then adding in staffing data for Registered Midwives (RM) and Maternity Assistants (MA) as variables of interest to the study question. Additional variables were added and removed one at a time and were only retained if they improved model fit by reducing Akaike's Information Criteria and Bayesian Information Criteria (forward selection). The following variables were tested : weekday or weekend (binary variable), higher than expected admissions plus discharges compared to the mean for each service (binary variable), skill mix as the proportion of registered staff (as a continuous variable), proportion of population over 40 years on each day (continuous variable), and proportion of population with Charlson comorbidity index >0 (continuous variable). Age over 40 years was chosen as a threshold in the analysis as a higher proportion of women in this age group are at risk of morbidity and mortality, and therefore they represent a vulnerable population (MBRRACE-UK, 2022). We did not have access to data on population ethnicity to include in the modelling. Checks for collinearity were performed by examining the variance inflation factor. The beta coefficients were exponentiated to report incident rate ratios to aid interpretation of the results.

Results

During the study period there were a total of 106,904 maternal admissions (see Table 18). Service B accounted for 78,882 (74%) of these admissions. Service A is a smaller service and had 5,754 admissions. Service C had 22,268 admissions and provided a shorter time-span of data, due to data collection system upgrades. Overall, a small number of the population were over 40 years old (3.3%) or had comorbidity (7.0%) on any day, and there was variation between maternity services in this measure. Staffing levels varied between the organisations; mean registered midwife HPPD was 12.7 in service A, 5.0 for service B and 6.9 in service C.

The rate of all reported incidents varied per maternity service, from 10.8 to 24.7 per 100 admissions. Incidents associated with harm varied per service, from 2.1 to 3.0 per 100 admissions. Where harm was rated as at least a moderate classification, the rate ranged from 0.07 to 0.52 incidents per 100 admissions. Data for specific types of incident are shown below in Table 18.

Table 18 Descriptive statistics on case mix, staffing and incidents per organisation

	Maternity A	Maternity B	Maternity C
Dates where data is available	13th April 2015- 29th Feb 2020	13th April 2015- 29th Feb 2020	30th March 2016- 29th Feb 2020*
Total number admissions in time period	5,754	78,882	22,268
Proportion of the population >40 years old averaged across all days	3.8%	3.0%	3.3%
Proportion of the population with any comorbidity averaged across all days	7.2%	8.2%	5.1%
Mean daily staffing levels RM HPPD	12.65	5.02	6.89
Mean daily staffing levels MA HPPD	5.22	2.11	2.58
Number of days out of total where RM staffing was below the mean (expected) level	61%	54%	54%
Average skill mix per day across the service (RM staff hours/RM+MA hours)	0.71	0.69	0.73
Number of incidents that occurred in each service (per 100 admissions)			
All incidents in Maternity setting	1423 (24.73)	8524 (10.81)	3108 (13.96)
Incidents associated with any harm	144 (2.50)	1677 (2.13)	667 (3.00)
Incidents rated >= moderate harm	30 (0.52)	52 (0.07)	80 (0.36)
Medicines incident	24 (0.42)	467 (0.59)	351 (1.58)
Stillbirth or neonatal death	30 (0.52)	111 (0.14)	Not available
Any type of delay	129 (2.24)	867 (1.10)	Not available
Haemorrhage	196 (3.41)	856 (1.09)	Not available
Third of fourth degree tear	196 (3.41)	570 (0.72)	Not available
Incident related to discharge	11 (0.19)	234 (0.30)	Not available
Reporting of low staffing or high workload	16 (0.28)	1151 (1.46)	81 (0.36)

*incident data available for shorter time period for maternity service C

Univariable analyses

Univariable analyses for incidents involving harm are presented in Table 19. Understaffing by midwives (IRR 1.104, 95% CI 1.014, 1.203) and maternity assistants (IRR 1.031, 95% CI 0.947, 1.122) were associated with an increased rate of incidents involving harm, although the finding was only statistically significant for midwives. Higher than expected service user turnover (admissions plus discharges) was associated with a statistically significant increased reporting of harm (IRR 1.203, 95% CI 1.105, 1.309). A higher proportion of the service user population who were over 40 years on a given day, having a more dilute skill mix, weekend versus weekday, and increased proportion of service user comorbidity were not associated with statistically significant increases in reported harm events (see Table 19).

Table 19 Results of univariable analyses for incidents involving harm

	Incident rate ratio for incidents involving harm	95% CI
Understaffing less than the mean for Registered Midwives	1.104	1.014, 1.203
Understaffing less than the mean for Maternity Assistants	1.031	0.947, 1.122
Understaffing less than the mean for Overall staffing (RM+MA)	1.313	0.932, 1.850
Weekend versus weekday	0.943	0.858, 1.036
Higher than expected service user turnover	1.203	1.105, 1.309
Skill mix, proportion of total staff who are Registered	1.661	0.523, 5.273
Proportion of population>40 years	3.223	0.340, 30.544
Proportion of population with Charlson comorbidity index>0	0.391	0.077, 1.983

RM Registered Midwife, MA Maternity assistant

Multivariable analyses

After the model fitting process (see Supplement S6), RM understaffing, MA understaffing, higher than expected service user turnover, and skill mix were retained in the model. Understaffing by registered midwives was associated with an 11% increase in harm incidents and this was statistically significant (adjusted IRR 1.110, 95% CI 1.002, 1.229, Table 20). The effects were in the opposite direction for understaffing by maternity assistants, and not statistically significant (adjusted IRR 0.919, 95% 0.813, 1.039). Having higher than expected number of admissions and discharges (service user turnover) was associated with an 19% increased risk of harm incidents (adjusted IRR 1.190, 95% CI 1.091, 1.299, statistically significant). Skill mix was associated with an increased risk of harm incidents although the result was not statistically significant and the confidence interval was wide (adjusted IRR 3.101, 95% CI 0.703, 13.677).

Table 20 Multivariable analysis of staffing and association with harm incidents

Harm Incidents	Incident rate ratio	95% CI
Understaffing RM below mean	1.110	1.002, 1.229
Understaffing MA below mean	0.919	0.813, 1.039
Higher than expected service user turnover	1.190	1.091, 1.299
Skill mix (proportion RM)	3.101	0.703, 13.677

RM Registered Midwife, MA Maternity assistant

Secondary outcomes

Table 21 reports coefficients for multivariable models using the secondary outcomes of incidents with at least moderate harm, medicines incidents, stillbirth or neonatal death, delay, haemorrhage, and third- or fourth-degree tear. Reports of low staffing or high workload were also studied and compared with the empirical measures of low staffing in HPPD. Full results are reported in supplementary material S10-S18. Tables S22-S24 of the supplementary material show a breakdown of all incidents by primary descriptor for each of the organisations.

Table 21 Results from adjusted models for secondary outcomes

IRR (95% CI)	Registered midwife understaffing	Maternity assistant understaffing	Higher than expected service user turnover
Reports of low staffing / high workload	1.483 (1.273, 1.728)	1.225 (1.015, 1.479)	1.349 (1.183, 1.539)
All incidents	1.007 (0.958, 1.059)	1.058 (0.997, 1.122)	1.176 (1.128, 1.277)
Incidents rated >= moderate harm	1.097 (0.720, 1.670)	1.197 (0.751, 1.909)	1.488 (1.058, 2.091)
Medicines incident	1.018 (0.860, 1.205)	1.032 (0.846, 1.260)	1.042 (0.904, 1.201)
Stillbirth or neonatal death	1.048 (0.688, 1.597)	0.924 (0.559, 1.531)	0.863 (0.601, 1.242)
Any type of delay	1.164 (0.997, 1.360)	0.889 (0.736, 1.075)	1.224 (1.070, 1.401)
Haemorrhage	0.963 (0.822, 1.129)	1.165 (0.961, 1.412)	1.317 (1.148, 1.511)
Third of fourth degree tear	0.846 (0.689, 1.039)	1.247 (0.980, 1.587)	1.459 (1.225, 1.738)
Incident related to discharge	1.113 (0.824, 1.503)	1.053 (0.726, 1.527)	1.512 (1.160, 1.970)

Staffing reported in relation to the mean (under mean vs at or above mean).

RM Registered Midwife, MA Maternity assistant

Incident reports of low staffing or high workload were associated with low staffing (HPPD) for both midwives and maternity assistants, and this finding was statistically significant for both groups. For other secondary outcomes there was an increased risk of most types of incident when registered midwife staffing was below the mean, although none were statistically significant and haemorrhage and perineal tears showed non-significant associations in the opposite direction. Similarly in the majority of analyses of maternity assistant staffing (except stillbirth/neonatal death and delay), the point estimate was in the direction of increased risk of incidents when staffing was below the mean, but not statistically significant.

Higher-than-expected service user turnover (admissions and discharges) had a statistically significant association with secondary outcome incidents in 7 of the 9 analyses in Table 21. The highest point estimate was 1.512 (95% CI 1.160, 1.970) for incidents related to discharge when turnover was higher than the mean.

Discussion

Almost £2.7 billion pounds was spent by the UK National Health Service in 2022/3 in settling damages and legal costs relating to health care adverse events, highlighting the importance of research and improvement in this area (NHS Resolution, 2023). Our study found evidence of an association between understaffing by registered midwives and an 11% increase in reports of incidents involving harm on days when staffing fell below the mean. In contrast, there was no evidence that low maternity assistant staffing was associated with increased incident rates other than reports of low staffing / high workload. In addition, higher than average service user turnover was associated with increased harm events.

Assuming our estimates represent true associations between understaffing and incidents, it is important to explore the mechanism of this effect. Investigations into maternity underperformance have highlighted poor communication, inadequate working relationships between professionals, lack of risk assessment, failure to escalate and not following guidelines as recurring themes (Kirkup, 2022; Ockenden, 2022). It is possible that these mechanisms could explain the link between low staffing, poor performance and subsequent adverse events although we did not have the capacity to explore this within our data. Chronic understaffing can also affect attendance at mandatory training which has safety implications.

Our research suggests that it may be harmful to reduce registered midwifery staffing as the estimates point towards an increase in adverse events when understaffing occurs. Solutions need to be found to the 'midwife exodus' (Moncrieff *et al.*, 2023) and vicious circle of low staffing and stretched working conditions which contribute to attrition (Royal College of Midwives, 2021). Policy makers should exercise caution in substituting unregistered staff to cover midwifery tasks as the effects of this change are not clear and may be detrimental. Our findings contribute to the debate about task shifting in maternity care which has seen the expansion of midwives' scope of practice (Gu *et al.*, 2020) and an increased number of tasks undertaken by maternity assistants (Taylor *et al.*, 2018). The effectiveness and safety of this change has not been confirmed in robust clinical studies and there is no evidence to support this from our study.

One new finding in our research is the consistent and strong association between service user turnover and the increased rates of adverse events in our analyses. This has not been identified within midwifery research before now, although Wilson *et al.* (2010) describes the limitation of using the midnight service user census alone to determine workload, as day attenders are not included. This study did not use a midnight census and yet it still found turnover to have a detrimental effect, which may be explained by the additional tasks and workload involved. High turnover is also likely to affect continuity of care with midwifery staff, which is associated with better outcomes (Sandall *et al.*, 2024). The shift of staff attention and assimilation of information as women are admitted and discharged creates a greater cognitive burden for staff, and may lead to more errors, omissions, or opportunities for missed communication (Jennings *et al.*, 2022). As turnover is more variable than the service user census it is harder to plan staffing to accommodate variation, although higher baseline staffing levels are more likely to be able to accommodate periodic increases in demand (Griffiths *et al.*, 2021).

The strengths of this study are that we were able to access a large multicentre dataset, daily staffing levels, and a breakdown of incidents by type and severity. This is more granular detail than previous studies and gives a valuable insight into contributing factors to maternity adverse incidents. We were able to adjust for other covariates, so that an assessment of staffing as an independent variable could be obtained. We recognise that the Charlson comorbidity index is not tailored specifically to maternity populations and more relevant indices such as the Maternal Comorbidity Index could have been used, however all indices require further appraisal and this is an evolving area (Aoyama *et al.*, 2017). Our findings are presented for staffing levels relative to the mean, and therefore we are unable to specify the actual staffing levels associated with greater harms. Limitations of this study were the use of observational data and reliance on staff reporting of adverse incidents which is known to be inconsistent among the workforce and likely to represent underreporting (Farquhar *et al.*, 2015; Johansen *et al.*, 2018). There was large variation in the total number of incidents that occurred per 100 admissions between each of the maternity services, which could reflect inconsistency in reporting as well as true variation. The cross-sectional nature of this study means that we are unable to imply causality between the exposure to understaffing and subsequent adverse events, although it does provide some suggestive evidence of a link between the two.

Future research using routine data could capture rosters from obstetric and neonatal medical colleagues, as staffing levels in these groups may be associated with adverse events and including them in models may modify the estimates seen for midwives and maternity assistants. Defining understaffing based on planned staffing levels could be considered in addition to mean levels for each service, as this is a more meaningful measure, especially when planned staffing has been calculated to optimise safety and effectiveness in the local population. Where possible, adjustment should be made for advanced maternal age, comorbidity, acuity, ethnic origin as well as population size and turnover within the service. If prospective studies are planned, the recording of adverse events using a predefined guide is advised to improve consistency in reporting this key variable. This would reduce the need for staff judgement on reporting and create a more robust measure. The effects of moving staff from wards to cover shortfalls in other areas should also be explored, both in terms of the safety for the areas they are removed from and the ability of staff to adapt quickly to a new environment partway through their shift. It would also be useful to explore the impact of exposure to understaffing and time-lagged outcomes presenting after discharge.

Further evidence on staffing could also be obtained during maternity investigations and quality monitoring inspections (Parkin *et al.*, 2023). This contextual information may be important to understand the environment that midwives are working within and additional pressure that they may face during some shifts. Emphasis on routine incident reporting is also important and the reporting of no-harm events has been suggested as a marker of a good safety culture within organisations (Cook *et al.*, 2020).

In conclusion, we found that midwifery understaffing is associated with an increased rate of harm reporting, and high turnover of service users is an independent risk factor. We cannot use this evidence to imply causality due to the cross-sectional design of this study. Further research is needed to clarify these findings including the contribution of other staff groups such as obstetricians and neonatal staff. Mothers and babies may be at risk of avoidable harm if there are insufficient registered midwives.

Chapter 3 Discussion

3.1 Summary of findings

Midwifery and support worker staffing levels have been noted to vary from one day to the next, and within and between organisations. This thesis provides information on staffing variation and explores associations with the quality of care, addressing some key gaps in the evidence base. Each of the four studies suggest that understaffing by midwives is associated with a reduction in care quality; measured by the experience of postnatal care, readmission rates and staff reports of clinical incidents. In summary:

- Every additional Full Time Equivalent midwife per 100 births was associated with a
  - 15% reduced odds of women reporting they had a delay in discharge
  - 20% increased odds of women reporting that staff always helped in a reasonable time
  - 15% increased odds of women always having the information or explanations they needed
  (Study 1)
- When specifically studying staffing rostered on postnatal wards, no association was found between registered midwives' staffing levels and women's experience of postnatal care. (Study 2)
- Postnatal wards with higher support worker staffing had a 24% greater odds of women reporting they were always treated with kindness and understanding, and a 28% greater odds of women reporting they always had help when they needed it. (Study 2)
- Lower than expected midwifery staffing was associated with an 11% higher odds of postpartum readmissions within 7 days of discharge. (Study 3)
- Lower than expected maternity support worker staffing was not associated with an increased odds of readmissions. (Study 3)
- Understaffing by registered midwives was associated with an 11% increase in harmful incidents. (Study 4)
- Understaffing by maternity support workers was not associated with an increase in harmful incidents. (Study 4)
- Having higher than the expected number of admissions and discharges (service user turnover) was associated with a 19% increased risk of harmful incidents.
  (Study 4)

Whilst some of the results are less definitive than others, the overall direction of effect is consistent. Low midwifery staffing was associated with other detrimental effects e.g. readmissions within 30 days of discharge and specific incidents, such as medicines errors and discharge incidents, but these were not statistically significant.

As all the findings come from observational studies, the relationship between staffing and consequences cannot be defined as causal (Parra *et al.*, 2021). The longitudinal design in study three lends support to causal inference as the exposure to staffing preceded the measurement of readmission, and time sequence of events is one of the Bradford Hill criteria (Cox, 2018). A causal link is plausible based on previous midwifery evidence in the same direction (Turner *et al.*, 2021) and the weight of research in nursing on understaffing and poorer outcomes (Dall'Ora *et al.*, 2022).

This chapter will continue with a discussion of the strengths and limitations of the PhD study methods, data sources and measurement of variables. The findings from the four studies will then be highlighted and linked with recommendations for practice and policy. The conceptual model in Figure 1 will be revisited, to include new knowledge and hypothesised relationships which can be tested in future research. This chapter finishes with recommendations for further research and overall conclusions.

3.2 Strengths and limitations

Findings from these studies have shed light on the contribution of midwives and support workers in English maternity services. The studies have been population based and conducted in multiple centres which gives potentially wider generalisability than narrower samples often seen in experimental studies (Smith *et al.*, 2011; Knight, 2018). A strength of this project is that multiple outcomes have been studied, assessing quality of care using both patient reported outcomes and events in routinely collected data.

Study results come from secondary data analysis of large datasets (between 13,264 and 106,904 records) and this has enabled regression analyses to be performed with adequate statistical power according to published guides (Maxwell, 2000; VanVoorhis *et al.*, 2007). Some results may have arisen by chance and therefore statistical significance is noted and confidence intervals are presented to show the precision of estimates. The primary outcome has been stated in advance for each analysis (Baldwin *et al.*, 2022) and analyses of secondary outcomes have been treated as exploratory (Li *et al.*, 2017). Adjustment for covariates has been employed to isolate the effects of staffing from other contributing variables, including patient characteristics, type of birth and organisational differences. Hierarchical models have been constructed to take account of higher level variables, such as clustering of similarities within each organisation (Leyland *et al.*, 2020). The range of studies each have particular and different limitations, however the results are fairly consistent that understaffing is associated with poorer quality care and risks to mothers and babies.

Measurement of staffing

Many previous studies did not measure staffing close to the woman, either by location or time period e.g. some studies used annual reports of full-time equivalent staff per 1000 births (Joyce *et al.*, 2004; Vanderlaan, 2023). Attempts were made to improve on this in the design of studies to varying degrees. The staffing data in study one was derived from full-time equivalent (FTE) staff in the organisation, and in study two it was the Care Hours Per Patient Day (CHPPD) dataset which averages staffing over one month in each postnatal ward. These aggregate figures mean that day-to-day variation in staffing exposure were not accounted for. In studies three and four, staffing data was derived from staffing rosters linked to payroll, so this data is likely to be correctly and precisely recorded, and represents the staff working in the organisation on each shift.

The definition of understaffing is integral to this enquiry. Studies one and two have considered staffing levels compared to other trusts, by separating trusts into tertiles of staffing levels and comparing the highest and lowest staffed trusts. A different approach was taken in studies three and four as roster data was available for each day in each service, and understaffing was defined in relation to the average staffing levels for each service. The second approach captures within-trust variation in staffing and is more likely to represent understaffing than comparing absolute figures across a large number of trusts.

Although it may have been preferable to compare staffing levels with planned staffing, this information was not available. In any case, it is not certain that planned levels would be robust and reflect optimal levels of staffing. The evidence base to support staff planning tools is weak (Griffiths *et al.*, 2023; Saville *et al.*, 2021a) and estimates of required staffing may be inaccurate if tools are used without professional judgement and triangulation with other methods (Saville *et al.*, 2021a).

One point to note is that staffing on postnatal wards can sometimes be reduced as midwives are moved to care for women arriving in labour as part of the escalation process. This has been noted by the Network of Professors in Midwifery and Maternal and Infant Health (APPG Baby Loss and Maternity, 2022) and is also reported in published sources (Ockenden, 2022; Dunkley-Bent, 2016; Bowers *et al.*, 2016; Robertson *et al.*, 2021). It is possible that the postnatal ward staffing recorded in the CHPPD data for study two has not accounted for this mid-shift movement. Estimates could therefore be prone to measurement bias, resulting in estimates being based on staff who are rostered to be there rather than those who are available to support women, thus weakening any staffing effects. This imprecision could explain why higher midwifery staffing on the postnatal ward was not associated with mothers positive experiences, whereas this association had been seen before when looking at organisational level staffing.

The CHPPD published dataset was assessed against the quality criteria in Appendix D. Little is known about its usefulness in health services research and only one published paper describing its use was found (Giannasi *et al.*, 2018). Almost all trusts presented some CHPPD data, however, there were inconsistencies in how maternity staffing was recorded, with only 93/123 trusts having postnatal wards clearly identified. Although guidance is given to trusts on how to calculate the monthly CHPPD (NHS Improvement, 2021), no data quality documents were found, so it is not known how data is cleaned, how missing data is handled, or whether the data is triangulated to assess validity. Much of the data remains hidden from public view in the restricted Model Health System, containing both actual and planned staffing levels along with a fill-rate calculation (NHS England, 2024b). Further testing and validation of this dataset has been called for (Giannasi *et al.*, 2018), although it is potentially useful for monitoring ward level staffing and for future research.

Measurement of outcomes

The reporting of postnatal experiences was measured by a survey of mothers following their discharge in studies one and two. Non-response may have biased the sample population as younger mothers and women from non-white ethnic groups were under-represented. Survey methods can be prone to recall bias and social desirability responses (Harrison *et al.*, 2020; Althubaiti, 2016), however the survey was distributed between two to six months after women gave birth and was conducted anonymously, so these biases are unlikely.

As well as studying the composite measure of harmful incidents, study four in this thesis brings new knowledge on the types of incidents reported and their severity. Rates of medicines incidents and discharge incidents had not been studied quantitatively before, and in this project, these were secondary analyses and exploratory in nature. Reporting of incidents in study four is an example where measurement may be inconsistent, as staff are relied upon to report incidents. Adverse incidents are under-reported in maternity services (Farquhar *et al.*, 2015; Johansen *et al.*, 2018; Bras *et al.*, 2023). The threshold for reporting may be different in each trust and staff motivation to do this may be influenced by a number of factors including safety culture, fear of consequences, seriousness of the incident and lack of time (Lindsay *et* *al.*, 2012; Liberati *et al.*, 2021; Bras *et al.*, 2023; Cook *et al.*, 2020). The consequences of underreporting would be to reduce the power of the analysis as fewer reports are made. Underreporting could also bias the observed association, although the direction of bias is unclear as reporting behaviour in relation to staffing may vary. In contrast, the measurement of readmissions is an objective measure as readmission is recorded in the patient administration system and has been linked to individual cases.

Sources of bias

Measurement error or imprecision can be a source of bias as described above. A particular problem with using secondary data is that not all variables of interest will have been measured, and this could lead to potentially confounding variables being omitted (Knight, 2018). In studies one and two, some variables were not available in the patient-level dataset and therefore were obtained from the published data at organisational level to try and account for differences between trusts (e.g. ethnic diversity of population). Socioeconomic status and body mass index were absent in all analyses, but parity, ethnicity and medical staff were included where this data was available. Mode of birth was available in three of the studies and this is an important variable as operative births are associated with higher acuity which is likely to attract greater staff deployment. Staffing relative to need is therefore represented in the data to some degree, although comorbidity and some individual characteristics have not been fully represented. If omitted variables are correlated with midwifery staffing (such as medical staffing) then calculated estimates could be smaller if medical staff contribute to a protective effect but were not accounted for (Griffiths *et al.*, 2016). Medical staffing has been associated with lower rates of readmissions in many specialities including obstetrics (Kim *et al.*, 2016; Rubbo *et al.*, 2023), although few studies have examined medical staffing to date.

The interpretation of data needs to consider the underlying relationships between variables. Sometimes covariates are not independent from one another, a concept known as multicollinearity (Shrestha, 2020). The variance inflation factor was used to test for this, and results indicated that levels of collinearity were low in each of these four studies. Simultaneity is where the dependent variable and a predictor can causally influence each other in either direction; so that staffing levels may influence the outcome, while the outcome could influence the level of staffing (Griffiths *et al.*, 2016) e.g. in areas with high adverse events, more staff may be allocated. The relationships observed may be a summary of simultaneous relationships in either direction if the dependent variable is not independent of all other variables (exogenous) (Antonakis *et al.*, 2010). The extent to which estimates have been affected by simultaneity is unclear.

Endogeneity can be corrected if randomised experimental studies are conducted, as randomisation aims to ensure groups are the same for both known and unknown variables (Antonakis *et al.*, 2010). However, it is unlikely that randomised studies would be conducted in this area due to feasibility and ethical constraints (Munier *et al.*, 2014), especially as a state of equipoise or genuine uncertainty is needed for studies to be considered ethical (Freedman, 2008).

3.3 Implications for practice and policy

The findings will now be discussed and linked to recommendations for practice and policy. Specific areas will be discussed such as women's experience of postnatal care and discharge, escalation plans, staffing and the risk of harm, workforce planning, delays in care, workload associated with admissions and discharges, and the role of maternity support workers.

Women's experience of postnatal care and discharge

The two studies carried out in postnatal care found that women were not always helped when they needed it, given information and explanations as needed, or treated with kindness and understanding. These findings echo those seen in the literature where women have given accounts of their postnatal care experience, highlighting that improvements are needed (Finlayson *et al.*, 2020; McLeish *et al.*, 2020; Baxter, 2017; Alderdice *et al.*, 2020). People in hospital can find it difficult to ask for the care they need, especially if staff are perceived as being distracted or dismissive of care requests (Hope *et al.*, 2022). Guidance from NICE urges all professionals to treat mothers with kindness, respect, dignity, and compassion (National Institute for Health and Care Excellence, 2023). High workload and poor staffing may dull the capacity for compassionate responses when providing care (Rydon-Grange, 2018). Furthermore, understaffing and high workload have been identified as key contributors to rude or unprofessional behaviour in health care settings (Keller *et al.*, 2020; Aunger *et al.*, 2023). Both midwives and support workers are bound by trust values and those in the NHS constitution (Department of Health and Social Care, 2023). Adding to the body of knowledge in this area fits with recent drives to improve the quality of maternity services, in particular listening to women and providing compassionate and timely care (Ockenden, 2022). Lack of compassion, listening and respect have been highlighted in instances of birth trauma, with long-term psychological effects (APPG Birth Trauma, 2024). It is important for maternity staff to uphold professional standards and woman-centred care despite staffing challenges.

The largest area identified for improvement in studies one and two was the proportion of women reporting they had a delay in discharge (45% of women). This finding fits with previous evidence that discharge is poorly conducted (Albsoul, 2019; APPG Baby Loss and Maternity, 2022). Discharge can be delayed or rushed, with key discharge preparation and information being missed (Haith-Cooper *et al.*, 2018). Inadequate discharge could lead to a suboptimal experience at home and contribute to morbidity and the need for maternal or neonatal readmission. This link is plausible as the quality of discharge planning in medical/surgical patients has been inversely related to rates of readmission (Henke *et al.*, 2017). Furthermore, a quality improvement project in postnatal women found that implementation of standardised discharge information was associated with a decrease in readmission rate from 2.2% to less than 1% (Day-Herzog, 2021). Although this mediator is speculative it reveals a new line of enquiry about the link between understaffing, the quality of discharge and readmission. In study three, exposure to lower than expected midwifery staffing was associated with an 11% higher odds of postpartum readmissions within 7 days of discharge, although this has not been linked to the quality of discharge as they were not studied simultaneously.

Escalation plans

Understaffing is more easily recognised on labour wards if one-to-one care in labour cannot be provided, and therefore escalation plans are enacted to ensure that this standard is met (Creswell *et al.*, 2023). This research shows that understaffing in other parts of the service, such as on postnatal wards, is linked with consequences, such as delays in discharge and a poorer care experience.

The solution to understaffing is not to take staff from other clinical areas as this does not make up the shortfall, and this type of movement can leave other areas dangerously short. The National Institute for Health and Care Excellence (2015) notes that the redeployment of staff must not cause midwifery 'red flag' events in other areas. However, midwives who were interviewed as part of the Ockenden review described instances of 'robbing Peter to pay Paul' when units were understaffed, as escalation processes depleted the workforce in other areas (Ockenden 2022, p118). Midwives should be involved in safe staffing discussions and escalation plans (National Institute for Health and Care Excellence, 2015) as they know their clinical areas, populations and workload, and can signal areas of risk. Blake *et al.* (2024) urge health care leaders to collaborate with front line staff to develop staffing guidelines, noting the importance of their contribution. Involvement in safe staffing initiatives may result in benefits beyond patient care if the work environment and midwifery retention also improve. Low staffing contributes to stress and demotivation (Health Education England, 2018) and concerns over staffing and the quality of care leads to midwives leaving the profession (Royal College of Midwives, 2021).

Staffing and the risk of harm

When recorded incidents were linked with staffing levels on the same day, understaffing by midwives was associated with an 11% increase in reported harmful incidents to mothers or babies. This figure is conservative as it does not account for harm which is evident after discharge or differences in incident reporting (Farquhar *et al.*, 2015; Johansen *et al.*, 2018). Increased incidents associated with midwifery understaffing aligns with findings from a number of studies (Vanderlaan, 2023; Sandall *et al.*, 2014; Hodnett *et al.*, 2002; Tucker *et al.*, 2003; Dani *et al.*, 2020; Makhfudli *et al.*, 2020; Gagnon *et al.*, 1997; Kashanian *et al.*, 2010; Clark *et al.*, 2014). The Care Quality Commission (2023a, p1) noted that in some organisations "there weren't always enough midwifery staff with the right skills and experience to keep people safe" which indicates that they have seen evidence of a link between understaffing and a risk to safety. Furthermore, the NHS staff survey showed that 59% of midwives had witnessed potentially harmful errors, near misses or incidents within the last month and only 7% of them said there were enough staff in their organisation to do their job properly (NHS, 2022).

Of the seven types of incidents noted in study four, five of them were in the direction of more incidents when women were exposed to understaffing by midwives (medicines incidents, stillbirth/neonatal death, delay, discharge incidents, moderate or greater harm incidents), although none were statistically significant. With regards to medicines errors, Karimi *et al.* (2016) found that excessive workload and a low ratio of midwives to women were cited by midwives as key contributors to errors. Holden *et al.* (2011) recommends reducing workload during medicines administration by minimising interruptions and concurrent demands, based on findings that nurses rated the likelihood of medicines errors to be higher when workload increased.

Workforce planning

The increased risk of harm and poorer care experience justifies the need to combat low staffing levels, either by using bank, agency or on-call staff. A better solution would be to set the baseline staffing level higher than the predicted workload so that staff are better able to meet fluctuations in demand (Saville *et al.*, 2021b). Given the emerging evidence outside of labour ward settings, it is timely to review resource allocation in all areas of maternity services. It is currently at the discretion of managers to decide ward-level staffing and there are no minimum ratios or guidance outside of care in labour (National Institute for Health and Care Excellence, 2015). The methods used to determine staffing requirements should be reviewed. Staffing tools have the potential to contribute, but need to be evidence based and used in combination with professional judgement (Griffiths *et al.*, 2023). The variables which make up the calculation in the Birthrate Plus tool have not changed in the past 20 years and there is no empirical evidence that this tool calculates the correct number of midwives needed (Griffiths *et al.*, 2023). Furthermore, Birthrate Plus calculates the required number of midwives for the establishment rather than recommending staffing numbers at ward level per day or night.

Workload associated with admissions and discharges

This research highlights the increased potential for error and harm when maternity services have an increased number of admissions and discharges. The number of people admitted and discharged each day represents additional workload for maternity services staff which is separate from the number of people being cared for per midwife (Twigg *et al.*, 2009). When services had higher than average service user turnover (where the admissions plus discharges exceeded the mean), this was associated with a 19% increase in the number of reported harm incidents. It was also associated with increases in six secondary outcomes (moderate or worse harm, medicines incidents, delay incidents, haemorrhage, perineal trauma and discharge incidents), all of which were statistically significant. The strength of this association was unexpected as there is little published literature which discusses the effects of high patient flow on staff workload and patient outcomes (Hughes *et al.*, 2015; Musy *et al.*, 2020; Park *et al.*, 2012), none of which includes midwifery. The additional workload of admissions and discharges needs to be recognised in workload planning, and appropriate staff deployed to undertake these activities as well as providing quality care to all women. Managers need to ensure staffing is planned to reflect current work environments rather than using historic staffing levels which may not reflect the service activity or the acuity of service users.

Delays in care

Delays in care may be an important mediator between low staffing and harmful incidents. Understaffing by midwives was associated with a 16% increase in the occurrence of delay, although this result was not statistically significant (study four). Delay is listed in six of the nine core ‘red flags’ events to prompt a review of midwifery staffing during the shift period, and is a key indicator of quality (National Institute for Health and Care Excellence, 2015). The impact of delays should be carefully monitored, as delay may be more than an inconvenience and could have profound consequences.

A thematic analysis of 92 investigations of safety incidents in midwifery units found that when demand exceeded staffing capacity this resulted in delays in safety-critical care (Maternity and Newborn Safety Investigations, 2024). In the Each Baby Counts report, delay in birth has been identified as a key contributory factor to stillbirth, early neonatal death and severe brain injury, contributing to 46% of cases (Royal College of Obstetricians and Gynaecologists, 2021). Lower than expected midwifery staffing has been associated with delays in reaching theatre for emergency caesarean section (Cerbinskaite *et al.*, 2011). A recent Care Quality Commission report identified that 42% of time-critical category one caesarean sections were delayed in one trust from April-July 2023 with fetal harm in some cases (Care Quality Commission, 2024). In the same trust, there were 941 delayed inductions in the period of 1st Jan 2023 to 31st July 2023, with delays of between 54 and 92 hours (Care Quality Commission, 2024). The problem is widespread; in a survey of 54 maternity units in the UK 56% of them reported there was often a delay in women being transferred to labour ward for induction, with a further 7% saying this always happened, predominantly due to staffing levels (Taylor *et al.*, 2024).

The rise in induction of labour puts more strain on labour wards. While induction of labour aims to reduce poor outcomes, delays in this process can be critical for vulnerable babies and lead to a poor experience for mothers (Robertson *et al.*, 2021; Harkness *et al.*, 2023). The intended benefits of increased induction of labour may not be realised due to a bottleneck in the pathway and staffing pressures (Taylor *et al.*, 2024). Further to this, a systematic review of 26 studies of errors and adverse events in obstetrics and gynaecology found delay to be one of the most frequently reported contributors (Klemann *et al.*, 2023).

Support workers

Although more support workers were associated with women's positive experience of postnatal care, understaffing by this staff group was not found to be predictive of increased harmful incidents or readmission rates. It may be that support workers perform fewer sensitive activities which could be related to the risk of readmission or harmful events. My scoping review which included both support workers and midwives did not find any studies suggesting that more support workers improved safety for mothers or newborns (Turner *et al.*, 2021), although literature in this area was sparse with only three quantitative studies examining this association (Gerova, 2014; Kim *et al.*, 2016; Sandall *et al.*, 2014). This lack of protective effect for support worker staffing is also consistent with published studies in nurse staffing (Fogg *et al.*, 2021; Griffiths *et al.*, 2019b).

As support workers make an uncertain contribution to safety outcomes, they cannot be considered as substitutes for midwives. Expectations and skills attached to the role have expanded and competencies are assessed against a standardised framework (Health Education England, 2019a; Health Education England, 2024). The skills passport underpinning the support worker level three apprenticeship includes physiological assessment of mothers and babies, newborn blood glucose monitoring, serum bilirubin testing and assisting in emergencies among many other skills (NHS Health Education England, 2020). Those undertaking support worker programmes are expected to demonstrate background knowledge and understanding, but will not have received the depth of education and assessment as those undertaking an undergraduate programme in midwifery to the standards expected by the Nursing and Midwifery Council (Nursing and Midwifery Council, 2019). A rapid review of global midwifery education concluded that countries that have adopted degree level education for midwives had lower maternal mortality rates (Sharif *et al.*, 2021), strengthening the argument that the level of expertise of registered midwives is a necessary part of safety.

Overall, this research points to the fact that staffing as a structural factor influences both the process of care and clinical outcomes. Maternity investigations into poor performance should closely examine staffing levels to understand the context of care, so practitioners' decisions and actions are not seen in isolation. Specific recommendations based on my research findings are summarised in Table 22.

Table 22 Recommendations for practice

Ensure the professional behaviour of staff is upheld despite staffing challenges.
The timeliness and quality of discharge should be prioritised.
Avoid escalation plans which mean removing clinical midwives from one area of maternity services to another as this shifts the understaffing problem and has consequences for care quality.
Plan and report staffing levels at ward level and evaluate staffing levels and the quality of care in each setting.
Involve front-line staff in formulating escalation plans.
Use temporary staffing to minimise harms associated with understaffing.
Set the baseline staffing level slightly higher than expected activity, so the service is better able to manage peaks in service activity.
Consider the impact of admissions and discharges on the workload of midwives and plan for this workload appropriately.
Delays in care due to short staffing should be monitored in case they contribute to suboptimal outcomes.
Staff planning should not attempt to replace shortfalls in registered midwives with support workers as their contribution to the quality of care is not the same.

This research has not been able to establish the optimal number of midwives and support workers to provide safe, high-quality care or determine the minimal level at which harms occur. This was not the purpose of the research as it aimed to understand more about the relationships and their direction and strength, while accounting for other influencing variables.

Implications for policy

Understaffing has consequences, and these need to be considered alongside the safeguards that are in place to protect the public. The regulation of safe staffing in England is less strict than in some other countries. NHS trusts in England are responsible for planning and deploying "sufficient numbers of suitably qualified, competent, skilled and experienced" staff to meet patients' needs (Care Quality Commission, 2021c; The Health and Social Care Act 2008 (Regulated Activities) Regulations, 2014). The Care Quality Commission can serve a Regulation 18 notice and take regulatory action, but cannot prosecute providers for a breach of this regulation. The standards of maternity care in England have declined and high profile investigations have been carried out with lessons for staffing, culture, teamwork, escalation and training (Ockenden, 2022; Kirkup, 2022; Lintern, 2021a). Unless the government takes action to recognise the critical role of midwives the natural experiment of declining midwife numbers will continue to be played out, along with its consequences. NHS trusts may ‘cut the cloth to fit’, and plan staffing levels based on affordability rather than need (Ball, 2023). A campaign is underway to adopt staffing ratios as a safety-critical red line under which staffing levels should never go, and to have this embedded within safe staffing legislation in England (Ranger, 2023).

Legislation has already been passed in Wales and Scotland which set out staffing requirements. In Wales, the duty to calculate and maintain nurse staffing levels applies to acute adult medical and surgical wards and paediatric inpatient wards (Welsh Government, 2021). In Scotland, the requirement for safe staffing covers both health and social care and includes midwifery staffing (Scottish Government, 2019a). Intentional changes in nurse staffing are being implemented in Ireland on medical and surgical wards (Department of Health, 2016), along with a prospective evaluation of changes in staffing levels and patient outcomes (Drennan *et al.*, 2018). Results from this evaluation will inform national implementation in Ireland.

In some parts of the world nurse-to-patient ratios are enforced by mandates and backed up by legislation. Ratios were introduced in California (USA) in 1999, Victoria (Australia) in 2015 and Queensland (Australia) in 2016 (Buchan, 2023; Van den Heede *et al.*, 2020; Olley *et al.*, 2018). Staffing ratios are now being implemented in six more states; South Australia, New South Wales, Australia Capital Territories, Western Australia, British Columbia and Oregon (Buchan, 2023). In some areas, ratios have been expanded to include antenatal and postnatal wards and other maternity inpatient areas (Association of Women's Health Obstetric Neonatal Nurses, 2022; Australian Capital Territory ACT, 2021; Australian Nursing Midwifery Foundation, 2015). This mandatory ‘top down’ approach has been described as a blunt instrument to force employer compliance with minimum staffing levels, while allowing providers to go above the ratio when indicated (Buchan, 2005; Munier *et al.*, 2014). Ratios have resulted in more staff being available and increased job satisfaction (Van den Heede *et al.*, 2020) as well as improvements in patient outcomes (McHugh *et al.*, 2021).

When NICE assessed the evidence on maternity staffing the committee debated whether specific ratios should be recommended for each stage of the maternity pathway (National Institute for Health and Care Excellence, 2015). They declined to recommend ratios based on the limited evidence at the time, and speculation that these minimums could be treated as a target or maximum level, and staffing would not be increased appropriately for women or newborns with complex needs (National Institute for Health and Care Excellence, 2015). There are now at least thirty-four studies which examine outcomes associated with variation in midwifery staffing, including the four studies presented here which outline staffing effects outside of the labour ward including readmissions, the experience of care, and harmful incidents. This expanded evidence base needs to be considered in future appraisals of staffing guidance. The labour ward setting has some degree of standardisation with one-to-one care as an expected minimum standard (Royal College of Obstetricians and Gynaecologists *et al.*, 2007). However, variability in staffing in the rest of the maternity service may be contributing to avoidable events. A safety net is needed for other maternity settings such as postnatal wards, especially as staffing numbers are not always transparent, and staff are used as a pool for other services to draw from. Bick *et al* (2020, p1) highlighted that "despite evidence of poor postnatal outcomes, policy consistently ignores postnatal care".

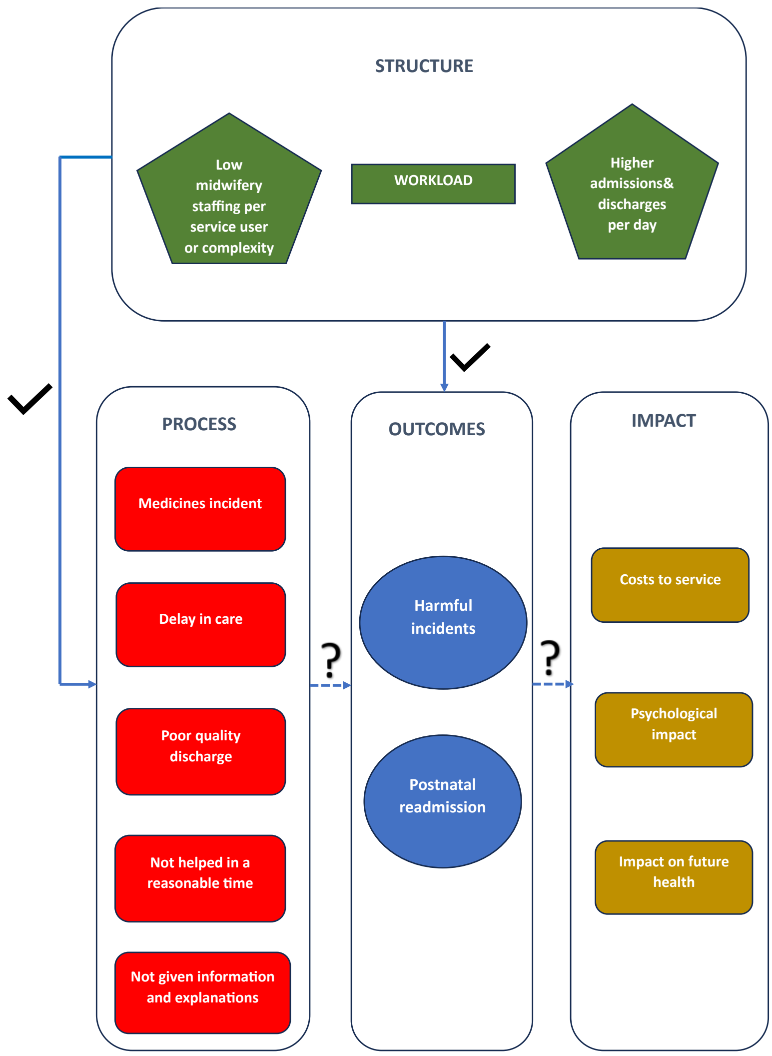
The quality of the evidence appears to be a barrier to research implementation, as most studies are observational and do not have the methodological rigour of randomised intervention studies. The burden of proof is high and it has been left for the workforce to prove the risks, rather than policy makers erring on the side of caution (Leary, 2021). This is contradictory to other areas of public policy as there are statutory minimum staff-to-child ratios in early years settings, minimum cabin crew members to passengers on flights, and legislation about drink-driving and lorry driver rest breaks (Department for Education, 2014; Civil Aviation Authority, 2023; Department for Transport, 2021; Department for Transport, 1988). These safety interventions have been introduced based on imperfect evidence for the protection of the public.

Munier *et al.* (2014) argue that the precautionary principle provides a strong justification for staffing ratios to be implemented. This means that action can be taken to safeguard the public in the absence of perfect evidence where there is a risk of significant harm (Bourguignon, 2015). State control of minimum staffing levels is needed, as those who run healthcare organisations have a vested interest in reducing costs (Munier *et al.*, 2014). Voluntary investment in staff cannot be relied upon, as the NHS is under significant financial pressure with difficult decisions on spending priorities, and many trusts have been asked to make cuts to balance the books (NHS Confederation, 2023; Lintern, 2024). Service pressures have increased post-covid (House of Commons, 2024) and the Spring budget of 2024 shows a budget decrease in real terms after accounting for population demographics (Health Foundation, 2024).

3.4 Implications for research

High workload can arise due to a high flow of service users, complexity and poorly matched staffing to demand. This project has established associations between structural factors (staffing and increased service user turnover, in green in Figure 3) with process measures which are measures of the quality of care (in red in Figure 3). In addition, studies three and four have found associations between structural staffing factors and the clinical outcomes of harmful events and maternal readmissions (in blue in Figure 3). The conceptual model first presented in Figure 1 has been updated to reflect these findings.

Figure 3 Updated conceptual model linking staffing to the quality of care and consequences



Extending this model, it is proposed that care processes which are incomplete may contribute to poor outcomes. This area has not been assessed in the project and has been marked with a question mark, linking the red to blue areas. It is hypothesised that a poor quality discharge, lack of information or insufficient support with breastfeeding could contribute to maternal and neonatal readmissions. Similarly, medicines incidents and delays in care could contribute to harmful incidents as suggested in the literature (Royal College of Obstetricians and Gynaecologists, 2021).

These incomplete care processes may be a mediator between low staffing and outcomes, as well as being quality measures in themselves. An example of this pattern is given by Simpson *et al.* (2020) who found that low adherence to staffing guidelines was associated with missed breastfeeding support, and this was also related to lower rates of exclusive breastfeeding. Figure 3 is not a complete representation of all relevant variables but offers some examples of how variation in staffing could be linked with care quality and consequences.

Improvements could be made to the project research design to include more variables within the same study. Roster data may enable observational studies of multiple staff groups, and comparison with planned staffing levels. Data fields in maternity information systems could be utilised to capture case mix, process and outcome variables for women and babies in a longitudinal design. Objective measures of care quality such as delays in care or missed vital signs observations could be obtained and linked with subsequent outcomes. Both maternal and neonatal readmissions could be included as outcome measures, as both have the potential to be influenced by poor quality care. Studies should be designed to include both cost and effectiveness. It is hypothesised that the additional investment in midwives may be offset by reduced clinical incidents, the cost of additional treatment, and bed days associated with complications or readmissions. Cost-effectiveness studies will enable comparison of the costs, consequences, and impact of different staffing decisions (in gold in Figure 3) .

Qualitative research is needed to understand more about the relationships between care and outcomes. Exploring reasons for readmission and contributors to harmful incidents could deepen the understanding about the pathways between staffing and outcomes. Infection/sepsis was the most common diagnosis on readmission in study three (23.3%), which aligns with findings from other studies (Sharvit *et al.*, 2014; Panda *et al.*, 2016). By understanding the reason for readmission and factors contributing to incidents, the activities of staff can be scrutinised to suggest where care improvements can be made, and to understand whether staffing levels influence these processes. Different responses to short staffing could also be explored to understand the options and potential benefits of different escalation strategies. Following this exploration, options could be modelled using real world data to understand the potential consequences of adopting different escalation strategies.

An intervention study will provide answers on setting a minimum standard of staffing and the impact on costs, care and outcomes. This could be conducted on a small scale as it is likely to be costly and resource intensive. Difficulties arise in selecting a control group or control time period due to the possibility of unmeasured confounding. A number of designs have been proposed to combat these difficulties as outlined by Shekelle (2013). An alternative approach is the use of machine learning techniques or data mining of NHS provider data. This could be possible if staffing and maternity information systems are linked, and analysts are able to identify key variables with accuracy and consistency. One advantage of this approach is that multiple inputs and outcomes could be studied at the same time, reflecting the complexity of staffing decisions and quality assessment. Further details on all proposed research can be found in Appendix K.

Factors and relationships contributing to safety are of course more complex than suggested in Figure 3 and extend beyond the staffing numbers. Liberati *et al.* (2021) identified seven features of safe maternity units and created the For Unit Safety framework consisting of commitment to safety, technical competence, teamwork, constant reinforcing of safe behaviours, multiple problem sensing systems and regular review of safety systems and processes. Staffing was raised under the 'problem-sensing' area and practitioners are encouraged to report staffing concerns. These system-level approaches are a move away from holding individual practitioners responsible for poor outcomes, as the context of work and institutional factors are recognised. Further research on the interaction between staffing numbers, expertise, systems, and culture are needed to fully understand these relationships.

3.5 Conclusions

In conclusion, there are material consequences associated with midwifery understaffing, affecting women's experience of care, readmission rates and harmful incidents. Due to methodological limitations, the relationships have not been confirmed as being causal but are highly suggestive that understaffing contributes to these preventable harms. The impact could be far-reaching, as readmissions are costly and adverse events can lead to suffering, the need for further treatment and litigation. This evidence, together with that of previous studies, highlights the key role midwives play in maintaining quality and safety in maternity services. The fact that maternity support workers did not contribute to safety or reduced readmissions suggests that they should be not deployed as a substitute for midwives. However, their role within postnatal care provision adds value, as trusts with more support workers on postnatal wards also had more women reporting positive experiences of care.

This evidence supports a systems-level approach to care quality, rather than focusing solely on the competence of individual practitioners. It supports the need to have the right staff, with the right skills, to be in the right place at the right time (National Quality Board, 2016). This investigation has shown that staffing is not always reported at ward level, so staff shortfalls may not be noticed if midwives are moved to work elsewhere. Staffing levels should be scrutinised throughout the woman's journey, rather than appraising levels in the maternity service as a whole or focusing mainly on labour care.

The demand for maternity services fluctuates and additional workload is created when there are a high number of admissions and discharges in one day. The impact of this variation is shown in the last of these studies, as more harmful incidents occurred on days with a higher number of admissions and discharges than usual. These findings highlight the importance of robust escalation plans, or setting staffing levels slightly higher so that unanticipated surges in workload can be met.

This research evidence has gone some way to understanding the relationship between staffing and outcomes. The next stepping stone is to evaluate the effects of multi-professional staffing variation and the consequences of a deliberate change in midwifery staffing to meet a minimum standard. Longitudinal studies can capture staffing close to service users and observe individual-level outcomes over time. Further work is needed to understand the mechanism by which understaffing influences outcomes and to model options for escalation to fill gaps between supply and demand.

Shortfalls in staffing are associated with adverse and far-reaching consequences. Action is needed at a local level to ensure that roster gaps are filled, and at a policy level to ensure that the pipeline of midwives is prioritised and staff are retained in maternity services. Midwifery staffing levels should be championed and seen as a fundamental requirement for high-quality care. Strategic action on workforce planning is critical, as expressed by Leary (2018) "when failure is not an option, hope is not a plan".

Appendix A Service user and staff consultation

Flyer to parents with link to survey https://bit.ly/3wtRFJr

We are looking for volunteers to take part in an anonymous survey about factors important to families during their postnatal stay in hospital.

As a participant in this study, you will be asked to complete an online questionnaire.
This will take no longer than 10 minutes to complete.

You can take part if you are
18 years or over
Have received care after the birth of your baby and stayed on a postnatal ward in the UK *or*
Have been a partner of someone receiving care on a postnatal ward
Had your baby within the last 5 years

UNIVERSITY OF Southampton

(Ethics/**ERGO Number: 64095),** photo Pixabay CCO

Evaluating postnatal inpatient care – parent survey

Organisations need to assess the quality of maternity care in the areas that are important to women and families. Different factors may be important in the antenatal, labour, and postnatal periods.

This survey aims to inform the way that service managers and researchers measure the quality of care **in postnatal wards**. It aims to understand the factors that are important to women and families, and also highlight areas that may be missed if staffing levels are below normal.

Please complete this survey if you are willing to express your views on this. The survey is anonymous and forms part of a wider research project on staffing levels and postnatal wards. Your views will help us gain a wider understanding on how services perform in response to your needs.

1. Please tell us about areas that are important to you when receiving care on a postnatal ward

2. Can you think of the things that staff did that were most helpful to you?

3. Are there things that you would have liked for staff to do that they didn't?

4. Did you feel that the levels of staffing impacted upon your care in any way, and if so how?

5. Do you have any suggestions about how care on the post-natal ward could be improved

6.. Please use this space to expand on any of your answers above

Please contact me if you would like to be involved in any future consultations about this research project. My address is lyt1n20@soton.ac.uk.

Flyer to staff with link to survey https://bit.ly/3s3JVKV

We are looking for members of staff to take part in an anonymous survey about the quality of care on postnatal wards and how this can be measured.

As a participant in this study, you will be asked to complete an online questionnaire.
This will take no longer than 10 minutes to complete.

You can take part if you are
* 18 years or over
* currently working (or have worked) on postnatal wards in the UK within the last 5 years, either in hospital or a birth centre
* a midwife or service manager

UNIVERSITY OF Southampton

(Ethics/**ERGO Number: 64095),** photo Pixabay CCO

Evaluating postnatal inpatient care – staff survey

This survey aims to explore the measurement of quality of care in postnatal wards. This will help to understand the activities that make an excellent service and also highlight care that may be missed if staffing levels are lower than expected.

Please complete this survey if you are willing to provide information on this. The survey is anonymous and forms part of a wider research project on staffing levels and postnatal wards.

1. What measures could be used to assess whether high quality care has been provided to women on a postnatal ward?

2. What measures could indicate that the care provided for *women* has not met their needs?

3. What measures could be used to assess whether high quality care has been provided to *newborns* on a postnatal ward?

4. What measures could indicate that the care provided for *newborns* has not met their needs?

5. If ward staffing levels were below normal, how could this affect outcomes and patient experience?

6. Please list any 'red flag' events that relate to the quality of inpatient postnatal care.

7. How do you think care may differ if the number of support workers on the postnatal ward increased, as a substitute for registered staff?

8. How is staffing planned for your local postnatal ward? (tick all that apply)

    ( ) professional judgement
    ( ) based on historical planning/norms
    ( ) safer nursing care tool
    ( ) birthrate plus ward acuity tool
    ( ) safecare in allocate
    ( ) another planning tool
    ( ) based on acuity of inpatients and numbers on ward (flexible approach)
    ( ) don't know

9. Please use this space to expand on any of your answers above

Please contact me if you would like to be involved in any future consultations about this research project. My address is lyt1n20@soton.ac.uk.

Appendix B Search strategy

Search strategy for Medline Ovid
(adapted for other online databases using exploded MeSH headings as appropriate)

1 childbirth.ab,ti.
2 birth.ab,ti.
3 labour.ab,ti.
4 newborn.ab,ti.
5 neonate.ab,ti.
6 mother-newborn.ab,ti.
7 mother-neonate.ab,ti.
8 caesarean.ab,ti.
9 postnatal.ab,ti.
10 postpartum.ab,ti.
11 "care after birth".ab,ti.
12 "care following birth".ab,ti.
13 maternity.ab,ti.
14 maternal.ab,ti.
15 midwifery.ab,ti.
16 midwives.ab,ti.
17 midwife.ab,ti.
18 exp labor, obstetric/ or exp parturition/
19 exp midwifery/ or exp obstetric nursing/
20 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
21 "staffing ratio".ab,ti.
22 "nurse to patient ratio".ab,ti.
23 understaffing.ab,ti.
24 staffing.ab,ti.
25 workload.ab,ti.
26 manpower.ab,ti.
27 "skill mix".ab,ti.
28 "skill-mix".ab,ti.
29 "work pressure".ab,ti.
30 "patient ratio* ".ab,ti.
31 "short staffing".ab,ti.
32 "midwife to patient ratio".ab,ti.
33 exp Health Workforce/
34 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
35 case-control studies/ or cohort studies/ or controlled before-after studies/ or cross-sectional studies/ or historically controlled study/ or interrupted time series analysis/
36 follow-up studies/ or longitudinal studies/ or prospective studies/ or retrospective studies/
37 35 or 36
38 20 and 34 and 37

Appendix C Scoping literature review

Published as
Turner, L., Griffiths, P. and Kitson-Reynolds, E. (2021) 'Midwifery and nurse staffing of inpatient maternity services – a systematic scoping review of associations with outcomes and quality of care', *Midwifery,* 103, pp. 103118.

Abstract

Objective

To undertake a scoping literature review of studies examining the quantitative association between staffing levels and outcomes for mothers, neonates, and staff. The purpose was to understand the strength of the available evidence, the direction of effects, and to highlight gaps for future research.

Data Sources

Systematic searches were conducted in Medline (Ovid), Embase (Ovid), CINAHL (EBCSCO), Cochrane Library, TRIP, Web of Science and Scopus.

Study Selection and Review methods

To be eligible, staffing levels had to be quantified for in-patient settings, such as ante-natal, labour/delivery or post-natal care. Staff groups included midwives, nurse midwives or equivalent, and assistant staff working under the supervision of professionals. Studies of the quality of care, patient outcomes and staff outcomes were included from all countries. All quantitative designs were included, including controlled trials, time series, cross-sectional, cohort studies and case controlled studies.

Data was extracted and sources of bias identified by considering the study design, measurement of exposure and outcomes, and risk adjustment. Studies were grouped by outcome noting the direction and significance of effects.

Results

The search yielded a total of 3280 records and 21 studies were included in this review originating from ten countries. There were three randomised controlled trials, eleven cohort

studies, one case control study and six cross sectional studies. Seventeen were multicentre studies and nine of them had over 30,000 participants.

Reduced incidence of epidural use, augmentation, perineal damage at birth, postpartum haemorrhage, maternal readmission, and neonatal resuscitation were associated with increased midwifery staff. Few studies have suggested a negative impact of increasing staffing rates, although a number of studies have found no significant differences in outcomes. Impact on the mode of birth were unclear. Increasing midwifery assistants was not associated with improved patient outcomes. No studies were found on the impact of low staffing levels for the midwifery workforce.

Conclusions and Implications for practice

Although there is some evidence that higher midwifery staffing is associated with improved outcomes, current research is insufficient to inform service planning. Studies mainly reported outcomes relating to labour, highlighting a gap in research evidence for the antenatal and postnatal periods. Further studies are needed to assess the costs and consequences of variations in maternity staffing, including the deployment of maternity assistants and other staff groups.

Keywords

Midwife ; Nurse; Staffing; Workload; Workforce planning; Patient safety

Appendix C

Introduction

Inpatient maternity services provide antenatal, intrapartum, and postnatal care for women and babies with additional needs, and for those choosing to give birth in a hospital environment. Use of inpatient care varies by country depending on levels of infrastructure, access, choice and cultural traditions (Romanzi, 2014). There is much variation in the staffing levels for these in-patient units (Zbiri *et al.*, 2018; Zhu *et al.*, 2018; Kennedy *et al.*, 2020). Complexity in maternity cases is increasing due to rising rates of diabetes, heart disease and hypertension, and provision of medicalised care in some countries (McDougall *et al.*, 2016). Therefore there is likely to be sustained demand for complex inpatient maternity care, requiring the expertise of core staff in these areas. Workforce and health financing are the major bottlenecks in providing skilled care at birth in many countries, hindering progress towards the 2030 targets for reducing preventable maternal and newborn deaths (Sharma *et al.*, 2015). In order to inform workforce planning, managers need evidence based guidelines to inform their staffing decisions.

Guidelines differ across the world, and California was one of the first states to mandate a staffing ratio of no more than two patients in active labour to one nurse (Coffman *et al.*, 2002). In the UK it is recommended that women should receive dedicated care from one midwife during labour (Royal College of Obstetricians and Gynaecologists *et al.*, 2007). Evidence underpinning such specific recommendations is sometimes sparse, although a Cochrane review confirmed that continuous support in labour (from hospital staff or birth supporters) was associated with a higher rate of vaginal birth, reduced caesarean section, reduced instrumental birth and improved Apgar scores (Hodnett *et al.*, 2013; Bohren *et al.*, 2017).

Maternity care is provided by both midwifery professionals and nursing professionals with additional midwifery training. Titles such as midwife, nurse-midwife, perinatal nurse or maternity nurse are common place (United Nations Population Fund, 2021). The composition of the maternity workforce varies worldwide and not all occupations exist in every country. The International Standard Classification of Occupations defines associate (assistant) professionals based on tasks performed. This is because educational arrangements, certification and licensing systems vary widely (International Labour Office, 2012; Marzalik *et al.*, 2018). For this reason the terms midwife and assistant will be used to describe the maternity workforce in this paper and includes practitioners performing equivalent roles.

The relationship between staffing and outcomes is important in determining the level at which harm can occur or the level at which there is no additional tangible benefit in deploying more midwives. This is important as cost-effectiveness must be considered due to the scarcity of resources and competing demands in health care. Maternity professionals have concerns about low staffing levels and report that this poses a threat to safety (Ashcroft *et al.*, 2003; Smith *et al.*, 2009; Karimi *et al.*, 2016; Simpson *et al.*, 2016). Staffing levels have been implicated in a number of near-miss cases and sub-optimal outcomes (Ashcroft *et al.*, 2003). Problems with inadequate staffing were identified in over a quarter of stillbirths during a three year period in one study (MBRRACE-UK, 2017).

The impact of inadequate staffing is far-reaching, and midwives have reported on the areas that have been missed due to high workload or time constraints (Simpson *et al.*, 2016; Simpson *et al.*, 2017; Haftu *et al.*, 2019). This includes measuring vital signs, medicines administration, noting changes in acuity, response in emergencies and emotional support (Bick *et al.*, 2014; Simpson *et al.*, 2016). This can lead to reduced opportunities to identify deterioration and to rescue from preventable patient harm, such as fetal demise in labour, neonatal hypoglycaemia or infection (Simpson *et al.*, 2017). One outcome that may be sensitive to staffing is the rate of term babies admitted to the neonatal unit (Clapp *et al.*, 2019), causing separation from mothers and great cost to the health service.

A large body of evidence exists within nursing to suggest that a number of outcomes are sensitive to changes in staffing, such as falls, pressure ulcers and mortality (Patrician *et al.*, 2011; Staggs *et al.*, 2012; Griffiths *et al.*, 2018). In an observational study of over 422,000 surgical patients in Europe, the increase in nurses workload by one patient increased the risk of a patient dying within 30 days by 7% (Aiken *et al.*, 2014). There have been fewer studies in the midwifery literature, although a substantial review was conducted by Bazian (2015) which summarised evidence from eight studies and highlighted a number of gaps in the research evidence. They found that most studies related to labour outcomes and mode of birth, although there was no consensus on the direction of effects for most maternal and fetal outcomes.

A further driver for interest in this area is the training and development of assistant staff. Their role provides the opportunity for task-shifting and complementing the work of midwives which has been highlighted by the World Health Organisation in their work on optimising health worker roles in maternity care (World Health Organization, 2012). It is unclear whether the evidence supports the widespread development of these roles, although an evaluation by Griffin *et al.* (2012) suggests a potential positive impact on breastfeeding, parent education and discharge procedures. Preliminary work has been undertaken on the economics of skill mix in maternity care by Cookson *et al.* (2014) and Laliotis *et al.* (2018). They expressed concern about the quality of the underpinning data on effectiveness, due to the use of aggregate measures of staffing and the potential for unmeasured confounding in observational studies.

This area is worthy of further exploration as a number of new studies have been published since the Bazian review (Bazian, 2015). Before future research is commissioned it is important to review the studies to date, and to establish what is known (and unknown) about the relationship between staffing and patient outcomes.

Methods

The aim of this scoping literature review was to identify and summarise studies which examine the association between staffing levels of midwives and the outcomes for mothers and neonates. The purpose was to examine the strength of the available evidence, the direction of effects, and to highlight gaps for future research.

The review addressed the following specific questions.

What is the extent and nature of the body of knowledge relating midwifery staffing to outcomes, in terms of the number of studies, designs, methodology, participants, settings and outcomes investigated?

Is there an association between the midwifery staffing levels for in-patient services and outcomes and quality of care, and do outcomes differ when the proportion of midwives to assistants varies?

Appendix C

Design

A scoping literature review methodology was selected in order to summarize the breadth of the evidence from a range of sources (Levac *et al.*, 2010). Unlike a systematic review, a scoping review allows researchers to identify all the relevant literature regardless of study design. A protocol was not registered in advance as this scoping review developed iteratively to discover the nature of the literature available.

Search strategy

Searches were completed in Medline (Ovid), Embase (Ovid), CINAHL (EBCSCO), Cochrane Library, TRIP, Web of Science and Scopus on 6th April 2020. Search terms were entered as key words and subject headings, to identify primary research relating to staffing and maternity care (See Appendix B for full search strategy). No limitations were placed on the date of publication.

The reference lists of eligible studies were scanned to identify further references. All eligible studies were entered into the Cited Reference Search in Web of Science to identify citations and potential new primary studies in the same field.

Study selection

Studies were eligible for inclusion if they investigated the quantitative association between a measure of midwifery staffing levels and/or skill mix and outcomes for mothers, babies, staff members, costs or quality of care. All quantitative designs were included including controlled trials, time series, cross-sectional, cohort studies and case controlled studies. Studies on the effects of implementing changes to staffing levels or mix were included, as were studies on the effects of implementing a mandatory minimum staffing policy or a tool to measure demand and guide staffing decisions. Studies from all countries were included.

To be eligible for inclusion, staffing levels had to be quantified in measures such as staff per bed, staff to mother ratio, or hours per patient day. An assumption was made that continuous support from a midwife in labour was similar to a staffing ratio of 1:1, and therefore papers reporting staffing in this way were eligible for inclusion. Staff groups include midwives, nurse midwives or equivalent, and assistant staff working under the supervision of professionals. Studies reporting a quantitative measure of subjective staffing adequacy were included but purely qualitative studies were excluded.

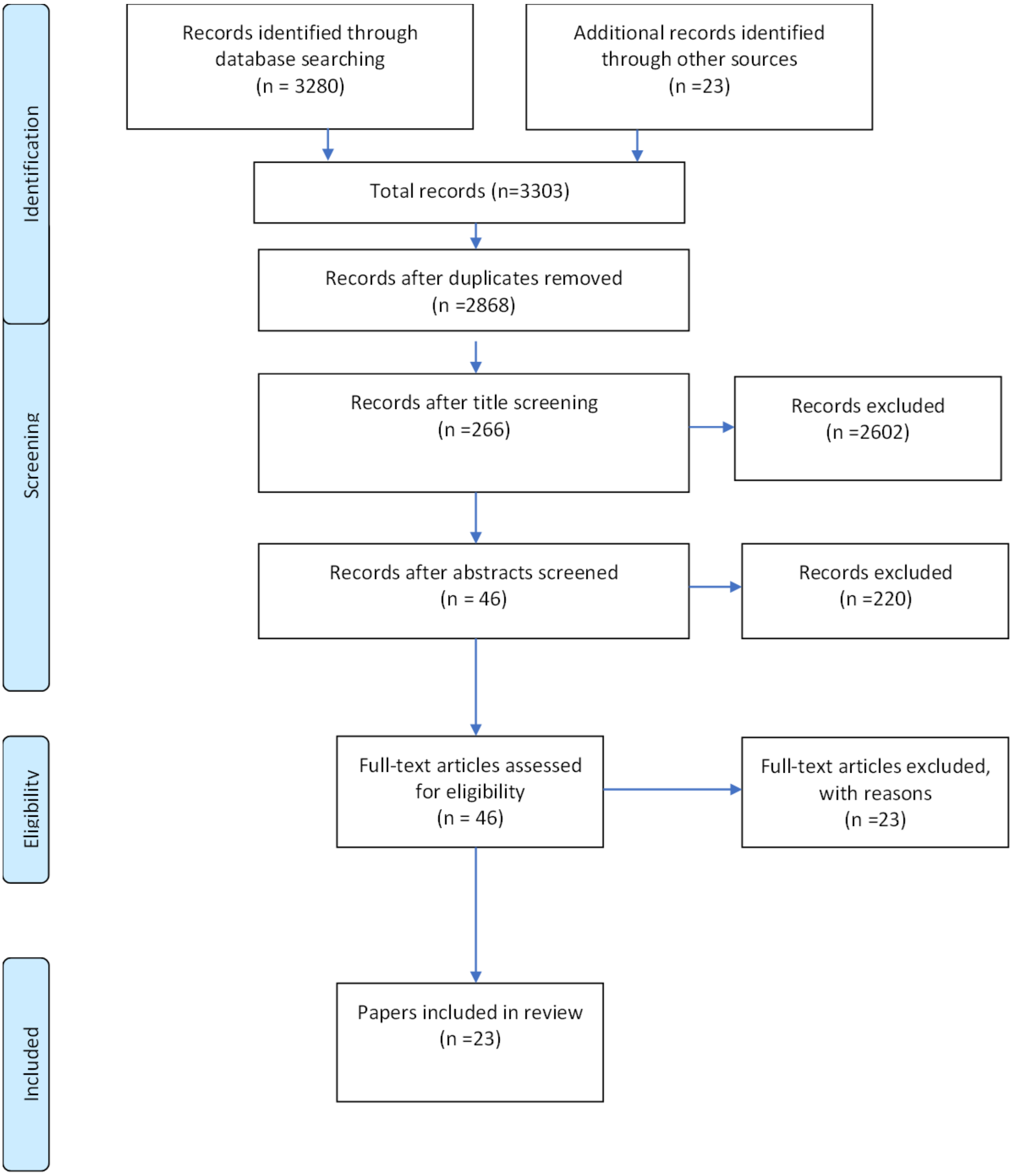
Staffing in any or all inpatient settings were considered including ante-natal, labour/delivery and post-natal care. Studies based in neonatal units and midwifery community settings were excluded.

All references arising from the search were imported into Endnote X9™ reference management software where duplicates were removed. Studies were screened and excluded if titles were unrelated to the subject area. The abstracts of 266 studies were read and studies excluded if it was clear that the inclusion criteria were not met by reading the abstract alone. Forty-six full text articles were screened against the inclusion criteria. All included papers were checked, and the decision verified by at least two reviewers. Of the excluded papers, double rating of a sample suggested a high level of agreement. Data charting was performed by one investigator.

Statistical meta-analysis was not attempted but all results were tabulated to show both the direction and statistical significance of the observed effects. From this a description of the overall pattern of results was derived. Sources of bias were identified by considering the study design, measurement of exposure and outcomes, and risk adjustment.

Appendix C

Figure 1 : Outcome of search strategy, PRISMA flow diagram



Appendix C

Results

Summary of included studies

The online searches yielded a total of 3280 records. The PRISMA flow diagram is shown in Figure 1. Twenty one separate studies published from 1988 -2020 were identified. These studies are tabulated in detail at the end of this paper. Data was extracted from 23 papers as two studies were reported separately. One study was available as an abstract only (Mercer, 2016). There were three randomised controlled trials, eleven cohort studies, one case control study and six cross-sectional studies.

Nine studies were conducted in the UK, and the remaining studies were conducted in USA, Canada, France, Germany, Italy, Indonesia, Korea, Thailand and Iran. Most studies included midwives, however the studies conducted in Korea and USA described care by nurses, and in Thailand by nurse-midwives. Models of care are not described in detail although are likely to vary in these different contexts. Six studies included only participants at low risk of complications. Three studies included only complex cases such as women having postpartum haemorrhage (Prapawichar *et al.*, 2020), those having oxytocin in labour (Clark *et al.*, 2014) or caesarean section (Kim *et al.*, 2016). The majority of studies (14/21) reported only outcomes relating to labour and birth. No studies of antenatal inpatient care were found, and there were four studies of postnatal care outcomes, including those studying readmission rates.

There were 17 multicentre studies and many were large. Nine studies had over 30,000 participants and five studies had over 400,000 participants. In terms of measurement of staffing, 16 studies used the term 'midwife' while others looked at staffing by 'nurses' or 'nurse-midwives' in a labour setting. Three studies also included the impact of assistant staffing, and eight studies also examined medical staffing in terms of obstetricians, anaesthetists or neonatal doctors.

Quality of the evidence

Three randomised controlled trials (Gagnon *et al.*, 1997; Hodnett *et al.*, 2002; Kashanian *et al.*, 2010) compared women receiving one-to-one care in labour with usual staffing levels, although all had some limitations. Hodnett et al. (2002) excluded women where one-to-one care was deemed medically necessary. Kashanian et al. (2010) included only 100 women and the usual labour care involved a lack of privacy, no birth companion and women were not permitted to eat and drink. The third RCT (Gagnon et al., 1997) was relatively small and incorporated other therapeutic measures along with the one-to-one care which limits the ability to assess the effects of the staffing ratio alone.

Of the eleven cohort studies, only the Tucker *et al.* (2003) study provided data on objective patient outcomes while also adjusting for baseline risk and other confounders. Other cohort studies considered care processes such as time to theatre transfer for caesarean section, quality of record keeping, mode of birth or labour interventions (Cerbinskaite *et al.*, 2011; Knape *et al.*, 2014; Rowe *et al.*, 2014; Bailey *et al.*, 2015; Zbiri *et al.*, 2018). These outcomes may not translate directly into benefits for women. The study by Clark *et al.* (2014) was conducted in a select group receiving Oxytocin, limiting the generalisability of findings. The measurement of staffing was based on opinion, and the background risk was not adjusted for. The Dani *et al.* (2020) study did not measure staffing exposure directly and was at risk of bias due to differences in settings and patient acuity between the two groups. Cohort studies by Kim *et al.* (2016) and Stilwell *et al.* (1988) were deemed to be at high risk of bias in the assessment of staffing exposure and had limited risk adjustment. Mercer (2016) was published only as an abstract and therefore the methodology could not be scrutinised.

Of the six cross-sectional studies, four were large scale studies which used routine data to assess exposure to staffing and patient-centred outcomes such as perineal damage, maternal mortality, readmission rates, still birth and neonatal mortality (Joyce *et al.*, 2004; Gerova *et al.*, 2010; Sandall *et al.*, 2014; Makhfudli *et al.*, 2020). Other cross sectional studies focused on the outcome of mode of birth (Joyce *et al.*, 2002; Gerova, 2014) or had a narrow focus on epidural use (Kpea *et al.*, 2015). All of these studies controlled for risk in terms of maternal age, deprivation, and some measures of clinical risk. These cross-sectional studies considered aggregate measures of staffing such as the number of midwives employed at institutional level or the number of midwives in relation to patients or births. This represents a major difficulty in determining whether staffing exposure is causally linked to outcomes for patients, as the time period and fluctuating staffing exposure may not match patient stay. It also does not account for deployment of midwives within the service as some may have non-clinical roles.

Maternal outcomes in relation to staffing

Nine studies examined the outcomes for mothers after birth (Table 23). On the whole, most of these suggest improved outcomes where more staff were present. The outcomes studied included severe maternal outcome (death or near miss), perineal trauma, post-partum haemorrhage, maternal readmission, satisfaction, and maternal infection.

Delivery with bodily integrity and intact perineum were more common when more midwives were employed (Sandall *et al.*, 2014). This finding of reduced perineal trauma was supported by studies by Gagnon et al. (1997) and Hodnett et al. (2002) although significance was not reached. In the case control study by Prapawichar et al. (2020), hospitals which had below the standard nurse midwife to patient ratio had significantly increased odds of postpartum haemorrhage OR 2.3 (95% CI 1.08 to 4.92, p=0.03). Two studies found that maternal readmission was lower when more midwives or nurses were employed in the organisation (Gerova 2010, Kim 2015).

In contrast to this, the study by Clark et al. (2014) found opposite effects for rates of complications in their population of high risk women receiving oxytocin. The lack of risk adjustment in this study could not eliminate confounding by indication, that is higher risk women had higher staffing levels because of the increased risk. Makhfudli et al. (2020) found that the odds of a severe maternal outcome, as defined by the World Health Organization (2019) was lower when women were admitted to units with higher nursing staffing (OR 0.48, 95% CI 0.31 to 0.74) but rates were increased in units where midwifery staffing was higher (OR 1.81, 95% (CI 1.07 to 3.06).

Table 23 Maternal outcomes in relation to staffing

Outcome measure	Favours more staff	Point estimate favours more staff (NS)	Point estimate favours less staff (NS)	Favours less staff
Severe maternal outcome (death or near miss)	Makhfudli 2020 (nurses)			Makhfudli 2020 (midwives)
Intact perineum/trauma	Sandall 2014	Gagnon 1997 Hodnett 2002		
Delivery with bodily integrity	Sandall 2014			
Postpartum haemorrhage	Prapawichar 2020			
Composite healthy mother		Sandall 2014		
Lower Maternal readmission	Gerova 2010 Kim 2015			
Satisfaction/preference	Hodnett 2002	Sandall 2014		
Multiple complications				Clark 2014
Endometritis			Clark 2014	
Amnionitis			Clark 2014	

Neonatal outcomes in relation to staffing

Ten studies examined the outcomes for neonates (Table 24). Outcomes studied included Apgar scores, birth asphyxia, need for neonatal resuscitation, breastfeeding, admission to the neonatal unit, stillbirth, neonatal death and a composite measure entitled healthy baby. Other potentially important outcomes for babies including neonatal readmission, neonatal hypoglycaemia, sustained breastfeeding, jaundice, and weight loss were not studied.

Three studies report significantly improved outcomes which favour more staff, and one study shows results in the opposite direction. Dani et al. (2020) found higher breastfeeding rates with increased staffing (88% vs 78%, p=0.048), although comparisons took place in two different settings. They also report lower neonatal unit admission (2% vs 9%), and this is supported by further studies by Hodnett et al. (2002) and Tucker et al. (2003), although these findings did not reach significance. Gagnon (1997) provides evidence to the contrary, with rates of neonatal unit admission of 7.2% vs 4.9%, RR1.46 (95% CI 0.67, 3.18), thereby presenting a mixed picture for this outcome. Considering the overall pattern, 11 studies have point estimates in favour of more staff while four show results favouring less staff.

Of the higher quality studies (Tucker et al., 2003; Sandall et al., 2014), these suggest that higher staffing was associated with improved neonatal outcomes. Tucker et al. (2003) reported that fewer babies needed neonatal resuscitation using advanced measures (OR 0.97, 95% CI 0.94, 0.99). This was also noted by Hodnett et al. (2002) although no risk adjustment was undertaken in this study.

Table 24 Neonatal outcomes in relation to staffing

Outcome measure	Favours more staff	Point estimate favours more staff (NS)	No difference or no data on direction	Point estimate favours less staff (NS)	Favours less staff
Apgar score		Tucker 2003 Kashanian 2010			Gagnon 1997
Lower Birth asphyxia		Clark 2014		Hodnett 2002	
Lower rates Neonatal resus	Hodnett 2002	Tucker 2003			
Lower rates Neonatal resus (excluding bag/mask only)	Tucker 2003				
Lower Stillbirth			Joyce 2004		
Lower Neonatal death			Joyce 2004 Stilwell1998		
Composite healthy baby		Sandall 2014			
Exclusive breastfeeding	Dani 2020				
Admission to Neonatal unit	Dani 2020	Hodnett 2002 Tucker 2003		Gagnon 1997	
Neonatal length of stay				Hodnett 2002	
Perinatal complications			Mercer 2016		

Events during labour

Ten studies examined events during labour in relation to staffing (Table 25). Outcomes studied included the quality of record keeping, continuous fetal monitoring in low risk women, fetal distress, augmentation of labour, epidural use, speed of theatre transfer for caesarean section, and length of labour. These care process measures are difficult to interpret as they may not translate into differences in patient outcomes. Many of the findings favour more staff, with seven comparisons reaching statistical significance in that direction. Ten further comparisons show non-significant results in favour of more staff. Three comparisons favour having less staff, although some of these result from subgroup analyses.

Fetal distress was lower in facilities that offered one-to-one care more frequently (Clark et al., 2014) and the completeness of the partogram improved (Bailey et al., 2015). Kpéa et al. (2015) found that if the midwifery workload was high, 58.3% of women had an epidural or spinal for pain relief, compared to 49.7% if the workload was not high (OR 1.1, 95% CI 1.0-1.2). This finding was also supported by other studies, although non-significant effects were seen (Gagnon et al., 1997; Joyce et al., 2002; Rowe et al., 2014). Lower staffing was associated with higher augmentation rates, and this reached significance for multiparous women (Rowe et al., 2014). These findings suggest higher intervention rates when staffing levels fall, possibly representing a lack of support for women to manage pain or to facilitate progress of labour.

Cerbinskaite et al. (2011)studied the time taken to enter theatre for emergency caesarean section, and found this to be reduced when more midwives were present. For example, transfer time to theatre for grade one caesarean section was achieved within 15 mins for 81/82 (99%) cases where staffing was one-to-one or better, compared to 34/40 (85%) when the ratio fell below this target.

Table 25 Events during labour in relation to staffing

Outcome measure	Favours more staff	Point estimate favours more staff (NS)	Point estimate favours less staff (NS)	Favours less staff
Completeness of partogram	Bailey 2015 (hrs 0-8 of shift)	Bailey 2015 (hrs 8-12 of shift)		
Completeness of note keeping		Bailey 2015 (hrs 0-8 of shift)	Bailey 2015 (hrs 8-12 of shift)	
Continuous fetal monitoring	Hodnett 2002			
Appropriate fetal monitoring		Tucker 2003 low risk women	Tucker 2003 high risk women	
Less Fetal distress	Clark 2014			
Less oxytocin use / augmentation	Rowe 2014 in multiparous	Gagnon 1997 Kashanian 2010 Rowe 2014 in primiparous		
Time to delivery interval for c-section	Cerbinskaite 2011			
Less Epidural use	Kpea 2015	Gagnon 1997 Joyce 2002 Rowe 2014 in nulliparous		
Shorter Length of labour	Kashanian 2010	Gagnon 1997		

Mode of birth in relation to staffing

Ten studies examined mode of birth as an outcome measure, examining rates of emergency caesarean section, instrumental birth and spontaneous vaginal birth (Table 26). The results were mixed, and no patterns emerged favouring more or less staff.

Appendix C

Measures of birth without assistance were defined differently in the studies, using the terminology 'normal birth' and 'spontaneous vaginal birth' at times. Within this theme, only Gerova (2014) found a significant association between increased staffing and more normal birth, while studies by Sandall (2014), Hodnett (2002) and Rowe (2014) offered inconclusive findings. An extension of this outcome 'straightforward birth' was used by Rowe (2014) to include unassisted birth with no serious perineal trauma or blood transfusion.

In terms of caesarean section rates, only two studies (Kashanian et al., 2010; Zbiri et al., 2018) found a positive association between more staff and reduced caesarean section rate. Rowe et al. (2014) found the opposite, in that understaffing was significantly associated with reduced caesarean section rates, and this was significant for nulliparous women. The majority of other studies examining this outcome found no significant differences (Gagnon et al., 1997; Hodnett et al., 2002; Joyce et al., 2002; Clark et al., 2014; Gerova, 2014; Sandall et al., 2014; Kim et al., 2016). All studies examining the effect of staffing on instrumental birth had non-significant findings and the directions of effect were not consistent (Joyce 2002, Gagnon 1997, Gerova 2014, Hodnett 2002, Rowe 2014).

Table 26 Mode of birth in relation to staffing

Outcome measure	Favours more staff	Point estimate favours more staff (NS)	Point estimate favours less staff (NS)	Favours less staff
Lower caesarean birth rate	Kashanian 2010 Zbiri 2018 (elective cs)	Clark 2014 Gagnon 1997 Hodnett 2002 Joyce 2002 Sandall 2014 (emergency)	Gerova 2014 Rowe 2014 in multiparous Sandall 2014 (elective) Zbiri 2018 (urgent or intrapartum cs)	Rowe 2014 in nulliparous
Lower Instrumental birth		Joyce 2002 Hodnett 2002 Rowe 2014 in nulliparous Knape 2014*	Gagnon 1997 Gerova 2014 Rowe 2014 in multiparous	
Increased Spontaneous vaginal birth / Normal birth	Gerova 2014	Sandall 2014 Rowe 2014 in nulliparous	Hodnett 2002 Rowe 2014 in multiparous	
Increased Straightforward birth			Rowe 2014 in nulliparous	Rowe 2014 in multiparous

*Knape (2014) studied lower caesarean section or operative birth as one outcome

Appendix C

Effect of midwifery assistant staffing

Three studies (Gerova 2014, Sandall 2014, Kim 2016) reported on the addition of assistants and relationship with outcomes. Gerova (2014) found that increases in assistants were not significantly related to the probability of emergency section (OR=0.99, 95%CI 0.96-1.03), instrumental birth (OR=1.003, 95%CI 0.96-1.05) or normal birth (OR=0.99, 95%CI 0.95-1.03). Kim (2016) evaluated the impact of increasing the total number of nurses, both licenced and unlicensed. As the total workforce increased, this was not significantly associated with the risk of readmission within 30 days (RR1.01, 95% CI 1.0,1.02).

Sandall (2014) concluded that assistant staffing levels were not statistically related to any of the healthy mother and healthy baby indicators in the adjusted analysis. Sensitivity analyses were performed in different risk groups and parity. Increasing assistants was associated with an increase in birth with bodily integrity for lower-risk women (OR 1.04) but not for higher-risk women (OR 0.96). The chances of the healthy mother outcome being met was reduced when the number of assistants increased, irrespective of parity (ORs range from 0.87 to 0.93). Assistant staffing levels were associated with a reduced healthy baby outcome (ORs range from 0.90 to 1.00 for women of different parity). When considered together, the above findings do not highlight substantial benefits or detriments for increasing assistant numbers in the workforce.

Effects on staff delivering care

There were no published studies which reported a numeric association between staffing levels and measures of staff wellbeing in the maternity services. No studies were found relating staff retention, job satisfaction or sickness absence to staffing levels.

Economic analyses

Economic analyses were included in primary studies by Clark (2014) and Sandall (2014). Clark (2014) noted that considerable investment would be required to implement one-to-one care for patients undergoing Oxytocin induction or augmentation. They found insufficient evidence of benefit in their trial to justify the additional costs.

Sandall (2014) modelled staffing in relation to cost per birth and found that higher midwifery staffing was associated with increased delivery costs. The relationship was not strong, and this variable plus hospital trust size and case mix accounted for only 17% of cost variation between hospital trusts. Cookson et al. (2014) provided an economic impact assessment based on the Sandall (2014) data above. In their calculations, an increase in one Full Time Equivalent midwife per 100 births provided an incremental cost effectiveness ratio of £85,560 per additional healthy mother and £193,426 per mother with bodily integrity.

Discussion

The body of evidence on midwifery staffing and outcomes is small and provides mixed results. While there is some evidence that increased staffing improves outcomes for mothers and neonates, this predominantly relates to labour care and outcomes within the first hour after birth. Some of the variables measured in the studies are measures of care and it is unclear whether they would translate into improved outcomes (Lilford *et al.*, 2007).

For the mother, increased staffing was associated with reduced epidural rates, augmentation, perineal damage during the birth, post-partum haemorrhage, and maternal readmission. For neonates, increased staffing was associated with higher breastfeeding rates and reduced need for neonatal resuscitation. Staffing may influence the quality of care in labour, as there was some evidence of improved record keeping and timeliness of emergency caesarean section. Increased attention by staff may reduce the risk of negative outcomes, while also supporting coping mechanisms in labour and supporting infant feeding (Hodnett *et al.*, 2013; World Health Organization, 2018b; Dani *et al.*, 2020).

Very few studies have suggested a negative impact of increasing staffing rates, although a large number have found no significant differences. It is possible that other prognostic variables such as age, parity and clinical risk may have overshadowed any effects of variation in staffing in these studies (Sandall et al., 2014). A significant limitation of the available evidence is that many of the studies have not measured staffing levels directly, which has an unknown effect on the accuracy of findings. A lack of risk adjustment is a major potential source of bias within many of the studies presented.

Results for mode of birth are hard to interpret as studies are not in agreement on whether rates of spontaneous birth, instrumental birth or caesarean section are associated with staffing levels. Higher staffing levels can result from the assessed need for more staff to care for high risk patients. This tends to mask the beneficial effect of higher staffing (Mark *et al.*, 2010).

Assisted birth may be entirely appropriate for high risk cases to prevent adverse maternal and fetal outcomes so should not be considered to be a detrimental outcome (Kirkup, 2015; Dietz *et al.*, 2016).

This review contributes to the debate on whether staffing ratios should be recommended in maternity care, including all in-patient wards. It is notable that staffing ratios for labour ward, antenatal and postnatal areas have been recommended in Australia (Australian Nursing Midwifery Foundation, 2015) and in the USA (Association of Women's Health Obstetric Neonatal Nurses, 2010). Guidance states that a systematic process should be used to calculate total midwifery staff, incorporating historical data and predicted demand (National Institute for Health and Care Excellence, 2015). Birthrate Plus is one such tool for workforce planning, which is based on indicators of need in the population, while facilitating one-to-one care in labour (Ball *et al.*, 2015). It has been used so far in Ireland, Australia, UK and China (Yao *et al.*, 2016). The tool does not collect data on outcomes, and therefore the adequacy of recommended resources cannot be evaluated. The impact of reducing or increasing staffing on outcomes is a pertinent question, especially as resources are scarce and staffing decisions should maximise cost-utility (Martin *et al.*, 2020).

Understaffing may result from the inability to employ and retain midwifery staff (Heinen *et al.*, 2013). This may result in the recruitment of alternative staff to complement existing midwives. This scoping review has found only three studies relating the number of assistant staff to patient outcomes. Outcomes were not improved by the addition of assistants, and Sandall et al. (2014) noted reductions in the composite outcome of healthy mother and healthy baby as the number of support workers increased. This fits with recent research in the nursing literature suggesting detrimental effects of diluting skill mix or having more or less nursing assistants than the average level (Aiken *et al.*, 2017; Griffiths *et al.*, 2019b).

Makhfudli et al. (2020) found that increasing nursing staffing was associated with less risk of maternal death or severe maternal outcomes, but the same was not true for midwives. It is possible that midwives were allocated the most complex obstetric cases who had a higher background risk for poor outcomes, or that nurses had improved training in preventing escalation of potentially life threatening conditions. The skill mix of the maternity workforce is changing, and additional skills are needed to care for women and babies with complex care needs and co-morbidities (World Health Organization, 2012; Health Education England, 2019).

The contribution of each of the staff groups towards outcomes is unclear. Some task shifting initiatives are being driven by necessity due to shortages of professional staff (World Health Organization, 2012) .

No research studies were found examining associations between staffing numbers and the wellbeing of midwives. In an online survey of almost 2000 midwives by Hunter *et al.* (2019), perceived inadequacy of resources was the strongest predictor of work-related burnout. This may lead to staff attrition (Heinen *et al.*, 2013), which is costly, not only for the employer but also considering the cost of training each midwife. The State of the World's Midwifery report highlighted voluntary attrition as one of the ten essential areas for workforce planning (Lopes *et al.*, 2017). Challenges in recruitment and attrition have been described as a gathering storm especially in the light of increased demands and complexity (Royal College of Midwives, 2017; Callander *et al.*, 2021).

It is important to note that most studies have been conducted on the labour ward/delivery suite, with a dearth of studies in antenatal and postnatal wards. Escalation plans often involve redeploying staff from these areas in order to meet need on the labour ward (Royal College of Midwives, 2016b) and if they are not well staffed at the outset this may lead to critical shortages. In future, more resources may be deployed in the community as Renfrew et al. (2014) recommend a change in focus from the recognition and treatment of pathology for the minority, to providing skilled care for all. With a finite number of midwives available, this may lead to difficult choices in the distribution of staff (World Health Organization, 2017)

Strengths and limitations

In this scoping review, literature searching was completed in a systematic way, however, there may be undetected studies in the grey literature or in press that have not been accessed. The eligibility screening was not performed independently for all the papers, so it remains possible that some excluded papers might have been included by another reviewer. The high levels of agreement obtained on samples means that it is unlikely that this would make a substantial change to the overall number of included studies or the conclusions about the body of literature as a whole. Although major methodological issues have been discussed, the quality of the evidence has not been rigorously evaluated, which is consistent with the scoping review methodology. This means that poorer quality studies have been included, and these findings are more prone to bias.

Recommendations for further research

Further evidence is needed so that policy makers can make informed decisions about staffing levels and configurations, and the likely impact on outcomes. High quality research is needed from a range of countries and settings to clarify the direction and strength of effects. Studies should examine a range of outcomes in addition to those on labour ward. These could include maternal mental health, neonatal weight loss, jaundice, sustained breastfeeding, and neonatal readmission following discharge home. The contribution of assistants and the impact on workforce wellbeing also requires further research.

Improved attempts should be made to measure staffing at a ward level or individual patient level if possible. The impact of different workforce configurations and staff groups should be considered as these comprehensive designs are starting to feature at the forefront of staffing research (Rubbo *et al.*, 2021). It is important that future studies adjust for underlying risk as well as other predictive factors such as parity, gestational age, pre-existing conditions, and socioeconomic status (Orkin, 2010). Economic studies could model health care costs in terms of staffing numbers, but also potential cost-savings related to intervention rates in labour, readmissions and the cost of advanced neonatal care or maternal morbidity.

Conclusion

This scoping review has found some evidence of a positive association between in-patient staffing levels and improved outcomes for women and neonates. The evidence is not conclusive and is limited by the methodological quality of studies. Further research is needed so that service providers can predict the impact of changes to skill mix and staffing levels on a wide range of patient outcomes.

Appendix C

Tabulation of studies

Author and date	Design	Participants and Setting	Measurement of staffing	Outcome measures	Potential confounders measured and included in analysis	Results
Bailey 2015 (UK)	Cohort study - prospective. Single centre	Records from 70 consecutive women admitted to labour ward. Records available for 61 of them who went into labour	Ratio of women to midwives on labour ward for each 4 hour block of time	Composite record keeping score, Quality of the partogram recordings. Stratified by 4 hour block (beginning, middle, end of shift) . No neonatal outcome measures.	No risk adjustment for potential confounders in the analysis. Presented results separately for beginning, middle and end of shifts (stratified reporting)	The quality of partogram completion decreased as workload increased (ratio of women to midwives) and this effect was significant in the first 4 hours and second 4 hours of the shift but not in the last 4 hours. Correlation coefficient was 0.76 ($p<0.05$) in first 4 hours of shift, 0.84 in 4-8 hours ($p<0.01$), and 0.54 in 8-12 hours of the shift ($p>0.05$). The scores for the composite measure of notekeeping were not affected by the ratio of women to midwives. Correlation coefficients were 0.14 ($p>0.05$) in first 4 hours, 0.65 ($p>0.05$) in 4-8 hours and -0.61 ($p>0.05$) in 8-12 hours of the shift.
Cerbinskaite 2011 (UK)	Cohort study - prospective. Single centre	5167 births, delivery suite in UK, excluded elective caesarean section. Study of 755 emergency c-sections.	Number of qualified midwives on shift, number of labouring women on labour ward, labouring woman to midwife ratio	Decision to delivery interval within 30 mins, transfer time to theatre within 15 mins. No neonatal outcome measures.	None	Transfer time to theatre for grade 1 c-sections within 15 mins was achieved for 81/82 (99%) cases where staffing 1:1 or better, compared to 34/40 (85%) when ratio fell below 1:1 ($p<0.001$). For grade 2 c-sections this was achieved for 155/168 (92%) within 15 mins with 1:1 staffing or better, compared to 29/43 (67%) when staffing ratio less than 1:1 ($p<0.001$). Grade 1 caesareans were performed with a decision to-delivery interval below 30-minutes were 77/82 (94%) if 1:1 care or better staffed, compared to 22/40 (55%) born when the ratio was lower than 1 midwife: 1 woman ($p<0.001$). For Grade 2 caesareans, rates of delivery within 30mins were 90/168 (54%) when 1:1 care or better, compared to 5/43 (12%) if ratio less than 1:1 ($p<0.001$).

Appendix C

Author and date	Design	Participants and Setting	Measurement of staffing	Outcome measures	Potential confounders measured and included in analysis	Results
Clark 2014 (USA)	Cohort study - retrospective, routine data. Multi centre	101,777 women receiving oxytocin for labour induction or augmentation	Facilities divided into four groups based on the frequency with which each facility provided 1:1 nurse staffing for such patients during 2010 (0 to 25%, 26 to 50%, 51 to 75%, or > 75%). Based on opinion of nurse leader.	Fetal distress, caesarean delivery, chorioamnionitis, endomyometritis, and a composite of adverse events based on coding. Birth asphyxia.	None	Reference group are hospitals providing 1:1 care 76%-100% of time or more. Odds of birth asphyxia 0.78 (95% CI 0.61-1.01) for 51-75% group, 1.05 (95% CI 0.79–1.39) for 26-50% and 1.01 (95% CI 0.81–1.26) for 0-25% group. Higher staffing ratios was associated with more caesarean births (p<0.0001). Odds of primary caesarean 0.95 (95% CI 0.91–0.99) for 51-75% group, 0.89 (95% CI 0.85–0.94) for 26-50% and 1.06 (95% CI 1.02–1.10) for 0-25% group. Higher staffing ratios was associated with more overall complications (p=0.002). Odds of overall complications 0.66 (95% CI 0.62–0.70) for 51-75% group, 0.88 (95% CI 0.83–0.95) for 26-50% and 0.79 (95% CI 0.75–0.83)for 0-25% group. Fetal distress was lower in facilities that offered 1:1 care more frequently (p<0.0001). Odds of fetal distress 1.05 (95% CI 0.99–1.11) for 51-75% group, 1.08 (95% CI 1.01–1.15) for 26-50% and 1.18 (95% CI 1.12–1.24)for 0-25% group. Includes modelling of cost data.
Dani 2020 (Italy)	Cohort study - retrospective. Multi centre	Healthy infants born after uncomplicated pregnancy, vaginal delivery without any labour analgesia. 110 in Midwife led Centre and 110 in Obstetric led centre	Comparison of 2 centres with different midwifery staffing ratios. Participants self selected to attend either centre. Centre 1 (midwifery led in-hospital centre) staffing ratios of 1:2.5 or 1:5 depending on time of day. Centre 2 (obstetric led) ratios of 1:7, 1:9 or 1:15 depending on time of day	Exclusive breastfeeding rate at discharge, rates of admission to neonatal unit, length of stay	Gestational age, Birthweight, Length, Head circumference, Apgar score, cord ph, weight loss, bilirubin levels, sodium levels, and need for phototherapy. Unclear which factors were entered into the logistic regression analysis.	Exclusive breastfeeding rate at discharge higher in midwifery led unit with more staff (88% vs 78%, P = 0.048). Mixed breastfeeding rate at discharge was lower (12% vs 20%, p= .048) in infants born in the midwife- than in the obstetrician-led centre. Admission rate to neonatal unit was lower in the midwifery unit- than in the obstetric area (2% vs 9%, p = 0.017). Length of stay was 2.6 days (+/-0.8) in midwifery unit and 3.1 days (+/-1.8) in obstetric unit, p=0.008. Logistic regression analysis showed that birth in the midwife-led unit increased the likelihood of exclusive breastfeeding (OR 2.04, 95% CI 1.07-3.92). Birth in the midwife-led centre did not affect the duration of stay in hospital (OR 95% CI 0.81, 95% CI 0.51-1.23).

Appendix C

Author and date	Design	Participants and Setting	Measurement of staffing	Outcome measures	Potential confounders measured and included in analysis	Results
Gagnon 1997 (Canada)	Randomised controlled trial. Single centre	413 nulliparous women, >37 weeks, singleton pregnancy in labour. Experimental group (n=209), Control (n=204). Excluded high risk women and those with cervical dilatation over 4 cm.	One-to-one care consisted of the presence of a nurse during labour and birth using defined supportive techniques. Alternative is usual care, where nurses assigned to two patients at a time, normally one in early labour and the other near delivery, no defined labour support techniques.	Defined by medical record review. C-section. Secondary outcomes : Use of oxytocin, labour duration, epidural use, instrumental birth, perineal trauma Neonatal outcomes : Admission to NICU, Apgar score (secondary outcomes)	None (RCT)	Results for experimental (1:1 care) vs control. Risk of oxytocin stimulation 39.2% vs 47.1%, RR 0.83 (95% CI 0.67, 1.04). Total caesarean section 13.9% vs 16.2% RR 0.86 (95% CI 0.54,1.36); caesarean section due to cephalopelvic disproportion or failure to progress 11% vs 10.8% , RR1.02 (95% CI 0.59, 1.77); epidural analgesia 66.5% vs 69.6% RR 0.96 (95% CI 0.84, 1.09); admission to the neonatal intensive care unit 7.2% vs 4.9%, RR1.46 (95% CI 0.67, 3.18); instrumental delivery 23% vs 21.6%, RR1.06 (95% CI 0.74, 1.53); perineal trauma 81.4% vs 83%, RR 0.98 (95% CI 0.89, 1.08); duration of labour 9.1hrs vs 9.4hrs, mean diff -0.3 (95% CI -1.0, 0.4). Mean Apgar score at 1 min (8.0 vs 8.3, mean diff -0.3 95% CI -0.5, -0.1), Mean Apgar score at 5 min (8.9 vs 9.0, mean diff -0.1 95% CI -0.3, -0.1),
Gerova 2010 (UK)	Cross sectional study, routinely collected data. Multi centre	615,042 mothers giving birth in 144 Trusts (out of 150 Trusts that provide maternity care in England)	NHS workforce statistics, Maternity matters benchmarking dataset. Midwife FTE-birth ratio. Also included other staff groups - medical staff, nurses, nursery nurse, healthcare assistants	Maternal readmission within 28 days, collected at Trust level. No neonatal outcome measures.	Risk adjustment performed at patient level to include age of mother; ethnicity; Carstairs deprivation index; Charlston co-morbidity index; delivery type; professional delivering; number of admissions in the previous 12 months; pre- and post-birth length of stay.	Higher numbers of midwives FTE per births were associated with a lower probability of readmission, after adjustment for risk, Coefficient B -4.81 (95% CI -4.87 to-4.75, p<0.0001). A higher ratio of consultant obstetrician FTE to midwives FTE was associated with a lower probability of readmission (Coefficient B -3.56 (95% CI -3.61 to -3.52, p>0.001). Support worker staffing ratios not included in regression model although data was collected.

Appendix C

Author and date	Design	Participants and Setting	Measurement of staffing	Outcome measures	Potential confounders measured and included in analysis	Results
Gerova 2014 (UK)	Cross sectional study, routinely collected data. Multi centre	261,481 deliveries in 143 NHS trusts for emergency caesarean section and instrumental deliveries; and 214,949 deliveries in 129 NHS trusts for normal birth. Women aged 15-44, who were nulliparous and had a term (>=37 weeks), singleton, live birth.	Maternity Workforce Dataset and Hospital Episode Statistics	Mode of birth. No neonatal outcome measures.	Adjusted for maternal age, ethnicity, deprivation (IMD), clinical composite risk (NICE 2007), gestational age and birth weight. The sample was homogeneous for parity, singleton/live births and at term deliveries (gestational age >37 weeks).	Standardized midwives FTE/birth ratio was positively related to the probability of normal birth (coeff 0.55, OR=1.06, 95%CI 1.01-1.11). 1 SD increase in FTE midwives increased the odds of normal birth for low risk women by 7.6% (OR=1.08, 95%CI 1.02-1.14). Standardized midwives FTE/birth ratio was not significantly related to the probability of emergency section (coeff -0.28, OR=0.97, 95%CI 0.93-1.02). Standardized midwives FTE/birth ratio was not significantly related to the probability of instrumental birth (coeff -0.51, OR=0.95, 95%CI 0.9-1.01). The study did not find any statistically significant relationship between healthcare assistants and birth outcomes. Standardized HCA FTE/birth ratio was not significantly related to the probability of emergency section (coeff -0.08, OR=0.99, 95%CI 0.96-1.03), probability of instrumental birth (coeff 0.03, OR=1.003, 95%CI 0.96-1.05), or probability of normal birth (coeff -0.009, OR=0.99, 95%CI 0.95-1.03).
Hodnett 2002 (USA Canada)	Randomised controlled trial. Multi centre	6915 women who had a live singleton fetus or twins, were 34 weeks gestation or more. Randomly assigned to continuous labour support by a specially trained nurse (n=3454) during labour or to usual care (n=3461). Setting : Thirteen hospitals	Continuous labor support = nurse was expected to provide continuous support to the woman for a minimum of 80% of the time from randomization to delivery (to allow for meal breaks/emergencies). Usual care = time depended on stage of labour, the condition of the mother and fetus, and the nurses' workload	caesarean delivery rate. Secondary outcomes : mode of birth, epidural, perineal trauma, length of labour, feeling of control, postnatal depression. Neonatal : Apgar score, need for resuscitation, need for nursery care, length of stay. Extracted from medical records.	None	The rates of caesarean delivery were 12.5% in the continuous labour support group and 12.6% in the usual care group; p=0.44). Women in the continuous labour support group were less likely to have continuous electronic fetal monitoring (75.0% vs 79.2% in the usual care group; p<0.001). No significant difference in operative vaginal delivery (15.7% vs 16.2%, p=0.54), spontaneous vaginal delivery (71.8% vs 71.2%, p=0.54), perineal trauma (52.9% vs 53.7%, p=0.50), time from randomisation to delivery (6.6hrs vs 6.6hrs, p=0.89), need for resuscitation (35.9% vs 38.2%, p=0.05), birth asphyxia (1.7% vs 1.2%, p=0.09), neonatal length of stay 47.7hrs vs 47.5hrs, need for higher level neonatal care (7.1% vs 7.3%, p=0.7). Asked about preferred

Appendix C

Author and date	Design	Participants and Setting	Measurement of staffing	Outcome measures	Potential confounders measured and included in analysis	Results
						amount of support in next labour this was 'almost all the time' for 63.4% in continuous support group and 46.6% for usual care group (p<0.01).
Joyce 2002 (UK)	Cross sectional study. Multi centre	540,834 births, all births in 65 hospitals	Hospital level data. Nationally held data on hospital staffing levels. Number of midwives per 1000 deliveries calculated	Mode of birth and epidural use in labour. No neonatal outcome measures	Adjusted for demographic factors known to be associated with perinatal outcomes; maternal age, birthweight and multiple births.	Midwifery staffing was not significantly associated with caesarean section rate (B=-0.117, p=0.181) or instrumental delivery rate (B=-0.087, p= 0.105) in the simple linear regression. Midwifery staffing was negatively correlated with epidural rates (B=-0.532, p=0.049) in simple linear regression. In the multifactorial analysis this effect on epidural rate was due to social class demography between the units, rather than midwifery staffing (coefficient, CI and p value not presented).
Joyce 2004 (UK)	Cross sectional study. Multi centre	540,834 births, all births in 65 maternity units	Hospital level data. Nationally held data on hospital staffing levels. Number of midwives per 1000 deliveries calculated	No maternal outcome measures. Still birth, neonatal mortality.	The following were entered into the multiple regression analysis : staffing rates (paediatricians, obstetricians, midwives), facilities (consultant sessions, delivery beds, special care baby unit, neonatal intensive care unit cots), interventions (vaginal births, caesarean sections, forceps, epidurals, inductions, general anaesthetic), parental data (parity, maternal age, social class, deprivation, multiple births)	Midwifery staffing (midwives per 1000 deliveries) was not a significant predictor variable for stillbirth (B 0.012, p=0.65) or neonatal mortality (B -0.012, p=0.50) in the simple linear regression. Data not presented for multiple regression model for midwifery staffing.

Appendix C

Author and date	Design	Participants and Setting	Measurement of staffing	Outcome measures	Potential confounders measured and included in analysis	Results
Kashanian 2010 (Iran)	Randomised controlled trial. Single centre	100 nulliparous women. Experimental group (n=50) continuous support in labour, Control group (n=50) no continuous support. Inclusion criteria were nulliparous women (low risk women), early labour	Experimental (Continuous support by midwife) group also had a single room, free movement, food and drink, explanations, massage, compresses. Control group (routine care) did not have a private room, did not receive one-to-one care, were not permitted food, and did not receive education and explanation about the labour process.	Duration of active phase of labour and second stage, proportion c-section, oxytocin use. Neonatal : Apgar score < 7 at 5 minutes	None (RCT)	Mean duration of the active phase of labour (167.9±76.3 min vs 247.7±101 min, p<0.001), second stage of labour (34.9±25.4 min vs 55.3±33.7 min, p=0.003), and the number of caesarean deliveries (8% vs 24%, P=0.03)were significantly lower in the intervention group compared with the control group. The rates of oxytocin use (22% vs 38%, p=0.09) and Apgar scores of less than 7 at 5 minutes (0% vs 2%, p=0.29) were similar between the two groups
Kim 2016 (Korea)	Cohort study - retrospective, routine data. Multi centre	633, 461 admissions in obstetrics and gynaecology, 438,191 were c-sections.	Hospital level data. The number of nurses was the sum of the Registered Nurses (RNs) and licensed practical nurses (LPNs) in the hospital. The proportion of RNs was the number of RNs among the total number of nurses (number of RNs)/(number of RNs+number of LPNs).	Readmission within 30 days. No neonatal outcome measures	Excluded hospitals with low inpatient volume (<50 patients) and excluded tertiary hospitals which had high variations in staffing numbers. Measured age, patient clinical complexity level and length of stay but unclear if adjusted for in the analysis.	For the subgroup analysis of caesarean delivery, the rate of readmission within 30 days was significantly lower as the proportion of RNs increased (RR 0.96, 95% CI 0.93 to 0.98, p=0.0021). Total number of nurses was not associated with the risk of readmission within 30 days (RR1.01, 95% CI 1.0 to 1.02). Also measured medical staffing.
Knape 2014 (Germany)	Cohort study - secondary analysis of a controlled trial in which the intervention midwife led care was introduced. Multi centre	1238 participants, Women were eligible for the study if they had a low-risk status. Secondary analysis from 999 cases where data available on attendance of midwives	workload or midwives variable dichotomised whether 1:1 care was given (100% or not).	Mode of birth. No neonatal outcome measures	Adjusted for parity, length of stay, epidural use, oxytocin use, birthweight, childbirth education class attendance, age, income, education, attendance of obstetrician, presence of students, partner support and time of admission.	The workload of midwives (1:1 care or <1:1 care) was significantly associated with fewer caesareans or operative births in univariate analysis (11% vs 20.1%, p=0.01). These effects were no longer significant in the multiple logistic regression when 19 variables were included (coefficients and p values not presented for these variables).

Appendix C

Author and date	Design	Participants and Setting	Measurement of staffing	Outcome measures	Potential confounders measured and included in analysis	Results
Kpea 2015 (France)	Cross sectional. Multi centre	Population 14,681 women in 535 maternity units. 7558 excluded as high risk. Study sample was 1835 women who preferred not to have epidural or spinal analgesia	Midwifery Workload - ratio of the number of midwives per shift in the labour ward to the number of annual deliveries; workload was considered high in the quartile with the lowest ratio (25% of maternity units with the fewest midwives per annual deliveries). Dichotomised as workload high or not.	Having epidural analgesia when not previously planned it. No neonatal outcome measures	Multiple regression model included age, parity, education, living with partner, childbirth class attendance, adequate prenatal care, adverse obstetric history, unfavourable conditions in current pregnancy, gestational age, oxytocin administration, mode of birth, public/private hospital and availability of anaesthetist..	If high midwifery workload, 58.3% had epidural/spinal, 49.7% if no high workload, chi-sq p=0.0007. The effect remained significant after adjustment for other factors in the model. High midwife workload aRR = 1.1 (95% CI, 1.0-1.2, p=0.03) compared to other 3 quartile which is absence of high workload.
Makhfudli 2020 (Indonesia)	Cross sectional Multicentre	8,266 deliveries from 11 maternity unis in 6 hospitals. Included only single live births and women aged 15-49 years	Midwife to birth ratio per year, taken from hospital database systems	Maternal deaths, near miss events (Grouped as severe maternal outcome). No neonatal outcomes measured.	Mode of birth, admission procedure, length of stay, age, place of residence, obstetric complications	Women admitted to units with higher midwifery staffing had an increased odds of having an severe maternal outcome (OR 1.81, 95% (CI 1.07 to 3.06). Women admitted to units with higher nurse staffing had a decreased odds of a severe maternal outcome (OR 0.48, 95% CI 0.31 to 0.74)
Mercer 2016 (USA) Abstract only	Cohort study Multicentre	101,120 pregnancies from 24 hospitals. Excluded scheduled caesarean, those delivering outside labour and delivery, multiple gestations, and neonatal deaths	Nurse to patient ratio (Total nursing hours per shift/births per shift/8 hours)	Postpartum haemorrhage, Shoulder dystocia, 5-minute Apgar below 4, Hypoxic Ischaemic Encephalopathy, Fetal trauma, and cord pH below 7.0.	Weekday vs Weekend, Night vs Day vs Evening shift, Small (below 3,500) vs Medium (3,500–5,499) vs Large (above 5,500) units	The frequencies of adverse perinatal complications did not vary with nurse to patient ratio. Estimate of effect, CI and p value not presented.

Appendix C

Author and date	Design	Participants and Setting	Measurement of staffing	Outcome measures	Potential confounders measured and included in analysis	Results
Mugford 1988 (UK) Reported earlier as Stilwell	Cohort study - retrospective, routine data	20 maternity units providing level 2 care (consultant obstetric units with facilities for sick neonates). Selected years 1978, 1980, 1982	Number of FTE qualified midwifery staff per 1000 births, weighted to take account of effect on workload of transfers	No maternal outcome measures. Stilwell study extended so mortality included all neonatal deaths, both in-house and after transfer, occurring in the first month (neonatal mortality).	Birthweight, paediatric medical staff, obstetric medical staff, nursing staff, workload (admissions, transfers, deliveries)	Only paediatric medical staffing was related to neonatal mortality. No other staffing variables were related to this outcome. p values, coefficients and CIs not presented
Prapawichar 2020 (Thailand)	Case-control study. Multi centre	Data from 14 hospitals. Cases: 153 women with post partum haemorrhage following vaginal delivery Control: matched sample of 1530 without post partum haemorrhage	Patient to nurse-midwife ratio for the institution (meeting standard criteria of 2:1 or not). Additional category of number of nurse-midwives > or < than 2 per shift - this does not account for workload.	Postpartum haemorrhage (PPH). No neonatal outcome measures	Maternal factors including demographic data, age, reproductive history, parity, gestational age, anaemia, twins, gestational diabetes mellitus, and past history of postpartum haemorrhage, method of delivery, health service factors such as number of beds, proportion of vaginal births, and training for PPH management.	In univariate analysis, the hospitals which had below the reference nurse-midwife to patient ratio had significantly increased odds of post partum haemorrhage (OR 1.83,95% CI 1.22 to 2.74 p=0.016). In multivariate analysis, the factor remained significant OR 2.31 (95% CI 1.08 to 4.92, p=0.03).
Rowe 2014 (UK)	Secondary analysis of cohort study. Multi centre	32,257 women planning a vaginal birth in an obstetric unit. Only low risk women included	Taken from staffing logs (available from 30 units). Under staffing defined as the percentage of shifts where there was less than 1 midwife on duty per woman on the delivery or labour suite. Staffing data was available for 30 of the 36 obstetric units. Staffing and activity logs completed	Instrumental birth, intrapartum c-section, composite measure of normal birth (defined as birth without induction of labour, epidural or spinal analgesia, general anaesthetic, forceps or ventouse, caesarean section or episiotomy), composite measure of	Adjusted for maternal characteristics: maternal age, ethnicity, English language fluency, marital status, Index of Multiple Deprivation quintile, body mass index and gestational age, and for the presence of complicating conditions identified at the start of care in labour	There was no significant difference in rates of normal birth for nulliparous (coeff -0.01, p=0.89) or multiparous women (coeff 0.05, p=0.48) if understaffing was present. There was no significant association between instrumental delivery and percentage of midwife under staffing for nulliparous (coeff 0.02, p=0.80) or multiparous women (-0.04, p=0.07). There was a significant association between midwife under staffing and lower intrapartum

Author and date	Design	Participants and Setting	Measurement of staffing	Outcome measures	Potential confounders measured and included in analysis	Results
			twice daily by midwives during data collection for the cohort study. Not linked to individual women.	straightforward birth (defined as birth without forceps or ventouse, intrapartum caesarean section, third or fourth degree perineal trauma or blood transfusion). No neonatal outcome measures.		caesarean section rate for nulliparous women (coeff -0.10, p=0.03) but not multiparous women (coeff -0.05, p=0.11). There was a significant association between percentage of midwife under staffing and increased straightforward birth for multiparous women (coeff 0.08, p=0.01) but not for nulliparous women (coeff 0.06, p=0.31). There was no significant difference in rates of epidural use for nulliparous (coeff 0.05, p=0.59) or multiparous women (coeff 0.00, p=0.94) if understaffing was present. There was no significant association in rates of augmentation and percentage of midwife under staffing for nulliparous (coeff -0.1, p=0.16) or multiparous women (-0.09, p=0.05).
Sandall 2014 (UK)	Cross sectional - retrospective, routine data. Multi centre	656,969 births	NHS Workforce Statistics. FTE midwives and maternity support staff per 100 maternities, FTE all staff per 100 maternities and skill mix (doctor/midwife and midwife/support worker ratio).	HES data maternity tail. Delivery with bodily integrity = delivery without caesarean, episiotomy, or a second-, third- or fourth-degree perineal tear, uterine damage. Composite measure healthy mother =delivery with bodily integrity, plus no instrumental birth, no sepsis, no anaesthetic complications, home within 2 days, no readmission within 28 days, intact perineum. Satisfaction. HES data baby tail - Composite measure healthy baby =weight 2.5-4.5kg, gestation 37-42 weeks, live baby.	Adjustments were made for background characteristics (age, parity, ethnicity, index of multiple deprivation, geographical location and region) and clinical risk. Also adjusted for Trust characteristics - size, type, staffing.	There was no significant improvement in women's satisfaction with care as a result of higher staffing, but the results favoured improvements where more staff were present (data not presented). In the adjusted analysis, a higher number of midwives (FTE per 100 maternities) was associated with improved chance of delivery with bodily integrity (OR 1.11, 95% CI 1.01 to 1.23) and an intact perineum (OR 1.13, 95% CI 1.01 to 1.27). No difference in spontaneous vaginal birth (OR 1.03, 95% CI 0.95 to 1.11), normal birth (OR 1.06 95% 0.97 to 1.17) healthy mother (OR 1.09, 95% CI 0.96 to 1.23), healthy baby (OR 1.03, 95% CI 0.91 to 1.16), elective c-s (OR 1.03, 95% CI 0.94 to 1.14) and emergency c-s (OR 0.98, 95% CI 0.90 to 1.07). In adjusted analysis, a higher number of support worker (FTE per 100 maternities was associated with no change in delivery with bodily integrity (OR 1.00, 95% CI 0.88 to 1.13).

Appendix C

Author and date	Design	Participants and Setting	Measurement of staffing	Outcome measures	Potential confounders measured and included in analysis	Results
						Support workers associated with intact perineum OR 1.02 (95% CI 0.88 to 1.17), spontaneous vaginal birth (OR 0.96, 95% CI 0.87 to 1.06), normal birth (OR 1.01, 95% CI 0.90 to 1.14), healthy mother (OR 0.89, 95% CI 0.78 to 1.03), healthy baby (OR 0.97, 95% CI 0.84 to 1.11), elective c-s (1.08, 95% CI 0.96 to 1.22) and emergency c-s (OR 0.99, 95% CI 0.89 to 1.11).
Stilwell 1988 (UK)	Cohort study - retrospective, routine data. Multi centre	20 maternity units providing level 2 care (consultant obstetric units with facilities for sick neonates).	Routine data held by each hospital : FTE numbers of nursing and midwifery staff every 6 months during study. State certified midwives by grade, medical staff by grade in specialities of obstetrics and paediatrics. Routine annual data also obtained from national source. Number of staff expressed as a ratio to total births in the unit.	No maternal outcome measures. Stillbirth (death after 28 weeks of pregnancy), Early neonatal mortality (within 1 week of birth). Grouped together as Perinatal Mortality Rate. Recorded on regional database or obtained from hospital.	Analysed low birthweight as independent variable. Analysed years separately. Analysed singleton births and coded as congenital malformation separately. Number of births in each unit was a weighting factor in regression analysis. Excluded GP maternity units and regional neonatal and obstetric referral units so sample more homogenous.	There was no significant correlation between nursing and midwifery staffing and rate of perinatal death. The obstetric, midwifery, and nursing variables were not selected by any of the regressions (p values, coefficients and CIs not presented)
Tucker 2003 (UK)	Cohort study - prospective. Multi centre	1561 consecutively delivered women with Continuous Electronic Fetal Monitoring (CEFM) on consultant-led labour wards. Excluded multiple pregnancies and elective c-sections and births in alongside units	Workload log collected 4 times a day by shift leaders Measured midwives on duty and women's measure of dependency. Workload data was expressed as unit occupancy and staffing ratios. Staffing ratios were the number of observed midwives divided by the calculated required number of midwives as calculated by Birthrate plus and two advisory documents.	CEFM use, appropriate CEFM, time for senior doctor response to abnormality. Workload measured at time of fetal heart abnormality used in analysis of this outcome. Apgar score < 7 at 5 minutes, admission to neonatal unit (NNU) >48 hours, and neonatal resuscitation. Data obtained from national dataset linked to birth registrations.	Adjusted for maternal comorbidity from ICD codes, unit workload at time of admission.	There were no adjusted associations between increased staffing and use of appropriate CEFM commencement for high risk women (OR 0.90, 95% CI 0.63,1.30), low risk women (OR 1.12, 95% CI 0.85, 1.47) or time lag in senior doctor review (OR -7.8 mins, 95%CI -52.4, 36.8). No differences in Apgar < 7 at 5 minutes (0.98, 9 5% CI 0.94, 1.04) or admission to NNU for >48 hours (OR 0.97, 95% CI 0.95, 1.00) by staffing ratios (after adjustment). There was a significant association between increasing staffing ratios and lower odds of advanced neonatal resuscitation (excluding bag and mask only) (0.97, 95% CI 0.94 to 0.99). This was not significant for all resuscitation measures (OR 0.98, 95% CI 0.96 to 1.00)

Appendix C

Author and date	Design	Participants and Setting	Measurement of staffing	Outcome measures	Potential confounders measured and included in analysis	Results
Zbiri 2008 (France)	Cohort study, retrospective. Multicentre	102,236 live deliveries, representing the populations giving birth in 11 hospitals	Full-time equivalents (FTEs) at hospital level. All professionals in the maternity unit, not those assigned to a particular ward. The numbers of FTEs were related to the total number of deliveries per year and expressed as numbers of FTEs per 100 deliveries.	Mode of delivery	Demographic characteristics (age, parity, nulliparous or parous), medical characteristics or other pregnancy conditions, hospital information used and staffing - number of obstetricians, anaesthesiologists, and midwives.	The higher the number of FTE midwives per 100 deliveries, the lower the probability of elective caesarean delivery (aOR 0.79, 95% CI 0.69–0.90, p-value < 0.001 Elasticity study : The likelihood of an elective caesarean delivery would be associated with a decrease of 3.4 percentage points if the midwife levels had increased by 10%. No significant differences with midwifery staffing and urgent caesarean aOR 1.40 (95% CI 0.76–2.60) or intrapartum caesarean aOR 1.11 (95% CI 0.84–1.48)

Appendix D Assessment of secondary data sources

In preparation for this research, I undertook a review of relevant publically available datasets. The following datasets were examined and critically appraised for their suitability as data sources: Maternity Safety Thermometer, Hospital Episode Statistics, Maternity Services Dataset, National Maternal and Perinatal Audit, Breastfeeding at 6-8 weeks, MBRRACE reports, RCOG Clinical Indicators, Friends and Family Test, CQC Maternity Services Survey, NMPA Organisational Survey, Care Hours per Patient Day and NHS Workforce Statistics. This review assisted in the selection of datasets contributing to studies one and two. Many of the above datasets were set aside based on the dataset quality and relevance to the study questions.

There is growing encouragement for researchers to make their primary data available for future studies, as detailed in their data management plans (Cox *et al.*, 2018). The UK Dataservice holds over 7,000 digital data collections which have been made available for secondary use. They encourage datasets to be used to answer new questions or investigate existing questions using alternative methods (UK Data Service, 2021). A second organisation, Health Data Research UK, provides a catalogue of UK health datasets so they are discoverable by researchers. This appendix investigates whether publicly available datasets can be used to investigate the relationship between staffing on postnatal wards and outcomes. An overview of each of the datasets is given below.

The **Maternity Safety Thermometer** (NHS Digital, 2020) is conducted on one day per month and reports on the proportion of women with an infection, sustained a 3rd or 4th degree tear, post partum haemorrhage, had a baby with Apgar score < 7 at 5 mins, were left alone at a time that worried them, or had safety concerns during labour and birth. The data does not contain any fields that can be related to postnatal care specifically. It is available from 2014-2020 and reported monthly at a trust level. This data has limited applicability for secondary analysis as there is no reporting on case mix or assessment of missing data.

The **Hospital Episode Statistics (HES)**(NHS Digital, 2019a; Herbert *et al.*, 2017) reports on all admitted patient episodes of care in English hospitals and provides monthly trust level data from 1989 onwards. HES has been included in numerous research projects related to maternity staffing and outcomes (Knight, 2018; Jones, 2019; Gerova, 2014; Gerova *et al.*, 2010; Sandall *et* *al.*, 2014). It is possible to calculate length of stay, maternal/neonatal readmission rates and movement of patients between clinical areas using this data. HES data also provides the number of births per provider. It is possible to adjust for age, ethnicity, deprivation, pre-existing conditions, procedures, gestational age and birthweight. Case-mix adjustment is important as some of the observed variations may be due to differences in demographic and clinical risk factors in the populations studied.

The **Maternity Services Dataset (MSDS)**(NHS Digital, 2023c) captures information on all mothers and babies from the time of the booking appointment to discharge from maternity services. It is available at trust level from 2015 onwards. MSDS contains many variables that are in HES, and some additional ones such as maternal smoking, employment, body mass index, continuity of carer, and linkage of mother and baby records. The MSDS does not yet contain all the births recorded in HES, although the coverage is improving especially as completion of MSDS is now part of the Maternity Incentive Scheme (NHS Resolution, 2020). As with HES, there are a number of patient details recorded in MSDS that could be used for case mix adjustment.

The **National Maternity and Perinatal Audit (NMPA**)(National Maternity and Perinatal Audit, 2019a) is an annual audit of maternal and neonatal care and outcomes. These include induction of labour, mode of birth, perineal trauma, obstetric haemorrhage, Apgar score, breastfeeding and readmission rates. There have been three publications to date (covering years 2015/2016, 2016/2017 and 2017/2018). Data has been obtained from the Maternity Information systems along with HES data, although in future the Maternity Services Dataset will be used as the data source for the NMPA.

Three outcomes are considered relevant to postnatal care including Maternal readmission, Breastfeeding at discharge and Term admission to neonatal units (NNU). All data at a trust level are published on the interactive website. Users are able to filter the data according to whether the woman has had a caesarean section or vaginal birth. The data on readmission is presented in crude form and there is an adjusted column in which readmission data is adjusted for case mix including : maternal age, ethnicity, deprivation, parity, previous caesarean, birthweight, gestational age, body mass index, smoking status, medical and obstetric conditions. The breastfeeding data is not adjusted. The data on admissions to NNU is not published but researchers have demonstrated the ability to link the NMPA and National Neonatal Research Database (NNRD) datasets with effective linkage of 96.7% (Aughey *et al.*, 2019). It is mentioned that data on neonatal outcomes will be included in the next report. The total number of births per provider is available, which may be used to adjust for the size of maternity units in planned analyses.

Perinatal mortality surveillance data (MBRRACE-UK, 2020) provides details of stillbirth and neonatal death for babies each year from 2013 onwards. This is presented at trust and Local Authority level and adjusted for patient level factors such as maternal age, deprivation, ethnicity, sex, multiple birth and gestational age. Organisational factors such as the number of births per trust and level of specialisation of the neonatal unit are also presented. The definition of neonatal death is a liveborn baby (born at 20+0 weeks gestational age or later) who died before 28 completed days after birth. It is possible that some of these babies have died without having care on the postnatal ward if they are born in a critical condition or are extremely premature.

The **CQC Maternity Services Survey** (Care Quality Commission *et al.*, 2021) is conducted in late January or February each year, and every woman who has given birth in each trust is contacted and asked to complete a questionnaire covering care in antenatal, labour and postnatal periods. The response rate for the 2019 survey was 36.5%. Data is publicly available for 2015-2023 (it was not undertaken in 2016 as at that time it ran every 2 years, and was not undertaken in 2020 due to Covid-19 pressures). Four outcome measures in this survey are particularly relevant to postnatal inpatient care quality. These questions are only answered by women who stayed in hospital after the birth. Some case mix details are available to allow for adjustment.

RCOG Indicators (Carroll *et al.*, 2016) were devised as a method of measuring maternity care quality from HES data. Reports are available for the years 2011/2 and 2013/4 at trust level. Indicators were devised with input from clinicians, methodologists and service users. These were assessed to checked for validity, statistical power, feasibility of technical specification and were adopted within early maternity dashboards in the UK (Geary *et al.*, 2018). Indicators include the proportion of induced labour, mode of birth, episiotomy, perineal trauma and admissions following delivery. Readmission rates are potentially staff-sensitive and these are measured as unplanned maternal readmission and unplanned neonatal readmission. Data is only available as part of published papers and therefore could not be re-analysed for this study. This RCOG indicator project was further expanded into the NMPA project listed above.

The **Friends and Family Test** (FFT) has been available since 2013 and asks patients to rate how likely they are to recommend the maternity service to friends and family if they needed similar care and treatment. The responses to choose from are Extremely likely; Likely; Neither likely or unlikely; Unlikely; Extremely unlikely; Don't know. Data is collected at four time points: antenatal, birth, postnatal ward and postnatal community. The response rate for the FFT is reported to be 18% for the birth timepoint (response rate not reported for postnatal). Re-analysis is likely to be of poor quality due to the high likelihood of selection bias in the sampling and inability to adjust for case mix. NHS England have stated on their website that the FFT data should not be classed as official statistics. It has been argued that comparisons between trusts should be avoided as the mode of administration is not standardised and the test is vulnerable to bias (Sizmur *et al.*, 2015).

Breastfeeding at 6-8 weeks was published on a quarterly and annual basis and was available from 2015-2019. The data collection has now been moved to the Maternity Services Dataset. Breastfeeding at 6-8 weeks recorded the number and proportion of infants who were fully, partially or not at all breastfed at 6 to 8 weeks after birth. It was reported at a Local Authority level rather than trust level, which limits the matching for analysis with maternity staffing. Case mix details are absent from this dataset.

Datasets available which report on staffing and organisational factors

The **NMPA Organisational Survey** (National Maternity and Perinatal Audit, 2019b) is a survey of all Birth Centres and Hospitals in England, Scotland and Wales and had response rate of 100% in 2019 (151 trusts, 130 of which are in England). Service provision in each of the trusts are listed, including the number of birth rooms, number of antenatal and postnatal beds and the presence or absence of transitional care beds. This contextual information may be useful when interpreting the data from analyses. It also provides a list of all trusts and sites, so the completeness of other datasets can be established. Smaller hospitals with maternity services have different challenges in terms of staffing, facilities and outcomes (Edwards, 2020), so now they can be identified by researchers for stratified analysis or exclusion if warranted. Funnel plots are sometimes used to take the size of the organisation into account as investigators would expect less random fluctuations to contribute to estimated rates in larger units (National Maternity and Perinatal Audit, 2019a).

Appendix D

From April 2018, monthly **Care Hours Per Patient Day** (**CHPPD)** data has been reported by NHS Improvement (National Quality Board, 2016). This covers all acute trusts with inpatient wards. In many trusts the postnatal wards can be identified, although some wards are combined with the antenatal inpatient areas. The hours of registered nurses/midwives and health support workers are calculated and these totals are divided by the counts of patients at midnight as an approximation for workload (Carter, 2016). Actual staffing is reported on the NHS Improvement site (Lintern, 2019) and planned staffing is no longer available from this source. The Model Health System (which is only available to trust staff) contains information on planned versus actual staffing levels (NHS England, 2024b).

The limitations of CHPPD data are that band four nursery nurses are employed on postnatal wards and they do not feature separately in this metric, although would be counted in the unregistered staff numbers. Nurses and Midwives are grouped together, although they have very different roles and competencies. Newborns did not count in the headcount until recently, so this staffing metric is difficult to interpret in postnatal wards, mixed antenatal/postnatal wards and wards with transitional care newborn beds.

CHPPD is not perfect as a measure of workload as it will underestimate the workload in large acute units, where women may have a short length of stay. The turnover of service users through the day can significantly add to workload as admissions and discharges are time consuming and would not be the same workload as having the same patient all day (Park *et al.*, 2016). A survey in 2018 found that almost half of women on the postnatal ward are discharged within 24 hours (Harrison *et al.*, 2018). Patient acuity and length of stay are not featured within this indicator. For the reasons above, CHPPD provides a crude estimate of staffing and workload, although one advantage is that CHPPD is presented by nearly all trusts in England (NHS Improvement, 2021).

NHS Workforce Statistics (NHS Digital, 2018c) is published by NHS Digital on a monthly basis and shows the number of full time equivalent (FTE) staff working within NHS trusts. Data is also available as headcounts. Data is available from 2009 onwards and separates registered midwives from registered nurses, giving some estimation of the maternity workforce in acute trusts. This trust level data can be matched to patient outcomes relating to postnatal care. The use of this highly aggregated data makes this comparison less precise as the trust level data may not give a good approximation for staff on the postnatal wards.

Assessing quality and utility of datasets

Health Data Research UK has developed a framework to assess the potential usefulness of datasets in relation to a specific purpose (Health Data Research UK, 2020). This includes the five categories of : data documentation, technical quality, coverage, access/provision, and value/interest. Within each category there are sub-categories, and each area can be scored as white, bronze, silver, gold and platinum. The aim is to help users exclude datasets that do not meet a specific threshold. Evaluations are available on https://web.www.healthdatagateway.org/ however, most of the above datasets have not yet been rated.

Another evaluation tool is used by the UK Government Data Quality Framework, which highlights a number of key areas to report (Government Data Quality Hub, 2020). These areas include completeness, uniqueness, consistency, timeliness, validity and accuracy.

The categories in these two assessment tools have been considered when tabulating the data sources. Additional columns have been added to assess the application and utility of data sources to the study question. The publicly available datasets have been tabulated below to systematically assess them against quality criteria (Table 27).

Appendix D

Table 27 Quality assessment of secondary data sources

		Maternity safety thermometer	**Hospital Episode Statistics HES**
Quality of data	Source of dataset	Survey on 1 day per month from providers	Routine submissions from providers
	Data definitions available	Not reported online	Yes, in meta data document / data dictionary
	Completeness	114 Trusts in England submitted Percentage of missing data not published	141 Trusts in England submitted Completeness varies per field e.g. 98% for method of delivery,81% duration of postnatal stay, 77% gestation length
	Key fields coded in standardised way	Not reported online	Yes, described in meta data document
	Data cleaning described /consistency	Not reported online	NHS Digital validates and cleans the HES extract. Data quality issues are discussed with hospital trusts
	Timeliness of upload to database	Not clear	Provisional monthly data published within 2 months
	Number of records	Number of records not available	Holds data on 591,759 births for 2019-20
	Other	Website reports that been discontinued as data incomplete	Reporting improved due to Payment by results (Burns *et al.*, 2012). Mother and baby records not linked
Utility to study question	Coherence	Reported as % without numerators or denominators. Many fields reported as 0% (unclear if missing data)	Relates to hospital activity / number of attendances, not individuals. Caution in interpretation.
	Frequency reported	Monthly	Monthly and annually
	Dates available	2014-March 2020 (now terminated)	1989 onwards
	Populations included	Community, hospital and midwifery units in England	All admissions to NHS hospitals in England, excludes home births
	Case mix details available	None	Gestation, delivery method, anaesthetic. Other fields collected but not published at provider level e.g age, ethnicity, socioeconomic factors
	Outcome measures reported (of interest to postnatal care)	None relating to postnatal specifically. Related : Proportion with maternal infection Proportion left alone at time that worries them	Patient episodes Maternal and neonatal readmission rates can be derived from this data
	Organisational level reported	Trust	Trust level published Collected at record level (admissions)
	Dataset available for secondary use	Yes, but graph form only	Yes, further data available via secondary users service

		Maternity Services Dataset MSDS	National Maternal and Perinatal Audit NMPA
Quality of data	Source of dataset	Routine submissions from providers	HES in England (In future will use MSDS). Different systems used in Scotland and Wales.
	Data definitions available	Yes, in technical output specification	Coding and data sources in technical specification
	Completeness	141 Trusts in England submitted The proportion of deliveries in the MSDS compared to HES was 58.7 per cent in 2019-20. This compares with 91% for 2018-19, 78% for 2016-17	99% Trusts for year 2016/2017 (n=149/151) England, Scotland, Wales. 97% registrable births. Completeness a concern for 2017/2018 dataset
	Key fields coded in standardised way	Yes, described in meta data document. Derived fields also described	Taken from several maternity systems, coding details described.
	Data cleaning described /consistency	NHS Digital validates and cleans the MSDS extract. Feedback on data quality is provided to Trusts	Checked for data quality: completeness, plausible distribution, internal consistency. Analysis restricted to high quality data. Quality assessment 97% upwards for birthweight, parity, gestational age, mode of birth, maternal age, index deprivation
	Timeliness of upload to database	Provisional monthly data published within 2-3 months	Latest report is 2017/2018, delay in publishing subsequent reports
	Number of records	Holds data for 41,560 births in Sept 2020	585 653 births for year 2017/2018 (89% births)
	Other	New version of the dataset in 2019-2020. Mother and baby records linked. Reporting is a requirement for NHS Incentive Scheme	Variation in the availability, quality and completeness of the data items.
Utility to study question	Coherence	Data fields clearly labelled	Numerators and denominators clear
	Frequency reported	Monthly	Annually, however 2018/2019 report delayed
	Dates available	April 2015 onwards, v2 from April 2019	2015/2016, 2016/2017, 2017/2018 runs 1st April-31st March
	Populations included	None excluded	Birth Centres, Hospitals, Home births only
	Case mix details available	Ethnic origin, age, Robson group, previous births, complex social factors, delivery method, maternal smoking, employment, body mass index, continuity	Stratified by births per year and maternity unit types & NNU type. Risk adjusted by NMPA for Maternal age; Ethnicity; Deprivation; Parity; BMI; Smoking; Previous caesarean section; Gestational age; Birthweight; Medical and obstetric conditions
	Outcome measures reported (of interest to postnatal care)	Maternal readmission, Breastfeeding at first feed and discharge, admissions to neonatal unit	Maternal readmission, Breastfeeding at first feed and discharge, Plans for neonatal readmission in future reports
	Organisational level reported	Published at Trust level but collected at patient level	Trust level.
	Dataset available for secondary use	Yes, further data available via secondary users service	Yes, available via interactive table

		Perinatal Mortality Surveillance MBRRACE	CQC Maternity Services Survey
Quality of data	Source of dataset	Official statistics on birth and death registration from 4 countries of UK e.g. ONS	Every woman given birth in Trusts in England contacted to complete postal survey
	Data definitions available	Yes, in technical document	Listed in quality and methodology report
	Completeness	All births and deaths, completeness varies by measure e.g. 99% ethnicity, 98% birthweight, 100% mode of birth.	126 Trusts took part in 2019. Response rate 36.5% 2023 response rate 41%
	Key fields coded in standardised way	Yes, as described in technical document	Structured questionnaire available for inspection, coding described
	Data cleaning described /consistency	Data checked for acceptable values, missing data was sought to improve reporting	Multi stage sample checks. Comprehensive data cleaning document and management of missing data described. Some women in the sample may not have received their antenatal and/or postnatal care from the trust at which they gave birth.
	Timeliness of upload to database	Published 2 years after last data collected	Within 12 months
	Number of records	735,745 births in 2018, latest report covers 2020 data	17,151 births in 2019 25,515 births in 2023
	Other	NHS Digital removes patient records from data provided where patient has requested an opt-out.	Prone to selection bias in response
Utility to study question	Coherence	Crude, stabilised and adjusted rate with confidence intervals presented	Some means for responses difficult to interpret
	Frequency reported	Annually	Now annually, used to be bi-annually
	Dates available	2013 onwards	2015-2023. Not done in 2016 or 2020. Undertaken late Jan/early Feb each year
	Populations included	Births from Jan to December 2018. Reports specifically on deaths occurring in this population.	Women who had a live birth during specified month in NHS trust (including home births). Exclusions listed
	Case mix details available	Stratified by number of births and type of NNU. Population characteristics presented in quintiles per CCG and Local authority (not Trust level) In report only - data adjusted for mother's age; socio-economic group, baby's ethnicity; baby's sex, multiple birth; gestational age at birth.	Percentage in each age group, ethnic group, religion and sexuality available by Trust. Questions in survey on gestational age, type of birth.
	Outcome measures reported (of interest to postnatal care)	Neonatal death : a liveborn baby who died before 28 completed days after birth.	Length of postnatal stay, delay in discharge, getting help when needed it, information, being treated with kindness
	Organisational level reported	CCG, Local authority and Trust level	Trust level and Ward level
	Dataset available for secondary use	Yes, in tabular form, downloadable tables from 2017	Yes, in tabular form

		RCOG Indicators	Friends and Family Test
Quality of data	Source of dataset	Derived from HES data for admitted patient care	Patient survey
	Data definitions available	Indicators clearly described. Devised with input from clinicians, methodologists and service users	Standard question and answers. Question modified in Sept 2019 Free text option for response
	Completeness	162 organisation sites submitted in 2013/2014. >30% of data missing on gestational age in 35/162 organisations (one of data quality measures)	130 organisations submitted in Feb 2020 Response rate 18% for birth timepoint (completeness not reported for postnatal survey)
	Key fields coded in standardised way	Yes, listed on RCOG website and in report	Yes, 6 point likert scale
	Data cleaning described /consistency	Duplicates removed. Excluded deliveries at hospitals which failed the data quality tests. Looked at missing data, data distribution and cross-checking	No techniques are applied to control for differences in sampling. May be administered at different timepoints from 2020.
	Timeliness of upload to database	2013/2014 data reported on in 2016	Approx 3 months
	Number of records	Total 624595 deliveries in 2013/2014 report	Total 915,353 responses on postnatal ward care in Feb 2020 1,145,422 in March 2024
	Other	No further reports expected. This work has now been subsumed within the National Maternity and Perinatal Audit	Prone to selection bias in sampling and response. Providers can choose their own data collection methodology. FFT must be implemented by all providers holding NHS Standard Contract.
Utility to study question	Coherence	Data presentation clear. Numerators and denominators presented, funnel plots presented	Denominator for use of postnatal services not clear, therefore response rate not available for this part of the survey
	Frequency reported	Two reports only	Monthly
	Dates available	2011/2012 and 2013/2014	2013 onwards, suspended March-Dec 2020, resumed Jan 2021 as break due to Covid
	Populations included	Deliveries to women aged between 15 and 45 with singleton, term, cephalic deliveries	Postnatal survey aimed at all women who use the postnatal ward
	Case mix details available	In report, stratified by parity and adjusted for age, ethnicity, level of socio-economic deprivation and clinical risk factors. Not available for secondary use	None
	Outcome measures reported (of interest to postnatal care)	Unplanned maternal readmission, unplanned neonatal readmission	Relates to 4 stages in patient journey, one of which is the postnatal ward experience
	Organisational level reported	Trust level	Trust and Hospital site levels
	Dataset available for secondary use	No, data only published in report form	Yes, in tabulated form

		Breastfeeding at 6-8 weeks	NMPA Organisational Survey
Quality of data	Source of dataset	Health visiting activity data at a local authority resident level	Survey responses from organisations
	Data definitions available	Defined in statistical release	Definitions provided for : Maternity unit types, continuity of carer, neonatal unit designations
	Completeness	129/149 local authorities submitted a return for quarter 3 2019/2020 Breastfeeding status known in 89.7%	100% Trusts (151 total, 130 of which are in England)
	Key fields coded in standardised way	Yes, based on definitions of 3 categories	Structured questionnaire available for inspection
	Data cleaning described /consistency	126/129 passed initial validation 67/129 local authorities passed all 3 stages of validation. Validation rules published	Not described in terms of handling of incomplete questionnaire / potential errors or inconsistencies
	Timeliness of upload to database	Approx 12 months	Within 12 months
	Number of records	131,462 infants in England for quarter 3 2019/2020	All NHS Trusts
	Other	Data is submitted by local authorities on a voluntary basis	Provides contextual information on organisations and facilities
Utility to study question	Coherence	Numerator, Denominators and missing data clear	Details and comparisons on website
	Frequency reported	Annually	2 reports to date, unclear if will be repeated
	Dates available	2015/16 -2019 (no further publications planned). Moved to MSDS	2017 and 2019 Surveys completed in Jan of each year
	Populations included	All infants due 6-8 week reviews in England	All NHS trusts and boards providing intrapartum care on site across England, Scotland and Wales
	Case mix details available	No	Not applicable
	Outcome measures reported (of interest to postnatal care)	Number/proportion of infants who have been fully, partially or not at all breastfed at 6 to 8 weeks	Survey of maternity and neonatal care provision, and of services available to women
	Organisational level reported	Region and Local authority resident level	Region, Trust and Site
	Dataset available for secondary use	Yes, in tabulated form	Yes, in tabular form and interactive charts

		Care Hours Per Patient Day	**NHS Workforce Statistics**
Quality of data	Source of dataset	Trust submissions	NHS Human Resources and payroll via Electronic staff record (ESR)
	Data definitions available	Clear explanations on data entry expected Standard codes used for specialties	Found in NHS data model and dictionary for National workforce dataset
	Completeness	Maternity data available from 120 Trusts in 2019 Some not reported postnatal ward separately	No missing organisations reported 216 Trusts submitted data in Sept 2020
	Key fields coded in standardised way	Some drop down boxes and automatic calculations in data entry portal	Yes, following data dictionary and ESR entry systems
	Data cleaning described /consistency	Trusts are responsible for quality-assuring safe-staffing monthly returns, validating them before submission and checking for consistency (data cleaning not done centrally)	Data corroborated by matching with occupation codes and earnings. Responsibility for data accuracy lies with the organisations providing the data.
	Timeliness of upload to database	Within 2 months	Approx 3 months
	Other	All trusts must submit CHPPD data via the Strategic Data Collection Service (SDCS). Only mothers are included in 23:59 census, not newborns in earlier data	Changes over time may reflect mergers between Trusts or new care providers.
Utility to study question	Coherence	Data tables clear and consistent	Data tables clear and consistent
	Frequency reported	Monthly	Monthly
	Dates available	April 2018 onwards	2009 onwards
	Populations included	Inpatient areas (including delivery suites) in acute and specialist Trusts, later versions includes community and mental health Trusts	NHS Hospital and Community Health Service staff working in NHS Trusts and CCGs in England Midwives reported separately to nurses
	Outcome measures reported (of interest to postnatal care)	Nursing, midwife and health care support staff Later measures to include nursing associates and allied health staff. Monthly returns for safe staffing and daily patient count at midnight	Headcount and full-time equivalents
	Organisational level reported	Trust and Ward level.	Region, CCG and Trust level
	Dataset available for secondary use	Yes, in tabular form and online via the Model Health System	Yes, in tabular form and interactive resource

Summary of findings

The tables above provide detailed analyses of the quality and usefulness of these datasets, and allows an objective judgement when selecting datasets. The best match to the research question is to examine data from the CQC Maternity Survey and the Care Hours Per Patient Day datasets, as these are both conducted at ward level and would give some information on whether ward staffing is associated with these postnatal outcomes. Adjustments can be made for case mix which is useful when patient characteristics vary substantially between providers (Paddison *et al.*, 2012). As detailed in the table, there are limitations posed by both of these datasets, so these would need to be highlighted.

A further option is to request aggregate data from national datasets on variables of interest. Ethical approval has now been granted for this to be done for the Maternity Survey, Maternity Services Dataset and HES (ERGO ID 62570). HES data has been used in publications to date and has reliably informed the RCOG indicators and NMPA audits in the past. There is a move towards the Maternity Services Dataset in preference to HES data, as it provides more fields for case mix adjustment, and allows researchers to follow the patient journey. One limitation is that this database is still under development, which means it holds fewer records than HES, and submissions from trusts have been less reliable so far.

One advantage of these datasets is that it is possible to adjust for case mix, as variables such as mode of birth, parity, gestational age and procedure codes are recorded. The dates for data requests could align with available data on staffing, such as the introduction of Care Hours Per Patient Day from April 2018. Data from the NMPA Organisational Survey could be used to enhance the analyses by providing some context on the available facilities within each organisation.

Some options were felt to have limited value in pursuing. The Breastfeeding at 6-8 weeks database is felt to be too far removed from the question to provide valuable evidence, as it reports at Local Authority level only. A secondary analysis on neonatal mortality from the MBRRACE data would be possible if matched with trust level staffing data. However, it would not be possible to adjust for risk based on the data available publicly. This outcome is also quite far removed from postnatal ward staffing, as variation in neonatal mortality may be explained predominantly by diagnosis, gestational age, events in labour and immediate neonatal care. The Maternity safety thermometer and Friends and Family test have significant areas of weakness and would therefore produce lower quality data for analysis. They are used more as a barometer within Trusts to highlight emerging issues and identify areas for investigation.

In conclusion, there appears to be value in pursuing the analysis of available secondary data as this may give some indication of the variation in staffing and outcomes, and associations between them. It will provide a guide on what can and cannot be achieved with the routine data available. Steps for secondary data analysis will be informed by guides such as those by Cheng *et al.* (2014). The findings above may be of value to future researchers who are looking to explore routine data sources to address research questions.

Appendix E Summary of analyses

Main staffing measure	Comparison for staffing level	Covariates available*	Additional analyses or data presentation	Sensitivity analysis
<u>Study 1 Experience</u> FTE midwives per 100 births (continuous)	Trusts, compared with each other	Number births per year Age Type of birth Ethnicity % Primiparous % Response rate	Tertiles of staffing (highest and mid tertile, with lowest as reference group) Converted to absolute risk difference based on predictions from model	Alternative dichotomisation of survey responses Adding in variable for response rate Model fit with interactions added and results presented where interaction improved fit
<u>Study 2 Experience</u> FTE midwives per 100 births (continuous) Ward level CHPPD registered and support workers (continuous)	Trusts, compared with each other Wards, compared with each other	Staffing medical fte Number births per year Age Type of birth Ethnicity % Primiparous % Response rate	Tertiles of staffing (highest and mid tertile, with lowest as reference group) Overall staffing and skill mix as covariates instead of staff groups	Alternative dichotomisation of survey responses Adding in variable for response rate Model fit with interactions added HPPD analyses repeated with outliers removed
<u>Study 3 Readmissions</u> HPPD midwives and support workers, measured over 2x12hr intervals	Exposure to understaffing defined as lower than expected (mean HPPD) for the organisation. Midwives and support workers separately.	Age Type of birth SHMI Skill mix compared to expected (mean) Patient turnover compared to expected (mean)	Absolute numbers of individuals cared for per midwife and support worker Low and high levels of staffing compared with near mean staffing (95%-105%) Secondary analysis by subgroups of mode of birth	None
<u>Study 4 Harm incidents</u> HPPD midwives and support workers, 24 hour period matched to the day of incident	Exposure to understaffing defined as lower than expected (mean HPPD) for the organisation. Midwives and support workers separately.	Weekend or weekday Patient turnover compared to expected (mean) Skill mix Proportion population aged over 40yrs Proportion of population wih comorbidity index >0	Secondary outcomes of specific harm incidents Low and high levels of staffing compared with near mean staffing (95%-105%) (not presented in paper but performed)	Staffing the calendar day before to capture imprecise matching to exposure and time lagged effects (not presented in paper but performed)

* not all covariates were used in the final models following best fit analyses

Appendix F Data management plan

Aim : To estimate the association between staffing levels and skill mix on the quality of maternity care

Research questions

Using secondary data from NHS organisations to answer the questions :

a) Is there an association between the Registered Midwife staffing and the quality of care for mothers and newborns?

b) How does the quality of care differ when the proportion of registered midwives and maternity assistants vary?

What policies will apply to your research?
Code of Practice for Research Degree Candidature and Supervision

University of Southampton Research Data Management Policy

Trusts to follow Information Commissioners Office code of practice on anonymisation to reduce risk of re-identification

Funder policies from NIHR and NHS Health Research Authority

What data/research material will you collect or create?
Aggregate secondary data on maternity staffing from published online datasets

Unpublished secondary data from the above national datasets at organisational level - requested from the UK DataService for the CQC Maternity Survey

Record level data on staffing and patient outcomes from hospital trust data management systems which have been de-identified

A research diary containing the results of meetings and key milestones and decisions will be kept. This will be photographed monthly and retained for reference.

How will your data/research material be documented and described?
Each dataset will be held separately and all variables will be labelled in as much detail as possible.

A data dictionary will be created to define key variables for transparency.

Data cleaning procedures will be documented and justified.

Storage locations for all files will be catalogued on a master spreadsheet. Folders will be used to group similar documents and file names will be as descriptive as possible.

No information will be deleted, and new version numbers will be added to amended spreadsheets.

A 'readme' textfile will be located next to each data set containing key messages to interpret the data.

Data will be obtained over a period of time, depending on accessibility of secondary datasets.

Codebooks will be created and maintained for all datasets relevant to this project. These will include of variable names, coding, abbreviations, etc

Consistency is important in the management of datasets over time, so they undergo the same processes of quality checking, cleaning and reformatting before analysis. This process will be documented and followed on each occasion.

Working data will be backed up onto a secure filestore kept at the University of Southampton on a weekly basis. No information will be deleted, and versions will be renamed and dated after each amendment.

How will you deal with any ethical and copyright issues?
No personal data will be accessed as part of this research. Measures have been taken in the parent study Data Management Plan to ensure that patients cannot be identified. This includes the use of pseudonymisation at source, lack of access to the key and supply of depersonalised data (e.g. age bands) from the trusts.

Although the researcher will be able to access individual records, the publication of data will be in a highly aggregated form. Individual hospital trusts will not be identified in the data.

Access to data will be limited to a small team of researchers needed to advise on the project. Sources will be acknowledged as some of the materials will come from national datasets. The sources will be notified when findings are submitted for publication.

How will your data/research materials be stored and backed up?
Data files will be held securely on a backed up University secured filestore.
Data will be backed up at the end of every week, or after major revisions have been made. Endnote libraries will be backed up in a similar way. Drafts of thesis chapters will be emailed to my staff account as a backup of this information.
No information will be held on paper, apart from the research diary and this will be photographed as a backup.

What are your plans for the long-term preservation of data/research materials supporting your research?
Data will be held for 10 years after collection or publication, whichever is the latest. Data will be held in the University repository (Pure) so it can be preserved in case it is needed for investigation or verification. The data collected as part of the parent project will be stored with that project, using the same data management plan.

Spreadsheets will be saved as csv files to allow easier access in future. Formatted text will be saved as rtf. These open formats are easier to preserve and reuse as they do not require specific software to access.

UK Data Service Terms and Conditions of access ask that:

They are informed of any published works that are based on data from their collection
Their data is destroyed at the end of the project and not deposited in any other database

They are offered any new data collections that have been derived from the materials supplied.

These restrictions will be upheld, and this relates to the CQC Maternity Survey 2018 and 2019 dataset.

What are your plans for sharing the data/research materials after the submission of your thesis?
My ethesis will be publicly available via the University of Southampton repository. As the datasets are not personal, I will explore the opportunity of making spreadsheets available for other researchers to use for re-analysis.

The spreadsheets would not be publicly available, and a submission request would need to be made and considered by my supervisor and the research team. The data would require further modification to remove reference to organisations.

Publishers may require a time limited embargo on releasing data to other parties and this would be respected.

Data Management Review
Actions to help you implement the plan:
Attended Data Management Plan online Q&A via Gradbook

Equipment and/or resources required:
None at present

Appendix G Study 1 Supplementary material

S1 Responses by Category

Four questions relating to postnatal care, response categories and frequency

Question in Maternity Survey	Response categories	Frequency
On the day you left hospital, was your discharge delayed for any reason? n=17,050, 561 missing	Yes No	7655 (44.9%) 9395 (55.1%)
If you needed attention while you were in hospital after the birth, were you able to get a member of staff to help you within a reasonable time? n=17,113, 498 missing	Yes, always Yes, sometimes No I did not want/need this Don't know/can't remember	9346 (54.6%) 4873 (28.5%) 1471 (8.6%) 1230 (7.2%) 193 (1.1%)
Thinking about the care you received in hospital after the birth of your baby, were you given the information or explanations you needed? n=17,145, 466 missing	Yes, always Yes, sometimes No Don't know/can't remember	11070 (64.6%) 4532 (26.4%) 1425 (8.3%) 118 (0.7%)
Thinking about the care you received in hospital after the birth of your baby, were you treated with kindness and understanding? n=17,008, 603 missing	Yes, always Yes, sometimes No Don't know/can't remember	12,613(74.2%) 3,693 (21.7%) 656 (3.9%) 46 (0.3%)

S2 Sensitivity analysis

S2.1 Sensitivity analysis after adding in variable for trust response rate

Before = full multi level, multivariable analysis
After = addition of response rate variable for each trust

	Multilevel models, nested in trust. aOR and 95% CI			
	Delay in discharge	Staff help reasonable time	Information / Explanations	Treated with kindness and understanding
Response rate in univariate analysis	P=0.232	P=0.026	P=0.182	P=0.001
FTE midwives per 100 births	Before 0.849 (0.753, 0.959) P=0.008 After 0.842 (0.746, 0.950) P=0.005	Before 1.200 (1.052, 1.369) P=0.007 After 1.214 (1.062, 1.388) p=0.004	Before 1.150 (1.040, 1.271) P=0.006 After 1.152 (1.040, 1.275) p=0.007	Before 1.059 (0.949, 1.181) P=0.306 After 1.073 (0.961, 1.199) p=0.211
Reference group low fte per 100 births 2.543 to 3.395				
mid fte per 100 births 3.396 to 3.706	Before 0.920 (0.815, 1.037) After 0.908 (0.805, 1.025)	Before 1.141 (0.999, 1.303) After 1.154 (1.009, 1.320)	Before 1.089 (0.985, 1.203) After 1.090 (0.984, 1.206)	Before 1.067 (0.956, 1.189) After 1.080 (0.968, 1.206)
high fte per 100 births 3.707 to 5.217	Before 0.789 (0.697, 0.894) After 0.782 (0.690, 0.886)	Before 1.191 (1.037, 1.367) After 1.202 (1.046, 1.381)	Before 1.130 (1.018, 1.255) After 1.131 (1.017, 1.257)	Before 1.080 (0.963, 1.211) After 1.093 (0.974, 1.226)

S2.2 Sensitivity analysis based on re-categorisation of responses 'yes always and yes sometimes' together

Before ='yes always'=1 'yes sometimes and 'no'=0
After = 'yes always and yes sometimes'=1 and 'no'=0

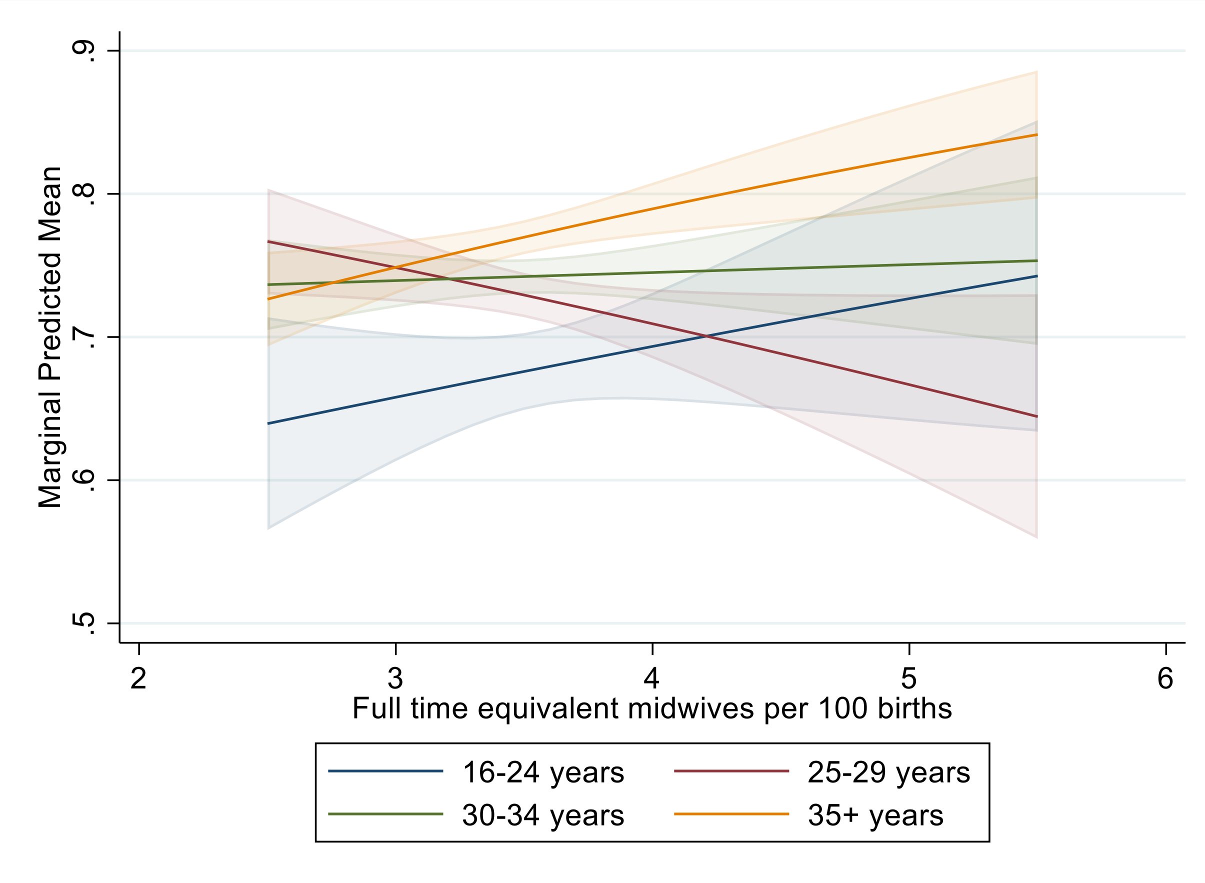
	Multilevel models, nested in trust. aOR and 95% CI		
	Staff help reasonable time	Information / Explanations	Treated with kindness and understanding
FTE midwives per 100 births	Before aOR 1.200 (1.052, 1.369) p=0.007	Before aOR 1.150 (1.040, 1.271) p=0.006	Before aOR 1.059 (0.949, 1.181) p=0.306
FTE midwives per 100 births After recoding	After aOR 1.196 (1.010, 1.418) p=0.038	After aOR 1.294 (1.113, 1.506) p=0.001	After aOR 1.198 (0.968, 1.483) p=0.097
Reference group low fte per 100 births 2.543 to 3.395			
mid fte per 100 births 3.396 to 3.706	Before 1.141 (0.999, 1.303) After 1.156 (0.980, 1.365)	Before 1.089 (0.985, 1.203) After 1.052 (0.911, 1.215)	Before 1.067 (0.956, 1.189) After 1.077 (0.875, 1.325)
high fte per 100 births 3.707 to 5.217	Before 1.191 (1.037, 1.367) After 1.194 (1.001, 1.424)	Before 1.130 (1.018, 1.255) After 1.321 (1.127, 1.548)	Before 1.080 (0.963, 1.211) After 1.177 (0.939, 1.476)

S2. 3 Sensitivity analysis : Testing model fit using AIC and BIC when including interaction variables

	Model 3 with all 6 predictor variables		**Best fit?**
Delay in discharge	With no interaction variables	AIC 23115.99 BIC (129) 23150.31 BIC 23208.82	Reference
	With interaction variable staffing (continuous) and age (categorical)	AIC 23118.55 BIC (129) 23161.45 BIC 23234.59	Model with no interaction variable
	With interaction variable staffing (continuous) and mode birth (categorical)	AIC 23118.71 BIC (129) 23161.61 BIC 23234.75	Model with no interaction variable
	With interaction variable staffing (continuous) and %primip (continuous)	AIC 23117.49 BIC (129) 23154.67 BIC 23218.05	Model with no interaction variable
	Model 3 with all 6 predictor variables		
Help in reasonable time	With no interaction variables	AIC 20690.76 BIC (129) 20725.08 BIC 20782.59	Reference
	With interaction variable staffing (continuous) and age (categorical)	AIC 20696.62 BIC (129) 20739.51 BIC 20811.4	Model with no interaction variable
	With interaction variable staffing (continuous) and mode birth (categorical)	AIC 20696.53 BIC (129) 20739.43 BIC 20811.31	Model with no interaction variable
	With interaction variable staffing (continuous) and %primip (continuous)	AIC 20692.48 BIC (129) 20791.96 BIC 20729.66	Model with no interaction variable
	Model 3 with all 6 predictor variables		
Information/Explanations	With no interaction variables	AIC 21590.04 BIC (129) 21624.36 BIC 21682.84	Reference
	With interaction variable staffing (continuous) and age (categorical)	AIC 21595.96 BIC (129) 21638.85 BIC 21711.96	Model with no interaction variable
	With interaction variable staffing (continuous) and mode birth (categorical)	AIC 21595.24 BIC (129) 21638.13 BIC 21711.25	Model with no interaction variable
	With interaction variable staffing (continuous) and %primip (continuous)	AIC 21591.83 BIC (129) 21629.00 BIC 21692.37	Model with no interaction variable
	Model 3 with all 6 predictor variables		
Treated with kindness and understanding	With no interaction variables	AIC 18772.04 BIC (129) 18806.36 BIC 18864.81	Reference
	With interaction variable staffing (continuous) and age (categorical)*	AIC 18763.46 BIC (129) 18806.36 BIC 18879.42	AIC lower with interaction variable BIC higher with interaction variable
	With interaction variable staffing (continuous) and mode birth (categorical)	AIC 18775.26 BIC (129) 18818.16 BIC 18891.22	Model with no interaction variable
	With interaction variable staffing (continuous) and %primip (continuous)*	AIC 18770.65 BIC (129) 18807.83 BIC 18871.15	AIC lower with interaction variable BIC higher with interaction variable

* Interactions calculated and plotted to examine effects (see below)

Interaction of age group with staffing levels for outcome of Kindness and Understanding



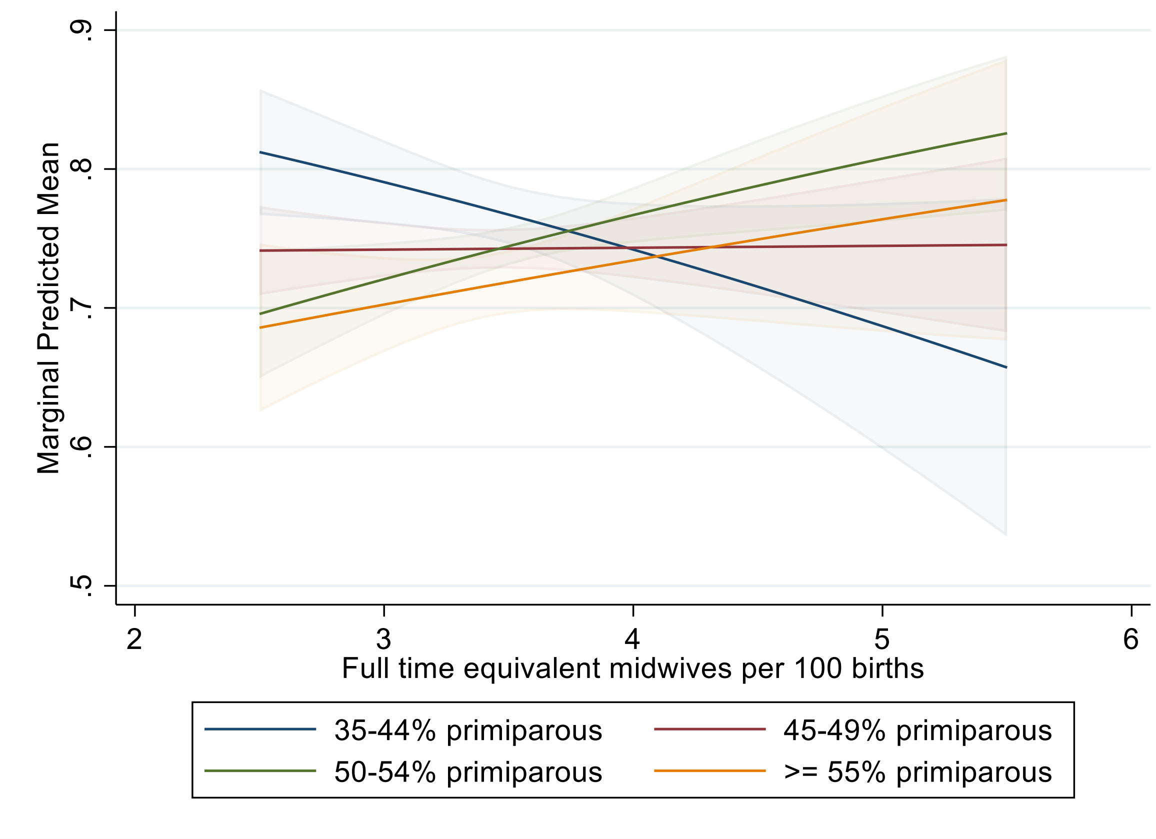

```
3 . margins workload3cat#age_group

Predictive margins                              Number of obs     =     16,819
Model VCE     : OIM

Expression    : Marginal predicted mean, predict()
```

	Margin	Delta-method Std. Err.	z	P>|z|	[95% Conf.	Interval]
workload3cat#age_group						
low fte per 100 births#16-24	.6708403	.0258542	25.95	0.000	.6201669	.7215136
low fte per 100 births#25-29	.748081	.0134144	55.77	0.000	.7217892	.7743727
low fte per 100 births#30-34	.7370832	.0104362	70.63	0.000	.7166287	.7575377
low fte per 100 births#35+	.7410023	.010326	71.76	0.000	.7207638	.7612408
mid fte per 100 births#16-24	.6756298	.0217341	31.09	0.000	.6330317	.7182278
mid fte per 100 births#25-29	.731175	.0131419	55.64	0.000	.7054172	.7569327
mid fte per 100 births#30-34	.7402354	.0105029	70.48	0.000	.7196502	.7608207
mid fte per 100 births#35+	.7794124	.0102088	76.35	0.000	.7594035	.7994214
high fte per 100 births#16-24	.6871024	.0232999	29.49	0.000	.6414355	.7327692
high fte per 100 births#25-29	.7041887	.0147813	47.64	0.000	.675218	.7331594
high fte per 100 births#30-34	.7506895	.0115816	64.82	0.000	.7279899	.7733891
high fte per 100 births#35+	.7902087	.0110556	71.48	0.000	.76854	.8118773

As above, the direction of effect differs for age group 25-29 years.

Outcome of Kindness and Understanding :

Interaction of percentage primiparous per trust with staffing levels.




```
7 . margins workload3cat#catprimip

  Predictive margins                              Number of obs     =     16,819
  Model VCE    : OIM

  Expression   : Marginal predicted mean, predict()
```

	Margin	Delta-method Std. Err.	z	P>|z|	[95% Conf.	Interval]
workload3cat#catprimip						
low fte per 100 births#35	.7710686	.017654	43.68	0.000	.7364674	.8056698
low fte per 100 births#45	.7422563	.0115284	64.38	0.000	.7196609	.7648516
low fte per 100 births#50	.725417	.0134494	53.94	0.000	.6990567	.7517772
low fte per 100 births#55	.7002967	.0203925	34.34	0.000	.6603281	.7402653
mid fte per 100 births#35	.7884213	.0214339	36.78	0.000	.7464117	.8304309
mid fte per 100 births#45	.7420631	.0126707	58.57	0.000	.717229	.7668972
mid fte per 100 births#50	.7511723	.011208	67.02	0.000	.7292051	.7731395
mid fte per 100 births#55	.7172461	.019121	37.51	0.000	.6797697	.7547226
high fte per 100 births#35	.7497879	.0176569	42.46	0.000	.7151811	.7843947

As above, the direction of effect differs for trusts with lowest proportion of primiparous women.

S3 Full Models with Best Fit

	Multilevel models, nested in trust		
Was your discharge delayed for any reason? Model with 4 variables as best fit	Univariable OR 95% CI	Multivariable OR 95% CI	p-value Multivariable
Mothers age			
16-24	Ref		
25-29	0.898 (0.790, 1.021)	0.893 (0.784, 1.015)	0.083
30-34	0.834 (0.739, 0.942)	0.829 (0.733, 0.938)	0.003
35+	0.802 (0.709, 0.907)	0.808 (0.713, 0.915)	0.001
Type of birth			
Spontaneous birth	Ref		
Instrumental birth	1.405 (1.285, 1.536)	1.406 (1.286, 1.538)	<0.001
Planned caesarean	0.927 (0.843, 1.020)	0.950 (0.862, 1.046)	0.298
Emergency caesarean	1.045 (0.959, 1.139)	1.054 (0.967, 1.149)	0.230
trust level characteristics			
Number of births per trust (thousands)	1.000 (1.000, 1.000)	1.000 (1.000, 1.000)	0.536
FTE midwives per 100 births	0.855 (0.761, 0.961)	0.849 (0.753, 0.959)	0.008

AIC 23115.06, BIC 23192.42, BIC (129) 23143.66

Staffing levels	Univariable OR	Multivariable OR	P value
low fte per 100 births 2.543 to 3.395	Ref		
mid fte per 100 births 3.396 to 3.706	0.926 (0.823, 1.041)	0.920 (0.815, 1.037)	0.173
high fte per 100 births 3.707 to 5.217	0.797 (0.707, 0.898)	0.789 (0.697, 0.894)	<0.001

AIC 23110.7 BIC 23142.16

	Multilevel models, nested in trust		
Were you able to get a member of staff to help you within a reasonable time?	Univariable OR 95% CI	Multivariable OR 95% CI	p-value Multivariable
Mothers age			
16-24	Ref		
25-29	1.182 (1.033, 1.353)	1.206 (1.053, 1.382)	0.007
30-34	1.266 (1.114, 1.440)	1.327 (1.166, 1.511)	<0.001
35+	1.367 (1.201, 1.556)	1.473 (1.291, 1.680)	<0.001
Type of birth			
Spontaneous birth	Ref		
Instrumental birth	0.768 (0.700, 0.843)	0.769 (0.700, 0.844)	<0.001
Planned caesarean	0.709 (0.642, 0.782)	0.673 (0.609, 0.744)	<0.001
Emergency caesarean	0.700 (0.640, 0.764)	0.688 (0.629, 0.752)	<0.001
Trust level characteristics			
Percentage primiparous	0.975 (0.964, 0.986)	0.978 (0.967, 0.990)	<0.001
Proportion white ethnic group	1.008 (1.004, 1.012)	1.006 (1.001, 1.011)	0.023
Number of births per trust (thousands)	1.000 (1.000, 1.000)	1.000 (1.000, 1.000)	0.959
FTE midwives per 100 births	1.246 (1.087, 1.427)	1.200 (1.052, 1.369)	0.007

AIC 20690.76 BIC 20782.59 BIC(129) 20725.08

	Univariable OR	Multivariable OR	P value
low fte per 100 births 2.543 to 3.395	Ref		
mid fte per 100 births 3.396 to 3.706	1.120 (0.972, 1.290)	1.141 (0.999, 1.303)	0.051
high fte per 100 births 3.707 to 5.217	1.123 (1.064, 1.418)	1.191 (1.037, 1.367)	0.013

AIC 20693.01 BIC 20792.48

	Multilevel models, nested in trust		
After the birth of your baby, were you given the information or explanations you needed?	Univariable OR 95% CI	Multivariable OR 95% CI	p-value Multivariable
Mothers age			
16-24	Ref		
25-29	1.159 (1.016, 1.323)	1.177 (1.029, 1.354)	0.017
30-34	1.102 (0.972, 1.250)	1.139 (1.003, 1.293)	0.045
35+	1.273 (1.122, 1.445)	1.339 (1.177, 1.524)	<0.001
Type of birth			
Spontaneous birth	Ref		
Instrumental birth	0.610 (0.556, 0.668)	0.613 (0.560, 0.672)	<0.001
Planned caesarean	0.770 (0.698, 0.850)	0.743 (0.673, 0.821)	<0.001
Emergency caesarean	0.611 (0.560, 0.667)	0.605 (0.554, 0.661)	<0.001
Trust level characteristics			
Percentage primiparous	0.983 (0.974, 0.991)	0.986 (0.978, 0.995)	0.003
Proportion white ethnic group	1.005 (1.002, 1.008)	1.003 (0.999, 1.006)	0.177
Number of births per trust (thousands)	1.000 (1.000, 1.000)	1.000 (1.000, 1.000)	0.601
FTE midwives per 100 births	1.171 (1.059, 1.295)	1.150 (1.040, 1.271)	0.006

AIC 21590.04 BIC 21682.84 BIC(129) 21624.36

	Univariable OR	Multivariable OR	P value
low fte per 100 births 2.543 to 3.395	Ref		
mid fte per 100 births 3.396 to 3.706	1.066 (0.962, 1.182)	1.089 (0.985, 1.203)	0.096
high fte per 100 births 3.707 to 5.217	1.150 (1.035, 1.279)	1.130 (1.018, 1.255)	0.022

AIC 21593.69 BIC 21694.23

	Multilevel models		
In hospital after the birth of your baby, were you treated with kindness and understanding?	Univariable OR	Multivariable OR	p-value Multivariable
Mothers age			
16-24	Ref		
25-29	1.260 (1.095, 1.450)	1.284 (1.114, 1.481)	0.001
30-34	1.310 (1.147, 1.496)	1.384 (1.209, 1.585)	<0.001
35+	1.460 (1.276, 1.671)	1.598 (1.392, 1.835)	<0.001
Type of birth			
Spontaneous birth	Ref		
Instrumental birth	0.602 (0.545, 0.665)	0.604 (0.547, 0.668)	<0.001
Planned caesarean	0.639 (0.575, 0.711)	0.603 (0.541, 0.671)	<0.001
Emergency caesarean	0.512 (0.466, 0.562)	0.504 (0.549, 0.554)	<0.001
Trust level characteristics			
Percentage primiparous	0.978 (0.968, 0.987)	0.983 (0.973, 0.992)	<0.001
Proportion white ethnic group	1.008 (1.004, 1.012)	1.006 (1.001, 1.009)	0.007
Number of births per trust (thousands)	1.000 (1.000, 1.000)	1.000 (1.000, 1.000)	0.296
FTE midwives per 100 births	1.110 (0.988, 1.247)	1.059 (0.949, 1.181)	0.306

AIC 18772.04 BIC 18864.81 BIC(129) 18806.36

	Univariable OR	Multivariable OR	P value
low fte per 100 births 2.543 to 3.395	Ref		
mid fte per 100 births 3.396 to 3.706	1.040 (0.923, 1.172)	1.067 (0.956, 1.189)	0.246
high fte per 100 births 3.707 to 5.217	1.128 (0.998, 1.275)	1.080 (0.963, 1.211)	0.187

AIC 18772.92 BIC 18873.41

S4 Exploring dependence and assessing goodness of fit

The Intra-cluster Correlation Coefficient (ICC) represents the dependence of scores between individuals in the same group, in this case meaning the level 2 variables (trusts). If the coefficient value is high (>.10), a multilevel analysis is extremely important to reduce the risk of type I error. For each of the four outcomes the ICC is less than 0.02 which shows a relatively low level of inter-dependence of observations within groups (lack of extreme clustering). We can conclude that most of variation is within the clusters rather than between clusters. Non-hierarchical models could have been used with similar results, as the clustering effect is low in this data.

	Delay in discharge	Staff help reasonable time	Information / Explanations	Treated with kindness and understanding
ICC	0.0155	0.018	0.006	0.007

Model fit was assessed so that the model with the least AIC score was used to generate the regression coefficients and odds ratios. Where a difference of less than 2 on the AIC scores was noted then this was not acted upon as it is not considered to be discriminatory at this level (Burnham *et al.*, 2004). Both AIC and BIC were used in order not to overfit or underfit the model to the data. Results of the goodness of fit tests are presented below.

Appendix G

Selecting a model and test model fit using AIC and BIC

		Model 1 (Staffing and Number of births)	Model 2 (Model 1 plus Maternal age and Type of Birth)	Model 3 (Model 2 plus trust case mix: parity and ethnicity)	Best fit?
Delay in discharge	AIC	23368.5	23115.06	23115.99	Model 2or3
	BIC (N=Trusts)	23379.94	23143.66	23150.31	Model 2
	BIC (N=Respondents)	23399.47	23192.42	23208.82	Model 2
Help in reasonable time	AIC	21020.96	20705.63	20690.76	Model 3
	BIC (N=Trusts)	21032.4	20734.23	20725.08	Model 3
	BIC (N=Respondents)	21051.6	20782.15	20782.59	Model 2or3
Information/ Explanations	AIC	22004.9	21597.29	21590.04	Model 3
	BIC (N=Trusts)	22016.34	21625.89	21624.36	Model 2or3*
	BIC (N=Respondents)	22035.87	21674.63	21682.84	Model 2*
	AIC	19259.94	18787.82	18772.04	Model 3
	BIC (N=Trusts)	19271.38	18816.41	18806.36	Model 3
	BIC (N=Respondents)	19290.89	18865.12	18864.81	Model 3

* estimates recalculated using Model 2 for Information and understanding, FTE staffing per 100 midwives aOR 1.162 (95% CI 1.049, 1.288)

S5 Testing assumptions of the model

The assumptions of the multilevel multivariable logistic regression model were tested using guidance in Schreiber-Gregory (2018).

Dependent variable structure : dependent variable is binary

Observation independence : observations do not come from repeated measures or matched data

Large sample size : need at minimum of 10 cases with the least frequent outcome for each independent variable in your model.

Absence of multicollinearity

Predictor variables were tested for collinearity by calculating the VIF (variance inflation factor) This is an indicator of how much of the inflation of the standard error could be caused by collinearity. As a rule of thumb, a VIF of 10 or greater is a cause for concern. The results below indicate that this assumption of independence is supported.

Table : Variance Inflating Factors

Variable	Delay in discharge	Staff help reasonable time	Information / Explanations	Treated with kindness and understanding
Number births per trust	1.48	1.49	1.48	1.49
FTE per 100 births	1.06	1.06	1.06	1.06
Age group cat 2	3.04	3.05	3.05	3.04
Age group cat 3	3.73	3.72	3.74	3.73
Age group cat 4	3.73	3.722	3.74	3.73
Type birth cat2	1.08	1.09	1.08	1.08
Type birth cat3	1.10	1.11	1.10	1.10
Type birth cat4	1.09	1.10	1.09	1.09
% primip	1.08	1.08	1.08	1.08
% white	1.47	1.47	1.47	1.47

S6 Coding for STATA 16.1

Glossary

i.C7	Type birth
D3	Delay in discharge
D5	Staff help reasonable time
D6	Information / Explanations
D7	Treated with kindness and understanding
D3 binary	dichotomy of D3 (‘yes always=1) (‘yes sometimes or no=0)
D5 binary	dichotomy of D3 (‘yes always=1) (‘yes sometimes or no=0)
D6 binary	dichotomy of D3 (‘yes always=1) (‘yes sometimes or no=0)
D7 binary	dichotomy of D3 (‘yes always=1) (‘yes sometimes or no=0)
DeliveriesHES17_18	number births per trust
fte_per_100births	FTE midwives per number birth per trust
I.age_group	bands of age groups
TrustCode	unique trustCode used to link datasets
primip	%primiparous mothers per trust
white	%white mothers per trust
i.workload3cat	tertiles of fte_per_100births
i.catprimip	primip as a categorical variable

Tabulation of 4 question responses

```
tabulate D3
tabulate D5
tabulate D6
tabulate D7
```

Missing values

```
codebook D3
codebook D5
codebook D6
codebook D7
```

Tabulation by subgroup

```
tabulate age_group D3, row
tabulate age_group D5binary, row
tabulate age_group D6binary, row
tabulate age_group D7binary, row
tabulate C7 D3, row
tabulate C7 D5binary, row
tabulate C7 D6binary, row
tabulate C7 D7binary, row
tabulate workload3cat D3, row
tabulate workload3cat D5binary, row
tabulate workload3cat D6binary, row
tabulate workload3cat D7binary, row
```

Models including model fit

```
melogit D3binary DeliveriesHES17_18 fte_per_100births ||TrustCode:, or
estat ic, n(129)
estat ic
```

```
melogit D3binary DeliveriesHES17_18 fte_per_100births i.age_group i.C7 ||TrustCode:, or
estat ic, n(129)
estat ic
melogit D3binary DeliveriesHES17_18 fte_per_100births i.age_group i.C7 primip white
||TrustCode:, or
estat ic, n(129)
estat ic
melogit D5binary DeliveriesHES17_18 fte_per_100births ||TrustCode:, or
estat ic, n(129)
estat ic
melogit D5binary DeliveriesHES17_18 fte_per_100births i.age_group i.C7 ||TrustCode:, or
estat ic, n(129)
estat ic
melogit D5binary DeliveriesHES17_18 fte_per_100births i.age_group i.C7 primip white
||TrustCode:, or
estat ic, n(129)
estat ic
melogit D6binary DeliveriesHES17_18 fte_per_100births ||TrustCode:, or
estat ic, n(129)
estat ic
melogit D6binary DeliveriesHES17_18 fte_per_100births i.age_group i.C7 ||TrustCode:, or
estat ic, n(129)
estat ic
melogit D6binary DeliveriesHES17_18 fte_per_100births i.age_group i.C7 primip white
||TrustCode:, or
estat ic, n(129)
estat ic
melogit D7binary DeliveriesHES17_18 fte_per_100births ||TrustCode:, or
estat ic, n(129)
estat ic
melogit D7binary DeliveriesHES17_18 fte_per_100births i.age_group i.C7 ||TrustCode:, or
estat ic, n(129)
estat ic
melogit D7binary DeliveriesHES17_18 fte_per_100births i.age_group i.C7 primip white
||TrustCode:, or
estat ic, n(129)
estat ic
```

Models including staffing grouped as tertiles

```
melogit D3binary DeliveriesHES17_18 i.workload3cat i.age_group i.C7 || TrustCode:, or
melogit D5binary DeliveriesHES17_18 i.workload3cat i.age_group i.C7 white primip ||
TrustCode:, or
melogit D6binary DeliveriesHES17_18 i.workload3cat i.age_group i.C7 white primip ||
TrustCode:, or
melogit D7binary DeliveriesHES17_18 i.workload3cat i.age_group i.C7 white primip ||
TrustCode:, or
```

Calculating predicted risk differences for staffing effects

```
melogit D3binary DeliveriesHES17_18 i.workload3cat i.age_group i.C7 || TrustCode:, or
margins workload3cat
margins, dydx(workload3cat)
melogit D5binary DeliveriesHES17_18 i.workload3cat i.age_group i.C7 white primip ||
TrustCode:, or
margins workload3cat
margins, dydx(workload3cat)
melogit D6binary DeliveriesHES17_18 i.workload3cat i.age_group i.C7 white primip ||
TrustCode:, or
margins workload3cat
margins, dydx(workload3cat)
melogit D7binary DeliveriesHES17_18 i.workload3cat i.age_group i.C7 white primip ||
TrustCode:, or
margins workload3cat
margins, dydx(workload3cat)
```

Checking model fit when adding Interaction variables (examples)

```
melogit D7binary DeliveriesHES17_18 c.fte_per_100births##c.primip i.age_group i.C7 white
||TrustCode:, or
estat ic, n(129)
estat ic
melogit D7binary DeliveriesHES17_18 c.fte_per_100births##i.age_group primip i.C7 white
||TrustCode:, or
estat ic, n(129)
estat ic
```

Plotting Interactions

```
melogit D7binary DeliveriesHES17_18 c.fte_per_100births##i.age_group i.C7 white primip
||TrustCode:, or
margins age_group, at(fte_per_100births=(2.5(0.1)5.5)) plot
melogit D7binary DeliveriesHES17_18 c.fte_per_100births##i.catprimip i.age_group i.C7 white
||TrustCode:,or
margins catprimip, at(fte_per_100births=(2.5(0.1)5.5)) plot
```

Diagnostics

```
melogit D3binary i.age_group i.C7 primip white DeliveriesHES17_18 fte_per_100births
||TrustCode:, or
estat ic
estat icc

regress D3binary DeliveriesHES17_18 fte_per_100births i.age_group i.C7 primip white
vif
regress D5binary DeliveriesHES17_18 fte_per_100births i.age_group i.C7 primip white
vif
regress D6binary DeliveriesHES17_18 fte_per_100births i.age_group i.C7 primip white
vif
regress D7binary DeliveriesHES17_18 fte_per_100births i.age_group i.C7 primip white
vif
```

Univariable analyses

```
melogit D3binary i.age_group ||TrustCode:, or
melogit D3binary i.C7 ||TrustCode:, or
melogit D3binary white ||TrustCode:, or
melogit D3binary white ||TrustCode:, or
melogit D3binary primip ||TrustCode:, or
melogit D3binary DeliveriesHES17_18 ||TrustCode:, or
melogit D3binary fte_per_100births ||TrustCode:, or
melogit D3binary i.workload3cat ||TrustCode:, or

melogit D5binary i.age_group ||TrustCode:, or
melogit D5binary i.C7 ||TrustCode:, or
melogit D5binary white ||TrustCode:, or
melogit D5binary primip ||TrustCode:, or
melogit D5binary DeliveriesHES17_18 ||TrustCode:, or
melogit D5binary fte_per_100births ||TrustCode:, or
melogit D5binary i.workload3cat ||TrustCode:, or

melogit D6binary i.age_group ||TrustCode:, or
melogit D6binary i.C7 ||TrustCode:, or
melogit D6binary primip ||TrustCode:, or
melogit D6binary white ||TrustCode:, or
melogit D6binary DeliveriesHES17_18 ||TrustCode:, or
melogit D6binary fte_per_100births ||TrustCode:, or
melogit D6binary i.workload3cat ||TrustCode:, or

melogit D7binary i.age_group ||TrustCode:, or
melogit D7binary i.C7 ||TrustCode:, or
melogit D7binary primip ||TrustCode:, or
melogit D7binary white ||TrustCode:, or
melogit D7binary DeliveriesHES17_18 ||TrustCode:, or
melogit D7binary fte_per_100births ||TrustCode:, or
melogit D7binary i.workload3cat ||TrustCode:, or
```

Data obtained from the UK Data Service/UK Data Archive, including subsets and derived data, *cannot* be submitted to journals alongside publications as this would be a breach of the End User Licence (EUL)

https://www.ukdataservice.ac.uk/help/faq/publication.aspx#Journals

Appendix H Study 2 Supplementary material

S1 Variable selection to go into the model – testing assumption of independence then model fit

S2 Distribution of staffing data

S3 Univariable analyses for age group, parity, type of birth, ethnicity, number of births in the Trust, response rate and medical staff

S4 Relationship between staffing and patient experience at Trust level (univariable)

S5 Relationship between staffing and patient experience at Trust level (adjusted models)

S6 Relationship between staffing and patient experience at postnatal ward level (univariable)

S7 Relationship between staffing and patient experience at postnatal ward level (adjusted models)

S8 Relationship between Overall staffing, Skill mix and patient experience at postnatal ward level (adjusted models, which were best fit according to AIC)

S9 Coding

S10 Sensitivity analysis after removing outliers

S11 Sensitivity analysis : Testing model fit using AIC and BIC when including interaction variables

S12 Sensitivity analyses using alternative dichotomy of question responses

S13 Null models for four questions and intra-class correlation coefficients

S1 Variable selection to go into the model – testing assumption of independence then model fit

The following do not appear to be collinear as the VIF is less than 10, therefore safe to go into model together for each of these outcome measures.

Question : DELAY

Variable	VIF	1/VIF
Age_group		
2	3.28	0.304594
3	4.31	0.231965
4	4.41	0.226595
2.Parity	1.21	0.823875
Typebirth		
2	1.19	0.840593
3	1.11	0.900374
4	1.15	0.869647
white	1.82	0.549811
Response_r~e	1.39	0.719052
annualbirt~S	1.35	0.742409
FTEper100b~s	1.22	0.820817
CHPPDRegis~i	1.37	0.732083
CHPPDHealt~e	1.32	0.755888
OG100births	1.15	0.868978
Mean VIF	1.88	

Question : HELP TIMELY WAY

Variable	VIF	1/VIF
Age_group		
2	3.26	0.306849
3	4.25	0.235546
4	4.35	0.230030
2.Parity	1.21	0.828524
Typebirth		
2	1.20	0.834757
3	1.13	0.886085
4	1.16	0.861295
white	1.82	0.548781
Response_r~e	1.40	0.716831
annualbirt~S	1.34	0.747088
FTEper100b~s	1.21	0.824564
CHPPDRegis~i	1.37	0.731649
CHPPDHealt~e	1.33	0.754309
OG100births	1.15	0.869084
Mean VIF	1.87	

Question : INFO

Variable	VIF	1/VIF
Age_group		
2	3.30	0.303160
3	4.34	0.230553
4	4.45	0.224800
2.Parity	1.21	0.823213
Typebirth		
2	1.19	0.840473
3	1.11	0.899574
4	1.15	0.869275
white	1.81	0.551760
Response_r~e	1.39	0.719972
annualbirt~S	1.34	0.744157
FTEper100b~s	1.22	0.819861
CHPPDRegis~i	1.37	0.732450
CHPPDHealt~e	1.32	0.755162
OG100births	1.15	0.867988
Mean VIF	1.88	

Question : KINDNESS

Variable	VIF	1/VIF
Age_group		
2	3.28	0.304847
3	4.31	0.231929
4	4.42	0.226335
2.Parity	1.21	0.824229
Typebirth		
2	1.19	0.841008
3	1.11	0.899987
4	1.15	0.869704
white	1.82	0.550350
Response_r~e	1.39	0.719667
annualbirt~S	1.35	0.743490
FTEper100b~s	1.22	0.819662
CHPPDRegis~i	1.37	0.732591
CHPPDHealt~e	1.32	0.756552
OG100births	1.15	0.868089
Mean VIF	1.88	

SELECTING MODELS OF BEST FIT : Text in red shows model chosen for main analysis

		AIC	BIC	BIC(93)	
NO DELAY	TRUST MEASURED STAFFING	AIC	BIC	BIC(93)	
	null model	17558.93	17573.83	17563.98	
	No_delay_binary ib3.Age_group i.Parity white i.Typebirth FTEper100births	16856.16	16937.82	16884.02	Improved model fit?
	add response rate	16856.26	16945.34	16886.66	No
	add number births	16858.15	16947.23	16888.54	No
	add O&G per 100 births	16858.06	16947.14	16888.45	No
	WARD MEASURED STAFFING	AIC	BIC	BIC(93)	
	No_delay_binary ib3.Age_group i.Parity white i.Typebirth CHPPDRegisteredNursesandMi CHPPDHealthcareSupportWorke ||TrustCode:, or	16989.47	17078.65	17019.86	Improved model fit?
	add response rate	16991	17087.61	17023.93	No
	add number births	16991.23	17087.85	17024.16	No
	add O&G per 100 births	16859.22	16955.72	16892.14	Yes
	WARD MEASURED : TOTAL STAFF AND SKILL MIX	AIC	BIC	BIC(93)	
	No_delay_binary ib3.Age_group i.Parity white i.Typebirth OverallCHPPD PercReg ||TrustCode:, or	16989.11	17078.29	17019.51	Improved model fit?
	add response rate	16990.7	17087.31	17023.62	No
	add number births	16990.88	17087.49	17023.8	No
	add O&G per 100 births	16858.7	16955.2	16891.62	Yes
HELP	TRUST MEASURED	AIC	BIC	BIC(93)	
	null model	15864.99	15879.78	15870.06	
	Help_binary ib3.Age_group i.Parity white i.Typebirth FTEper100births	15210.56	15291.48	15238.41	Improved model fit?
	add response rate	15211.71	15300	15242.11	No
	add number births	15210.05	15298.33	15240.44	No
	add O&G per 100 births	15212.54	15300.82	15242.93	No
	WARD MEASURED	AIC	BIC	BIC(93)	
	Help_binary ib3.Age_group i.Parity white i.Typebirth CHPPDRegisteredNursesandMi CHPPDHealthcareSupportWorke ||TrustCode:, or	15308.74	15397.13	15339.13	Improved model fit?
	add response rate	15310.64	15406.39	15343.56	No
	add number births	15307.17	15402.92	15340.1	No
	add O&G per 100 births	15210.85	15306.49	15243.77	Yes
	WARD MEASURED : TOTAL STAFF AND SKILL MIX	AIC	BIC	BIC(93)	
	Help_binary ib3.Age_group i.Parity white i.Typebirth OverallCHPPD PercReg ||TrustCode:, or	15308.15	15396.54	15338.54	Improved model fit?
	add response rate	15310.07	15405.82	15343	No
	add number births	15306.55	15402.31	15339.48	No
	add O&G per 100 births	15210.03	15305.67	15242.96	Yes
	interaction overall staff and skill mix				

		AIC	BIC	BIC(93)	
INFO	TRUST MEASURED	AIC	BIC	BIC(93)	
	null model	16374.35	16389.26	16379.41	
	Info_binary ib3.Age_group i.Parity white i.Typebirth FTEper100births	15474.65	15556.26	15502.51	Improved model fit?
	add response rate	15476.03	15565.05	15506.42	No
	add number births	15476.39	15565.41	15506.78	No
	add O&G per 100 births	15476.51	15565.54	15506.91	No
	WARD MEASURED	AIC	BIC	BIC(93)	
	Info_binary ib3.Age_group i.Parity white i.Typebirth CHPPDRegisteredNursesandMi CHPPDHealthcareSupportWorke ||TrustCode:, or	15594.84	15683.96	15625.23	Improved model fit?
	add response rate	15596.84	15693.39	15629.76	No
	add number births	15595.89	15692.44	15628.81	No
	add O&G per 100 births	15481.7	15578.14	15514.62	Yes
	WARD MEASURED : TOTAL STAFF AND SKILL MIX	AIC	BIC	BIC(93)	
	Info_binary ib3.Age_group i.Parity white i.Typebirth OverallCHPPD PercReg ||TrustCode:, or	15594.88	15684.01	15625.28	Improved model fit?
	add response rate	15596.88	15693.44	15629.81	No
	add number births	15595.92	15692.48	15628.85	No
	add O&G per 100 births	15481.78	15578.22	15514.7	Yes
KINDNESS	TRUST MEASURED	AIC	BIC	BIC(93)	
	null model	14288.45	14303.37	14293.51	
	Kind_binary ib3.Age_group i.Parity white i.Typebirth FTEper100births	13545.28	13626.94	13573.14	Improved model fit?
	add response rate	13546.39	13635.47	13576.78	No
	add number births	13545.26	13634.35	13575.66	No
	add O&G per 100 births	13547.26	13636.35	13577.65	No
	WARD MEASURED	AIC	BIC	BIC(93)	
	Kind_binary ib3.Age_group i.Parity white i.Typebirth CHPPDRegisteredNursesandMi CHPPDHealthcareSupportWorke ||TrustCode:, or	13622.58	13711.77	13652.98	Improved model fit?
	add response rate	13624.31	13720.93	13657.23	No
	add number births	13621.84	13718.46	13654.76	No
	add O&G per 100 births	13545.12	13641.63	13578.05	Yes
	WARD MEASURED : TOTAL STAFF AND SKILL MIX	AIC	BIC	BIC(93)	Improved model fit?
	Kind_binary ib3.Age_group i.Parity white i.Typebirth OverallCHPPD PercReg ||TrustCode:, or	13622.13	13711.32	13652.52	
	add response rate	13623.88	13720.5	13656.81	No
	add number births	13621.37	13717.99	13654.3	No
	add O&G per 100 births	13544.51	13641.02	13577.43	Yes

S2 Distribution of staffing data

The patterns of data according to Registered staff and Support staff within Trusts can be seen below.

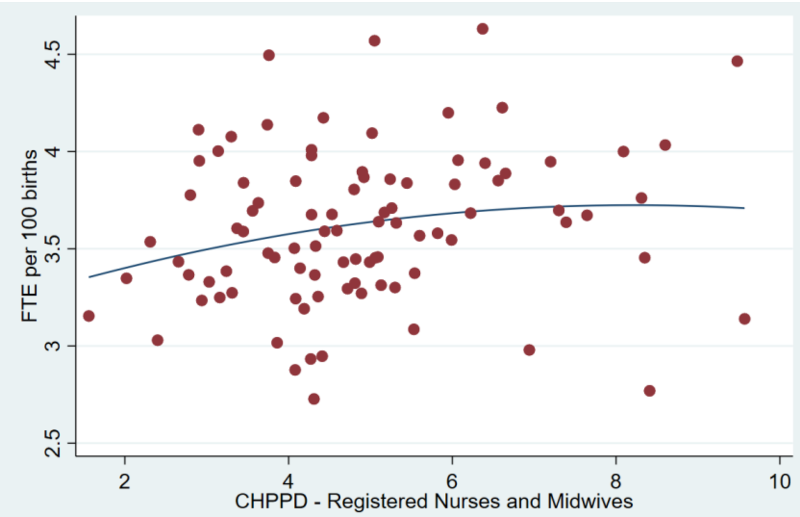
Distribution of Trusts according to Registered and Support staff by tertile

Number of Trusts	Low support staff CHPPD tertile (0.26-2.19)	Mid support staff CHPPD tertile (2.22-2.91)	HIgh support staff CHPPD tertile (2.95-6.45)	Total
Low Registered CHPPD tertile (1.56-4.14)	21*	7	3	31
Mid Registered CHPPD tertile (4.19-5.17)	5	13	13	31
High Registered CHPPD tertile (5.24-9.57)	6	10	15	31
Total	32	30	31	93

*two Trusts on the border had identical values for support worker staffing, therefore 21 in this category

Trust level(y) and ward level (x) measures of staffing appear to have little relationship between them (on visual inspection).

Scatterplot of Registered staff CHPPD and FTE midwives per organisation



A weak relationship is seen when Pearson and Spearmans coefficients are calculated.

Pearson Correlation coefficient between these two variables is 0.1388, p=0.000
This measures of the strength of a linear association between two variables.
Spearman's rho = 0.1974 Nonparametric test of independence, Prob > |t| = 0.0000

S3 Univariable analyses for age group, parity, type of birth, ethnicity, number of births in the Trust, response rate and medical staff

Question related to being Discharged without delay

		Indication of model fit
	Empty model	AIC 17558.92
Age group (comparison 30-34) 16- 25 year olds 25 - 29 year olds 35+ year olds	 1.26 (1.09, 1.46) 1.07 (0.97, 1,17) 0.97 (0.89, 1.05)	 AIC 17551
Parity (comparison primiparous) Multiparous	 1.43 (1.33, 1.53)	 AIC 17228.36
Type birth (comparison spontaneous birth) instrumental birth planned caesarean emergency caesarean	 0.67 (0.61, 0.74) 1.08 (0.97, 1.20) 0.87 (0.78, 0.96)	 AIC 17259.94
% white ethnicity	1.00 (1.00, 1.00)	AIC 17559.11
Number of births in Trust per year	1.00 (1.00, 1.00)	AIC 17559.5
% response rate per Trust	1.00 (1.00, 1.01)	AIC 17559.71
FTE O&Gper100births	1.00 (0.77, 1.31)	AIC 17424.37

Question related to Always having help when needed it

		Indication of model fit
	Empty model	AIC 15864.99
Age group (comparison 30-34) 16 – 25 year olds 25 - 29 year olds 35+ year olds	 0.95 (0.82, 1.11) 1.02 (0.92, 1.13) 1.00 (1.52, 1.80)	 AIC 15870.32
Parity (comparison primiparous) Multiparous	 .701 (.653, .753)	 AIC 15588.74
Type birth (comparison spontaneous birth) instrumental birth planned caesarean emergency caesarean	 .649 (.583, .723) .691 (.619, .771) .680 (.613, .754)	 AIC 15536.37
% white ethnicity	1.006 (1.001, 1.010)	AIC 15862.09
Number of births in Trust per year	1.000 (1.000, 1.000)	AIC 15859.81
% response rate per Trust	1.007 (.997, 1.017)	AIC 15865.23
FTE O&Gper100births	.950 (.670, 1.347)	AIC 15766.32

Appendix H

Question related to Always having Info and explanations

		Indication of model fit
	Empty model	AIC 16374.35
Age group (comparison 30-34) 16 – 25 year olds 25 - 29 year olds 35+ year olds	 1.01 (0.86, 1.18) 0.97 (0.88, 1.08) 1.09 (1.00, 1.18)	 AIC 16374.9
Parity (comparison primiparous) Multiparous	 1.823 (1.691, 1.967)	 AIC 15890.25
Type birth (comparison spontaneous birth) instrumental birth planned caesarean emergency caesarean	 .527 (.475, .587) .738 (.660, .825) .548 (.495, .607)	 AIC 15954.53
% white ethnicity	1.004 (1.000, 1.008)	AIC 16372.26
Number of births in Trust per year	1.000 (1.000, 1.000)	AIC 16372.45
% response rate per Trust	1.004 (.995, 1.012)	AIC 16375.57
FTE O&Gper100births	.947 (.706, 1.271)	AIC 16267.14

Question related to Always being treated kindness and understanding

		Indication of model fit
	Empty model	AIC 14288.45
Age group (comparison 30-34) 16 - 25 year olds 25 - 29 year olds 35+ year olds	 0.76 (0.64, 0.89) 1.03 (0.92, 1.16) 1.04 (0.95, 1.15)	 AIC 14279.93
Parity (comparison primiparous) Multiparous	 1.731 (1.592, 1.881)	 AIC 13916.3
Type birth (comparison spontaneous birth) instrumental birth planned caesarean emergency caesarean	 .561 (.500, .631) .627 (.557, .707) .512 (.458, .571)	 AIC 13920.35
% white ethnicity	1.006 (1.002, 1.011)	AIC 14282.91
Number of births in Trust per year	1.000 (1.000, 1.000)	AIC 14283.7
% response rate per Trust	1.008 (.999, 1.018)	AIC 14287.22
FTE O&Gper100births	.893 (.639, 1.247)	AIC 14210.48

S4 Relationship between staffing and patient experience at Trust level (univariable)

Question related to being Discharged without delay

No_delay_binary	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
FTEper100births	**1.158181**	**.0796622**	**2.14**	**0.033**	**1.012113**	**1.32533**

Question related to Always having help when needed it

Help_binary	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
FTEper100births	**1.180279**	**.1067003**	**1.83**	**0.067**	**.9886298**	**1.409079**

Question related to Always having Info and explanations

Kind_binary	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
FTEper100births	**1.107811**	**.0974954**	**1.16**	**0.245**	**.9322958**	**1.316369**

Question related to Always being treated kindness and understanding

Info_binary	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
FTEper100births	**1.216374**	**.0917152**	**2.60**	**0.009**	**1.049267**	**1.410094**

Mid and Highest tertile compared with lowest tertile as the reference group

Question related to being Discharged without delay

No_delay_binary	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
tertile_FTEper100births						
Mid	1.062613	.0680112	0.95	0.343	.937335	1.204634
High	1.16991	.0771611	2.38	0.017	1.028044	1.331353

Question related to Always having help when needed it

Help_binary	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
tertile_FTEper100births						
Mid	1.063952	.090884	0.73	0.468	.8999356	1.257861
High	1.156302	.1008854	1.66	0.096	.9745526	1.371946

Question related to Always having Info and explanations

Info_binary	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
tertile_FTEper100births						
Mid	1.05398	.0739439	0.75	0.454	.9185756	1.209345
High	1.217423	.0881948	2.72	0.007	1.056275	1.403155

Question related to Always being treated kindness and understanding

Kind_binary	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
tertile_FTEper100births						
Mid	1.058578	.0875082	0.69	0.491	.9002386	1.244767
High	1.092482	.0926134	1.04	0.297	.925241	1.289952

S5 Relationship between staffing and patient experience at Trust level (adjusted models)

Question related to being Discharged without delay

No_delay_binary	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Age_group						
16 - 25 year olds	.8290465	.064717	-2.40	0.016	.7114303	.9661074
25 - 29 year olds	.9539742	.0483773	-0.93	0.353	.8637163	1.053664
35+ year olds	.9737298	.0424191	-0.61	0.541	.8940404	1.060522
Parity						
Multiparous	1.325131	.0533965	6.99	0.000	1.224501	1.434029
white	1.001709	.0019056	0.90	0.369	.9979812	1.005451
Typebirth						
An assisted vaginal birth	.7515481	.0417945	-5.14	0.000	.6739388	.8380947
A planned caesarean birth	1.032393	.0577177	0.57	0.569	.9252456	1.151948
An emergency caesarean birth	.935154	.0493424	-1.27	0.204	.8432772	1.037041
FTEper100births	1.133439	.0794059	1.79	0.074	.9880181	1.300263

No_delay_binary	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Age_group						
16 - 25 year olds	.8282041	.0646564	-2.41	0.016	.7106988	.9651374
25 - 29 year olds	.9536996	.0483644	-0.93	0.350	.8634658	1.053363
35+ year olds	.9732645	.0423909	-0.62	0.534	.8936273	1.059999
Parity						
Multiparous	1.324803	.0533829	6.98	0.000	1.2242	1.433674
white	1.002183	.0018784	1.16	0.245	.9985078	1.005871
Typebirth						
An assisted vaginal birth	.7515738	.0417944	-5.14	0.000	.6739644	.8381201
A planned caesarean birth	1.032088	.0577018	0.56	0.572	.9249705	1.15161
An emergency caesarean birth	.9351167	.0493401	-1.27	0.204	.8432442	1.036999
tertile_FTEper100births						
Mid	1.04587	.0673003	0.70	0.486	.9219432	1.186455
High	1.146939	.0758403	2.07	0.038	1.007524	1.305645

Appendix H

Question related to Always having help when needed it

Help_binary	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Age_group						
16 - 25 year olds	.9371872	.0774459	-0.79	0.432	.7970508	1.101962
25 - 29 year olds	1.015021	.0547677	0.28	0.782	.9131591	1.128245
35+ year olds	.9949463	.046127	-0.11	0.913	.9085249	1.089588
Parity						
Multiparous	1.267841	.0544251	5.53	0.000	1.165534	1.379128
white	1.004376	.0024313	1.80	0.071	.9996219	1.009152
Typebirth						
An assisted vaginal birth	.7085038	.0409379	-5.96	0.000	.6326435	.7934604
A planned caesarean birth	.6665222	.0384535	-7.03	0.000	.5952597	.746316
An emergency caesarean birth	.7204055	.0393739	-6.00	0.000	.6472237	.8018619
FTEper100births	1.124908	.1012676	1.31	0.191	.9429514	1.341976

Help_binary	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Age_group						
16 - 25 year olds	.9367203	.0774155	-0.79	0.429	.7966401	1.101432
25 - 29 year olds	1.014982	.0547688	0.28	0.783	.9131188	1.128209
35+ year olds	.9945995	.0461062	-0.12	0.907	.9082167	1.089198
Parity						
Multiparous	1.267747	.0544216	5.53	0.000	1.165447	1.379027
white	1.004866	.0024098	2.02	0.043	1.000154	1.009601
Typebirth						
An assisted vaginal birth	.7084349	.0409331	-5.97	0.000	.6325835	.7933813
A planned caesarean birth	.6664399	.0384497	-7.03	0.000	.5951846	.7462259
An emergency caesarean birth	.7204517	.0393765	-6.00	0.000	.647265	.8019136
tertile_FTEper100births						
Mid	1.031155	.0862913	0.37	0.714	.8751685	1.214943
High	1.123365	.0956068	1.37	0.172	.9507738	1.327286

Question related to Always having Info and explanations

Info_binary	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Age_group						
16 - 25 year olds	1.07934	.0896794	0.92	0.358	.9171368	1.270229
25 - 29 year olds	.9955578	.0533371	-0.08	0.934	.8963203	1.105782
35+ year olds	1.021566	.0471854	0.46	0.644	.9331471	1.118363
Parity						
Multiparous	1.670548	.0716108	11.97	0.000	1.535928	1.816968
white	1.002786	.0020505	1.36	0.174	.9987756	1.006813
Typebirth						
An assisted vaginal birth	.6393692	.0365835	-7.82	0.000	.5715412	.7152468
A planned caesarean birth	.6932869	.0406211	-6.25	0.000	.6180725	.7776544
An emergency caesarean birth	.6272416	.0341649	-8.56	0.000	.5637301	.6979085
FTEper100births	1.164132	.088023	2.01	0.044	1.003785	1.350093

Info_binary	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Age_group						
16 - 25 year olds	1.078169	.0895948	0.91	0.365	.9161211	1.268881
25 - 29 year olds	.9955632	.0533407	-0.08	0.934	.8963195	1.105796
35+ year olds	1.021006	.0471499	0.45	0.653	.9326529	1.11773
Parity						
Multiparous	1.670211	.0715952	11.97	0.000	1.53562	1.816598
white	1.003452	.0020161	1.72	0.086	.9995085	1.007411
Typebirth						
An assisted vaginal birth	.6394202	.0365848	-7.82	0.000	.5715897	.7153001
A planned caesarean birth	.6930553	.0406085	-6.26	0.000	.6178642	.7773967
An emergency caesarean birth	.6272258	.0341636	-8.56	0.000	.5637166	.69789
tertile_FTEper100births						
Mid	1.031172	.0711696	0.44	0.656	.9007055	1.180537
High	1.186799	.0843826	2.41	0.016	1.032419	1.364264

Question related to Always being treated kindness and understanding

Full model results for Kindness

Kind_binary	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Age_group						
16 - 25 year olds	.7878058	.0683271	-2.75	0.006	.6646511	.9337801
25 - 29 year olds	1.05724	.0627745	0.94	0.349	.9410937	1.187721
35+ year olds	1.01313	.051319	0.26	0.797	.9173785	1.118876
Parity						
Multiparous	1.580659	.0748189	9.67	0.000	1.440613	1.734319
white	1.004817	.0024185	2.00	0.046	1.000088	1.009568
Typebirth						
An assisted vaginal birth	.6653412	.0414274	-6.54	0.000	.588904	.7516997
A planned caesarean birth	.5869838	.037083	-8.43	0.000	.518622	.6643566
An emergency caesarean birth	.5774266	.0337823	-9.39	0.000	.5148697	.6475842
FTEper100births	1.052926	.0939693	0.58	0.563	.8839578	1.254192

Kind_binary	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Age_group						
16 - 25 year olds	.7872564	.0682833	-2.76	0.006	.6641812	.9331379
25 - 29 year olds	1.057088	.0627662	0.94	0.350	.9409571	1.187552
35+ year olds	1.013047	.0513081	0.26	0.798	.9173148	1.118769
Parity						
Multiparous	1.580425	.0748071	9.67	0.000	1.440401	1.73406
white	1.004978	.0023942	2.08	0.037	1.000296	1.009682
Typebirth						
An assisted vaginal birth	.6654428	.0414328	-6.54	0.000	.5889955	.7518124
A planned caesarean birth	.5868714	.0370771	-8.44	0.000	.5185208	.6642319
An emergency caesarean birth	.5773561	.033778	-9.39	0.000	.5148071	.6475047
tertile_FTEper100births						
Mid	1.028349	.0849557	0.34	0.735	.8746209	1.209098
High	1.069988	.0903006	0.80	0.423	.9068653	1.262453

S6 Relationship between staffing and patient experience at postnatal ward level (univariable)

Question related to being Discharged without delay

Delay_binary	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
CHPPDOverall	.9889771	.0119179	-0.92	0.358	.9658922	1.012614

Delay_binary	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
percentage_Registered	1.005315	.003466	1.54	0.124	.9985452	1.012132

No_delay_binary	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
CHPPDRegisteredNursesandMi	1.00527	.0170368	0.31	0.756	.9724266	1.039222

No_delay_binary	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
CHPPDHealthcareSupportWorke	1.045618	.028787	1.62	0.105	.9906917	1.103589

Question related to Always having help when needed it

Help_binary	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
CHPPDOverall	1.02516	.0161411	1.58	0.115	.9940073	1.057289

Help_binary	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
percentage_Registered	.9937852	.0045203	-1.37	0.171	.984965	1.002685

Help_binary	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
CHPPDRegisteredNursesandMi	1.022373	.0228094	0.99	0.321	.9786306	1.06807

Help_binary	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
CHPPDHealthcareSupportWorke	1.075082	.038569	2.02	0.044	1.002084	1.153396

Question related to Always having Info and explanations

Info_binary	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
CHPPDOverall	1.015671	.013498	1.17	0.242	.9895565	1.042474

Info_binary	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
percentage_Registered	1.000623	.0038707	0.16	0.872	.9930652	1.008238

Info_binary	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
CHPPDRegisteredNursesandMi	1.021081	.0190565	1.12	0.264	.9844059	1.059123

Info_binary	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
CHPPDHealthcareSupportWorke	1.026444	.0315522	0.85	0.396	.9664284	1.090186

Question related to Always being treated kindness and understanding

Kind_binary	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
CHPPDOverall	1.030706	.0154194	2.02	0.043	1.000923	1.061375

Kind_binary	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
percentage_Registered	.9966913	.0043881	-0.75	0.452	.9881279	1.005329

Kind_binary	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
CHPPDRegisteredNursesandMi	**1.035198**	**.0219393**	**1.63**	**0.103**	**.9930784**	**1.079104**

Kind_binary	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
CHPPDHealthcareSupportWorke	**1.069358**	**.0369238**	**1.94**	**0.052**	**.9993829**	**1.144232**

S7 Relationship between staffing and patient experience at postnatal ward level (adjusted models)

Question related to being Discharged without delay (Individual staff groups)

No_delay_binary	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Age_group						
16 - 25 year olds	.833683	.0650615	-2.33	0.020	.7154385	.9714704
25 - 29 year olds	.954085	.0483831	-0.93	0.354	.8638163	1.053787
35+ year olds	.971303	.0423172	-0.67	0.504	.8918052	1.057887
Parity						
Multiparous	1.326825	.0534621	7.02	0.000	1.226072	1.435858
white	1.002528	.001944	1.30	0.193	.9987248	1.006345
Typebirth						
An assisted vaginal birth	.7499334	.0417066	-5.17	0.000	.6724875	.8362982
A planned caesarean birth	1.032992	.0577504	0.58	0.562	.9257843	1.152615
An emergency caesarean birth	.9365593	.0494174	-1.24	0.214	.8445431	1.038601
CHPPDRegisteredNursesandMi	.9797909	.0182853	-1.09	0.274	.9446	1.016293
CHPPDHealthcareSupportWorke	1.063569	.0322758	2.03	0.042	1.002154	1.128748
OG100births	1.041192	.1418475	0.30	0.767	.797199	1.359862

No_delay_binary	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Age_group						
16 - 25 year olds	.8325794	.0649844	-2.35	0.019	.7144762	.9702052
25 - 29 year olds	.9549952	.0484376	-0.91	0.364	.8646255	1.05481
35+ year olds	.9723116	.042367	-0.64	0.519	.8927209	1.058998
Parity						
Multiparous	1.327145	.0534803	7.02	0.000	1.226358	1.436215
white	1.002099	.001979	1.06	0.288	.9982272	1.005985
Typebirth						
An assisted vaginal birth	.7504746	.0417408	-5.16	0.000	.6729656	.8369107
A planned caesarean birth	1.032342	.0577203	0.57	0.569	.9251905	1.151903
An emergency caesarean birth	.9358985	.0493853	-1.26	0.209	.8439423	1.037874
TertileRegCHPPD						
Mid	.9052446	.0701793	-1.28	0.199	.777636	1.053794
High	.9918566	.0745782	-0.11	0.913	.8559465	1.149347
TertileSupportCHPPD						
Mid	1.063565	.0767745	0.85	0.393	.9232499	1.225205
High	1.08514	.0834272	1.06	0.288	.9333496	1.261617
OG100births	1.056639	.1505106	0.39	0.699	.7992434	1.396928

Question related to Always having help when needed it (Individual staff groups)

Help_binary	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Age_group						
16 - 25 year olds	.9410591	.0777436	-0.74	0.462	.8003808	1.106464
25 - 29 year olds	1.015228	.054772	0.28	0.779	.9133573	1.12846
35+ year olds	.9926009	.0460159	-0.16	0.873	.9063874	1.087015
Parity						
Multiparous	1.269739	.0544987	5.56	0.000	1.167293	1.381176
white	1.005061	.0024287	2.09	0.037	1.000312	1.009833
Typebirth						
An assisted vaginal birth	.7076899	.0408908	-5.98	0.000	.631917	.7925487
A planned caesarean birth	.6668367	.0384679	-7.02	0.000	.595547	.7466601
An emergency caesarean birth	.7215008	.0394285	-5.97	0.000	.648217	.8030696
CHPPDRegisteredNursesandMi	.9837475	.0232524	-0.69	0.488	.9392131	1.030394
CHPPDHealthcareSupportWorke	1.09231	.0418682	2.30	0.021	1.013257	1.177532
OG100births	1.051442	.1803129	0.29	0.770	.7512976	1.471495

Help_binary	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Age_group						
16 - 25 year olds	.9410204	.0777125	-0.74	0.462	.8003944	1.106354
25 - 29 year olds	1.015657	.0547876	0.29	0.773	.9137569	1.128921
35+ year olds	.9938622	.0460664	-0.13	0.894	.9075534	1.088379
Parity						
Multiparous	1.270143	.0545097	5.57	0.000	1.167676	1.381602
white	1.005049	.0023799	2.13	0.033	1.000395	1.009724
Typebirth						
An assisted vaginal birth	.707054	.0408537	-6.00	0.000	.6313497	.7918358
A planned caesarean birth	.6659584	.0384152	-7.05	0.000	.5947662	.7456721
An emergency caesarean birth	.7201039	.0393463	-6.01	0.000	.6469723	.801502
TertileRegCHPPD						
Mid	.7674661	.0718697	-2.83	0.005	.6387752	.9220837
High	.8866464	.0808112	-1.32	0.187	.7416001	1.060062
TertileSupportCHPPD						
Mid	1.127912	.0985365	1.38	0.168	.9504134	1.33856
High	1.279189	.1189803	2.65	0.008	1.066013	1.534995
OG100births	1.173787	.2024301	0.93	0.353	.8371282	1.645836

Question related to Always having help when needed it (Individual staff groups)

Info_binary	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Age_group						
16 - 25 year olds	1.084671	.0901048	0.98	0.328	.9216958	1.276463
25 - 29 year olds	.9966935	.0534036	-0.06	0.951	.897333	1.107056
35+ year olds	1.01915	.0470838	0.41	0.681	.9309225	1.11574
Parity						
Multiparous	1.672556	.0717045	12.00	0.000	1.53776	1.819168
white	1.003411	.0021229	1.61	0.108	.9992587	1.00758
Typebirth						
An assisted vaginal birth	.6385582	.0365414	-7.84	0.000	.5708087	.714349
A planned caesarean birth	.6939218	.0406569	-6.24	0.000	.6186408	.7783636
An emergency caesarean birth	.6284449	.0342315	-8.53	0.000	.5648097	.6992497
CHPPDRegisteredNursesandMi	1.003711	.0205904	0.18	0.857	.9641553	1.04489
CHPPDHealthcareSupportWorke	1.02442	.0341283	0.72	0.469	.9596664	1.093542
OG100births	1.024965	.1528817	0.17	0.869	.7651478	1.373006

Info_binary	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Age_group						
16 - 25 year olds	1.082424	.0898601	0.95	0.340	.9198835	1.273685
25 - 29 year olds	.9967382	.053389	-0.06	0.951	.897403	1.107069
35+ year olds	1.02014	.0471152	0.43	0.666	.9318525	1.116793
Parity						
Multiparous	1.672878	.0716958	12.01	0.000	1.538097	1.81947
white	1.003793	.002048	1.86	0.063	.9997873	1.007815
Typebirth						
An assisted vaginal birth	.6377368	.0364889	-7.86	0.000	.5700841	.713418
A planned caesarean birth	.6923381	.0405611	-6.28	0.000	.6172343	.7765805
An emergency caesarean birth	.6275273	.0341712	-8.56	0.000	.5640031	.6982063
TertileRegCHPPD						
Mid	.8662064	.0692564	-1.80	0.072	.7405675	1.01316
High	.9933371	.0772112	-0.09	0.931	.8529696	1.156804
TertileSupportCHPPD						
Mid	.9462	.0705136	-0.74	0.458	.8176152	1.095007
High	1.082206	.0861039	0.99	0.321	.9259454	1.264836
OG100births	1.123431	.1656745	0.79	0.430	.8414307	1.499943

Question related to Always being treated kindness and understanding (Individual staff groups)

Kind_binary	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Age_group						
16 - 25 year olds	.790116	.0684979	-2.72	0.007	.6666491	.9364497
25 - 29 year olds	1.057232	.0627624	0.94	0.349	.9411066	1.187686
35+ year olds	1.011508	.0512304	0.23	0.821	.9159208	1.11707
Parity						
Multiparous	1.582016	.0748672	9.69	0.000	1.441879	1.735774
white	1.004731	.0024129	1.97	0.049	1.000013	1.009471
Typebirth						
An assisted vaginal birth	.6654546	.0414301	-6.54	0.000	.5890119	.7518181
A planned caesarean birth	.5872556	.0370961	-8.43	0.000	.5188694	.6646551
An emergency caesarean birth	.5782584	.0338263	-9.36	0.000	.5156196	.6485068
CHPPDRegisteredNursesandMi	1.00144	.0235131	0.06	0.951	.9563994	1.048602
CHPPDHealthcareSupportWorke	1.072748	.0408993	1.84	0.065	.995509	1.15598
OG100births	1.005771	.1702791	0.03	0.973	.7217533	1.401552

Kind_binary	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Age_group						
16 - 25 year olds	.7899796	.0684751	-2.72	0.007	.666552	.9362626
25 - 29 year olds	1.057182	.062756	0.94	0.349	.9410682	1.187622
35+ year olds	1.012806	.0512944	0.25	0.802	.9170999	1.118501
Parity						
Multiparous	1.582844	.0749053	9.70	0.000	1.442636	1.73668
white	1.004591	.0023957	1.92	0.055	.9999065	1.009297
Typebirth						
An assisted vaginal birth	.6651167	.0414104	-6.55	0.000	.5887104	.7514395
A planned caesarean birth	.5866139	.0370558	-8.44	0.000	.5183018	.6639294
An emergency caesarean birth	.5773287	.0337683	-9.39	0.000	.5147969	.6474562
TertileRegCHPPD						
Mid	.8333108	.0783581	-1.94	0.052	.6930532	1.001953
High	.9489788	.0868758	-0.57	0.567	.7931072	1.135484
TertileSupportCHPPD						
Mid	1.144114	.1001406	1.54	0.124	.9637548	1.358227
High	1.239299	.1155591	2.30	0.021	1.032299	1.487808
OG100births	1.082912	.1873085	0.46	0.645	.7715484	1.519929

S8 Relationship between Overall staffing, Skill mix and patient experience at postnatal ward level (adjusted models, which were best fit according to AIC)

Question related to being Discharged without delay

No_delay_binary	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Age_group						
16 - 25 year olds	.8338304	.065073	-2.33	0.020	.7155649	.9716423
25 - 29 year olds	.9544587	.0484011	-0.92	0.358	.8641562	1.054198
35+ year olds	.9712989	.042317	-0.67	0.504	.8918015	1.057883
Parity						
Multiparous	1.32705	.0534721	7.02	0.000	1.226278	1.436103
white	1.002459	.0019377	1.27	0.204	.9986687	1.006264
Typebirth						
An assisted vaginal birth	.7502665	.0417245	-5.17	0.000	.6727873	.8366683
A planned caesarean birth	1.033073	.0577556	0.58	0.561	.9258557	1.152707
An emergency caesarean birth	.9365326	.0494168	-1.24	0.214	.8445176	1.038573
CHPPDOverall	1.007746	.0116953	0.66	0.506	.9850826	1.030931
percentage_Registered	.9932293	.0032806	-2.06	0.040	.9868202	.9996801
OG100births	1.031814	.1399797	0.23	0.817	.7909045	1.346104

No_delay_binary	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Age_group						
16 - 25 year olds	.8363293	.065265	-2.29	0.022	.7177145	.9745473
25 - 29 year olds	.9554121	.0484477	-0.90	0.368	.8650226	1.055247
35+ year olds	.9708937	.0422951	-0.68	0.498	.8914371	1.057433
Parity						
Multiparous	1.328203	.053519	7.04	0.000	1.227343	1.437351
white	1.002752	.0019515	1.41	0.158	.9989341	1.006584
Typebirth						
An assisted vaginal birth	.749717	.0416924	-5.18	0.000	.6722973	.8360522
A planned caesarean birth	1.032658	.0577307	0.57	0.565	.9254869	1.15224
An emergency caesarean birth	.9368964	.0494306	-1.24	0.217	.8448551	1.038965
tertile_overallCHPPD						
Mid	1.132594	.0737393	1.91	0.056	.9969083	1.286746
High	1.009243	.0653937	0.14	0.887	.8888783	1.145907
tertile_perc_registered						
Mid	.9269593	.0602881	-1.17	0.244	.8160181	1.052984
High	.8592405	.0552462	-2.36	0.018	.7575048	.9746396
OG100births	1.016746	.1395461	0.12	0.904	.7769389	1.33057

Question related to Always having help when needed it

Help_binary	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Age_group						
16 - 25 year olds	.9412371	.0777571	-0.73	0.464	.8005343	1.10667
25 - 29 year olds	1.015602	.0547916	0.29	0.774	.9136954	1.128875
35+ year olds	.9924363	.0460082	-0.16	0.870	.9062372	1.086834
Parity						
Multiparous	1.269967	.0545097	5.57	0.000	1.167501	1.381427
white	1.004995	.0024138	2.07	0.038	1.000275	1.009737
Typebirth						
An assisted vaginal birth	.7079825	.0409069	-5.98	0.000	.6321795	.7928747
A planned caesarean birth	.6668888	.038471	-7.02	0.000	.5955934	.7467186
An emergency caesarean birth	.7214811	.0394272	-5.97	0.000	.6481998	.8030471
CHPPDOverall	1.01967	.0148436	1.34	0.181	.9909882	1.049182
percentage_Registered	.9911114	.0041231	-2.15	0.032	.9830632	.9992255
OG100births	1.038886	.1769532	0.22	0.823	.7440171	1.450617

Help_binary	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Age_group						
16 - 25 year olds	.9425889	.0778331	-0.72	0.474	.8017434	1.108177
25 - 29 year olds	1.016582	.054832	0.30	0.760	.9145986	1.129937
35+ year olds	.991302	.0459497	-0.19	0.851	.905212	1.08558
Parity						
Multiparous	1.268757	.0544393	5.55	0.000	1.166421	1.380071
white	1.004142	.0023711	1.75	0.080	.9995053	1.0088
Typebirth						
An assisted vaginal birth	.707338	.0408639	-5.99	0.000	.6316142	.7921402
A planned caesarean birth	.6675312	.0385033	-7.01	0.000	.5961755	.7474273
An emergency caesarean birth	.7214631	.0394156	-5.98	0.000	.6482023	.803004
tertile_overallCHPPD						
Mid	.9069559	.0720316	-1.23	0.219	.7762161	1.059716
High	1.051721	.0837882	0.63	0.527	.8996788	1.229459
tertile_perc_registered						
Mid	.7868062	.0626472	-3.01	0.003	.6731212	.9196917
High	.8047121	.06356	-2.75	0.006	.6893006	.9394474
OG100births	1.186404	.1991012	1.02	0.308	.853856	1.648467

Question related to Always having Info and explanations

Info_binary	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Age_group						
16 - 25 year olds	1.084622	.0901026	0.98	0.328	.9216516	1.27641
25 - 29 year olds	.9968196	.0534095	-0.06	0.953	.8974479	1.107194
35+ year olds	1.019169	.0470849	0.41	0.681	.9309392	1.115761
Parity						
Multiparous	1.672574	.0717065	12.00	0.000	1.537775	1.81919
white	1.003374	.0021205	1.59	0.111	.9992262	1.007538
Typebirth						
An assisted vaginal birth	.6386645	.0365462	-7.84	0.000	.570906	.714465
A planned caesarean birth	.6939428	.0406584	-6.24	0.000	.618659	.7783877
An emergency caesarean birth	.6284379	.0342316	-8.53	0.000	.5648025	.6992428
CHPPDOverall	1.010776	.0128871	0.84	0.401	.9858306	1.036352
percentage_Registered	.9987974	.0036283	-0.33	0.740	.9917113	1.005934
OG100births	1.02165	.1521026	0.14	0.886	.7630898	1.367818

Info_binary	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Age_group						
16 - 25 year olds	1.08481	.0900849	0.98	0.327	.9218668	1.276554
25 - 29 year olds	.9970069	.0534066	-0.06	0.955	.8976394	1.107374
35+ year olds	1.018595	.0470532	0.40	0.690	.9304245	1.115122
Parity						
Multiparous	1.670538	.0715987	11.97	0.000	1.53594	1.816932
white	1.002756	.002107	1.31	0.190	.9986343	1.006894
Typebirth						
An assisted vaginal birth	.6380256	.0365094	-7.85	0.000	.5703352	.7137498
A planned caesarean birth	.6945084	.0406897	-6.22	0.000	.6191666	.7790179
An emergency caesarean birth	.6280308	.0342014	-8.54	0.000	.5644509	.6987724
tertile_overallCHPPD						
Mid	.8904317	.0626348	-1.65	0.099	.7757564	1.022059
High	1.010404	.0712455	0.15	0.883	.8799849	1.160152
tertile_perc_registered						
Mid	.8726051	.0613862	-1.94	0.053	.7602164	1.001609
High	.9393161	.0656941	-0.90	0.371	.8189931	1.077317
OG100births	1.129966	.1682135	0.82	0.412	.8440158	1.512796

Appendix H

Question related to Always being treated kindness and understanding

Kind_binary	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Age_group						
16 - 25 year olds	.7902889	.0685134	-2.71	0.007	.666794	.9366559
25 - 29 year olds	1.057493	.0627764	0.94	0.346	.9413415	1.187976
35+ year olds	1.011385	.0512244	0.22	0.823	.9158098	1.116936
Parity						
Multiparous	1.582245	.0748806	9.70	0.000	1.442082	1.73603
white	1.004703	.0024027	1.96	0.050	1.000005	1.009423
Typebirth						
An assisted vaginal birth	.6656724	.0414433	-6.54	0.000	.5892053	.7520634
A planned caesarean birth	.5873124	.0370999	-8.43	0.000	.5189192	.6647198
An emergency caesarean birth	.5782733	.0338277	-9.36	0.000	.5156318	.6485246
CHPPDOverall	1.025331	.0148646	1.73	0.084	.9966071	1.054883
percentage_Registered	.9938144	.0041043	-1.50	0.133	.9858027	1.001891
OG100births	.9988355	.1682757	-0.01	0.994	.7179438	1.389625

Kind_binary	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Age_group						
16 - 25 year olds	.7900053	.0684713	-2.72	0.007	.6665836	.9362791
25 - 29 year olds	1.057562	.0627727	0.94	0.346	.9414163	1.188036
35+ year olds	1.010832	.0511978	0.21	0.832	.9153065	1.116328
Parity						
Multiparous	1.580111	.0747669	9.67	0.000	1.44016	1.733661
white	1.004067	.0024351	1.67	0.094	.9993053	1.008851
Typebirth						
An assisted vaginal birth	.6651633	.0414115	-6.55	0.000	.5887549	.751488
A planned caesarean birth	.5878039	.0371302	-8.41	0.000	.5193547	.6652745
An emergency caesarean birth	.5780372	.0338084	-9.37	0.000	.5154309	.6482479
tertile_overallCHPPD						
Mid	.9588956	.0779272	-0.52	0.606	.8177041	1.124466
High	1.082259	.0884797	0.97	0.334	.9220222	1.270342
tertile_perc_registered						
Mid	.8428862	.0687607	-2.10	0.036	.7183398	.9890266
High	.868152	.0703121	-1.75	0.081	.7407242	1.017501
OG100births	1.09604	.188558	0.53	0.594	.782329	1.535548

S9 Coding

use 2019 Edited_data_mat_survey_13,264x93 subset.dta"

NULL MODEL AND ESTIMATE CLUSTERING EFFECTS BY TRUST

```
melogit No_delay_binary ||TrustCode:, or
estat ic
estat ic, n(93)
estat icc
melogit Help_binary ||TrustCode:, or
estat ic
estat ic, n(93)
estat icc
melogit Info_binary ||TrustCode:, or
estat ic
estat ic, n(93)
estat icc
melogit Kind_binary ||TrustCode:, or
estat ic
estat ic, n(93)
estat icc
```

TRUST MEASURES OF STAFFING
With covariates explained in methodology

```
melogit No_delay_binary ib3.Age_group i.Parity  white i.Typebirth FTEper100births ||TrustCode:,
or
estat ic
estat ic, n(93)
melogit Help_binary ib3.Age_group i.Parity  white i.Typebirth FTEper100births ||TrustCode:, or
estat ic
estat ic, n(93)
melogit Info_binary ib3.Age_group i.Parity  white i.Typebirth FTEper100births ||TrustCode:, or
estat ic
estat ic, n(93)
melogit Kind_binary ib3.Age_group i.Parity  white i.Typebirth FTEper100births ||TrustCode:, or
estat ic
estat ic, n(93)

melogit No_delay_binary ib3.Age_group i.Parity  white i.Typebirth i.tertile_FTEper100births
||TrustCode:, or
melogit Help_binary ib3.Age_group i.Parity  white i.Typebirth i.tertile_FTEper100births
||TrustCode:, or
melogit Info_binary ib3.Age_group i.Parity  white i.Typebirth i.tertile_FTEper100births
||TrustCode:, or
melogit Kind_binary ib3.Age_group i.Parity  white i.Typebirth i.tertile_FTEper100births
||TrustCode:, or
```

Testing model fit with additional covariates

```
melogit No_delay_binary ib3.Age_group i.Parity  white i.Typebirth FTEper100births
Response_rate ||TrustCode:, or
estat ic
estat ic, n(93)
melogit Help_binary ib3.Age_group i.Parity  white i.Typebirth FTEper100births Response_rate
||TrustCode:, or
estat ic
estat ic, n(93)
melogit Info_binary ib3.Age_group i.Parity  white i.Typebirth FTEper100births Response_rate
||TrustCode:, or
estat ic
estat ic, n(93)
melogit Kind_binary ib3.Age_group i.Parity  white i.Typebirth FTEper100births
Response_rate||TrustCode:, or
estat ic
estat ic, n(93)


melogit No_delay_binary ib3.Age_group i.Parity  white i.Typebirth FTEper100births
annualbirthsHES||TrustCode:, or
estat ic
estat ic, n(93)
melogit Help_binary ib3.Age_group i.Parity  white i.Typebirth FTEper100births annualbirthsHES
||TrustCode:, or
estat ic
estat ic, n(93)
melogit Info_binary ib3.Age_group i.Parity  white i.Typebirth FTEper100births annualbirthsHES
||TrustCode:, or
estat ic
estat ic, n(93)
melogit Kind_binary ib3.Age_group i.Parity  white i.Typebirth FTEper100births annualbirthsHES
||TrustCode:, or
estat ic
estat ic, n(93)

melogit No_delay_binary ib3.Age_group i.Parity  white i.Typebirth FTEper100births OG100births
||TrustCode:, or
estat ic
estat ic, n(93)
melogit Help_binary ib3.Age_group i.Parity  white i.Typebirth FTEper100births OG100births
||TrustCode:, or
estat ic
estat ic, n(93)
melogit Info_binary ib3.Age_group i.Parity  white i.Typebirth FTEper100births OG100births
||TrustCode:, or
estat ic
estat ic, n(93)
melogit Kind_binary ib3.Age_group i.Parity  white i.Typebirth FTEper100births OG100births
||TrustCode:, or
estat ic
estat ic, n(93)
```

POSTNATAL WARD STAFFING MEASURE

Staff as individual staff groups

melogit No_delay_binary ib3.Age_group i.Parity white i.Typebirth CHPPDRegisteredNursesandMi CHPPDHealthcareSupportWorke ||TrustCode:, or
estat ic
estat ic, n(93)
melogit Help_binary ib3.Age_group i.Parity white i.Typebirth CHPPDRegisteredNursesandMi CHPPDHealthcareSupportWorke ||TrustCode:, or
estat ic
estat ic, n(93)
melogit Info_binary ib3.Age_group i.Parity white i.Typebirth CHPPDRegisteredNursesandMi CHPPDHealthcareSupportWorke ||TrustCode:, or
estat ic
estat ic, n(93)
melogit Kind_binary ib3.Age_group i.Parity white i.Typebirth CHPPDRegisteredNursesandMi CHPPDHealthcareSupportWorke ||TrustCode:, or
estat ic
estat ic, n(93)

Testing model fit with additional covariates
melogit No_delay_binary ib3.Age_group i.Parity white i.Typebirth CHPPDRegisteredNursesandMi CHPPDHealthcareSupportWorke Response_rate ||TrustCode:, or
estat ic
estat ic, n(93)
melogit Help_binary ib3.Age_group i.Parity white i.Typebirth CHPPDRegisteredNursesandMi CHPPDHealthcareSupportWorke Response_rate ||TrustCode:, or
estat ic
estat ic, n(93)
melogit Info_binary ib3.Age_group i.Parity white i.Typebirth CHPPDRegisteredNursesandMi CHPPDHealthcareSupportWorke Response_rate ||TrustCode:, or
estat ic
estat ic, n(93)
melogit Kind_binary ib3.Age_group i.Parity white i.Typebirth CHPPDRegisteredNursesandMi CHPPDHealthcareSupportWorke Response_rate ||TrustCode:, or
estat ic
estat ic, n(93)

melogit No_delay_binary ib3.Age_group i.Parity white i.Typebirth CHPPDRegisteredNursesandMi CHPPDHealthcareSupportWorke annualbirthsHES ||TrustCode:, or
estat ic
estat ic, n(93)
melogit Help_binary ib3.Age_group i.Parity white i.Typebirth CHPPDRegisteredNursesandMi CHPPDHealthcareSupportWorke annualbirthsHES ||TrustCode:, or
estat ic
estat ic, n(93)
melogit Info_binary ib3.Age_group i.Parity white i.Typebirth CHPPDRegisteredNursesandMi

CHPPDHealthcareSupportWorke annualbirthsHES ||TrustCode:, or
estat ic
estat ic, n(93)
melogit Kind_binary ib3.Age_group i.Parity white i.Typebirth CHPPDRegisteredNursesandMi CHPPDHealthcareSupportWorke annualbirthsHES ||TrustCode:, or
estat ic
estat ic, n(93)

melogit No_delay_binary ib3.Age_group i.Parity white i.Typebirth CHPPDRegisteredNursesandMi CHPPDHealthcareSupportWorke OG100births ||TrustCode:, or
estat ic
estat ic, n(93)
melogit Help_binary ib3.Age_group i.Parity white i.Typebirth CHPPDRegisteredNursesandMi CHPPDHealthcareSupportWorke OG100births ||TrustCode:, or
estat ic
estat ic, n(93)
melogit Info_binary ib3.Age_group i.Parity white i.Typebirth CHPPDRegisteredNursesandMi CHPPDHealthcareSupportWorke OG100births ||TrustCode:, or
estat ic
estat ic, n(93)
melogit Kind_binary ib3.Age_group i.Parity white i.Typebirth CHPPDRegisteredNursesandMi CHPPDHealthcareSupportWorke OG100births ||TrustCode:, or
estat ic
estat ic, n(93)
This model has been reported in the paper as medical staff has improved model fit in ward level models.

S10 Sensitivity analysis after removing outliers

Mild outliers for CHPPD were removed when they were more than 1.5 x IQR more unusual than Q1 or Q3. This resulted in the removal of data for 2 Trusts for Registered CHPPD data, no outlying Trusts for Support CHPPD data, and 1 Trust for Overall CHPPD data. There were no Extreme outliers classified as 3 x IQR more unusual than Q1 or Q3

Method of identifying outliers taken from Dunn P. Scientific Research and Methodology : An introduction to quantitative research and statistics in science, engineering and health 2021.https://bookdown.org/pkaldunn/Book/identifying-outliers.html

Removing the Trusts meant that individual patient data was removed from the analysis. The models have been repeated using data with outlying values removed and treated as missing.

Question related to being Discharged without delay

No_delay_binary	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Age_group						
16 - 25 year olds	.8252052	.065023	-2.44	0.015	.7071158	.9630158
25 - 29 year olds	.9471051	.0484278	-1.06	0.288	.8567895	1.046941
35+ year olds	.9684952	.0425136	-0.73	0.466	.888654	1.05551
Parity						
Multiparous	1.32565	.0538264	6.94	0.000	1.224241	1.435459
white	1.001689	.0020856	0.81	0.418	.9976093	1.005785
Typebirth						
An assisted vaginal birth	.7509775	.0421378	-5.10	0.000	.6727682	.8382786
A planned caesarean birth	1.030218	.058018	0.53	0.597	.9225562	1.150445
An emergency caesarean birth	.9333635	.0496208	-1.30	0.195	.841004	1.035866
CHPPDRegOutliersremoved	.974136	.0192657	-1.32	0.185	.9370984	1.012637
CHPPDSupportOutliersremoved	1.074851	.0336923	2.30	0.021	1.010803	1.142957
OG100births	.9898923	.1379762	-0.07	0.942	.7532571	1.300866

Question related to Always having help when needed it

Help_binary	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Age_group						
16 - 25 year olds	.9369518	.0779687	-0.78	0.434	.7959472	1.102936
25 - 29 year olds	1.015423	.0551487	0.28	0.778	.9128872	1.129475
35+ year olds	.9928871	.0462755	-0.15	0.878	.9062081	1.087857
Parity						
Multiparous	1.266734	.0546882	5.48	0.000	1.163957	1.378587
white	1.005236	.002525	2.08	0.038	1.000299	1.010197
Typebirth						
An assisted vaginal birth	.7053885	.0410402	-6.00	0.000	.629368	.7905915
A planned caesarean birth	.6680768	.0387679	-6.95	0.000	.5962549	.7485501
An emergency caesarean birth	.7294864	.0401174	-5.74	0.000	.654947	.8125091
CHPPDRegOutliersremoved	.9607709	.0232005	-1.66	0.097	.9163582	1.007336
CHPPDSupportOutliersremoved	1.097216	.0419366	2.43	0.015	1.018025	1.182567
OG100births	.9690056	.163934	-0.19	0.852	.69554	1.34999

Question related to Always having Info and explanations

Info_binary	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Age_group						
16 - 25 year olds	1.083675	.0907853	0.96	0.337	.9195792	1.277052
25 - 29 year olds	.9993767	.0539902	-0.01	0.991	.8989676	1.111001
35+ year olds	1.019767	.0474535	0.42	0.674	.9308751	1.117147
Parity						
Multiparous	1.676955	.0724265	11.97	0.000	1.540844	1.82509
white	1.002762	.0022958	1.20	0.228	.9982722	1.007271
Typebirth						
An assisted vaginal birth	.6376749	.0367984	-7.80	0.000	.5694806	.7140355
A planned caesarean birth	.6953617	.041049	-6.15	0.000	.619387	.7806555
An emergency caesarean birth	.6336533	.0347815	-8.31	0.000	.5690218	.7056259
CHPPDRegOutliersremoved	.9995976	.0218565	-0.02	0.985	.9576646	1.043367
CHPPDSupportOutliersremoved	1.032728	.0357685	0.93	0.352	.9649494	1.105267
OG100births	.9871191	.1513924	-0.08	0.933	.7308404	1.333265

Question related to Always being treated kindness and understanding

Kind_binary	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Age_group						
16 - 25 year olds	.793399	.0692622	-2.65	0.008	.6686263	.9414556
25 - 29 year olds	1.068324	.0638409	1.11	0.269	.9502475	1.201072
35+ year olds	1.018548	.05184	0.36	0.718	.9218467	1.125393
Parity						
Multiparous	1.581193	.0752156	9.63	0.000	1.440437	1.735704
white	1.004475	.002549	1.76	0.078	.9994914	1.009483
Typebirth						
An assisted vaginal birth	.6644497	.0416445	-6.52	0.000	.5876421	.7512963
A planned caesarean birth	.5858618	.0371973	-8.42	0.000	.5173102	.6634976
An emergency caesarean birth	.5801343	.034129	-9.26	0.000	.5169551	.6510348
CHPPDRegOutliersremoved	.9846237	.0240464	-0.63	0.526	.9386037	1.0329
CHPPDSupportOutliersremoved	1.080328	.0418931	1.99	0.046	1.001262	1.165638
OG100births	.9373579	.1595293	-0.38	0.704	.6714893	1.308494

S11 Sensitivity analysis : Testing model fit using AIC and BIC when including interaction variables

	Continuous CHPPD models		Best fit?
Delay in discharge	Core model with no interaction variables	AIC 16856.16 BIC 16937.82 BIC (93)16884.02	Reference
	With interaction variable RegisteredxSW	AIC BIC BIC (93)	Best fit without interaction included
	With interaction variable RegisteredxParity	AIC BIC BIC (93)	Best fit without interaction included
	With interaction variable RegisteredxType birth	AIC BIC BIC (93)	Best fit without interaction included
	With interaction variable RegisteredxAge group	AIC BIC BIC (93)	Best fit without interaction included
Help in reasonable time	Core model with no interaction variables	AIC 15210.56 BIC 15291.48 BIC (93) 15238.41	Reference
	With interaction variable RegisteredxSW	AIC BIC BIC (93)	Best fit without interaction included
	With interaction variable RegisteredxParity	AIC BIC BIC (93)	Best fit without interaction included
	With interaction variable RegisteredxType birth	AIC BIC BIC (93)	Best fit without interaction included
	With interaction variable RegisteredxAge group	AIC BIC BIC (93)	Best fit without interaction included
Information/Explanations	Core model with no interaction variables	AIC 15474.65 BIC 15556.26 BIC (93) 15502.51	Reference
	With interaction variable RegisteredxSW	AIC BIC BIC (93)	Best fit without interaction included
	With interaction variable RegisteredxParity	AIC BIC BIC (93)	Best fit without interaction included

	Continuous CHPPD models		Best fit?
	With interaction variable RegisteredxType birth	AIC BIC BIC (93)	Best fit without interaction included
	With interaction variable RegisteredxAge group	AIC BIC BIC (93)	Best fit without interaction included
	Core model with no interaction variables	AIC 13545.28 BIC 13626.94 BIC (93) 13573.14	Reference
	With interaction variable RegisteredxSW	AIC BIC BIC (93)	Best fit without interaction included
Treated with kindness and understanding	With interaction variable RegisteredxParity	AIC BIC BIC (93)	Best fit without interaction included
	With interaction variable RegisteredxType birth	AIC BIC BIC (93)	Best fit without interaction included
	With interaction variable RegisteredxAge group	AIC BIC BIC (93)	Best fit without interaction included

S12 Sensitivity analyses using alternative dichotomy of question responses

The models have been repeated using data with recoding of responses,
with yes always / yes sometimes = 1, no=0

Help when you needed it?

Help_alternative	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Age_group						
16 - 25 year olds	.6928473	.1059059	-2.40	0.016	.5134832	.9348649
25 - 29 year olds	.7552682	.0778333	-2.72	0.006	.617137	.9243168
35+ year olds	1.021887	.0965142	0.23	0.819	.8491984	1.229692
Parity						
Multiparous	1.170449	.1009388	1.83	0.068	.9884292	1.385989
white	1.007766	.0038181	2.04	0.041	1.00031	1.015277
Typebirth						
An assisted vaginal birth	.6548121	.0729684	-3.80	0.000	.5263368	.8146472
A planned caesarean birth	.5887467	.0658384	-4.74	0.000	.4728685	.7330214
An emergency caesarean birth	.6060173	.0631667	-4.81	0.000	.4940401	.7433749
FTEper100births	1.086306	.1552168	0.58	0.562	.8209715	1.437395

Help_alternative	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Age_group						
16 - 25 year olds	.6961155	.1063408	-2.37	0.018	.5159993	.9391035
25 - 29 year olds	.7549323	.0777942	-2.73	0.006	.6168697	.923895
35+ year olds	1.019131	.096252	0.20	0.841	.846912	1.226371
Parity						
Multiparous	1.172616	.1011072	1.85	0.065	.9902896	1.388512
white	1.008555	.00387	2.22	0.026	1.000999	1.016169
Typebirth						
An assisted vaginal birth	.6540291	.0728817	-3.81	0.000	.5257068	.8136744
A planned caesarean birth	.5890518	.0658687	-4.73	0.000	.4731195	.7333921
An emergency caesarean birth	.6070667	.0632716	-4.79	0.000	.4949027	.7446514
CHPPDRegisteredNursesandMi	.973949	.037303	-0.69	0.491	.9035132	1.049876
CHPPDHealthcareSupportWorke	1.096407	.06761	1.49	0.136	.9715888	1.237261
OG100births	1.127682	.3104452	0.44	0.662	.6574384	1.934275

Given the information or explanations you needed?

Info_alternative	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Age_group						
16 - 25 year olds	.8321217	.1151335	-1.33	0.184	.6344734	1.09134
25 - 29 year olds	.8911626	.083813	-1.23	0.221	.7411434	1.071548
35+ year olds	1.192305	.1049676	2.00	0.046	1.003344	1.416854
Parity						
Multiparous	1.971618	.1653508	8.09	0.000	1.672771	2.323856
white	1.003129	.0029828	1.05	0.293	.9972998	1.008992
Typebirth						
An assisted vaginal birth	.6460446	.0644157	-4.38	0.000	.5313627	.7854778
A planned caesarean birth	.7170317	.0829838	-2.87	0.004	.5715139	.899601
An emergency caesarean birth	.5287072	.0492014	-6.85	0.000	.4405574	.6344946
FTEper100births	1.19057	.1329613	1.56	0.118	.9565198	1.48189

Info_alternative	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Age_group						
16 - 25 year olds	.8384395	.1159925	-1.27	0.203	.6393131	1.099588
25 - 29 year olds	.8937164	.0840724	-1.19	0.232	.743236	1.074664
35+ year olds	1.186905	.1045678	1.94	0.052	.9986751	1.410613
Parity						
Multiparous	1.97868	.1659955	8.13	0.000	1.678674	2.332301
white	1.004783	.0030935	1.55	0.121	.9987376	1.010864
Typebirth						
An assisted vaginal birth	.6438627	.0642152	-4.41	0.000	.5295406	.7828658
A planned caesarean birth	.716855	.0829744	-2.88	0.004	.5713558	.8994065
An emergency caesarean birth	.5292305	.0492679	-6.84	0.000	.4409645	.6351643
CHPPDRegisteredNursesandMi	.9783445	.0292936	-0.73	0.465	.9225823	1.037477
CHPPDHealthcareSupportWorke	1.021891	.0498072	0.44	0.657	.9287881	1.124326
OG100births	1.233829	.269517	0.96	0.336	.8041167	1.893176

Treated with kindness and understanding?

Kind_alternative	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Age_group						
16 - 25 year olds	.4746474	.0856836	-4.13	0.000	.3332052	.6761305
25 - 29 year olds	.8035339	.1143964	-1.54	0.124	.6078851	1.062152
35+ year olds	.9840989	.1264747	-0.12	0.901	.7649689	1.266
Parity						
Multiparous	1.472103	.1756604	3.24	0.001	1.165112	1.859982
white	1.00928	.0042402	2.20	0.028	1.001003	1.017625
Typebirth						
An assisted vaginal birth	.6292352	.0967837	-3.01	0.003	.4654664	.8506241
A planned caesarean birth	.5282433	.0834143	-4.04	0.000	.3876338	.7198571
An emergency caesarean birth	.4077429	.0542267	-6.75	0.000	.3141833	.5291634
FTEper100births	1.005725	.1628379	0.04	0.972	.7322514	1.381332

Kind_alternative	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Age_group						
16 - 25 year olds	.474244	.0855205	-4.14	0.000	.3330462	.6753039
25 - 29 year olds	.805755	.1147004	-1.52	0.129	.6095835	1.065057
35+ year olds	.9791872	.125854	-0.16	0.870	.7611348	1.259708
Parity						
Multiparous	1.477227	.1763113	3.27	0.001	1.169106	1.866554
white	1.010711	.0042975	2.51	0.012	1.002323	1.019169
Typebirth						
An assisted vaginal birth	.6305499	.0969672	-3.00	0.003	.466466	.852352
A planned caesarean birth	.5280239	.0833668	-4.04	0.000	.3874913	.7195238
An emergency caesarean birth	.4069389	.0541181	-6.76	0.000	.3135663	.5281155
CHPPDRegisteredNursesandMi	.9952952	.0431159	-0.11	0.913	.9142777	1.083492
CHPPDHealthcareSupportWorke	.9972009	.0686539	-0.04	0.968	.8713253	1.141261
OG100births	1.56094	.4959743	1.40	0.161	.837384	2.909696

S13 Null models for four questions and intra-class correlation coefficients

Question related to being Discharged without delay
melogit No_delay_binary ||TrustCode:, or

```
Group variable:        TrustCode                 Number of groups  =         93

                                                 Obs per group:
                                                               min =         69
                                                               avg =      137.8
                                                               max =        290

Integration method: mvaghermite                  Integration pts.  =          7

                                                 Wald chi2(0)      =          .
Log likelihood =  -8777.459                      Prob > chi2       =          .
--------------------------------------------------------------------------------
No_delay_binary |      Odds   Std. Err.      z    P>|z|     [95% Conf. Interval]
----------------+---------------------------------------------------------------
          _cons |  1.257418    .035108     8.20   0.000     1.190456    1.328146
----------------+---------------------------------------------------------------
TrustCode       |
      var(_cons)|  .0406256   .0105375                      .0244351    .0675438
--------------------------------------------------------------------------------
Note: Estimates are transformed only in the first equation.
LR test vs. logistic model: chibar2(01) = 48.24        Prob >= chibar2 = 0.0000

. estat ic

Akaike's information criterion and Bayesian information criterion

-----------------------------------------------------------------------------
       Model |          N   ll(null)  ll(model)      df         AIC        BIC
-------------+---------------------------------------------------------------
           . |     12,814          .  -8777.459       2    17558.92   17573.83
-----------------------------------------------------------------------------
```

Question related to Always having help when needed it
melogit Help_binary ||TrustCode:, or

```
Mixed-effects logistic regression                Number of obs     =     12,017
Group variable:        TrustCode                 Number of groups  =         93

                                                 Obs per group:
                                                               min =         57
                                                               avg =      129.2
                                                               max =        279

Integration method: mvaghermite                  Integration pts.  =          7

                                                 Wald chi2(0)      =          .
Log likelihood = -7930.4953                      Prob > chi2       =          .
------------------------------------------------------------------------------
 Help_binary |      Odds   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       _cons |  1.656823   .0610742    13.70   0.000     1.541341    1.780956
-------------+----------------------------------------------------------------
TrustCode    |
   var(_cons)|  .0892295   .0188166                      .0590213    .1348989
------------------------------------------------------------------------------
Note: Estimates are transformed only in the first equation.
LR test vs. logistic model: chibar2(01) = 122.94      Prob >= chibar2 = 0.0000

. estat ic

Akaike's information criterion and Bayesian information criterion

-----------------------------------------------------------------------------
       Model |          N   ll(null)  ll(model)      df         AIC        BIC
-------------+---------------------------------------------------------------
           . |     12,017          .  -7930.495       2    15864.99   15879.78
-----------------------------------------------------------------------------
```

Question related to Always having Info and explanations

melogit Info_binary ||TrustCode:, or

```
Mixed-effects logistic regression               Number of obs     =     12,758
Group variable:        TrustCode                Number of groups  =         93

                                                Obs per group:
                                                              min =         69
                                                              avg =      137.2
                                                              max =        292

Integration method: mvaghermite                 Integration pts.  =          7

                                                Wald chi2(0)      =          .
Log likelihood = -8185.1745                     Prob > chi2       =          .
------------------------------------------------------------------------------
 Info_binary |       Odds   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       _cons |   1.929865   .0597545    21.23   0.000     1.816231    2.050608
-------------+----------------------------------------------------------------
TrustCode    |
   var(_cons)|   .0533741   .0130468                       .033057    .0861784
------------------------------------------------------------------------------
Note: Estimates are transformed only in the first equation.
LR test vs. logistic model: chibar2(01) = 63.73       Prob >= chibar2 = 0.0000

. estat ic

Akaike's information criterion and Bayesian information criterion

-----------------------------------------------------------------------------
       Model |          N   ll(null)  ll(model)      df         AIC        BIC
-------------+---------------------------------------------------------------
           . |     12,758          .  -8185.175       2    16374.35   16389.26
-----------------------------------------------------------------------------
Note: BIC uses N = number of observations. See [R] BIC note.
```

Question related to Always being treated kindness and understanding

melogit Kind_binary ||TrustCode:, or

```
Group variable:        TrustCode              Number of groups  =         93

                                              Obs per group:
                                                            min =         69
                                                            avg =      137.9
                                                            max =        293

Integration method: mvaghermite               Integration pts.  =          7

                                              Wald chi2(0)      =          .
Log likelihood = -7142.2246                   Prob > chi2       =          .
```

Kind_binary	Odds	Std. Err.	z	P>|z|	[95% Conf.	Interval]
_cons	3.120413	.1101971	32.22	0.000	2.911736	3.344045
TrustCode						
var(_cons)	.0718947	.0169541			.0452863	.1141369

```
Note: Estimates are transformed only in the first equation.
LR test vs. logistic model: chibar2(01) = 74.88        Prob >= chibar2 = 0.0000

. estat ic

Akaike's information criterion and Bayesian information criterion
```

Model	N	ll(null)	ll(model)	df	AIC	BIC
.	12,829	.	-7142.225	2	14288.45	14303.37

```
Note: BIC uses N = number of observations. See [R] BIC note.
```

The Intra-class Correlation Coefficient (ICC) represents the dependence of scores between individuals in the same group, in this case meaning the level 2 variables (Trusts).

If the coefficient value is high (>.10), a multilevel analysis is extremely important to reduce the risk of type I error.

For each of the four outcomes the ICC is less than 0.03 which shows a relatively low level of inter-dependence of observations within groups (lack of extreme clustering). We can conclude that most of variation is within the clusters rather than between clusters. Non-hierarchical models could have been used with similar results, as the clustering effect is low in this data.

	Delay in discharge	Staff help reasonable time	Information / Explanations	Treated with kindness and understanding
ICC	0.0122	0.0264	0.0160	0.0214

Appendix I Study 3 Supplementary material

S1 Model fit and missing data

S2 Diagnosis codes for the 2903 postpartum readmissions

S3 Staffing levels expressed as Individuals per Registered Midwife and Maternity Assistants

S4 Staffing on day and night shifts over time in each of the Trusts

S5 Skill mix of staff within the three Trusts

S6 Trends in staffing over time in each of the Trusts

S7 Mean admissions per day and night in each Trust

S8 Univariable analyses

S9 Full models for staffing below the mean compared to mean staffing (HPPD)

S10 Full models with staffing expressed as individuals per midwife/maternity assistant (absolute levels)

S11 Additional analysis : High and low staffing categories compared with near mean staffing

S12 Frequency of exposure to staffing categories in study population

S13 Results of full models by subset of population

S14 Flow chart for data selection

S15 Coding

Appendix I

S1 Model fit and missing data

S1.1 Model fit by Akaike information criterion (AIC) and Bayesian information criterion (BIC)

Postpartum readmission	7 days from discharge model		30 days from discharge model	
	AIC	BIC	AIC	BIC
Empty model nested in Trust	18036.62	18054.76	23539.27	23557.41
Age category added	18031.47	18058.68	23527.22	23554.43
Mode of birth added	17667.94	17703.96	23024.88	23060.91
RM<mean staffing added	17240.87	17285.81	22518.88	22563.81
MA<mean staffing added	17112.23	17166.03	22296.37	22350.17
SHMI added	17008.74	17071.47	22149.12	22211.84
Skill mix added (did not improve model fit so excluded from full model)	17010.53	17082.21	22148.77	22220.45
Turnover added (did not improve model fit so excluded from full model)	17012	17092.65	22149.99	22230.63

RM Registered Midwife, MA Maternity Assistant, SHMI Standardised Hospital Mortality Indicator

S1.2 Collinearity testing

Test for collinearity using the Variance inflation factor (VIF)

	VIF
understaffRMless1	1.37
understaffMAless1	1.90
age_category	1.00
Mode_birth	1.00
SHMI_risk	1.00
Higher expected turnover	1.02
Less expected skill mix	1.56

RM Registered Midwife, MA Maternity Assistant

VIF scores are low (<2) so collinearity was not detected. A VIF indicating high collinearity would be >10.

S1.3 Missing data per person in the study population (women who had a birth admission)

Age	None
Length of stay	None
Mode birth	None
SHMI	385/64,250 (0.6%)
Staffing Registered midwives	1,258/64,250 (1.96%)
Staffing Maternity Assistants	2,452/64,250 (3.82%)

(Maternity assistant staffing data was missing from Trust A after 28.1.2019)

S2 Diagnosis codes for the 2903 postpartum readmissions

ICD codes for primary diagnosis matched to description Where categories are broad the second diagnosis code has been reported at the end of this table	**Count**	%
Total number of readmissions	**2903**	
Other complications of the puerperium, not elsewhere classified*	482	16.6%
Care and examination of lactating mother**	373	12.8%
Delayed and secondary postpartum haemorrhage	310	10.7%
Puerperal sepsis	246	8.5%
Infection of obstetric surgical wound	227	7.8%
Other specified diseases and conditions complicating pregnancy, childbirth and the puerperium***	159	5.5%
Disruption of caesarean section wound	104	3.6%
Disruption of perineal obstetric wound	103	3.5%
Maternal care for rhesus isoimmunization	71	2.4%
Nonpurulent mastitis associated with childbirth	63	2.2%
Unspecified maternal hypertension	57	2.0%
Haematoma of obstetric wound	45	1.6%
Urinary tract infection following delivery	43	1.5%
Persons encountering health services in other specified circumstances	40	1.4%
Pyrexia of unknown origin following delivery	39	1.3%
Fitting and adjustment of urinary device	33	1.1%
Anaemia complicating pregnancy, childbirth and the puerperium	30	1.0%
Diseases of the digestive system complicating pregnancy, childbirth and the puerperium	26	0.9%
Care and examination immediately after delivery	25	0.9%
Spinal and epidural anaesthesia-induced headache during the puerperium	24	0.8%
Other prophylactic chemotherapy	23	0.8%
Spinal and epidural anaesthesia-induced headache during labour and delivery	21	0.7%
Gestational [pregnancy-induced] hypertension	20	0.7%
Other infection of genital tract following delivery	17	0.6%
Prophylactic immunotherapy	16	0.6%
Other specified pregnancy-related conditions	15	0.5%
Other maternal infectious and parasitic diseases complicating pregnancy, childbirth and the puerperium	14	0.5%
Pre-eclampsia, unspecified	14	0.5%

ICD codes for primary diagnosis matched to description Where categories are broad the second diagnosis code has been reported at the end of this table	**Count**	**%**
Retained portions of placenta and membranes, without haemorrhage	13	0.4%
Routine postpartum follow-up	11	0.4%
Supervision of other normal pregnancy	11	0.4%
Other specified puerperal infections	9	0.3%
Diseases of the respiratory system complicating pregnancy, childbirth and the puerperium	8	0.3%
Unspecified infection of urinary tract in pregnancy	8	0.3%
Complication of the puerperium, unspecified	7	0.2%
Diseases of the circulatory system complicating pregnancy, childbirth and the puerperium	7	0.2%
Obstetric blood-clot embolism	7	0.2%
Attention to surgical dressings and sutures	6	0.2%
Elevated blood-pressure reading, without diagnosis of hypertension	6	0.2%
Examination and observation for other specified reasons	6	0.2%
Mental disorders and diseases of the nervous system complicating pregnancy, childbirth and the puerperium	6	0.2%
Other immediate postpartum haemorrhage	6	0.2%
Maternal care due to uterine scar from previous surgery	5	0.2%
Other and unspecified disorders of breast associated with childbirth	5	0.2%
Postpartum coagulation defects	5	0.2%
Second degree perineal laceration during delivery	5	0.2%
Superficial thrombophlebitis in the puerperium	5	0.2%
Unspecified pre-existing hypertension complicating pregnancy, childbirth and the puerperium	5	0.2%
Other conditions with ICD codes affecting <5 women in dataset each (condensed for reporting in this table)	115	4.0%
Blank	7	0.2%

* 68/478 had blank second diagnosis code, 179/478 had ICD indicating a type of pain as second diagnosis code
** 226/373 had blank second diagnosis code, 125/373 had 'Healthy person accompanying sick person' as second diagnosis code
***24/159 had blank second diagnosis code, no pattern seen in remaining ICD codes

When totalling the above 677/2903 (23.3%) of postpartum readmissions were due to infection or sepsis, 316/2903 (10.9%) were due to haemorrhage

Missing ICD diagnosis code for readmissions 7/2903 (0.2%)

S3 Staffing levels expressed as Individuals per Registered Midwife (RM) and Maternity Assistant (MA)

Trust	Mean RM HPPD	Individuals per Midwife	Mean MA HPPD	Individuals per Maternity Assistant
A	11.747	2.330	4.869	5.934
B	5.940	4.104	1.759	14.205
C	6.906	3.576	2.650	9.387
All Trusts (non weighted average)	6.520	3.879	2.146	12.67

RM Registered Midwife, MA Maternity Assistant, HPPD= Hours Per Patient Day

Staffing was calculated for each Trust in the study period and averaged per day.
The ‘individuals cared for per staff member’ was calculated using the following formula = 24/HPPD.

S4 Staffing on day and night shifts over time in each of the Trusts

Data for staffing for whole admitted population during specified time periods

Year	DAY or NIGHT	Mean RM HPPD	Mean MA HPPD	Mean Overall HPPD
Trust A				
2015	Day	10.75	4.56	15.32
2015	Night	11.10	3.66	14.77
2016	Day	11.73	5.47	17.20
2016	Night	11.76	5.18	16.94
2017	Day	14.22	6.04	20.26
2017	Night	13.54	5.46	19.00
2018	Day	14.08	5.97	20.04
2018	Night	13.81	5.09	18.90
2019	Day	14.68	5.77	19.06
2019	Night	14.28	4.84	17.96
2020	Day	12.57	Not available	Not available
2020	Night	12.44	Not available	Not available
Trust B				
2015	Day	7.00	1.82	8.83
2015	Night	5.09	1.52	6.60
2016	Day	6.93	1.86	8.80
2016	Night	4.99	1.53	6.52
2017	Day	7.19	2.08	9.27
2017	Night	5.04	1.65	6.70
2018	Day	6.71	1.81	8.52
2018	Night	4.81	1.34	6.15
2019	Day	6.92	2.15	9.07
2019	Night	4.89	1.72	6.61
2020	Day	6.61	2.35	8.96
2020	Night	4.84	2.09	6.93
Trust C				
2015	Day	7.05	1.98	9.03
2015	Night	5.82	2.01	7.83
2016	Day	7.02	2.17	9.19
2016	Night	5.91	2.12	8.03
2017	Day	7.23	2.52	9.75
2017	Night	6.06	2.37	8.44
2018	Day	7.34	2.76	10.10
2018	Night	6.16	2.64	8.80
2019	Day	7.91	2.84	10.76
2019	Night	6.96	2.85	9.81
2020	Day	8.62	3.25	11.87
2020	Night	7.84	3.10	10.94

RM = registered midwife MA=maternity assistant HPPD= Hours Per Patient Day

S5 Skill mix of staff within the three Trusts

This table indicates the skill mix and seniority of staff within Registered Midwife and Maternity Assistant groups.

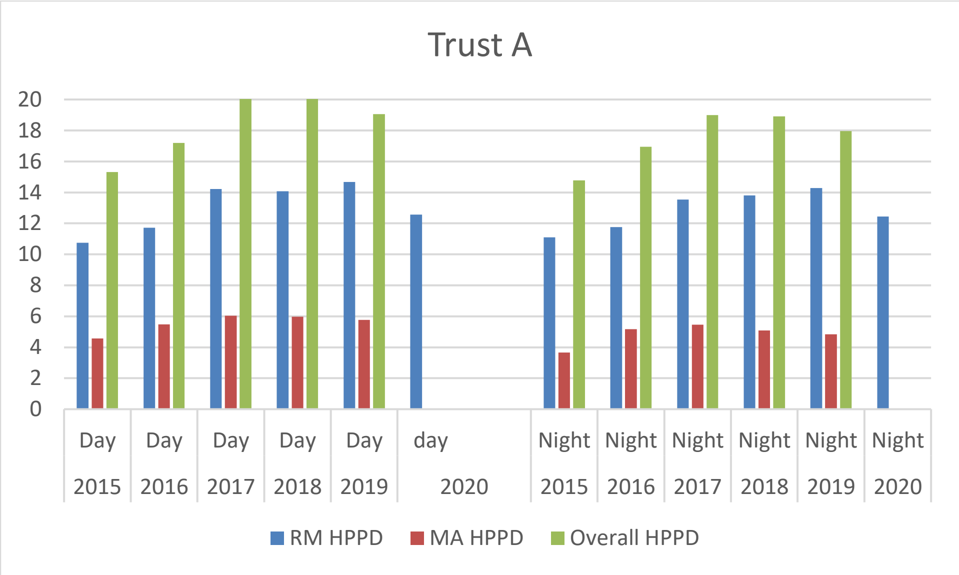
	Sum of worked hours and % of total in each staff group					
	Total sum of worked hrs	RM Band 6 or above	Registered midwives	Registered nurses	Band 3 care assistants	Band 2 care assistants
Trust A*	316,880	33.5%	70.7%	0.09%	2.2%	26.8%
Trust B	1,990,058	60.4%	77.4%	0%	3.5%	19.1%
Trust C	933,846	59.8%	73.4% (nurses not listed separately)		7.3%	19.2%

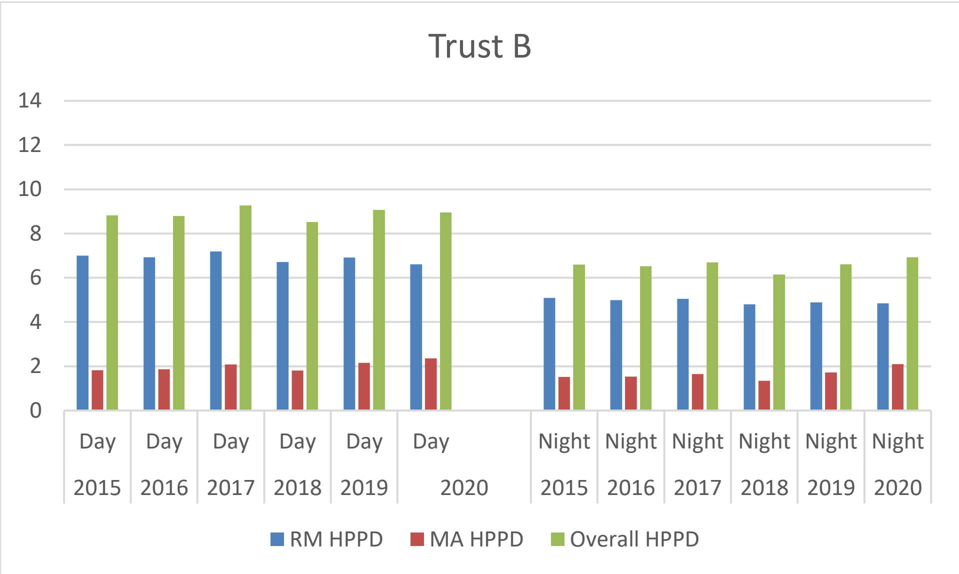
*up to 28.1.2019 as care assistant unavailable after this date

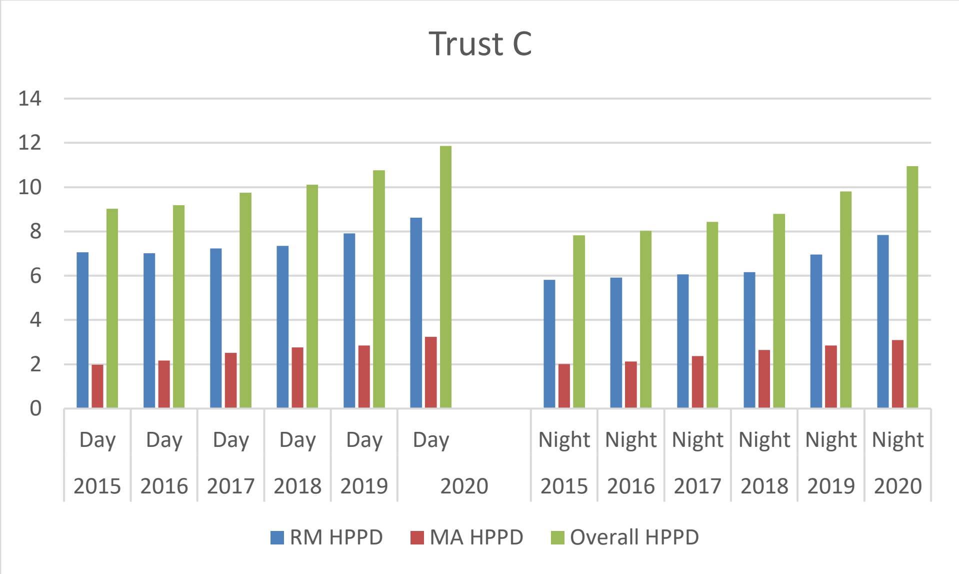
The bands refer to NHS Employers Agenda for Change pay scales.
Band 3 is a senior maternity assistant, Band 6 is a senior registered midwife.

S6 Trends in staffing over time in each of the Trusts

RM = registered midwife MA=maternity assistant HPPD= Hours Per Patient Day







S7 Mean admissions per day and night in each Trust

	Mean admissions per Day	Mean admissions per Night
Trust A	3.2	1.7
Trust B	39.0	28.4
Trust C	15.6	13.5

S8 Univariable analyses

Based on dataset with 64,250 records. Cases leading to birth only and their exposure to staffing and outcomes. Each independent variable was entered into a regression model with only this variable and the readmission outcome variable, nested within hospital Trust.
S8.1 Age category

For outcome of readmission within 7 days
(other age categories are compared with the 20-24 age group)

	Readmitted within 7 days		
	OR	95% CI	
Age category			
<20 years	1.009	0.770	1.323
20-24 years	1.000	reference category	
25-29 years	0.954	0.828	1.100
30-34 years	1.040	0.906	1.195
35-39 years	1.043	0.893	1.219
40+ years	1.476	1.193	1.827

For outcome of readmission within 30 days
(other age categories are compared with the 20-24 age group)

	Readmitted within 30 days		
	OR	95% CI	
Age category			
<20 years	0.994	0.787	1.256
20-24 years	1.000	reference category	
25-29 years	1.013	0.897	1.143
30-34 years	1.095	0.973	1.233
35-39 years	1.125	0.986	1.284
40+ years	1.454	1.208	1.750

S8.2 Mode of birth

For outcome of readmission within 7 days
(other birth categories are compared with spontaneous vaginal birth)

	Readmitted within 7 days		
	OR	95% CI	
Assisted birth	1.838	1.622	2.083
Emergency caesarean birth	1.888	1.685	2.116
Spontaneous vaginal birth	1.000	reference category	
Planned caesarean birth	1.500	1.310	1.717

For outcome of readmission within 30 days
(other birth categories are compared with spontaneous vaginal birth)

	Readmitted within 30 days		
	OR	95% CI	
Assisted birth	1.828	1.642	2.036
Emergency caesarean birth	2.041	1.854	2.247
Spontaneous vaginal birth		reference category	
Planned caesarean birth	1.706	1.526	1.908

S8.3 SHMI risk

For outcome of readmission within 7 days

	OR	95% CI
SHMI risk	1.554	0.601 4.021

For outcome of readmission within 30 days

	OR	95% CI
SHMI risk	1.546	0.671 3.560

S8.4 Understaffing by Registered Midwives, Maternity Assistants and Overall staffing

For outcome of readmission within 7 days

	Readmitted within 7 days	
	OR	95% CI
Registered Midwife staffing <mean	1.065	0.974 1.166
Maternity Assistant staffing <mean	0.984	0.898 1.077
Overall staffing <mean	1.054	0.964 1.154

For outcome of readmission within 30 days

	Readmitted within 30 days	
	OR	95% CI
Registered Midwife staffing <mean	1.041	0.965 1.123
Maternity Assistant staffing <mean	0.980	0.908 1.059
Overall staffing <mean	1.041	0.964 1.123

S8.5 Turnover (admissions + discharges) more than expected (mean) value for Trust

For outcome of readmission within 7 days

	Readmitted within 7 days	
	OR	95% CI
Turnover > mean	0.972	0.889 1.062

For outcome of readmission within 30 days

	Readmitted within 30 days	
	OR	95% CI
Turnover > mean	0.966	0.896 1.042

S8.6 Skill mix lower than expected (mean) levels for service

For outcome of readmission within 7 days

	Readmitted within 7 days	
	OR	95% CI
Skill mix <mean	1.017	0.928 1.113

For outcome of readmission within 30 days

	Readmitted within 30 days	
	OR	95% CI
Skill mix <mean	0.979	0.907 1.057

S9 Full models for staffing below the mean compared to mean staffing (HPPD)

For outcome of readmission within 7 days

Variable	OR readmission 7 days	95% CI
<20 years	1.066	0.810 1.402
20-24 years	1.000	reference category
25-29 years	0.914	0.790 1.057
30-34 years	0.983	0.853 1.133
35-39 years	0.983	0.837 1.153
40+ years	1.368	1.099 1.703
Assisted birth	1.873	1.648 2.128
Emergency caesarean birth	1.912	1.701 2.148
Spontaneous vaginal birth	1.000	reference category
Planned caesarean birth	1.518	1.321 1.745
Exposed to staffing below mean Registered midwives (HPPD)	1.108	1.003 1.223
Exposed to staffing below mean Maternity assistants (HPPD)	0.957	0.866 1.057
SHMI risk	0.687	0.108 4.360

For outcome of readmission within 30 days

Variable	OR readmission 30 days	95% CI
<20 years	1.065	0.840 1.350
20-24 years	1.000	reference category
25-29 years	0.969	0.856 1.098
30-34 years	1.024	0.906 1.156
35-39 years	1.046	0.913 1.198
40+ years	1.318	1.089 1.594
Assisted birth	1.850	1.657 2.065
Emergency caesarean birth	2.077	1.883 2.291
Spontaneous vaginal birth	1.000	reference category
Planned caesarean birth	1.707	1.522 1.915
Exposed to staffing below mean Registered midwives (HPPD)	1.080	0.994 1.174
Exposed to staffing below mean Maternity assistants (HPPD)	0.965	0.887 1.049
SHMI risk	0.8868	0.2421 3.2480

S10. Full models with staffing expressed as individuals per midwife/maternity assistant (absolute level)

For outcome of readmission within 7 days

Variable	OR readmission 7 days	95% CI	
<20 years	1.066	0.811	1.402
20-24 years	1.000	reference category	
25-29 years	0.913	0.789	1.056
30-34 years	0.983	0.853	1.133
35-39 years	0.983	0.838	1.154
40+ years	1.368	1.099	1.702
Assisted birth	1.873	1.648	2.128
Emergency caesarean birth	1.912	1.721	2.148
Spontaneous vaginal birth	1.000	reference category	
Planned caesarean birth	1.519	1.322	1.745
Number of individuals to care for per midwife	1.063	0.960	1.177
Number of individuals to care for per maternity assistant	0.998	0.978	1.018
SHMI risk	0.691	0.109	4.370

For outcome of readmission within 30 days

Variable	OR readmission 30 days	95% CI	
<20 years	1.066	0.840	1.351
20-24 years	1.000	reference category	
25-29 years	0.969	0.856	1.098
30-34 years	1.025	0.907	1.157
35-39 years	1.046	0.913	1.199
40+ years	1.317	1.088	1.593
Assisted birth	1.850	1.657	2.064
Emergency caesarean birth	2.077	1.883	2.291
Spontaneous vaginal birth	1.000	reference category	
Planned caesarean birth	1.706	1.520	1.913
Number of individuals to care for per midwife	1.013	0.929	1.105
Number of individuals to care for per maternity assistant	1.002	0.986	1.019
SHMI risk	0.889	0.243	3.255

S11 Additional analysis : High and low staffing categories compared with mean staffing

Observed (O) and Expected (E) staffing levels were calculated,
with E being the mean for each service.
The ratio of O/E was derived from these figures
The reference category was defined as O/E between 0.95 and 1.05
Low staffing was defined as O/E <0.95
High staffing was defined as O/E >1.05
This grouping allowed the mean (plus 5% either side of the mean) to be considered as an 'expected' level of staffing, allowing for a small amount of variability. The criteria for 'low' and 'high' were set outside this expected level.

This grouping was considered to be more meaningful that splitting the data into tertiles or quantiles or using standard deviations, as it is more reflective of a real clinical scenario and will provide a better insight to service planners.

For outcome of readmission within 7 days

Variable	OR readmission 7 days	95% CI	
<20 years	1.068	0.812	1.404
20-24 years	1.000	reference category	
25-29 years	0.914	0.790	1.057
30-34 years	0.984	0.854	1.134
35-39 years	0.984	0.838	1.154
40+ years	1.370	1.101	1.706
Assisted birth	1.873	1.648	2.127
Emergency caesarean birth	1.911	1.701	2.147
Spontaneous vaginal birth	1.000	reference category	
Planned caesarean birth	1.518	1.321	1.744
Midwifery staffing			
Low, 95% of mean or less	1.056	0.943	1.182
Near to mean 95%-105%	1.000	reference category	
High 105% of mean or more	0.973	0.862	1.098
Maternity assistant staffing			
Low, 95% of mean or less	0.924	0.816	1.046
Near to mean 95%-105%	1.000	reference category	
High 105% of mean or more	0.935	0.825	1.059
SHMI risk	0.693	0.111	4.335

SHMI Standardised Hospital Mortality Indicator

For outcome of readmission within 30 days

Variable	OR readmission 7 days	95% CI	
<20 years	1.066	0.841	1.351
20-24 years	1.000	reference category	
25-29 years	0.970	0.856	1.099
30-34 years	1.025	0.908	1.158
35-39 years	1.046	0.913	1.199
40+ years	1.319	1.090	1.595
Assisted birth	1.850	1.657	2.065
Emergency caesarean birth	2.076	1.882	2.290
Spontaneous vaginal birth	1.000	reference category	
Planned caesarean birth	1.705	1.520	1.913
Midwifery staffing			
Low, 95% of mean or less	1.002	0.911	1.102
Near to mean 95%-105%	1.000	reference category	
High 105% of mean or more	0.957	0.865	1.060
Maternity assistant staffing			
Low, 95% of mean or less	0.968	0.871	1.076
Near to mean 95%-105%	1.000	reference category	
High 105% of mean or more	0.968	0.870	1.077
SHMI risk	0.889	0.243	3.247

SHMI Standardised Hospital Mortality Indicator

S12 Frequency of exposure to staffing categories in study population

For registered midwives the staffing categories breakdown is as follows

1,258/64,250 (1.96%) staffing values known to be missing as reported in supplement 1.3

Staffing caregory	Frequency	Percent
Low, 95% of mean or less	24,954	39.61
Near to mean 95%-105%	18,576	29.49
High 105% of mean or more	19,462	30.90

For maternity assistants the staffing categories breakdown is as follows

2,452/64,250 (3.82%) staffing values known to be missing as reported in supplement 1.3

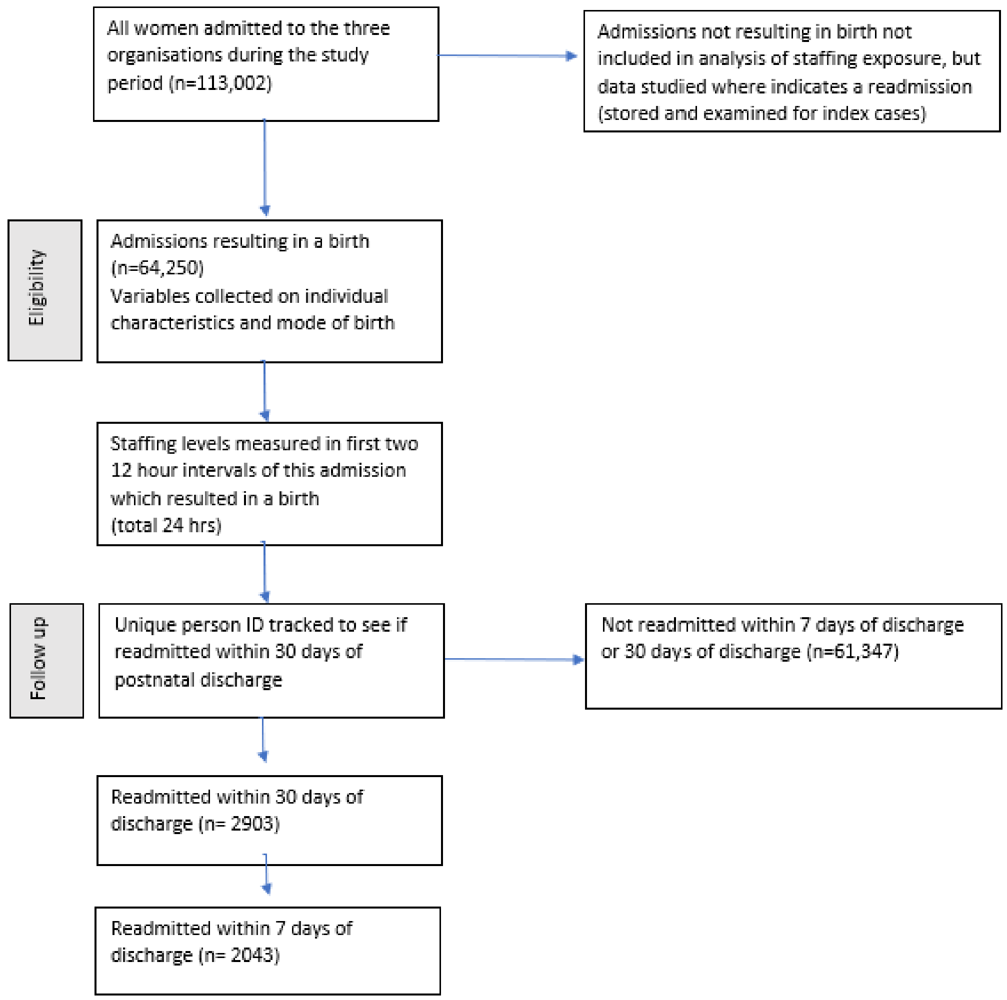
Staffing caregory	Frequency	Percent
Low, 95% of mean or less	26,374	42.68
Near to mean 95%-105%	12,520	20.26
High 105% of mean or more	22,903	37.06

S13 Results of full models by subset of population

Odds of readmission within 7 days, by subset of mode of birth

	Readmission rate	Exposed to staffing below mean Registered midwives (HPPD)	OR 95% CI	Exposed to staffing below mean Maternity assistants (HPPD)	OR 95% CI
Whole cohort	3.18%	1.108	1.003, 1.223	0.957	0.866, 1.057
Assisted birth	4.59%	1.315	1.033, 1.675	0.876	0.689, 1.114
Emergency caesarean	4.67%	1.219	0.991, 1.499	0.893	0.726, 1.098
Spontaneous birth	2.66%	0.983	0.849, 1.139	0.988	0.852, 1.146
Planned caesarean	3.85%	1.113	0.858, 1.444	1.082	0.833, 1.405

S14 Flow chart for data selection



S15 Coding

Univariable analysis

melogit INDEXHRGPostnatalR7days ib5.age_category_combined || Trustid :, allbaselevels or
melogit INDEXHRGPostnatalR7days ib4.del_method || Trustid :, allbaselevels or
melogit INDEXHRGPostnatalR7days SHMI_risk || Trustid :, or
melogit INDEXHRGPostnatalR7days understaffRNless1 || Trustid :, or
melogit INDEXHRGPostnatalR7days understaffNAless1 || Trustid :, or
melogit INDEXHRGPostnatalR7days understaffOverallLess1 || Trustid :, or
Repeated at 30 days

Model fit

estat ic after each model to gain AIC and BIC
melogit INDEXHRGPostnatalR7days || Trustid :
melogit INDEXHRGPostnatalR7days age_category_combined || Trustid :
melogit INDEXHRGPostnatalR7days age_category_combined birth_method|| Trustid :
melogit INDEXHRGPostnatalR7days age_category_combined birth_method understaffRNless1|| Trustid :
melogit INDEXHRGPostnatalR7days age_category_combined birth_method understaffRNless1 understaffNAless1|| Trustid :
melogit INDEXHRGPostnatalR7days age_category_combined birth_method understaffRNless1 understaffNAless1 SHMI_risk || Trustid :
melogit INDEXHRGPostnatalR7days age_category_combined birth_method understaffRNless1 understaffNAless1 SHMI_risk LessExpectedSkillMix || Trustid :
melogit INDEXHRGPostnatalR7days age_category_combined birth_method understaffRNless1 understaffNAless1 SHMI_risk LessExpectedSkillMix HighrerExpectedTurnover || Trustid :

Full model coding

melogit INDEXHRGPostnatalR7days ib4.age_category_combined ib4.del_method understaffRNless1 understaffNAless1 SHMI_risk|| Trustid :, allbaselevels cformat(%9.4f) or

melogit INDEXHRGPostnatalR30days ib4.age_category_combined ib4.del_method understaffRNless1 understaffNAless1 SHMI_risk|| Trustid :, allbaselevels cformat(%9.4f) or

staffing as categories

melogit INDEXHRGPostnatalR7days ib4.age_category_combined ib4.birth_method ib2.StaffCatRN ib2.StaffCatNA SHMI_risk|| Trustid :, allbaselevels cformat(%9.4f) or

melogit INDEXHRGPostnatalR30days ib4.age_category_combined ib4.birth_method ib2.StaffCatRN ib2.StaffCatNA SHMI_risk|| Trustid :, allbaselevels cformat(%9.4f) or

By subgroup of birth method

bysort birth_method: melogit INDEXHRGPostnatalR7days ib4.age_category_combined understaffRNless1 understaffNAless1 SHMI_risk|| Trustid :, allbaselevels cformat(%9.3f) or

Appendix J Study 4 Supplementary material

S1 Distribution of staffing in each maternity service

S2 Number of harmful incidents per day in relation to staffing

S3 Distribution of harm incidents in each of the maternity services

S4 Testing for collinearity

S5 Choice of model for count data

S6 Model fitting by AIC and BIC values

S7 Testing for clustering of data points in each organisation

S8 Results from final multivariable model with primary outcome of all harm incidents

S9 Additional analysis : High and low staffing categories compared with mean staffing

S10 Secondary analysis with the outcome of any reported incident

S11 Secondary analysis with the outcome of incidents rated as moderate harm or above

S12 Secondary analysis with the outcome of medicines incidents

S13 Secondary analysis with the outcome of stillbirth or neonatal death

S14 Secondary analysis with the outcome of delay in care

S15 Secondary analysis with the outcome of maternal haemorrhage

S16 Secondary analysis with the outcome of third or fourth degree tear

S17 Secondary analysis with the outcome of discharge incident

S18 Secondary analysis with the outcome of reported low staffing or high workload

S19 Sensitivity analysis using staffing the day before for primary outcome

S20 Relationship between staff-reported incidents of low staffing/high workload and harmful incidents

S21 Missing data

S22 Breakdown of all incidents Service A

S23 Breakdown of all incidents Service B

S24 Breakdown of all incidents Service C

S25 Coding

S1 Distribution of staffing in each maternity service

	RM HPPD Mean	RM HPPD Std err	MA HPPD Mean	MA HPPD Std err
Service A	12.653	0.1427	5.2209	0.0621
Service B	5.0227	0.0172	2.1114	0.0112
Service C	6.8889	0.0348	2.5759	0.0147

RM Registered midwives, MA Maternity assistants

S2 Number of harmful incidents per day in relation to staffing

When understaffed by registered midwives

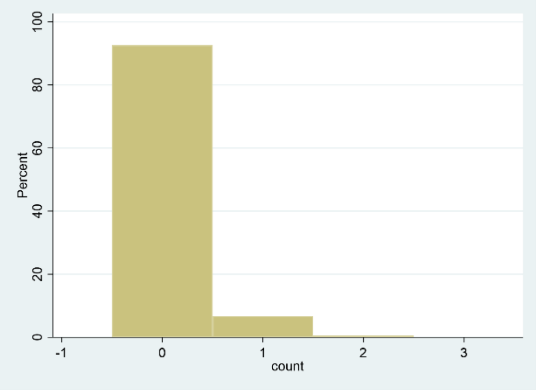
Number of harmful incidents	0	1	2	3	4	5	6	Total
Staff mean or above	1,421 66.22%	476 22.18%	171 7.97%	60 2.80%	14 0.65%	4 0.19%	0 0.00%	2,146 100.00%
Staff below mean	1,845 66.30%	603 21.67%	235 8.44%	71 2.55%	21 0.75%	4 0.14%	4 0.14%	2,783 100.00%
Total	3,266 66.26%	1,079 21.89%	406 8.24%	131 2.66%	35 0.71%	8 0.16%	4 0.08%	4,929 100.00%

When understaffed by maternity assistants

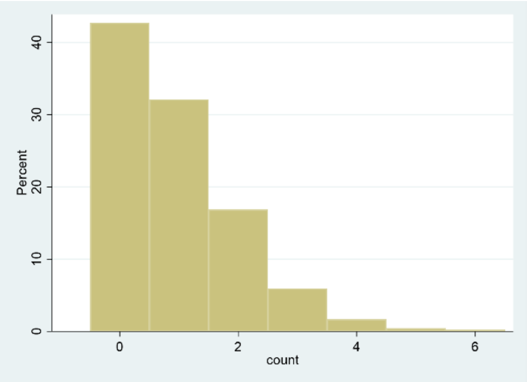
Number of harmful incidents	0	1	2	3	4	5	6	Total
Staff mean or above	1,726 67.50%	551 21.55%	204 7.98%	55 2.15%	19 0.74%	1 0.04%	1 0.04%	2,557 100%
Staff below mean	1,540 64.92%	528 22.26%	202 8.52%	76 3.20%	16 0.67%	7 0.30%	3 0.13%	2,372 100%
Total	3,266 66.26%	1,079 21.89%	406 8.24%	131 2.66%	35 0.71%	8 0.16%	4 0.08%	4,929 100%

S3 Distribution of harmful incidents in each of the maternity services

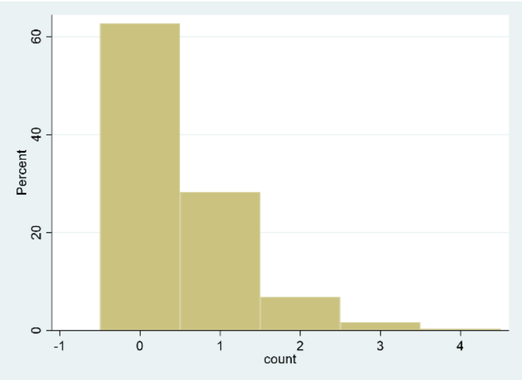
Maternity service A (number of incidents per day)



Maternity service B (number of incidents per day)



Maternity service C (number of incidents per day)



High proportion of zeros noted and positive skew to data

Variance is greater than mean for all maternity services (over dispersed)

S4 Testing for collinearity

Predictor variables were tested for collinearity by calculating the VIF (variance inflation factor) This is an indicator of how much of the inflation of the standard error could be caused by collinearity. As a guide, a VIF of ten or greater is a sign of severe multi-collinearity (O'Brien, 2007). The results below indicate that this assumption of independence is supported.

	Variance inflation factor
Proportion any comorbidity	1.03
Proportion aged Forty or More	1.00
Higher_expected turnover	1.13
proportion_RM	1.36
daycode_weekend	1.09
undermeanstaff MA	1.81
undermeanstaff RM	1.54

S5 Choice of model for count data

Testing Poisson versus Negative Binomial models using likelihood ratio test

LR chi sq 2(1) = 38.85
Prob >chi2 = 0.00000

For empty models
Model fit with poisson, AIC 8303.547, BIC 8323.055
Model fit with negative binomial AIC 8267.194, BIC 8293.205

The Negative Binomial (NB) regression model was chosen as it is suitable for over dispersed data e.g. where variance > mean (see charts in S3) and it performed better on the chisquared liklihood-ratio test and model fit by AIC and BIC

The mean number of (patient days) per day in each service as the exposure variable to account to the number of people in the service on any one day.

S6 Model fitting by AIC and BIC values for negative binomial empty model plus the addition of covariates for primary outcome of harmful incidents

Model fit was assessed so that the model with the least AIC score was used to generate the regression coefficients and odds ratios. Where a difference of less than 2 on the AIC scores was noted then this was not acted upon as it is not considered to be discriminatory at this level (Burnham *et al.*, 2004). Both AIC and BIC were used in order not to overfit or underfit the model to the data. Results of the goodness of fit tests are presented below.

Analysis number	Model tested	AIC	BIC	Decision
1	Empty model	8232.344	8251.853	
2	1 adding RM staffing	8229.155	8255.167	
3	1 adding RM and MA staffing	**8231.079**	**8263.593**	Keep both RM and MA in full model as variables of interest. Use these AIC/BIC to test adding other variables against one at a time
Line 3 was used as a comparison as it included the staffing variables of interest. The aim was to select a model with the lowest AIC and BIC and a difference of 2 units was used as a threshold for improved model fit				
4	3 adding weekend/weekday	8230.641	8269.658	Do not include weekend/weekday in full model as does not improve model fit
5	3 adding Turnover	8216.777	8255.794	Keep turnover in full model as improves model fit
6	3 adding Skill mix	7968.274	8006.789	Keep skill mix in full model as improves model fit
7	3 adding proportion age over 40 yrs	8231.867	8270.885	Do not include age over 40 in full model as does not improve model fit
8	3 adding Charlson comorbidity	8231.831	8270.849	Do not include comorbidity in full model as does not improve model fit
9	Full model including RM staffing, MA staffing, Turnover and Skill mix	7954.899	7999.833	Coding for full model*

*_menbreg Any_harm_incident undermeanstaffRM undermeanstaffMA Higher_expectedturnover proportion_RM, exposure(mean_pat_days_org) || organisation:, allbaselevels irr

S7 Tests for clustering of data points in each organisation

The Intra-cluster Correlation Coefficient (ICC) represents the dependence of scores between individuals in the same higher-level unit or group (Musca *et al.*, 2011). If the ICC coefficient value is high (>.10), multilevel analysis is important to reduce the risk of type I error.

For the primary outcome (any harm incident) the ICC was 0.299 which shows a moderate level of inter-dependence of observations within groups (clustering). Model fit is better with the hierarchical analysis as indicated by lower AIC and BIC results.

	1. Single level negative binomial	2. Multi level negative binomial
AIC	7974.47	7954.90
BIC	8012.99	7999.83
ICC	0	0.299

1. nbreg Any_harm_incident undermeanstaffRM undermeanstaffMA Higher_expectedturnover proportion_RM, exposure(mean_pat_days_org) irr estat ic

2. menbreg Any_harm_incident undermeanstaffRM undermeanstaffMA Higher_expectedturnover proportion_RM, exposure(mean_pat_days_org) || organisation:, irr estat ic

S8 Results from final multivariable model with primary outcome of all harm incidents

Harm_incidents	IRR	Std. Err.	Z	P>|z	[95% Conf. Interval]	
undermeanstaffRM	1.110	0.058	1.99	0.046	1.002	1.229
undermeanstaffMA	0.919	0.057	1.35	0.177	0.813	1.039
Higher_expectedturnover	1.190	0.053	3.92	0.000	1.091	1.299
proportion_RM	3.101	2.348	1.49	0.135	0.703	13.677
_cons	0.003	0.001	-11.07	0.000	0.001	0.007
ln(mean_pat_days_org)	1.000	(exposure)				
/lnalpha	-1.624	0.210			-2.035	-1.213
var(_cons)	0.027	0.025			0.004	0.171

S9 Additional analysis : High and low staffing categories compared with mean staffing

Observed (O) and Expected (E) staffing levels were calculated,
with E being the mean for each service.
The ratio of O/E was derived from these figures
The reference category was defined as O/E between 0.95 and 1.05
Low staffing was defined as O/E <0.95
High staffing was defined as O/E >1.05
This grouping allowed the mean (plus 5% either side of the mean) to be considered as an 'expected' level of staffing, allowing for a small amount of variability. The criteria for 'low' and 'high' were set outside this expected level.

This grouping was considered to be more meaningful that splitting the data into tertiles or quantiles or using standard deviations, as it is more reflective of a real clinical scenario and will provide a better insight to service planners.

Harm_incidents	IRR	Std. Err.	Z	P>|z	[95% Conf. Interval]	
StaffcatRM						
StaffCat RM<0.95	1.007	0.059	0.11	0.909	0.898	1.129
StaffCarRM 0.95-1.05	1.000	(base)				
StaffCatRM >1.05	0.958	0.060	-0.68	0.498	0.848	1.084
StaffcatMA						
StaffCatMA <0.95	0.985	0.068	-0.23	0.822	0.860	1.127
StaffCatMA 0.95-1.05t	1.000	(base)				
StaffCatMA >1.05	1.039	0.071	0.56	0.577	0.909	1.187
Higher_expectedturnover	1.195	0.053	3.99	0.000	1.095	1.305
proportion_RM	2.312	1.927	1.01	0.314	0.452	11.842
_cons	0.003	0.002	-9.55	0.000	0.001	0.010
ln(mean_pat_days_org)	1.000	(exposure)				
/lnalpha	-1.611	0.208			-2.018	-1.204
var(_cons)	0.028	0.027			0.004	0.178

S10 Secondary analysis with the outcome of any reported incident

Any_incidents	IRR	Std. Err.	Z	P>|z|	[95% Conf. Interval]	
undermeanstaffRM	1.007	0.026	0.27	0.783	0.958	1.059
undermeanstaffMA	1.058	0.032	1.86	0.063	0.997	1.122
Higher_expectedturnover	1.176	0.025	7.51	0.000	1.128	1.227
proportion_RM	0.828	0.298	-0.52	0.601	0.409	1.677
_cons	0.040	0.012	-11.04	0.000	0.023	0.071
ln(mean_pat_days_org)	1.000	(exposure)				
/lnalpha	-2.182	0.091			-2.360	-2.004
var(_cons)	0.063	0.052			0.013	0.320

S11 Secondary analysis with the outcome of incidents rated as moderate harm or above

harm_moderateplus	IRR	Std. Err.	Z	P>|z|	[95% Conf. Interval]	
undermeanstaffRM	1.097	0.235	0.43	0.667	0.720	1.670
undermeanstaffMA	1.197	0.285	0.76	0.450	0.751	1.909
Higher_expectedturnover	1.488	0.258	2.29	0.022	1.058	2.091
proportion_RM	0.146	0.437	-0.64	0.520	0.000	50.900
_cons	0.002	0.003	-3.01	0.003	0.000	0.103
ln(mean_pat_days_org)	1.000	(exposure)				
/lnalpha	0.415	0.613			-0.786	1.615
var(_cons)	0.680	0.577			0.129	3.588

S12 Secondary analysis with the outcome of medicines incidents

medicines_incident	IRR	Std. Err.	Z	P>|z|	[95% Conf. Interval]	
undermeanstaffRM	1.018	0.088	0.21	0.837	0.860	1.205
undermeanstaffMA	1.032	0.105	0.31	0.755	0.846	1.260
Higher_expectedturnover	1.042	0.076	0.56	0.572	0.904	1.201
proportion_RM	1.082	1.373	0.06	0.951	0.090	13.013
_cons	0.002	0.002	-6.64	0.000	0.000	0.011
ln(mean_pat_days_org)	1.000	(exposure)				
/lnalpha	-1.649	0.582			- 2.790	-0.508
var(_cons)	0.358	0.309			0.066	1.944

S13 Secondary analysis with the outcome of stillbirth or neonatal death

stillbirthornnd	IRR	Std. Err.	Z	P>|z|	[95% Conf. Interval]	
undermeanstaffRM	1.047912	.2251551	0.22	0.828	.6877575	1.596668
undermeanstaffMA	.9244814	.238015	-0.30	0.760	.5581483	1.531252
Higher_expectedturnover	.8638948	.1600263	-0.79	0.430	.6008774	1.242041
proportion_RM	.0552131	.1597032	-1.00	0.317	.0001905	16.00052
_cons	.0056749	.0115587	-2.54	0.011	.0001048	.3073845
ln(mean_pat_days_org)	1	(exposure)				
/lnalpha	.7855324	.4598692			-.1157946	1.686859
var(_cons)	.3853879	.4114015			.0475599	3.122882

S14 Secondary analysis with the outcome of delay in care

delay	IRR	Std. Err.	Z	P>|z|	[95% Conf. Interval]	
undermeanstaffRM	1.164	0.092	1.92	0.055	0.997	1.360
undermeanstaffMA	0.889	0.086	-1.22	0.224	0.736	1.075
Higher_expectedturnover	1.224	0.084	2.95	0.003	1.070	1.401
proportion_RM	3.017	3.330	1.00	0.317	0.347	26.247
_cons	0.002	0.001	-8.31	0.000	0.000	0.007
ln(mean_pat_days_org)	1.000	(exposure)				
/lnalpha	-1.548	0.351			-2.237	-0.859
var(_cons)	0.053	0.059			0.006	0.470

S15 Secondary analysis with the outcome of maternal haemorrhage

haemorrhage	IRR	Std. Err.	Z	P>|z|	[95% Conf. Interval]	
undermeanstaffRM	0.963	0.078	-0.46	0.644	0.822	1.129
undermeanstaffMA	1.165	0.114	1.55	0.121	0.961	1.412
Higher_expectedturnover	1.317	0.092	3.93	0.000	1.148	1.511
proportion_RM	1.567	1.742	0.40	0.686	0.177	13.840
_cons	0.003	0.002	-7.31	0.000	0.001	0.013
ln(mean_pat_days_org)	1.000	(exposure)				
/lnalpha	-1.045	0.260			-1.555	-0.536
var(_cons)	0.152	0.157			0.020	1.147

S16 Secondary analysis with the outcome of third or fourth degree tear

third_fourthtear	IRR	Std. Err.	Z	P>|z|	[95% Conf. Interval]	
undermeanstaffRM	0.846	0.089	-1.60	0.111	0.689	1.039
undermeanstaffMA	1.247	0.153	1.80	0.072	0.980	1.587
Higher_expectedturnover	1.459	0.130	4.23	0.000	1.225	1.738
proportion_RM	0.277	0.377	-0.94	0.346	0.019	4.003
_cons	0.008	0.009	-4.48	0.000	0.001	0.066
ln(mean_pat_days_org)	1.000	(exposure)				
/lnalpha	0.345	0.140			0.070	0.620
var(_cons)	0.555	0.560			0.077	4.010

S17 Secondary analysis with the outcome of discharge incident

discharge	IRR	Std. Err.	Z	P>|z|	[95% Conf. Interval]	
undermeanstaffRM	1.113	0.171	0.70	0.484	0.824	1.503
undermeanstaffMA	1.053	0.200	0.27	0.785	0.726	1.527
Higher_expectedturnover	1.512	0.204	3.06	0.002	1.160	1.970
proportion_RM	0.058	0.127	-1.30	0.193	0.001	4.201
_cons	0.004	0.006	-3.71	0.000	0.000	0.075
ln(mean_pat_days_org)	1.000	(exposure)				
/lnalpha	-1.066	0.910			-2.848	0.717
var(_cons)	0.000	0.000			.	.

S18 Secondary analysis with the outcome of reported low staffing or high workload

staffing_incident	IRR	Std. Err.	Z	P>|z|	[95% Conf. Interval]	
undermeanstaffRM	1.483	0.116	5.05	0.000	1.273	1.728
undermeanstaffMA	1.225	0.118	2.11	0.035	1.015	1.479
Higher_expectedturnover	1.349	0.091	4.46	0.000	1.183	1.539
proportion_RM	2.286	2.540	0.74	0.457	0.259	20.182
_cons	0.000	0.000	-8.27	0.000	0.000	0.003
ln(mean_pat_days_org)	1.000	(exposure)				
/lnalpha	-0.626	0.155			-0.930	-0.322
var(_cons)	0.833	0.717			0.154	4.503

S19 Sensitivity analysis using staffing the day before for primary outcome

Included to capture imprecisely matched incidents or time lagged effects

Harm_incidents	IRR	Std. Err.	Z	P>z	[95% Conf. Interval]	
undermeanstaffRM	1.021	0.053	0.39	0.695	0.921	1.131
undermeanstaffMA	0.919	0.058	-1.35	0.176	0.813	1.039
Higher_expectedturnover	1.153	0.051	3.19	0.001	1.056	1.258
proportion_RM	2.571	1.952	1.24	0.214	0.581	11.384
_cons	0.003	0.002	-10.68	0.000	0.001	0.009
ln(mean_pat_days_org)	1.000	(exposure)				
/lnalpha	-1.592	0.205			-1.993	-1.191
var(_cons)	0.026	0.025			0.004	0.167

S20 Relationship between staff-reported incidents of low staffing/high workload and harmful incidents

Harm_incidents	IRR	Std. Err.	Z	P>|z	[95% Conf. Interval]	
undermeanstaffRM	1.148	0.058	2.75	0.006	1.040	1.267
_cons	0.387	0.258	-1.42	0.155	0.104	1.432
var(_cons)	1.335	1.096			0.267	6.666

S21 Missing data

Maternity assistant staffing was missing for 396 days in Trust A
No other missing data in dataset

S22 Breakdown of all incidents Service A

(first descriptive column only, incidents >1% of total incidents listed in table)

Percentage of all reported incidents	
Simple complication of treatment*	21.50%
Third or fourth degree tears	13.77%
Unexpected admission to Neo-Natal Unit	4.43%
Failure in referral process	4.08%
Labour or delivery – other	3.37%
Post-partum haemorrhage > 1,000ml	3.16%
Delay or failure to monitor	1.90%
Failure to follow up	1.90%
Failure/delay to order correct tests, image etc	1.90%
Diagnostic Images / specimens - mislabelled / unlabelled	1.83%
Patient incorrectly identified	1.76%
Diagnostic images / specimens - inadequate / incomplete	1.62%
Stillbirth	1.62%
Unexpected re-admission or re-attendance	1.62%
Documentation (including records, identification) other	1.55%
Failure to note relevant information in patient's record	1.55%
Delay / difficulty in obtaining clinical assistance	1.48%
Communication failure - outside of immediate team	1.26%
Delay in diagnosis for no specified reason	1.19%
Cord PH < 7.15	1.12%
Unplanned admission / transfer to specialist care unit	1.12%
Breach of patient confidentiality	1.05%
Failure in booking process	1.05%

*when examining second column this was mainly post partum haemorrhage and shoulder dystocia

S23 Breakdown of all incidents Service B
(first descriptive column only, incidents >1% of total listed in table)

Maternity triggers*	39.98%
Communication failure	7.09%
Delay / failure to treatment or procedure	6.43%
Documentation and Health Records	6.41%
Staffing	6.21%
Medication	5.40%
Medical Devices	3.67%
Blood Transfusion	3.65%
Nursing/Midwifery Staffing	2.87%
Access, Admission, Discharge and Transfer issue	2.37%
Sharps incident	1.82%
Diagnosis, Scans and Tests	1.70%
Tissue Viability	1.24%
Aggression, Violence and Harassment	1.23%
Other (Patient-Safety)	1.22%

*includes post partum haemorrhage, unplanned neonatal unit admission, shoulder dystocia, third degree tear, low cord pH, low apgar score

S24 Breakdown of all incidents Service C

(first descriptive column only, incidents >1% of total listed in table)

Clinical Event	48.22%
Non Clinical Event	18.74%
Medication	11.53%
Pathology/Blood/Screening	8.49%
Accident including slips, trips and falls	4.26%
Staff Shortage	2.80%
Equipment	1.31%
Tissue Damage	1.25%

S25 Coding

Univariable model, using multilevel negative binomial

menbreg Any_harm_incident undermeanstaffRM, exposure(mean_pat_days_org) || sw:, irr cformat(%9.3f)

menbreg Any_harm_incident undermeanstaffMA, exposure(mean_pat_days_org) || sw:, irr cformat(%9.3f)

menbreg Any_harm_incident ib1.daycode_weekend , exposure(mean_pat_days_org) || sw:, irr cformat(%9.3f)

menbreg Any_harm_incident ib0.turnover , exposure(mean_pat_days_org) || sw:, irr cformat(%9.3f) allbaselevels

menbreg Any_harm_incident ib0.lowerExpectedskillmix , exposure(mean_pat_days_org) || sw:, irr cformat(%9.3f) allbaselevels

menbreg Any_harm_incident proportion_RM , exposure(mean_pat_days_org) || sw:, irr cformat(%9.3f)

menbreg Any_harm_incident NproportionFortyorMore , exposure(mean_pat_days_org) || sw:, irr cformat(%9.3f)

menbreg Any_harm_incident NproportionAnyCCI , exposure(mean_pat_days_org) || sw:, irr cformat(%9.3f)

Testing for collinearity

regress undermeanstaffRM undermeanstaffMA daycode_weekend proportion_RM Higher_expectedturnover NproportionFortyorMore NproportionAnyCCI

vif

Model fit & results
Used mean number of (patient days) per day in each service as the exposure variable but kept the count the same as raw data =number of incidents

Testing Poisson versus Negative Binomial models using likelihood ratio test
quietly poisson Any_harm_incident undermeanstaffRM undermeanstaffMA, exposure(mean_pat_days_org) nolog

est store poisson

quietly nbreg Any_harm_incident undermeanstaffRM undermeanstaffMA, exposure(mean_pat_days_org) nolog

est store nbreg

lrtest poisson nbreg, stats force

The Negative Binomial (NB) regression model was chosen as it is suitable for over dispersed data e.g. where variance > mean.

Model fitting

Empty model

quietly menbreg Any_harm_incident, exposure(mean_pat_days_org) || sw:, irr cformat(%9.3f)
estat ic

Adding in RM staffing variable
quietly menbreg Any_harm_incident undermeanstaffRM, exposure(mean_pat_days_org) || sw:, irr cformat(%9.2f)

Add in RM + MA staffing variables (did not reduce AIC by more than 2 and BIC increased)
quietly menbreg Any_harm_incident undermeanstaffRM undermeanstaffMA , exposure(mean_pat_days_org) || sw:, irr cformat(%9.2f)

Adding in weekend/weekday
(did not reduce AIC by more than 2 and BIC increased) – taken out again
quietly menbreg Any_harm_incident undermeanstaffRM undermeanstaffMA ib1.daycode_weekend , exposure(mean_pat_days_org) || sw:, allbaselevels irr cformat(%9.3f)

Adding in turnover
quietly menbreg Any_harm_incident undermeanstaffRM undermeanstaffMA Higher_expectedturnover , exposure(mean_pat_days_org) || sw:, allbaselevels irr cformat(%9.3f)

Adding in skill mix
quietly menbreg Any_harm_incident undermeanstaffRM undermeanstaffMA proportion_RM , exposure(mean_pat_days_org) || sw:, allbaselevels irr cformat(%9.3f)

Adding in age
quietly menbreg Any_harm_incident undermeanstaffRM undermeanstaffMA NproportionFortyorMore , exposure(mean_pat_days_org) || sw:, allbaselevels irr cformat(%9.3f)
(did not reduce AIC by more than 2 and BIC increased) – taken out again

Adding in CCI
quietly menbreg Any_harm_incident undermeanstaffRM undermeanstaffMA NproportionAnyCCI , exposure(mean_pat_days_org) || sw:, allbaselevels irr cformat(%9.3f)
(did not reduce AIC by more than 2 and BIC increased)– taken out again

Full model with staffing variables plus those that reduced AIC (not weekend, age or CCI)

menbreg Any_harm_incident undermeanstaffRM undermeanstaffMA Higher_expectedturnover proportion_RM, exposure(mean_pat_days_org) || sw:, allbaselevels irr cformat(%9.3f)

As categories
menbreg Any_harm_incident i.StaffCatRN i.StaffCatNA Higher_expectedturnover proportion_RM, exposure(mean_pat_days_org) || sw:, allbaselevels irr cformat(%9.3f)

Sensitivity analysis -Staffing the day before
menbreg Any_harm_incident M1undermeanstaffRM M1undermeanstaffMA M1Higher_expectedturnover M1proportion_RM , exposure(mean_pat_days_org) || sw:, allbaselevels irr cformat(%9.3f)

Modelling secondary outcomes using multi level negative binomial regression

menbreg Any_incidents undermeanstaffRM undermeanstaffMA Higher_expectedturnover proportion_RM , exposure(mean_pat_days_org) || sw:, allbaselevels irr cformat(%9.3f)

menbreg harm_moderateplus undermeanstaffRM undermeanstaffMA Higher_expectedturnover proportion_RM, exposure(mean_pat_days_org) || sw:, allbaselevels irr cformat(%9.3f)

menbreg medicines_incident undermeanstaffRM undermeanstaffNM Higher_expectedturnover proportion_RM, exposure(mean_pat_days_org) || sw:, allbaselevels irr cformat(%9.3f)

menbreg stillbirthornnd undermeanstaffRM undermeanstaffMA Higher_expectedturnover proportion_RM, exposure(mean_pat_days_org) || sw:, allbaselevels irr cformat(%9.3f)

menbreg delay undermeanstaffRM undermeanstaffMA Higher_expectedturnover proportion_RM, exposure(mean_pat_days_org) || sw:, allbaselevels irr cformat(%9.3f)

menbreg haemorrhage undermeanstaffRM undermeanstaffMA Higher_expectedturnover proportion_RM, exposure(mean_pat_days_org) || sw:, allbaselevels irr cformat(%9.3f)

menbreg third_fourthtear undermeanstaffRM undermeanstaffMA Higher_expectedturnover proportion_RM, exposure(mean_pat_days_org) || sw:, allbaselevels irr cformat(%9.3f)

menbreg discharge undermeanstaffRM undermeanstaffMA Higher_expectedturnover proportion_RM, exposure(mean_pat_days_org) || sw:, allbaselevels irr cformat(%9.3f)

menbreg staffing_incident undermeanstaffRM undermeanstaffMA Higher_expectedturnover proportion_RM, exposure(mean_pat_days_org) || sw:, allbaselevels irr cformat(%9.3f)

Appendix K Proposals for future research

Proposed study 1: Retrospective longitudinal study using routine data

Proposed study 2: Qualitative study on understaffing mechanisms leading to adverse events

Proposed study 3: Qualitative study on responses to short staffing and escalation plans

Proposed study 4: Prospective longitudinal study to evaluate a deliberate change in staffing

Proposed study 5: Data mining of maternity information systems with integrated staff rosters

Proposed study 1: Retrospective longitudinal study using routine data

A retrospective longitudinal study is proposed to build on the design of study three to improve effect estimates and minimise endogeneity. Staff would be identified by professional groups, and include obstetric, neonatal and anaesthetic staff as investigations into patient harm have revealed significant gaps in medical as well as midwifery rosters (Ockenden, 2022; Kirkup, 2022). The availability of medical staff may modify the effects observed with variation in midwifery staff, as staffing effects can be attenuated with the addition of other staff groups (Ball, 2017). Understaffing could be defined as lower than planned staffing, rather than relating staffing to average levels. Deviation from planned staffing would be more accurate in identifying a shortfall based on an estimation of what staffing is required. However, this planned level would need to have been set using robust measures taking into account the characteristics of the population and service activity.

Data could be extracted from maternity information systems to include demographic details, clinical risk factors, observations, pregnancy details, birth events and postnatal outcomes. The digital maternity record standard (NHS Digital, 2018a) aims to ensure that maternity records are consistently recorded, even where there are different software systems. As entries are date-stamped it should be possible to track data longitudinally to note the sequence of events. The recorded events could include care that is missed or incomplete, as well as outcomes. This type of data has been used in previous studies to understand the potential mediators of subsequent outcomes, such as missed observations of vital signs (Griffiths *et al.*, 2018).

Data fields like body mass index and ethnic group are areas where adjustment within studies has been incomplete in the past, and maternity systems will hold these data fields and enable these factors to be fully considered in the analyses. It would also be possible to extract data on delays in care, postpartum haemorrhage, perineal damage, neonatal readmission and low Apgar scores using recorded data, rather than relying on staff incident reports.

Future studies should also estimate costs for each staff group, as service planners need to be able to weigh up the additional costs of higher staffing levels against measures of effectiveness and potential savings if consequences such as readmissions are prevented. In the face of budgetary constraints and workforce shortages, the relative costs and benefits of different staff configurations need to be evaluated.

Proposed study 2: Qualitative study on understaffing mechanisms leading to adverse events

It is unclear exactly how understaffing affects the outcomes for mothers and babies. Understanding the mechanism of effect will help to focus staffing efforts so that staff can target areas which make the largest improvements in the care of women and babies.

Qualitative research is proposed to explore the mechanisms by which understaffing can lead to adverse outcomes, readmissions and poorer care experience. This research would aim to understand the aspects of care that are affected when wards are understaffed or when there are higher numbers of admissions and discharges per day. Contributing factors to adverse events could be examined, especially the knock-on effect of understaffing on processes, teamwork and decision making which may affect safety. Aspects of Vincent's risk framework (Vincent *et al.*, 1998) could be explored in depth to understand how these factors link together and contribute to a higher risk of poor outcomes and experiences.

Answers to these questions could be gained from interviews or focus groups, involving heads of midwifery, senior midwifery managers, midwives, doctors, support workers and administrative staff. In addition, it would be useful to know how staffing and need for midwives have changed over time, relating to the changing care needs, acuity and comorbidity in the populations cared for. Other contributors to workload such as additional roles and digital workload could also be explored as secondary questions.

Proposed study 3: Qualitative study on responses to short staffing and escalation plans

Different responses to short staffing could be examined to understand how effective these are and what consequences may result from staff redeployment, the use of temporary staff and task shifting. Just one paper was found evaluating reconfiguration options when there are staff shortages, which found there was little benefit in reducing community births and concentrating staff in obstetric units (Grollman *et al.*, 2022). However, the authors note that their models are not intended to be used for severe and substantial shortages which cannot be met by service reconfigurations.

There is a lack of research on escalation strategies within maternity services to understand how best to do this in response to high workload or staff insufficiency. Local Maternity Systems publish their own strategies which include timely discharge of patients, early recognition of capacity issues, rescheduling elective work, cancelling study leave, redeploying midwives in specialist roles to work clinically, cancelling community visits, contacting bank staff and asking staff to work additional hours, and in extreme circumstances temporary closure of maternity units to new admissions (Greater Manchester and Eastern Cheshire Local Maternity System, 2019).

Research is needed on strategies to improve the safety and care experience when there are short-term staffing deficits to meet the volume of work. It is proposed that this could be achieved via a Delphi study of maternity managers, staff members and service users. Implementation of favoured strategies could be subject to service evaluations to note the feasibility, acceptability and effectiveness of different strategies. Increasing the available workforce would be the optimal solution, but based on the current workforce crisis and while waiting for staffing solutions promised in the NHS Long-term Workforce plan (NHS England, 2023c), this area of research is needed to respond effectively to inevitable staff pressures.

Proposed study 4: Prospective longitudinal study to evaluate a deliberate change in staffing

To move the evidence forward in a significant way, there is a need for intervention studies which assess the impact of a deliberate change in staffing levels such as adopting staff-to-patient ratios (Shekelle, 2013). This has an advantage over observational studies of natural variation, as the staffing variable can be manipulated and patients can be followed longitudinally to observe for subsequent outcomes. It may be difficult to provide consistent staffing in the current climate unless there is legislation to enforce a change or incentives to maintain staffing levels for the study period. Such studies can tell us whether direct state intervention yields better staffing and whether those staffing improvements result in better patient outcomes.

Studies would need to be carefully designed and could consist of time series analyses, difference-in-difference studies, or controlled before and after studies (Shekelle, 2013). It is unlikely that randomised controlled trials would be conducted due to ethical barriers, financial impacts and practicalities (Costa *et al.*, 2016; Munier *et al.*, 2014). Studies in the USA after the implementation of mandated nurse-to-patient ratios found mixed results, although the intervention was limited to one state (Spetz *et al.*, 2009; Aiken *et al.*, 2010) and many analyses did not include a control population for comparison (Costa *et al.*, 2016). An intervention study has been completed in Queensland Australia where a prospective panel study of 27 hospitals with agreed staffing ratios were compared with 28 comparison hospitals which were not subject to ratios (McHugh *et al.*, 2021). This demonstrates that the methodology is possible and provides a robust study design to examine the effects of altering staffing levels on patient outcomes and related costs.

Proposed study 5: Data mining of maternity information systems with integrated staff rosters

Routine data provides opportunities for localised information about staffing inputs and consequences. If staffing data could be integrated into maternity information systems, this would provide opportunities for learning from data patterns and the potential to optimise staffing inputs that are associated with the desired outcomes. This would enhance knowledge by modelling a range of outcomes simultaneously and exploring trade-offs between improvements in one outcome compared to changes in another. My research has explored different aspects of quality through different studies, but not considered outcomes simultaneously unlike the real-life decisions that managers are faced with.

The proposed research approach would be based on established data mining techniques and tools (Shu *et al.*, 2023; IBM, 2024; Santos-Pereira *et al.*, 2022). This method could avoid the need to export data offsite if knowledge discovery tools can be built into existing software and data analysts can work in-house with organisations to understand relationships between staffing and consequences. This approach will lead to localised solutions rather than relying on the generalisability of external research conducted in another setting. Data mining techniques have been used in the past to study relationships between workforce requirements and performance, so this data-driven approach is possible (Leary *et al.*, 2016; Elkholosy *et al.*, 2024; Leary *et al.*, 2020). Professional opinion would be needed to interpret the results in the context of local services and priorities. The use of 'big data' in healthcare is still relatively underused (Bates *et al.*, 2018) but the possibilities are worth exploring and may yield important insights into workforce configurations.

Appendix L Dissemination

In addition to the publications from this PhD, the following opportunities for dissemination have been used:

April 2021	Evidence Brief 'What is the relationship between midwifery staffing levels and outcomes?' Evidence_Brief_Maternity_staffing
July 2021	Publication of scoping review which was completed in preparation for this research (Appendix C)
Sept 2021	Midwifery staffing and the experiences of mothers on postnatal wards (poster). Maternity Safety conference. Birmingham
March 2022	Evidence Brief 'Are poor experiences on postnatal wards linked to staffing levels?' Evidence brief_postnatal staffing
April 2022	Academic review on midwifery staffing. Presented to NHS England and Improvement at the Fundamentals of Safe Staffing in maternity services workshop. Online presentation.
Oct 2022	Contribution to call for evidence by APPG Baby Loss and Maternity, postnatal care research featured in Safe staffing: The impact of staffing shortages in maternity and neonatal care
Oct 2022-Jan 2023	Invited onto the Safer Midwifery Staffing Steering Group: Evidence & Research sub group which reported to NHS England and Improvement.
Feb 2023	Live webinar. Season 9 EP4 - Midwifery Staffing Levels and the Impact on Postnatal Care. Midwifery Hour. Discussed first two papers on postnatal staffing https://www.matflix.co.uk/series-9-ep-4-midwifery-staffing-levels-and-the-impact-on-postnatal-care/
Dec 2023	Co-organiser and presenter at Midwifery workforce research conference on Safe and Sustainable Staffing (online conference). Presented study four on harmful incidents and midwifery understaffing.

Dec 2023 Postgraduate Researchers Poster Showcase at University of Southampton, for staff and students. Presented 'The association between midwifery staffing and reported harmful incidents: A cross-sectional analysis of routinely collected data'

Feb 2024 Poster presentation at National Maternity Research Programme Vision Seminar Programme (Birmingham in person event), poster as Dec 2023

Glossary of Terms

Acuity................................. The assessment of the intensity of care that is required.

Akaike Information Criterion. Used to compare the relative quality of different statistical models, represents the trade-off between goodness of fit and the simplicity of a model. Models with the lowest AIC are preferred.

APGAR (score) .... Assessment of the physical well-being of a baby, measured immediately after birth. The score is named after Dr Virginia Apgar

All-Party Parliamentary Group.Consists of members of the House of Commons and the House of Lords. An informal cross-party group with no official status within Parliament.

Attenuate .... A loss of intensity (the effect size decreases)

Bayesian information criterion.Used to guide model selection. Models with the lowest BIC are preferred.

Caesarean birth .... Delivery of a baby via surgery through the mother's abdomen.

Care Hours Per Patient Day .. Measures total staff time spent on direct patient care. It covers both permanent and temporary care staff but excludes students. CHPPD relates only to hospital wards where patients stay overnight (NHS Improvement, 2018).

Case-control study .... Type of observational study which examines the factors associated with outcomes. Studies start with a group of cases and a second comparison group is constructed who do not have the outcome of interest.

Case-mix adjustment........... Adjusting for individual differences e.g. age, parity, ethnicity, type of birth.

Causality............................ The relationship between cause and effect.

Cohort study .... A type of epidemiological study in which a group (cohort) of people with an identified characteristic is followed over time.

Confidence interval............. A range of values which indicate the precision of an estimate. The 95% confidence interval would contain the true value on 95 occasions (out of 100) if 100 different samples were drawn.

Continuity of care(r) .... Model where a known midwife or a small group of known midwives, supports a woman throughout the antenatal, intrapartum, and postnatal continuum (World Health Organization, 2018a).

Cross sectional study .... A type of observational study design. In a cross-sectional study, the investigator measures exposures and outcomes at a single point in time.

CQC Maternity survey .... Annual survey that looks at the experiences of women and other pregnant people who had a live birth in February of each year. Survey data includes antenatal, labour and postnatal care experiences.

Data sharing agreement .... An agreement between two or more parties that outlines which data will be shared and how the data can be used.

Dependency........................ The amount of care/time needed by a patient, the state of relying on somebody/something.

Deploy .... Refers to assigning people to serve in various locations or on specific tasks.

Elective Caesarean .... Caesarean section planned prior to the onset of labour.

Emergency Caesarean .... Caesarean section undertaken after labour has started. Life threatening category 1 caesareans aim for birth within 30 minutes of the decision.

Endogeneity .... The correlation between the independent variable and unexplained variation in the dependent variable. Endogeneity can arise in several ways: measurement error, omitted variable bias, sample selection bias, and simultaneity. Endogeneity can lead to inaccurate conclusions due to biased estimates.

Establishment .... Refers to the number of staff needed to deliver care, includes both filled and vacant positions e.g. midwives in a service.

Exposure .... Refers to any variable that may explain or predict the outcome. Exposure is measured before the onset of disease or outcome.

Exogenous........................... An exogenous variable is a variable that is independent of all other variables. Exogenous variables in causal modelling are the variables with no causal links leading to them from other variables in the model.

Full time equivalent .... Calculates the number of hours worked as multiples of full time working hours. Accounts for the contribution of part time working and is more detailed than a head count measure. Can also be referred to as whole time equivalent.

Full model .... Model which includes all available explanatory variables in a regression model.

Generalisability .... See Validity (external).

Head count .... Refers to the number of individuals who are working within an organisation. This does not differentiate between those who are full time or part time.

Hierarchical models............ Also known as multilevel models. An example is provided by patients, at the first level, being in wards at the second, which are part of hospitals at the third level. Takes account of clustering of observations in higher levels.

Intracluster correlation coefficient .... A measure of the relatedness of data which is arranged in clusters. Compares the variance within clusters with the variance between clusters.

ICD Code .... Designed to promote international comparability in health statistics.

Incident rate ratio .... The ratio of two incidence rates. The incidence rate is defined as number of events compared to the number of people at risk during the study period.

Induction of labour............... Measures taken to begin labour using artificial methods.

Instrumental birth .... Birth that is assisted by forceps or ventouse.

Intrapartum .... The time period where labour is established.

Interactions......................... Tests whether the relationship between a predictor and outcome is modified by a third variable.

Logistic regression .... Regression analysis when the dependent variable is dichotomous (e.g readmission)

Longitudinal study .... A study which follows individuals over periods of time with continuous or repeated measures during the study period.

Maternity Incentive Scheme . A financial incentive scheme designed to enhance maternity safety.

Maternity services............... Providers of maternity care, typically within NHS Trusts which are large publicly funded organisations.

Maternity support worker ..... A health-care assistant who provides maternity care but is not a registered practitioner. Support workers act under the supervision of a registered practitioner. Also known as maternity assistant (internationally).

Measurement error .... The difference between the measurement and the true value. Measurement error can lead to biased estimates of effect.

Medical staff........................ Includes all grades of doctor, including foundation year staff, training grades and consultants.

Midwife .... A person who has completed a midwifery education programme based on the ICM Essential Competencies for Midwifery Practice and the framework of the ICM Global Standards for Midwifery Education, recognised in the country where it is located; who has acquired the requisite qualifications to be registered and/or legally licensed to practice midwifery and use the title ‘midwife,’ and who demonstrates competency in the scope of practice of the midwife (International Confederation of Midwives, 2011)

Model fit............................. Measures how well a statistical model describes a set of observations.

Multicollinearity.................. Occurs when two or more independent variables are highly correlated in a multiple regression model.

Multiparous........................ A pregnant woman who has previously given birth.

NHS Trust........................... An organisation within the National Health Service, which serves a geographical area or has a specialised function

Nursing Midwifery Council.... The regulator for nursing and midwifery professions in the UK.

Nulliparous .... A pregnant woman who has not previously given birth.

Observational study............ A type of study where individuals are observed or outcomes are measured, but no interventions are applied to change the outcome. Examples are cohort, cross-sectional and case-control studies.

Odds ratio .... The odds of an outcome occurring in one group versus it occurring in a reference group. The odds that an outcome (e.g. readmission) happens to a woman who belongs to a particular group (e.g. those who have been exposed to low staffing), compared with the odds of the outcome happening to women who belongs to another group (e.g. those who have not been exposed to low staffing).

Omitted variable bias.......... Occurs when a relevant predictor variable is not included in a model. This variable may correlate with both the dependent variable and other predictors, resulting in biased estimates.

Operative birth.................... Caesarean or instrumental birth.

Perinatal Mortality Review Tool.A tool used to review all deaths of all term intrapartum stillbirths, neonatal and post-neonatal deaths using a multidisciplinary approach.

Person-centred care .... A holistic approach to health care that takes the whole person into account instead of a narrow perspective focusing on their condition or symptoms (The Health Foundation, 2016).

Postpartum haemorrhage .... Blood loss exceeding 500 mls within 24 hours of birth.

Predictor variable .... A variable that is used to predict or forecast the outcome in another variable. Predictor variables are independent variables (x) which may influence the dependent variable (y)

Prospective study .... Investigators study a group of individuals and observe them from the present time into the future.

Randomised controlled Trial. A comparison of 'experimental' and 'control' interventions in an experimental way. Assignment of participants to groups is randomly allocated which balances both known and unknown prognostic factors.

Retrospective study .... Uses existing data and samples information about individuals which relates to their past, a type of non-intervention study

Risk adjustment.................. A method of adjusting for the characteristics of an individual (e.g., age, parity, ethnicity) or the organisation (e.g. number of births) that may affect the occurrence of the outcome of interest.

Risk of bias .... A systematic error or deviation from the truth in the results. Biases can operate in either direction. Rigorous studies are more likely to provide estimates that are closer to the truth with reduced risk of bias.

Sample selection bias .... Occurs when the sample is not randomly selected, and bias can be introduced by the selection process.

Saving Babies Lives Care Bundle.Evidence based guidelines to make maternity care safer to help reduce rates of stillbirth and early neonatal death.

Secondary analysis .... Investigators use data collected by other researchers, but for another purpose or to address different questions.

Sensitivity analyses............. A process whereby the analysis is repeated in different ways to assess whether the results remain consistent or change.

Simultaneity .... Predictor and dependent variables can causally influence each other leading to simultaneity, and this can operate in both directions.

Skill mix.............................. The combination of different categories of healthcare staff with varying educational and clinical experience.

Spontaneous vaginal birth .... A vaginal birth that occurs without vacuum or forceps.

Staffing .... The process of recruiting, selecting, and appointing employees to positions within an organisation.

Statistical significance .... Measures the probability of the null hypothesis being true compared to the acceptable level of uncertainty.

Stillbirth .... A baby that is born dead after 24 completed weeks of pregnancy.

Validity (external) .... The extent to which clinical research studies can be applied to wider populations.

Validity (internal)................. The extent to which the results of clinical research are free from bias.

Variance Inflation Factor ...... Measures the amount of multicollinearity in regression analysis.

Woman .... An adult female human being. While not all gestational parents identify as women, this term has been used throughout this thesis as it has been used in the data sources which were accessed and represents most people giving birth.

References

Aiken, L., Sloane, D., Ball, J., Bruyneel, L., Rafferty, A. and Griffiths, P. (2018) 'Patient satisfaction with hospital care and nurses in England: an observational study', *BMJ Open,* 8(1), pp. e019189. Available at: https://doi.org/10.1136/bmjopen-2017-019189

Aiken, L., Sloane, D., Bruyneel, L., Van den Heede, K., Griffiths, P., Busse, R., Diomidous, M., Kinnunen, J., Kozka, M., Lesaffre, E., McHugh, M. D., Moreno-Casbas, M. T., Rafferty, A. M., Schwendimann, R., Scott, P. A., Tishelman, C., van Achterberg, T., Sermeus, W. and RN4Cast consortium (2014) 'Nurse staffing and education and hospital mortality in nine European countries: a retrospective observational study', *The Lancet,* 383(9931), pp. 1824-30. Available at: https://doi.org/10.1016/S0140-6736(13)62631-8

Aiken, L., Sloane, D., Cimiotti, J., Clarke, S., Flynn, L., Seago, J., Spetz, J. and Smith, H. (2010) 'Implications of the California nurse staffing mandate for other states', *Health Serv Res,* 45(4), pp. 904-21. Available at: https://doi.org/10.1111/j.1475-6773.2010.01114.x

Aiken, L., Sloane, D., Griffiths, P., Rafferty, A., Bruyneel, L., McHugh, M., Maier, C., Moreno-Casbas, T., Ball, J. and Ausserhofer, D. (2017) 'Nursing skill mix in European hospitals: cross-sectional study of the association with mortality, patient ratings, and quality of care', *BMJ Quality & Safety,* 26(7), pp. 559-568. Available at: https://doi.org/10.1136/bmjqs-2016-005567

Albsoul, R. (2019) *Investigating missed nursing care in an Australian acute care hospital: An exploratory study.* (Doctoral dissertation). Queensland University of Technology [Online] Available at: https://eprints.qut.edu.au/132413/ (Accessed 29th March 2024)

Alderdice, F., Hamilton, K., McNeill, J., Lynn, F., Curran, R. and Redshaw, M. (2016) *Birth NI: a survey of women's experience of maternity care in Northern Ireland*. Available at: https://ora.ox.ac.uk/objects/uuid:f58cbfbd-3523-485f-a737-93560844c502 (Accessed: 29th Jan 2022).

Alderdice, F., McLeish, J., Henderson, J., Malouf, R., Harvey, M. and Redshaw, M. (2020) 'Women's ideal and real expectations of postnatal care during their first pregnancy: An online survey in England', *Midwifery,* 89(102815). Available at: https://doi.org/10.1016/j.midw.2020.102815

Althubaiti, A. (2016) 'Information bias in health research: definition, pitfalls, and adjustment methods', *J Multidiscip Healthcare,* 9, pp. 211-7. Available at: https://doi.org/10.2147/JMDH.S104807

Antonakis, J., Bendahan, S., Jacquart, P. and Lalive, R. (2010) 'On making causal claims: A review and recommendations', *The Leadership Quarterly,* 21(6), pp. 1086-1120. Available at: https://doi.org/10.1016/j.leaqua.2010.10.010

Aoyama, K., D'Souza, R., Inada, E., Lapinsky, S. E. and Fowler, R. A. (2017) 'Measurement properties of comorbidity indices in maternal health research: a systematic review', *BMC Pregnancy Childbirth,* 17(372). Available at: https://doi.org/10.1186/s12884-017-1558-3

APPG Baby Loss and Maternity (2022) *Safe Staffing: The impact of staffing shortages in maternity and neonatal care. Report of the Baby Loss and Maternity All Party Parliamentary Groups*. Available at: https://www.sands.org.uk/sites/default/files/Staffing%20shortages%20-%20APPG%20report,%20Oct%2022%20(final).pdf (Accessed: 31st March 2024).

APPG Birth Trauma (2024) *Listen to mums: ending the postcode lottery on perinatal care*. Available at: https://www.theo-clarke.org.uk/sites/www.theo-clarke.org.uk/files/2024-05/Birth%20Trauma%20Inquiry%20Report%20for%20Publication_May13_2024.pdf (Accessed: 14th May 2024).

Ashcroft, B., Elstein, M., Boreham, N. and Holm, S. (2003) 'Prospective semistructured observational study to identify risk attributable to staff deployment, training, and updating opportunities for midwives', *BMJ,* 327(7415), pp. 584. Available at: https://doi.org/10.1136/bmj.327.7415.584

Asiamah, N., Mensah, H. and Oteng-Abayie, E. (2017) 'Do larger samples really lead to more precise estimates? A simulation study', *American Journal of Educational Research,* 5(1), pp. 9-17. Available at: https://doi.org/doi:10.12691/education-5-1-2

Association of Women's Health Obstetric Neonatal Nurses (2010) 'Guidelines for professional registered nurse staffing for perinatal units Executive Summary', *Journal of Obstetric, Gynecologic & Neonatal Nursing,* 40, pp. 131-134. Available at: https://doi.org/10.1111/j.1552-6909.2010.01214.x

Association of Women's Health Obstetric Neonatal Nurses (2022) *Standards for professional registered nurse staffing for perinatal Units*. Available at: https://www.awhonn.org/education/staffing-standards/ (Accessed: 31st March 2024).

Asthana, A. (2017) *NHS maternity wards in England forced to close 382 times last year*. The Guardian. Available at: https://www.theguardian.com/society/2017/aug/08/nhs-maternity-wards-england-forced-closures-labour (Accessed: 10th Sept 2023)

Aughey, H., Blotkamp, A., Carroll, F., Cromwell, D., Gurol-Urganci, I., Harris, T., Hawdon, J., Jardine, J., Knight, H. and Mamza, L. (2019) *Technical report: linking the National Maternity and Perinatal Audit data set to the National Neonatal Research Database for 2015/16*: Royal College of Obstetrics and Gynaecology. Available at: https://dora.dmu.ac.uk/items/a1ec6ff6-6f3b-4672-9063-c33a027d619f (Accessed 31st March 2024).

Aunger, J., Maben, J., Abrams, R., Wright, J., Mannion, R., Pearson, M., Jones, A. and Westbrook, J. (2023) 'Drivers of unprofessional behaviour between staff in acute care hospitals: a realist review', *BMC Health Serv Res,* 23. Available at: https://doi.org/10.1186/s12913-023-10291-3

Australian Capital Territory ACT (2021) *Review of nursing and midwifery staffing models. Nursing and midwives towards a safer culture*. Available at: https://www.health.act.gov.au/sites/default/files/2022-02/N%26M_Midwifery%20Staffing%20Models.pdf (Accessed: 31st March 2024).

Australian Institute of Health and Welfare (2023) *National core maternity indicators* Available at: https://www.aihw.gov.au/getmedia/764b3831-4a50-44b5-ab1c-671b9afc7ee2/national-core-maternity-indicators.pdf?v=20240111124105&inline=true (Accessed: 31st March 2024)

Australian Nursing Midwifery Foundation (2015) *Nurse/Midwife: Patient ratios-It's a matter of saving lives*. Available at: https://www.anmfvic.asn.au/~/media/f06f12244fbb4522af619e1d5304d71d (Accessed: 31st March 2024).

Babaei, S. and Taleghani, F. (2019) 'Compassionate Care Challenges and Barriers in Clinical Nurses: A Qualitative Study', *Iran J Nurs Midwifery Res,* 24(3), pp. 213-219. Available at: https://doi.org/10.4103/ijnmr.IJNMR_100_18

Bailey, S., Wilson, G. and Yoong, W. (2015) 'What factors affect documentation by midwives? A prospective study assessing relationship between length of shift, workload and quality of note keeping', *Midwifery,* 31(8), pp. 787-92. Available at: https://doi.org/10.1016/j.midw.2015.04.001

Baldwin, J. R., Pingault, J. B., Schoeler, T., Sallis, H. M. and Munafo, M. R. (2022) 'Protecting against researcher bias in secondary data analysis: challenges and potential solutions', *Eur J Epidemiol,* 37(1), pp. 1-10. Available at: https://doi.org/10.1007/s10654-021-00839-0

Ball, J. (2017) *Nurse Staffing Levels, Care Left Undone, & Patient Mortality in Acute Hospitals. Stockholm (Doctoral Thesis).* [Online] Available at: https://openarchive.ki.se/xmlui/handle/10616/45563#:~:text=Research%20since%20the%201980s%20has%20established%20an%20association,greater%20chance%20that%20some%20nursing%20care%20is%20missed. (Accessed: 23rd April 2022)

Ball, J. (2023) *Nurse staffing research evidence and NHS policy*. Royal College of Nursing Safe Staffing Summit. Available at: https://youtu.be/i1EZjnbuIhs (Accessed: 1st April 2024)

Ball, J. and Griffiths, P. (2022) 'Consensus Development Project (CDP): An overview of staffing for safe and effective nursing care', *Nurs Open,* 9(2), pp. 872-879. Available at: https://doi.org/10.1002/nop2.989

Ball, J. and Washbrook, M. (2010) 'Birthrate Plus: using ratios for maternity workforce planning', *British Journal of Midwifery,* 18(11), pp. 724-731. Available at: https://doi.org/10.12968/bjom.2010.18.11.79560

Ball, J. and Washbrook, M. (2015) *Safe staffing in midwifery care: Gathering data and learning lessons with Birthrate Plus®*. The Health Foundation. Available at: https://improve.bmj.com/sites/default/files/resources/3.safe_staffing_in_midwifery_care-v3.pdf (Accessed: 12th August 2021)

Bates, D., Heitmueller, A., Kakad, M. and Saria, S. (2018) 'Why policymakers should care about "big data" in healthcare', *Health Policy and Technology,* 7(2), pp. 211-216. Available at: https://doi.org/10.1016/j.hlpt.2018.04.006

Baxter, J. (2017) *Listening to women after birth: their perceptions of postnatal support and the potential value of having a postnatal debriefing session with a midwife.* City, University of London [Online] Available at: https://openaccess.city.ac.uk/id/eprint/17911/ (Accessed: 31st March 2024)

Baxter, J. and Macfarlane, A. (2005) 'Postnatal caesarean care: evaluating the skill mix', *British Journal of Midwifery,* 13(6), pp. 378-384. Available at: https://doi.org/10.12968/bjom.2005.13.6.18357

Bazian (2015) *Safe midwifery staffing for maternity settings. The relationship between midwifery staffing at a local level and maternal and neonatal outcomes, and factors affecting these requirements*. Available at: https://www.nice.org.uk/guidance/ng4/evidence/evidence-review-2-pdf-5134718 (Accessed: 31st March 2024).

Beake, S., McCourt, C. and Bick, D. (2005) 'Women's views of hospital and community-based postnatal care: the good, the bad and the indifferent', *Evidence-Based Midwifery,* 3(2), pp. 80-87. Available at: https://www.researchgate.net/publication/285245685_Women's_views_of_hospital_and_community-based_postnatal_care_the_good_the_bad_and_the_indifferent (Accessed 31st March 2024)

Bender, R. and Blettner, M. (2002) 'Calculating the "number needed to be exposed" with adjustment for confounding variables in epidemiological studies', *Journal of Clinical Epidemiology,* 55(5), pp. 525-530. Available at: https://doi.org/10.1016/S0895-4356(01)00510-8

Betran, A., Ye, J., Moller, A., Zhang, J., Gulmezoglu, A. and Torloni, M. (2016) 'The Increasing Trend in Caesarean Section Rates: Global, Regional and National Estimates: 1990-2014', *PLoS One,* 11(2), pp. e0148343. Available at: https://doi.org/10.1371/journal.pone.0148343

Bhavnani, V. and Newburn, M. (2010) *Left to your own devices: The postnatal care experiences of 1260 first-time mothers*: National Childbirth Trust. Available at: https://www.nct.org.uk/sites/default/files/related_documents/PostnatalCareSurveyReport5.pdf (Accessed: 2nd April 2022).

Bick, D., Duff, E. and Shakespeare, J. (2020) 'Better Births–But why not better postnatal care?', *Midwifery,* 80 (102674), pp. 1-3. Available at: https://doi.org/10.1016/j.midw.2019.102574

Bick, D., Sandall, J., Furuta, M., Wee, M., Isaacs, R., Smith, G. and Beake, S. (2014) 'A national cross sectional survey of heads of midwifery services of uptake, benefits and barriers to use of obstetric early warning systems (EWS) by midwives', *Midwifery,* 30(11), pp. 1140-1146. Available at: https://doi.org/10.1016/j.midw.2014.03.016

Birthrights (2022) *Systemic racism, not broken bodies : An inquiry into racial injustice and human rights in UK maternity care*. Available at: https://www.birthrights.org.uk/wp-content/uploads/2022/05/Birthrights-inquiry-systemic-racism_exec-summary_May-22-web.pdf (Accessed: 6th June 2022).

Blackman, I., Hadjigeorgiou, E. and McNeill, L. (2020) 'Causal links to missed Australian midwifery care: What is the evidence?', *European Journal of Midwifery,* 4(41), pp. 1-10. Available at: https://doi.org/10.18332/ejm/127769

Blake, N., Cardenas-Lopez, K., Kahwaji, N., Panaflor, V., Sandoval, R., Santana, L., Shih, A. and Ulit, M. (2024) 'Leadership and Staff Working Collaboratively to Develop Appropriate Staffing Guidelines', *AACN Adv Crit Care*, pp. e1-e7. Available at: https://doi.org/10.4037/aacnacc2024465

Bland, M. (2015) *An introduction to medical statistics.* Oxford: Oxford University Press. ISBN 0192518399.

Blume, K., Dietermann, K., Kirchner-Heklau, U., Winter, V., Fleischer, S., Kreidl, L., Meyer, G. and Schreyogg, J. (2021) 'Staffing levels and nursing-sensitive patient outcomes: Umbrella review and qualitative study', *Health Serv Res,* 56(5), pp. 885-907. Available at: https://doi.org/10.1111/1475-6773.13647

Bohren, M., Hofmeyr, G., Sakala, C., Fukuzawa, R. and Cuthbert, A. (2017) 'Continuous support for women during childbirth', *Cochrane Database of Systematic Reviews,* 7(7). Available at: https://doi.org/10.1002/14651858.CD003766.pub6

Bonar, S. (2019) *England short of almost 2,500 midwives, new birth figures confirm*. Available at: http://www.rcm.org.uk/news-views/rcm-opinion/2019/england-short-of-almost-2-500-midwives-new-birth-figures-confirm (Accessed 22nd April 2022)

Bourguignon, D. (2015) *The precautionary principle: Definitions, applications and governance*. Available at: https://www.europarl.europa.eu/RegData/etudes/IDAN/2015/573876/EPRS_IDA(2015)573876_EN.pdf (Accessed: 8th March 2024).

Bowers, J. and Cheyne, H. (2016) 'Reducing the length of postnatal hospital stay: implications for cost and quality of care', *BMC Health Serv Res,* 16(1), pp. 16. Available at: https://doi.org/10.1186/s12913-015-1214-4

Bradford, B., Wilson, A., Portela, A., McConville, F., Fernandez Turienzo, C. and Homer, C. (2022) 'Midwifery continuity of care: A scoping review of where, how, by whom and for whom?', *PLoS global public health,* 2(10), pp. e0000935. Available at: https://doi.org/10.1371/journal.pgph.0000935

Bras, C., Figueiredo, M. and Ferreira, M. (2023) 'Safety culture in maternity hospital: Perception of nurse-midwives', *J Adv Nurs,* 00, pp. 1-15. Available at: https://doi.org/10.1111/jan.15969

Bridges, J., Gould, L., Hope, J., Schoonhoven, L. and Griffiths, P. (2019a) 'The Quality of Interactions Schedule (QuIS) and person-centred care: concurrent validity in acute hospital settings', *International Journal of Nursing Studies Advances,* 1(100001). Available at: https://doi.org/10.1016/j.ijnsa.2019.100001

Bridges, J., Griffiths, P., Oliver, E. and Pickering, R. (2019b) 'Hospital nurse staffing and staff-patient interactions: an observational study', *BMJ Quality & Safety,* 28(9), pp. 706-713. Available at: https://doi.org/10.1136/bmjqs-2018-008948

Brown, R. and Mulligan, A. (2023) '‘Maternal request’caesarean sections and medical necessity', *Clinical ethics,* 18(3), pp. 312-320. Available at: https://doi.org/doi.org/10.1177/14777509231183365

Brown, S., Davey, M. and Bruinsma, F. (2005) 'Women's views and experiences of postnatal hospital care in the Victorian Survey of Recent Mothers 2000', *Midwifery,* 21(2), pp. 109-26. Available at: https://doi.org/10.1016/j.midw.2004.09.006

Brown, T. (2020) *Nurse staffing, satisfaction and hospital readmission rates in skilled nursing facilities: a quantitative, correlational study. Doctoral Thesis*.: University of Phoenix. Available at: https://www.proquest.com/docview/2395252910?pq-origsite=gscholar&fromopenview=true&sourcetype=Dissertations%20&%20Theses (Accessed: 16th April 2023).

Buchan, J. (2005) 'A certain ratio? The policy implications of minimum staffing ratios in nursing', *Journal of Health Services Research & Policy,* 10(4), pp. 239-244. Available at: https://doi.org/10.1258/135581905774414204

Buchan, J. (2023) *Learning from ratios in Australia*. Royal College of Nursing Safe Staffing Summit. Available at: https://youtu.be/HUBu8uPyBq8 (Accessed: 1st April 2024)

Buchan, J., Gershlick, B., Charlesworth, A. and Seccombe, I. (2019) *Falling short: the NHS workforce challenge*: The Health Foundation. Available at: https://www.health.org.uk/publications/reports/falling-short-the-nhs-workforce-challenge (Accessed: 6th June 2021).

Burnham, K. and Anderson D (2004) 'Multimodel inference : understanding AIC and BIC in model selection', *Sociological methods and research,* 33(2), pp. 261-304. Available at: https://doi.org/10.1177/0049124104268644

Burns, E. M., Rigby, E., Mamidanna, R., Bottle, A., Aylin, P., Ziprin, P. and Faiz, O. (2012) 'Systematic review of discharge coding accuracy', *J Public Health (Oxf),* 34(1), pp. 138-48. Available at: https://doi.org/10.1093/pubmed/fdr054

Busse, R., Panteli, D. and Quentin, W. (2019) *An introduction to healthcare quality: defining and explaining its role in health systems*. Available at: https://www.ncbi.nlm.nih.gov/books/NBK549276/pdf/Bookshelf_NBK549276.pdf (Accessed: 24th Nov 2023).

Callander, E., Sidebotham, M., Lindsay, D. and Gamble, J. (2021) 'The future of the Australian midwifery workforce–impacts of ageing and workforce exit on the number of registered midwives', *Women and Birth,* 34(1), pp. 56-60. Available at: https://doi.org//10.1016/j.wombi.2020.02.023

Cameron, A. and Trivedi, P. (2013) *Regression Analysis of Count Data.* California: Cambridge University Press.

Campbell, D. (2019) *Concerns over birthing options as NHS shuts midwife-led centres*. The Guardian, Mon 11 Feb 2019 Available at: https://www.theguardian.com/society/2019/feb/11/concerns-over-birthing-options-as-nhs-shuts-midwife-led-centres-england#:~:text=But%20NHS%20chiefs%20have%20sparked,that%20all%20have%20been%20promised (Accessed: 10th September 2023)

Care Quality Commission (2015) *Delivering cost effective care in the NHS: Working together to develop how CQC will assess the use of resources in NHS acute trusts*. Available at: https://www.cqc.org.uk/sites/default/files/20151028_delivering_cost_effective_care_in_the_NHS.pdf (Accessed: 10th March 2024)

Care Quality Commission (2020) *Many women have a positive experience of maternity services, but for some care continues to fall short*. Available at: https://www.cqc.org.uk/news/releases/many-women-have-positive-experience-maternity-services-some-care-continues-fall-short (Accessed: 10th Sept 2021)

Care Quality Commission (2021a) *Mid and South Essex NHS Foundation Trust Inspection Report*. Available at: https://api.cqc.org.uk/public/v1/reports/bb75fed9-ee62-41c7-99f1-abd704c8a669?20211223165531 (Accessed: 20th Feb 2022).

Care Quality Commission (2021b) *The Princess Alexandra Hospital NHS Trust Inspection report*. Available at: https://api.cqc.org.uk/public/v1/reports/6816c75d-bd3e-481f-826f-8292320c3a16?20211223170103 (Accessed: 20th Feb 2022).

Care Quality Commission (2021c) *Regulation 18: Staffing*. Available at: https://www.cqc.org.uk/guidance-providers/regulations-enforcement/regulation-18-staffing (Accessed: 28th April 2022).

Care Quality Commission (2022a) *Areas of concern*. Available at: https://www.cqc.org.uk/publication/state-care-202122/concern (Accessed: 2nd Feb 2024)

Care Quality Commission (2022b) *Maternity survey 2021*. Available at: https://www.cqc.org.uk/publications/surveys/maternity-survey-2021 (Accessed: 2nd August 2022).

Care Quality Commission (2023a) *CQC rates maternity services inadequate at North Middlesex University Hospital*. Available at: https://www.cqc.org.uk/press-release/cqc-rates-maternity-services-inadequate-north-middlesex-university-hospital (Accessed 31st March 2024)

Care Quality Commission (2023b) *The state of health care and adult social care in England 2022/3*. Available at: https://www.cqc.org.uk/publications/major-report/state-care/2022-2023 (Accessed: 21st Jan 2024).

Care Quality Commission (2024) *The Tunbridge Wells Hospital at Pembury Inspection report*. Available at: https://www.cqc.org.uk/location/RWFTW (Accessed: 16th March 2024)

Care Quality Commission and Picker Institute Europe (2020) 'Maternity Survey, 2018. [data collection]. UK Data Service. SN: 8596'. Available at: https://doi.org/10.5255/UKDA-SN-8596-1

Care Quality Commission and Picker Institute Europe (2021) 'Maternity Survey, 2019. [data collection]. UK Data Service. SN: 8790'. Available at: https://doi.org/10.5255/UKDA-SN-8790-1

Carroll, F., Knight, H., Cromwell, D., Gurol-Uganchi, I. and van der Muelen, J. (2016) *Patterns of maternity care in English NHS trusts 2013/14*. Available at: https://masic.org.uk/wp-content/uploads/2023/11/2013_05-Patterns-of-Maternity-Care-in-English-NHS-Hospitals-2011-12.pdf (Accessed: 6th Oct 2020).

Carter, P. (2016) 'Operational productivity and performance in English NHS acute hospitals: unwarranted variations', *London: Department of Health*. Available at: https://doi.org/https://assets.publishing.service.gov.uk/media/5a80bdfae5274a2e87dbb8f5/Operational_productivity_A.pdf (Accessed: 1st December 2020)

Cerbinskaite, A., Malone, S., McDermott, J. and Loughney, A. (2011) 'Emergency caesarean section: influences on the decision-to-delivery interval', *J Pregnancy,* 2011(640379). Available at: https://doi.org/10.1155/2011/640379

Cheng, H. and Phillips, M. (2014) 'Secondary analysis of existing data: opportunities and implementation', *Shanghai Arch Psychiatry,* 26(6), pp. 371-5. Available at: https://doi.org/10.11919/j.issn.1002-0829.214171

Chin, D., Bang, H., Manickam, R. and Romano, P. (2016) 'Rethinking thirty-day hospital readmissions: shorter intervals might be better indicators of quality of care', *Health Affairs,* 35(10), pp. 1867-1875. Available at: https://doi.org/10.1377/hlthaff.2016.0205

Chowdhury, M. and Turin, T. (2020) 'Variable selection strategies and its importance in clinical prediction modelling', *Fam Med Community Health,* 8(1), pp. e000262. Available at: https://doi.org/10.1136/fmch-2019-000262

Civil Aviation Authority (2023) *Number and composition of cabin crew*. Available at: https://regulatorylibrary.caa.co.uk/965-2012/Content/Regs/04290_OROCC100_Number_and_composition_of_cabin_crew.htm#:~:text=(3)%20one%20cabin%20crew%20member,in%2Dcommand%20or%20the%20commander. (Accessed: 10th March 2024)

Clapp, M., James, K., Bates, S. and Kaimal, A. (2019) 'Unexpected term NICU admissions: a marker of obstetrical care quality?', *American Journal of Obstetrics and Gynecology,* 220(4), pp. 395. e1-e12. Available at: https://doi.org//10.1016/j.ajog.2019.02.001

Clapp, M., Little, S., Zheng, J., Kaimal, A. and Robinson, J. (2017) 'Hospital-level variation in postpartum readmissions', *JAMA,* 317(20), pp. 2128-2129. Available at: https://doi.org/10.1001/jama.2017.2830

Clapp, M., Little, S., Zheng, J. and Robinson, J. (2016) 'A multi-state analysis of postpartum readmissions in the United States', *Am J Obstet Gynecol,* 215(1), pp. 113 e1-e10. Available at: https://doi.org/10.1016/j.ajog.2016.01.174

Clapp, M., Little, S., Zheng, J., Robinson, J. and Kaimal, A. (2018) 'The relative effects of patient and hospital factors on postpartum readmissions', *J Perinatol,* 38(7), pp. 804-812. Available at: https://doi.org/10.1038/s41372-018-0125-8

Clark, R., Peele, M. and Lake, E. (2022) 'Nursing resources by type of maternity unit across regions of the United States', *J Obstet Gynecol Neonatal Nurs,* 51(3), pp. 290-301. Available at: https://doi.org/10.1016/j.jogn.2022.02.001

Clark, S., Saade, G., Meyers, J., Frye, D. and Perlin, J. (2014) 'The clinical and economic impact of nurse to patient staffing ratios in women receiving intrapartum oxytocin', *Am J Perinatol,* 31(2), pp. 119-24. Available at: https://doi.org/10.1055/s-0033-1338175

Coffman, J., Seago, J. and Spetz, J. (2002) 'Minimum nurse-to-patient ratios in acute care hospitals in California', *Health Affairs,* 21(5), pp. 53-64. Available at: https://doi.org/10.1377/hlthaff.21.5.53

Collins, K. and Draycott, T. (2015) 'Measuring quality of maternity care', *Best Practice & Research Clinical Obstetrics & Gynaecology,* 8(29), pp. 1132-1138. Available at: https://doi.org/10.1016/j.bpobgyn.2015.03.021

Combs, C., Goffman, D. and Pettker, C. (2022) 'Society for Maternal-Fetal Medicine special statement: a critique of postpartum readmission rate as a quality metric', *American Journal of Obstetrics and Gynecology,* 226(4), pp. B2-B9. Available at: https://doi.org/10.1016/j.ajog.2021.11.1355

Cook, R., Jones, S., Williams, G., Worsley, D., Walker, R., Radford, M. and Leary, A. (2020) 'An observational study on the rate of reporting of adverse event on healthcare staff in a mental health setting: An application of Poisson expectation maximisation analysis on nurse staffing data', *Health Informatics J,* 26(2), pp. 1333-1346. Available at: https://doi.org/10.1177/1460458219874637

Cookson, G., Jones, S., van Vlymen, J. and Laliotis, I. (2014) 'The cost-effectiveness of midwifery staffing and skill mix on maternity outcomes', *A Report for the National Institute for Health and Care Excellence*. Available at: https://www.nice.org.uk/guidance/ng4/evidence/economicevaluation-%20report-5277277 (Accessed: 13th Oct 2020)

Costa, D. and Yakusheva, O. (2016) 'Why causal inference matters to nurses: the case of nurse staffing and patient outcomes', *Online J Issues Nurs,* 21(2), pp. 2. Available at: https://doi.org/10.3912/OJIN.Vol21No02Man02

Cox, A. and Verbaan, E. (2018) *Exploring research data management.* London: Facet publishing. Available at: https://doi.org/10.29085/9781783302802.

Cox, L. (2018) 'Modernizing the Bradford Hill criteria for assessing causal relationships in observational data', *Crit Rev Toxicol,* 48(8), pp. 682-712. Available at: https://doi.org/10.1080/10408444.2018.1518404

Creswell, L., Lindow, B., Lindow, S., MacIntyre, A., O'Gorman, N., Hehir, M. and O'Connell, M. (2023) 'A retrospective observational study of labour ward work Intensity: The challenge of maternity staffing', *Eur J Obstet Gynecol Reprod Biol,* 286, pp. 90-94. Available at: https://doi.org/10.1016/j.ejogrb.2023.05.021

Crowe, C. and Manley, K. (2019) 'Person-centred, safe and effective care in maternity services: the need for greater change towards best practice', *International Practice Development Journal,* 9(1), pp. 1-20. Available at: https://doi.org/10.19043/ipdj.91.008

Dall'Ora, C., Saville, C., Rubbo, B., Turner, L., Jones, J. and Griffiths, P. (2022) 'Nurse staffing levels and patient outcomes: A systematic review of longitudinal studies', *Int J Nurs Stud,* 134, pp. 104311. Available at: https://doi.org/10.1016/j.ijnurstu.2022.104311

Dani, C., Papini, S., Iannuzzi, L. and Pratesi, S. (2020) 'Midwife-to-newborn ratio and neonatal outcome in healthy term infants', *Acta Paediatr,* 109(9), pp. 1787-1790. Available at: https://doi.org/10.1111/apa.15180

Davis, A. (2013) *Choice, policy and practice in maternity care since 1948*. History and Policy. Available at: https://www.historyandpolicy.org/policy-papers/papers/choice-policy-and-practice-in-maternity-care-since-1948 (Accessed: 18th May 2024)

Day-Herzog, D. (2021) *Reducing the Postpartum Readmission Rate with Standardized Discharge Teaching*. [Online] Available at: https://repository.usfca.edu/capstone/1236 (Accessed: 29th Feb 2024)

De Bienassis, K. and Klazinga, N. (2022) *Developing international benchmarks of patient safety culture in hospital care: findings of the OECD patient safety culture pilot data collection and considerations for future work*. Available at: https://www.oecd.org/els/developing-international-benchmarks-of-patient-safety-culture-in-hospital-care-95ae65a3-en.htm (Accessed: 21st July 2023).

de Rooy, L. and Johns, A. (2010) 'Management of the vulnerable baby on the postnatal ward and transitional care unit', *Early Hum Dev,* 86(5), pp. 281-5. Available at: https://doi.org/10.1016/j.earlhumdev.2010.05.004

Delaney, J. and Seeger, J. (2013) *Sensitivity analysis*. Developing a protocol for observational comparative effectiveness research: a user's guide. Available at: https://pubmed.ncbi.nlm.nih.gov/23469377/ (Accessed: 22nd March 2024)

Dent, J., Smeeton, N., Whiting, L. and Watson, T. (2024) 'The importance of recovery and staffing on midwives' emotional wellbeing: A UK national survey', *Midwifery,* 132(103961). Available at: https://doi.org/10.1016/j.midw.2024.103961

Department for Education (2014) *Early years foundation stage (EYFS) statutory framework*. Available at: https://www.gov.uk/government/publications/early-years-foundation-stage-framework--2 (Accessed: 10th March 2024)

Department for Health and Social Care (2024) '£35 million investment to boost maternity safety (press release)'. Available at: https://www.gov.uk/government/news/35-million-investment-to-boost-maternity-safety#:~:text=Almost%20%C2%A335%20million%20will,thousands%20of%20extra%20health care%20workers. (Accessed: 18th May 2024)

Department for Transport (1988) *Road Traffic Act 1988*. Available at: https://www.legislation.gov.uk/ukpga/1988/52/part/I/crossheading/motor-vehicles-drink-and-drugs (Accessed: 2nd April 2024).

Department for Transport (2021) *The drivers' hours and tachographs (temporary exceptions) (no. 4) regulations 2021* Available at: https://www.legislation.gov.uk/uksi/2021/1207/pdfs/uksiem_20211207_en.pdf (Accessed: 2nd April 2024).

Department of Health (2013) *Children, young people and maternity services: Maternity care facilities*. Available at: https://www.england.nhs.uk/wp-content/uploads/2021/05/HBN_09-02_Final.pdf (Accessed: 12th August 2023).

Department of Health (2016) *Framework for safe nurse staffing and skill mix in general and specialist medical and surgical care settings in adult hospitals in Ireland*. . Available at: https://www.gov.ie/en/campaigns/25860-framework-for-safe-nurse-staffing-and-skill-mix/#:~:text=The%20Framework%20for%20Safe%20Nurse,on%20patient%20acuity%20and%20dependency. (Accessed: 8th March 2024)

Department of Health and Social Care (2021) *Safer Maternity Care*. Available at: https://www.england.nhs.uk/wp-content/uploads/2021/03/agenda-item-9.4-safer-maternity-care-progress-report-2021-amended.pdf (Accessed: 21st Jan 2024)

Department of Health and Social Care (2023) *The NHS Constitution for England*. Available at: https://www.gov.uk/government/publications/the-nhs-constitution-for-england/the-nhs-constitution-for-england (Accessed: 25th Feb 2024)

Devane, D., Barrett, N., Gallen, A., O'Reilly, M., Nadin, M., Conway, G., Biesty, L. and Smith, V. (2019) 'Identifying and prioritising midwifery care process metrics and indicators: a Delphi survey and stakeholder consensus process', *BMC Pregnancy Childbirth,* 19(1), pp. 198. Available at: https://doi.org/10.1186/s12884-019-2346-z

Dharni, N., Essex, H., Bryant, M., Cronin de Chavez, A., Willan, K., Farrar, D., Bywater, T., Dickerson, J. and Better Start Bradford Innovation Hub (2021) 'The key components of a successful model of midwifery-led continuity of carer, without continuity at birth: findings from a qualitative implementation evaluation', *BMC Pregnancy Childbirth,* 21, pp. 1-11. Available at: https://doi.org/10.1186/s12884-021-03671-2

Dietz, H. P. and Campbell, S. (2016) 'Toward normal birth–but at what cost?', *American Journal of Obstetrics and Gynecology,* 215(4), pp. 439-444. Available at: https://doi.org/10.1016/j.ajog.2016.04.021

Donabedian, A. (1966) 'Evaluating the quality of medical care', *Milbank Mem Fund Quarterly,* 44(3), pp. 166-206. Available at: https://www.ncbi.nlm.nih.gov/pubmed/5338568 (Accessed: 1st Sept 2023)

Downe, S., Finlayson, K., Oladapo, O., Bonet, M. and Gülmezoglu, A. M. (2018) 'What matters to women during childbirth: a systematic qualitative review', *PLoS One,* 13(4), pp. e0194906. Available at: https://doi.org/10.1371/journal.pone.0194906

Downe, S., Finlayson, K., Tunçalp, Ö. and Metin Gülmezoglu, A. (2016) 'What matters to women: a systematic scoping review to identify the processes and outcomes of antenatal care provision that are important to healthy pregnant women', *BJOG: An International Journal of Obstetrics & Gynaecology,* 123(4), pp. 529-539. Available at: https://doi.org/10.1111/1471-0528.13819

Dowswell, T., Middleton, P. and Weeks, A. (2009) *Antenatal day care units versus hospital admission for women with complicated pregnancy*. Cochrane Database of Systematic Reviews. Available at: https://www.cochrane.org/CD001803/PREG_antenatal-day-care-units-versus-hospital-admission-for-women-with-pregnancy-complications#:~:text=Two%20studies%20provided%20evidence%20that,and%20were%20satisfied%20with%20it. (Accessed: 2nd Feb 2024)

Drennan, J., Duffield, C., Scott, A., Ball, J., Brady, N., Murphy, A., Dahly, D., Savage, E., Corcoran, P., Hegarty, J. and Griffiths, P. (2018) 'A protocol to measure the impact of intentional changes to nurse staffing and skill-mix in medical and surgical wards', *J Adv Nurs,* 74(12), pp. 2912-2921. Available at: https://doi.org/10.1111/jan.13796

Driscoll, A., Grant, M., Carroll, D., Dalton, S., Deaton, C., Jones, I., Lehwaldt, D., McKee, G., Munyombwe, T. and Astin, F. (2018) 'The effect of nurse-to-patient ratios on nurse-sensitive patient outcomes in acute specialist units: a systematic review and meta-analysis', *Eur J Cardiovasc Nurs,* 17(1), pp. 6-22. Available at: https://doi.org/10.1177/1474515117721561

Dunkley-Bent, J. (2016) *Safe Midwifery Staffing. Ward Acuity Tool Launch Conference*. . Available at: https://www.birthrateplus.co.uk/wp-content/uploads/2016/11/BR-Ward-Acuity-Tool-Presentation-to-Conference-2016.pdf (Accessed: 12th August 2021)

Dunn, P. (2021) *Scientific Research and Methodology: An introduction to quantitative research in science and health*. Available at: https://bookdown.org/pkaldunn/Book/ (Accessed: 21st Mar 2024)

Dykes, F. (2005) 'A critical ethnographic study of encounters between midwives and breast-feeding women in postnatal wards in England', *Midwifery,* 21(3), pp. 241-252. Available at: https://doi.org/10.1016/j.midw.2004.12.006

Edwards, N., Vaughan, L., Palmer, B. (2020) *Maternity services in smaller hospitals: a call to action*. Available at: https://www.nuffieldtrust.org.uk/research/maternity-services-in-smaller-hospitals-a-call-to-action (Accessed: 16th April 2023)

Elkholosy, H., Ead, R., Hammad, A. and AbouRizk, S. (2024) 'Data mining for forecasting labor resource requirements: a case study of project management staffing requirements', *International Journal of Construction Management,* 24(5), pp. 561-572. Available at: https://doi.org/10.1080/15623599.2022.2112898

Ellberg, L., Lundman, B., Persson, M. and Hogberg, U. (2005) 'Comparison of health care utilization of postnatal programs in Sweden', *J Obstet Gynecol Neonatal Nurs,* 34(1), pp. 55-62. Available at: https://doi.org/10.1177/0884217504273128

Etcheverry, C., Betran, A., de Loenzien, M., Robson, M., Kabore, C., Lumbiganon, P., Carroli, G., Mac, Q., Gialdini, C. and Dumont, A. (2024) 'How does hospital organisation influence the use of caesarean sections in low- and middle-income countries? A cross-sectional survey in Argentina, Burkina Faso, Thailand and Vietnam for the QUALI-DEC project', *BMC Pregnancy Childbirth,* 24(1), pp. 67. Available at: https://doi.org/10.1186/s12884-024-06257-w

Facchini, G. (2022) 'Low staffing in the maternity ward: Keep calm and call the surgeon', *Journal of Economic Behavior & Organization,* 197, pp. 370-394. Available at: https://doi.org/10.1016/j.jebo.2022.03.013

Farquhar, C., Armstrong, S., Kim, B., Masson, V. and Sadler, L. (2015) 'Under-reporting of maternal and perinatal adverse events in New Zealand', *BMJ Open,* 5(7), pp. e007970. Available at: https://doi.org/10.1136/bmjopen-2015-007970

Fawcett, J. (2016) *The impact of postnatal care on a woman's overall maternity experience: an analysis of stories from Patient Opinion*. Available at: https://www.careopinion.org.uk/resources/blog-resources/1-files/postnatal-care-march-2016.docx (Accessed: 3rd Nov 2020).

Feenstra, M., Nilsson, I. and Danbjørg, D. (2019) 'Broken expectations of early motherhood: Mothers' experiences of early discharge after birth and readmission of their infants', *Journal of clinical nursing,* 28(5-6), pp. 870-881. Available at: https://doi.org/10.1111/jocn.14687

Finlayson, K., Crossland, N., Bonet, M. and Downe, S. (2020) 'What matters to women in the postnatal period: A meta-synthesis of qualitative studies', *PLoS One,* 15(4), pp. e0231415. Available at: https://doi.org/10.1371/journal.pone.0231415

Fischer, C., Lingsma, H., Marang-van de Mheen, P., Kringos, D. S., Klazinga, N. S. and Steyerberg, E. W. (2014) 'Is the readmission rate a valid quality indicator? A review of the evidence', *PLoS One,* 9(11), pp. e112282. Available at: https://doi.org/10.1371/journal.pone.0112282

Fogg, C., Bridges, J., Meredith, P., Spice, C., Field, L., Culliford, D. and Griffiths, P. (2021) 'The association between ward staffing levels, mortality and hospital readmission in older hospitalised adults, according to presence of cognitive impairment: a retrospective cohort study', *Age and Ageing,* 50(2), pp. 431-439. Available at: https://doi.org/10.1093/ageing/afaa133

Ford, J., Algert, C., Morris, J. and Roberts, C. (2012) 'Decreasing length of maternal hospital stay is not associated with increased readmission rates', *Australian and New Zealand Journal of Public Health,* 5(36), pp. 430-434. Available at: https://doi.org/10.1111/j.1753-6405.2012.00882.x

Forster, D., McLachlan, H., Yelland, J., Rayner, J., Lumley, J. and Davey, M. (2006) 'Staffing in postnatal units: is it adequate for the provision of quality care? Staff perspectives from a state-wide review of postnatal care in Victoria, Australia', *BMC Health Serv Res,* 6(83). Available at: https://doi.org/10.1186/1472-6963-6-83

Francis, R. (2013) *Report of the Mid Staffordshire NHS Foundation Trust public inquiry: executive summary*: The Stationery Office. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/279124/0947.pdf (Accessed: 12th May 2021).

Freedman, B. (2008) 'Equipoise and the ethics of clinical research', *in Research Ethics*: Routledge. London. 1st Edition. Available at: https://doi.org/10.4324/9781315244426, pp. 427-431.

Freeman, J. (2020) 'Multiple testing including post hoc tests'. Available at: https://www.sheffield.ac.uk/media/30898/download?attachment (Accessed: 22nd Mar 2024)

Gagnon, A., Waghorn, K. and Covell, C. (1997) 'A randomized trial of one-to-one nurse support of women in labor', *Birth,* 24(2), pp. 71-7. Available at: https://www.ncbi.nlm.nih.gov/pubmed/9271971 (Accessed: 17th Jan 2024)

Geary, R., Knight, H., Carroll, F., Gurol-Urganci, I., Morris, E., Cromwell, D. and van der Meulen, J. (2018) 'A step-wise approach to developing indicators to compare the performance of maternity units using hospital administrative data', *BJOG,* 125(7), pp. 857-865. Available at: https://doi.org/10.1111/1471-0528.15013

Gelman, A. and Park, D. (2009) 'Splitting a predictor at the upper quarter or third and the lower quarter or third', *The American Statistician,* 63(1), pp. 1-8. Available at: https://doi.org/10.1080/00031305.2013.760987

Gerova, V. (2014) *Association between mode of birth, staffing and structural characteristics in NHS trusts with maternity services in England (2010/11).* PhD, King's College London [Online] Available at: https://kclpure.kcl.ac.uk/portal/en/theses/association-between-mode-of-birth-staffing-and-structural-characteristics-in-nhs-trusts-with-maternity-services-in-england-201011(05474111-c115-4e7f-9c13-2908d8d7f64c).html (Accessed: 3rd Oct 2020)

Gerova, V., Griffiths, P., Jones, S. and Bick, D. (2010) *The association between midwifery staffing and outcomes in maternity units in England: observational study using routinely collected data*, Kings College London. Available at: https://eprints.soton.ac.uk/168511/ (Accessed: 13th Oct 2020).

Giannasi, A. and Rudman, J. (2018) 'Using the care hours per patient day tool: one hospital's experience', *British Journal of Nursing,* 27(3), pp. 156-160. Available at: https://doi.org/10.12968/bjon.2018.27.3.156.

Girsen, A., Leonard, S., Butwick, A., Joudi, N., Carmichael, S. and Gibbs, R. (2022) 'Early postpartum readmissions: identifying risk factors at birth hospitalization', *AJOG Global Reports,* 2(100094). Available at: https://doi.org/10.1016/j.xagr.2022.100094

Goldacre, B., Morley, J., (2022) *Better, Broader, Safer: Using health data for research and analysis. A review commissioned by the Secretary of State for Health and Social Care. Department of Health and Social Care.* Available at: https://assets.publishing.service.gov.uk/media/624ea0ade90e072a014d508a/goldacre-review-using-health-data-for-research-and-analysis.pdf (Accessed: 18th Jan 2024)

Goldfield, N., McCullough, E., Hughes, J., Tang, A., Eastman, B., Rawlins, L. and Averill, R. (2008) 'Identifying potentially preventable readmissions', *Health Care Financ Rev,* 30(1), pp. 75-91. Available at: https://www.ncbi.nlm.nih.gov/pubmed/19040175 (Accessed: 5th Feb 2023)

Goodwin, L., Taylor, B., Kokab, F. and Kenyon, S. (2018) 'Postnatal care in the context of decreasing length of stay in hospital after birth: The perspectives of community midwives', *Midwifery,* 60, pp. 36-40. Available at: https://doi.org/10.1016/j.midw.2018.02.006

Government Data Quality Hub (2020) *The government data quality framework*. Available at: https://www.gov.uk/government/publications/the-government-data-quality-framework (Accessed: 31st Dec 2020)

Graham, K., Wilker, E., Howell, M., Davis, R. and Marcantonio, E. (2015) 'Differences between early and late readmissions among patients: a cohort study', *Annals of Internal Medicine,* 162(11), pp. 741-749. Available at: https://doi.org/10.7326/M14-2159

Grassley, J., Clark, M. and Schleis, J. (2015) 'An institutional ethnography of nurses' support of breastfeeding on the night shift', *J Obstet Gynecol Neonatal Nurs,* 44(5), pp. 567-77. Available at: https://doi.org/10.1111/1552-6909.12728

Greater Manchester and Eastern Cheshire Local Maternity System (2019) 'Escalation and unit diversion protocol for maternity'. Available at: https://www.royalberkshire.nhs.uk/Downloads/GPs/GP%20protocols%20and%20guidelines/Maternity%20Guidelines%20and%20Policies/Professional%20guidelines/Escalation%20and%20unit%20diversion%20PROTOCOL_V13.3_CG483_JUL19.pdf (Accessed: 13th Oct 2020)

Griffin, R. (2020) *"A career, not just a job" A cost-benefit analysis of enhancing Maternity Support Worker roles through utilisation of the apprenticeship standard to implement the Health Education England Maternity Support Worker Competency, Education and Career Development Framework. Health Education England, Kings College London*.

Griffin, R., Richardson, M. and Morris-Thompson, T. (2012) 'An evaluation of the impact of maternity support workers', *British Journal of Midwifery,* 20(12), pp. 884-889. Available at: https://doi.org/10.12968/bjom.2012.20.12.884

Griffiths, P., Ball, J., Bloor, K., Bohning, D., Briggs, J., Dall'Ora, C., Iongh, A. D., Jones, J., Kovacs, C., Maruotti, A., Meredith, P., Prytherch, D., Saucedo, A., Redfern, O., Schmidt, P., Sinden, N. and Smith, G. (2018) 'Nurse staffing levels, missed vital signs and mortality in hospitals: retrospective longitudinal observational study', *NIHR Journals Library,* 6, pp. ISSN 2050-4349. Available at: https://doi.org/10.3310/hsdr06380

Griffiths, P., Ball, J., Drennan, J., Dall'Ora, C., Jones, J., Maruotti, A., Pope, C., Recio Saucedo, A. and Simon, M. (2016) 'Nurse staffing and patient outcomes: Strengths and limitations of the evidence to inform policy and practice. A review and discussion paper based on evidence reviewed for the National Institute for Health and Care Excellence Safe Staffing guideline development', *Int J Nurs Stud,* 63, pp. 213-225. Available at: https://doi.org/10.1016/j.ijnurstu.2016.03.012

Griffiths, P., Dall'Ora, C., Ball, J., Culliford, D., Emmanuel, T., Jones, J., Lambert, F., Meredith, P., Rubbo, B., Schmidt, O. and Saville, C. (2019a) *Consequences, costs and cost-effectiveness of different workforce configurations in English acute hospitals: a longitudinal retrospective study using routinely collected data (protocol)*. Available at: https://fundingawards.nihr.ac.uk/award/NIHR128056 (Accessed: 1st Oct 2023).

Griffiths, P., Maruotti, A., Recio Saucedo, A., Redfern, O., Ball, J., Briggs, J., Dall'Ora, C., Schmidt, P., Smith, G. and Missed Care Study Group (2019b) 'Nurse staffing, nursing assistants and hospital mortality: retrospective longitudinal cohort study', *BMJ Quality & Safety,* 28(8), pp. 609-617. Available at: https://doi.org/10.1136/bmjqs-2018-008043

Griffiths, P., Saville, C., Ball, J. E., Jones, J., Monks, T. and Safer Nursing Care Tool study team (2021) 'Beyond ratios-flexible and resilient nurse staffing options to deliver cost-effective hospital care and address staff shortages: A simulation and economic modelling study', *International Journal of Nursing Studies,* 117(103901). Available at: https://doi.org/10.1016/j.ijnurstu.2021.103901

Griffiths, P., Turner, L., Lown, J. and Sanders, J. (2023) 'Evidence on the use of Birthrate Plus® to guide safe staffing in maternity services – A systematic scoping review', *Women and Birth,* 37, pp. 317-324. Available at: https://doi.org/10.1016/j.wombi.2023.11.003

Grollman, C., Daniele, M., Brigante, L., Knight, G., Latina, L., Morgan, A. and Downe, S. (2022) 'Maternity service reconfigurations for intrapartum and postnatal midwifery staffing shortages: modelling of low-risk births in England', *BMJ Open,* 12(9), pp. e051747. Available at: https://doi.org/10.1136/bmjopen-2021-051747

Gu, C., Wang, X., Li, L., Ding, Y. and Qian, X. (2020) 'Midwives' views and experiences of providing midwifery care in the task shifting context: a meta-ethnography approach', *Global Health Journal,* 4(3), pp. 96-106. Available at: https://doi.org/10.1016/j.glohj.2020.08.001

Haftu, M., Girmay, A., Gebremeskel, M., Aregawi, G., Gebregziabher, D. and Robles, C. (2019) 'Commonly missed nursing cares in the obstetrics and gynecologic wards of Tigray general hospitals; Northern Ethiopia', *PLoS One,* 14(12), pp. e0225814. Available at: https://doi.org/10.1371/journal.pone.0225814

Haith-Cooper, M., Stacey, T. and Bailey, F. (2018) 'Hospital postnatal discharge and sepsis advice: Perspectives of women and midwifery students', *British Journal of Midwifery,* 26(4), pp. 248-253. Available at: https://doi.org/10.12968/bjom.2018.26.4.248

Harkness, M., Yuill, C., Cheyne, H., McCourt, C., Black, M., Pasupathy, D., Sanders, J., Heera, N., Wallace, C. and Stock, S. J. (2023) 'Experience of induction of labour: a cross-sectional postnatal survey of women at UK maternity units', *BMJ Open,* 13(5). Available at: https://doi.org/10.1136/bmjopen-2023-071703

Harrell, F. (2015) *Regression modeling strategies: with applications to linear models, logistic and ordinal regression, and survival analysis*. Vanderbilt University: Springer.

Harrison, S., Alderdice, F., Henderson, J. and Quigley, M. (2018) *You and your baby. A national survey of health and care*. Available at: https://www.npeu.ox.ac.uk/maternity-surveys (Accessed: 3rd Nov 2020).

Harrison, S., Alderdice, F., Henderson, J. and Quigley, M. (2021) *You and your baby 2020. A national survey of health and care*. Available at: https://www.npeu.ox.ac.uk/maternity-surveys (Accessed: 9th Jan 2022).

Harrison, S., Alderdice, F., Henderson, J., Redshaw, M. and Quigley, M. (2020) 'Trends in response rates and respondent characteristics in five National Maternity Surveys in England during 1995-2018', *Arch Public Health,* 78, pp. 46. Available at: https://doi.org/10.1186/s13690-020-00427-w

Health and Social Care Information Centre (2015) *NHS Maternity Statistics - England, 2014–2015*. Available at: https://digital.nhs.uk/data-and-information/publications/statistical/nhs-maternity-statistics/2014-15#:~:text=The%20number%20of%20deliveries%20taking,since%202013%2D14%20to%20636%2C643.&text=59.3%20per%20cent%20(321%2C803)%20of,(75%2C245)%20were%20caesarean%20onset. (Accessed: 9th Feb 2024)

Health Data Research UK (2020) *Data utility framework*. Available at: https://www.hdruk.ac.uk/wp-content/uploads/2020/11/201105-Updates-to-the-Data-Utility-Framework-v2.pdf (Accessed: 31st Dec 2020)

Health Education England (2018) 'Reducing pre-registration attrition and improving retention report'. Available at: https://www.hee.nhs.uk/sites/default/files/documents/RePAIR%20Report%202018_FINAL_0.pdf (Accessed: 18th May 2024)

Health Education England (2019a) *Maternity support worker competency, education and career development framework*. Available at: https://www.hee.nhs.uk/our-work/maternity/maternity-support-workers (Accessed: 13th Oct 2020).

Health Education England (2019b) *Maternity workforce strategy – transforming the maternity workforce*. Available at: https://www.hee.nhs.uk/sites/default/files/document/MWS_Report_Web.pdf (Accessed: 13th Oct 2020).

Health Education England (2024) *Maternity support worker competency, education and career development framework*. Available at: https://www.hee.nhs.uk/our-work/maternity/maternity-support-workers (Accessed: 18th May 2024).

Health Foundation (2019) *A critical moment: NHS staffing trends, retention and attrition*. Health Foundation, London. Available at: https://www.health.org.uk/sites/default/files/upload/publications/2019/A%20Critical%20Moment_1.pdf (Accessed: 13th Oct 2020)

Health Foundation (2024) *Health care funding*. Available at: https://www.health.org.uk/publications/long-reads/health-care-funding (Accessed: 19th May 2024)

Heinen, M., van Achterberg, T., Schwendimann, R., Zander, B., Matthews, A., Kózka, M., Ensio, A., Sjetne, I. S., Moreno Casbas, T., Ball, J. and Schoonhoven, L. (2013) 'Nurses' intention to leave their profession: a cross sectional observational study in 10 European countries', *International Journal of Nursing Studies,* 50(2), pp. 174-184. Available at: https://doi.org/10.1016/j.ijnurstu.2012.09.019

Hemkens, L., Contopoulos-Ioannidis, D. and Ioannidis, J. (2016) 'Routinely collected data and comparative effectiveness evidence: promises and limitations', *CMAJ,* 188(8), pp. E158-E164. Available at: https://doi.org/10.1503/cmaj.150653

Henderson, J., Gao, H. and Redshaw, M. (2013) 'Experiencing maternity care: the care received and perceptions of women from different ethnic groups', *BMC Pregnancy Childbirth,* 13(1), pp. 196. Available at: https://doi.org/10.1186/1471-2393-13-196

Hendy, P., Patel, J. H., Kordbacheh, T., Laskar, N. and Harbord, M. (2012) 'In-depth analysis of delays to patient discharge: a metropolitan teaching hospital experience', *Clin Med (Lond),* 12(4), pp. 320-3. Available at: https://doi.org/10.7861/clinmedicine.12-4-320

Henke, R., Karaca, Z., Jackson, P., Marder, W. and Wong, H. (2017) 'Discharge planning and hospital readmissions', *Med Care Res Rev,* 74(3), pp. 345-368. Available at: https://doi.org/10.1177/1077558716647652

Herbert, A., Wijlaars, L., Zylbersztejn, A., Cromwell, D. and Hardelid, P. (2017) 'Data Resource Profile: Hospital Episode Statistics Admitted Patient Care (HES APC)', *Int J Epidemiol,* 46(4), pp. 1093-1093i. Available at: https://doi.org/10.1093/ije/dyx015

Ho, F. and Cole, T. (2023) 'Non-linear predictor outcome associations', *BMJ Med,* 2(1), pp. e000396. Available at: https://doi.org/10.1136/bmjmed-2022-000396

Hodnett, E., Lowe, N., Hannah, M., Willan, A., Stevens, B., Weston, J., Ohlsson, A., Gafni, A., Muir, H. and Myhr, T. (2002) 'Effectiveness of nurses as providers of birth labor support in North American hospitals: a randomized controlled trial', *Journal of the American Medical Association,* 288(11), pp. 1373-1381. Available at: https://doi.org/10.1001/jama.288.11.1373

Hodnett, E. D., Gates, S., Hofmeyr, G. and Sakala, C. (2013) 'Continuous support for women during childbirth', *Cochrane Database of Systematic Reviews,* (7). Available at: https://doi.org/10.1002/14651858.CD003766.pub5.

Holden, R., Scanlon, M., Patel, N., Kaushal, R., Escoto, K., Brown, R., Alper, S., Arnold, J., Shalaby, T., Murkowski, K. and Karsh, B. (2011) 'A human factors framework and study of the effect of nursing workload on patient safety and employee quality of working life', *BMJ Quality & Safety,* 20(1), pp. 15-24. Available at: https://doi.org/10.1136/bmjqs.2008.028381

Hope, J., Schoonhoven, L., Griffiths, P., Gould, L. and Bridges, J. (2022) '"I'll put up with things for a long time before I need to call anybody': Face work, the Total Institution and the perpetuation of care inequalities', *Sociology of Health & Illness,* 44(2), pp. 469-487. Available at: https://doi.org/10.1111/1467-9566.13435

House of Commons (2021) *The Health and Social Care Committee's Expert Panel: Evaluation of the Government's progress against its policy commitments in the area of maternity services in England*. Available at: https://committees.parliament.uk/work/1161/expert-panel-evaluation-of-the-governments-commitments-in-the-area-of-maternity-services-in-england/ (Accessed: 23rd Jul 2021).

House of Commons (2023) *Government Response to the Committee's Report on Workforce: recruitment, training and retention in health and social care*. Available at: https://committees.parliament.uk/publications/39117/documents/192286/default/ (Accessed: 10th Mar 2024)

House of Commons (2024) *NHS key statistics: England*. Available at: https://researchbriefings.files.parliament.uk/documents/CBP-7281/CBP-7281.pdf (Accessed: 19th May 2024).

Howell, E. and Zeitlin, J. (2017) 'Improving hospital quality to reduce disparities in severe maternal morbidity and mortality', *Semin Perinatol,* 41(5), pp. 266-272. Available at: https://doi.org/10.1053/j.semperi.2017.04.002

Hughes, R., Bobay, K., Jolly, N. and Suby, C. (2015) 'Comparison of nurse staffing based on changes in unit-level workload associated with patient churn', *Journal of Nursing Management,* 23(3), pp. 390-400. Available at: https://doi.org/10.1111/jonm.12147

Hunter, B., Fenwick, J., Sidebotham, M. and Henley, J. (2019) 'Midwives in the United Kingdom: Levels of burnout, depression, anxiety and stress and associated predictors', *Midwifery,* 79, pp. 102526. Available at: https://doi.org/10.1016/j.midw.2019.08.008

IBM (2024) 'What is data mining?'. Available at: https://www.ibm.com/topics/data-mining (Accessed: 3rd April 2024)

International Confederation of Midwives (2011) *ICM International Definition of the Midwife*. Available at: https://internationalmidwives.org/resources/international-definition-of-the-midwife/ (Accessed: 5th April 2024)

International Labour Office (2012) 'International standard classification of occupations ISCO-08 '. Available at: https://www.ilo.org/wcmsp5/groups/public/---dgreports/---dcomm/---publ/documents/publication/wcms_172572.pdf

Ivziku, D., Ferramosca, F., Filomeno, L., Gualandi, R., De Maria, M. and Tartaglini, D. (2022) 'Defining nursing workload predictors: A pilot study', *Journal of Nursing Management,* 30(2), pp. 473-481. Available at: https://doi.org/doi.org/10.1111/jonm.13523

Izugbara, C. and Wekesah, F. (2018) 'What does quality maternity care mean in a context of medical pluralism? Perspectives of women in Nigeria', *Health policy and planning,* 33(1), pp. 1-8. Available at: https://doi.org/10.1093/heapol/czx131

Jardine, J., Relph, S., Magee, L., von Dadelszen, P., Morris, E., Ross-Davie, M., Draycott, T. and Khalil, A. (2021) 'Maternity services in the UK during the coronavirus disease 2019 pandemic: a national survey of modifications to standard care', *BJOG,* 128(5), pp. 880-889. Available at: https://doi.org/10.1111/1471-0528.16547

Jeffs, L., Dhalla, I., Cardoso, R. and Bell, C. (2014) 'The perspectives of patients, family members and healthcare professionals on readmissions: preventable or inevitable?', *J Interprof Care,* 28(6), pp. 507-12. Available at: https://doi.org/10.3109/13561820.2014.923988

Jennings, B., Baernholdt, M. and Hopkinson, S. (2022) 'Exploring the turbulent nature of nurses' workflow', *Nurs Outlook,* 70(3), pp. 440-450. Available at: https://doi.org/10.1016/j.outlook.2022.01.002

Johansen, L., Braut, G., Andresen, J. and Oian, P. (2018) 'An evaluation by the Norwegian health care supervision authorities of events involving death or injuries in maternity care', *Acta Obstet Gynecol Scand,* 97(10), pp. 1206-1211. Available at: https://doi.org/10.1111/aogs.13391

Jones, E. (2019) *An investigation of postnatal length of stay in hospital and infant readmission to hospital. PhD Thesis*: University of Birmingham. Available at: https://etheses.bham.ac.uk/id/eprint/9025/13/Jones2019PhD_redacted.pdf (Accessed: 13th Oct 2020)

Joyce, R., Webb, R. and Peacock, J. (2002) 'Predictors of obstetric intervention rates: case-mix, staffing levels and organisational factors of hospital of birth', *J Obstet Gynaecol,* 22(6), pp. 618-25. Available at: https://doi.org/10.1080/0144361021000020385

Joyce, R., Webb, R. and Peacock, J. (2004) 'Associations between perinatal interventions and hospital stillbirth rates and neonatal mortality', *Archives of Disease in Childhood-Fetal and Neonatal Edition,* 89(1), pp. F51-F56. Available at: https://doi.org/10.1136/fn.89.1.F51

Kalisch, B., Friese, C., Choi, S. and Rochman, M. (2011) 'Hospital nurse staffing: choice of measure matters', *Med Care,* 49(8), pp. 775-9. Available at: https://doi.org/10.1097/MLR.0b013e318222a6df

Kalisch, B. and Williams, R. (2009) 'Development and psychometric testing of a tool to measure missed nursing care', *J Nurs Adm,* 39(5), pp. 211-9. Available at: https://doi.org/10.1097/NNA.0b013e3181a23cf5

Kane, R., Shamliyan, T., Mueller, C., Duval, S. and Wilt, T. (2007) 'The association of registered nurse staffing levels and patient outcomes: systematic review and meta-analysis', *Med Care,* 45(12), pp. 1195-204. Available at: https://doi.org/10.1097/MLR.0b013e3181468ca3

Karimi, F., Ebrahimipour, H., Hooshmand, E., Bayrami, R., Pourshirazi, M., Afiat, M., Esmaili, H. and Vafaee Najar, A. (2016) 'Medication errors and its contributing factors among midwives', *Journal of Midwifery and Reproductive Health,* 4(4), pp. 748-756. Available at: https://doi.org/10.22038/jmrh.2016.7563

Kashanian, M., Javadi, F. and Haghighi, M. (2010) 'Effect of continuous support during labor on duration of labor and rate of cesarean delivery', *Int J Gynaecol Obstet,* 109(3), pp. 198-200. Available at: https://doi.org/10.1016/j.ijgo.2009.11.028

Keller, S., Yule, S., Zagarese, V. and Parker, S. (2020) 'Predictors and triggers of incivility within healthcare teams: a systematic review of the literature', *BMJ Open,* 10(6), pp. e035471. Available at: https://doi.org/10.1136/bmjopen-2019-035471

Kennedy, H., Balaam, M. C., Dahlen, H., Declercq, E., de Jonge, A., Downe, S., Ellwood, D., Homer, C., Sandall, J. and Vedam, S. (2020) 'The role of midwifery and other international insights for maternity care in the United States: An analysis of four countries', *Birth,* 47(4), pp. 332-345. Available at: https://doi.org/10.1111/birt.12504

Kim, S., Han, K., Lee, H., Kwon, J. and Park, E. (2016) 'Positive effects of medical staffing on readmission within 30 days after discharge: a retrospective analysis of obstetrics and gynecology data', *European Journal of Public Health,* 26(6), pp. 935-939. Available at: https://doi.org/10.1093/eurpub/ckw102

Kings Fund (2022) *NHS trusts in deficit*. Available at: https://www.kingsfund.org.uk/insight-and-analysis/data-and-charts/nhs-trusts-deficit (Accessed: 9th Mar 2024)

Kipkore, S. (2022) *Risk factors, indications and outcomes of post cesarean section readmission at Kenyatta N. hospital: a case-control study. masters thesis.*, University of Nairobi [Online] Available at: http://erepository.uonbi.ac.ke/handle/11295/162743 (Accessed: 25th Mar 2023)

Kirkup, B. (2015) *The Report of the Morecambe Bay Investigation*. Available at: http://data.parliament.uk/DepositedPapers/Files/DEP2015-0267/The_Report_of_the_Morecambe_Bay.pdf (Accessed: 23rd April 2022).

Kirkup, B. (2022) *Reading the Signals*. Available at: https://www.gov.uk/government/publications/maternity-and-neonatal-services-in-east-kent-reading-the-signals-report (Accessed: 19th Oct 2022).

Klemann, D., Rijkx, M., Mertens, H., van Merode, F. and Klein, D. (2023) 'Causes for medical errors in obstetrics and gynaecology', *Healthcare,* 11(11), pp. 1636. Available at: https://doi.org/10.3390/healthcare11111636

Knape, N., Mayer, H., Schnepp, W. and zu Sayn-Wittgenstein, F. (2014) 'The association between attendance of midwives and workload of midwives with the mode of birth: secondary analyses in the German healthcare system', *BMC Pregnancy Childbirth,* 14(300). Available at: https://doi.org/10.1186/1471-2393-14-300

Knight, H. (2018) *Using routinely collected data to evaluate the performance and quality of English NHS maternity services.* London School of Hygiene & Tropical Medicine [Online] Available at: https://researchonline.lshtm.ac.uk/id/eprint/4650762/ (Accessed: 3rd Oct 2020)

Knight, H., Cromwell, D., Van der Meulen, J., Gurol-Urganci, I., Richmond, D. and Mahmood, T. (2013) *Patterns of maternity care in English NHS hospitals 2011/12*. Royal College of Obstetricians and Gynaecologists. Available at: https://masic.org.uk/wp-content/uploads/2023/11/2013_05-Patterns-of-Maternity-Care-in-English-NHS-Hospitals-2011-12.pdf (Accessed: 4th Feb 2024)

Kokab, F., Jones, E., Goodwin, L., Taylor, B. and Kenyon, S. (2022) 'Community midwives views of postnatal care in the UK; A descriptive qualitative study', *Midwifery,* 104(103183). Available at: https://doi.org/10.1016/j.midw.2021.103183

Kpea, L., Bonnet, M., Le Ray, C., Prunet, C., Ducloy-Bouthors, A. and Blondel, B. (2015) 'Initial preference for labor without neuraxial analgesia and actual use: results from a national survey in France', *Anesth Analg,* 121(3), pp. 759-766. Available at: https://doi.org/10.1213/ANE.0000000000000832

Laliotis, I. and Cooksona, G. (2018) *Labour productivity and skill mix in maternity services: Evidence from the English NHS*. Available at: https://www.surrey.ac.uk/sites/default/files/2018-09/dp-no-11-labour-productiviy-skill-mix-maternity-NHS.pdf (Accessed: 16th Jan 2021).

Lamont, T., Chatfield, C. and Walshe, K. (2023) 'What we know and don't know about the health and social care workforce', *BMJ,* 382, pp. 1569-1570. Available at: https://doi.org/10.1136/bmj.p1569

Lasater, K., McHugh, M., Rosenbaum, P., Aiken, L., Smith, H., Reiter, J., Niknam, B., Hill, A., Hochman, L., Jain, S. and Silber, J. (2021) 'Valuing hospital investments in nursing: multistate matched-cohort study of surgical patients', *BMJ Quality & Safety,* 30(1), pp. 46-55. Available at: https://doi.org/10.1136/bmjqs-2019-010534

Launder, M. (2022) *'Midwives quitting because of unsafe staffing,' warns RCM*. Available at: https://www.nursinginpractice.com/clinical/womens-health/midwives-quitting-because-of-unsafe-staffing-warns-rcm/ (Accessed: 16th Apr 2022)

Leary, A. (2018) *Patient Safety Congress 2018 | James Reason Lecture* Available at: https://www.youtube.com/watch?v=4sqlyvKvFlI (Accessed: 23rd Mar 2024)

Leary, A. (2021) 'Why does healthcare reject the precautionary principle?', *The BMJ Opinion*. Available at: https://blogs.bmj.com/bmj/2021/03/12/alison-leary-why-does-healthcare-reject-the-precautionary-principle/ (Accessed: 7th Mar 2024)

Leary, A., Cook, R., Jones, S., Radford, M., Smith, J., Gough, M. and Punshon, G. (2020) 'Using knowledge discovery through data mining to gain intelligence from routinely collected incident reporting in an acute English hospital', *International journal of health care quality assurance,* 33(2), pp. 221-234. Available at: https://doi.org/10.1108/IJHCQA-08-2018-0209

Leary, A., Cook, R., Jones, S., Smith, J., Gough, M., Maxwell, E., Punshon, G. and Radford, M. (2016) 'Mining routinely collected acute data to reveal non-linear relationships between nurse staffing levels and outcomes', *BMJ Open,* 6(12), pp. 1-7. Available at: https://doi.org/10.1136/bmjopen-2016-011177

Lee, E. and Kalisch, B. (2021) 'Identification and comparison of missed nursing care in the United States of America and South Korea', *J Clin Nurs,* 30(11-12), pp. 1596-1606. Available at: https://doi.org/10.1111/jocn.15712

Levac, D., Colquhoun, H. and O'Brien, K. K. (2010) 'Scoping studies: advancing the methodology', *Implementation science,* 5(1), pp. 69. Available at: https://doi.org/10.1186/1748-5908-5-69

Leyland, A. and Groenewegen, P. (2020) *Multilevel modelling for public health and health services research: health in context*: Springer Nature. Available at: https://doi.org/10.1007/978-3-030-34801-4_13

Li, G., Taljaard, M., Van den Heuvel, E., Levine, M., Cook, D., Wells, G., Devereaux, P. and Thabane, L. (2017) 'An introduction to multiplicity issues in clinical trials: the what, why, when and how', *International Journal of Epidemiology,* 46(2), pp. 746-755. Available at: https://doi.org/http://dx.doi.org/10.1093/ije/dyw320

Liberati, E., Tarrant, C., Willars, J., Draycott, T., Winter, C., Kuberska, K., Paton, A., Marjanovic, S., Leach, B., Lichten, C., Hocking, L., Ball, S., Dixon-Woods, M. and Scaling Authorship Group (2021) 'Seven features of safety in maternity units: a framework based on multisite ethnography and stakeholder consultation', *BMJ Quality & Safety,* 30(6), pp. 444-456. Available at: https://doi.org/10.1136/bmjqs-2020-010988

Lilford, R., Brown, C. and Nicholl, J. (2007) 'Use of process measures to monitor the quality of clinical practice', *BMJ,* 335(7621), pp. 648-650. Available at: https://doi.org/10.1136/bmj.39317.641296.AD

Lindsay, P., Sandall, J. and Humphrey, C. (2012) 'The social dimensions of safety incident reporting in maternity care: The influence of working relationships and group processes', *Social science & medicine,* 75(10), pp. 1793-1799. Available at: https://doi.org/10.1016/j.socscimed.2012.06.030

Lintern, S. (2019) *Exclusive: Government drops key safe staffing measure*. HSJ. Available at: https://www.hsj.co.uk/workforce/exclusive-government-drops-key-safe-staffing-measure/7024892.article (Accessed: 3rd Dec 2020)

Lintern, S. (2021a) 'Nottingham maternity scandal: Midwives reveal their fears for the safety of mothers and babies'. Available at: https://www.independent.co.uk/news/health/nottingham-maternity-midwives-babies-safety-b1889219.html (Accessed: 27th July 2021)

Lintern, S. (2021b) *Nurses drafted in to shore up understaffed maternity unit*. Available at: https://www.independent.co.uk/news/health/maternity-nurses-midwives-shortage-basildon-b1890583.html (Accessed: 27th Jul 2021)

Lintern, S. (2024) *NHS told to cut spending on doctors and nurses to save £4.5bn*. Available at: https://www.thetimes.co.uk/article/421a041e-8ce7-40c8-b3bb-abcd61c6537f?shareToken=ecc2d9947c13abcb39ea22e45257b4fc (Accessed: 4th April 2024)

Liu, S., Heaman, M., Kramer, M., Demissie, K., Wen, S., Marcoux, S. and Maternal Health Study Group of the Canadian Perinatal Surveillance System (2002) 'Length of hospital stay, obstetric conditions at childbirth, and maternal readmission: a population-based cohort study', *American Journal of Obstetrics and Gynecology,* 187(3), pp. 681-687. Available at: https://doi.org/10.1067/mob.2002.125765

Lopes, S., Guerra-Arias, M., Buchan, J., Pozo-Martin, F. and Nove, A. (2017) 'A rapid review of the rate of attrition from the health workforce', *Human Resources for Health,* 15(1), pp. 1-9. Available at: https://doi.org/10.1186/s12960-017-0195-2

Lyndon, A., Simpson, K., Spetz, J., Fletcher, J., Gay, C. and Landstrom, G. (2022a) 'Psychometric properties of the perinatal missed care survey and missed care during labor and birth', *Appl Nurs Res,* 63. Available at: https://doi.org/10.1016/j.apnr.2021.151516

Lyndon, A., Simpson, K., Spetz, J., Zhong, J., Gay, C. L., Fletcher, J. and Landstrom, G. (2022b) 'Nurse-reported staffing guidelines and exclusive breast milk feeding', *Nurs Res,* 71(6), pp. 432-440. Available at: https://doi.org/10.1097/NNR.0000000000000620

Ma, C., McHugh, M. and Aiken, L. (2015) 'Organization of hospital nursing and 30-day readmissions in Medicare patients undergoing surgery', *Med Care,* 53(1), pp. 65-70. Available at: https://doi.org/10.1097/MLR.0000000000000258

Makarova, N., Janke, T., Schmittinger, J., Agricola, C., Ebinghaus, M., Blome, C. and Zyriax, B. (2024) 'Women's expectations, preferences and needs in midwifery care–results from the qualitative Midwifery Care (MiCa) study: Childbirth and early parenthood', *Midwifery,* 132(103990). Available at: https://doi.org/doi.org/10.1016/j.midw.2024.103990

Makhfudli, M., Efendi, F., Kurniati, A., Pradanie, R. and Sebayang, S. (2020) 'Staffing characteristics and their associations with the severe maternal outcomes at Indonesian tertiary hospitals', *Journal of nursing and social sciences related to health and illness (Kontakt)*, pp. 40-46. Available at: https://doi.org/10.32725/kont.2020.007

Malouf, R., Henderson, J. and Alderdice, F. (2019) 'Expectations and experiences of hospital postnatal care in the UK: a systematic review of quantitative and qualitative studies', *BMJ Open,* 9(7), pp. e022212. Available at: https://doi.org/10.1136/bmjopen-2018-022212

Mark, B. and Harless, D. (2010) 'Nurse staffing and post-surgical complications using the present on admission indicator', *Research in nursing & health,* 33(1), pp. 35-47. Available at: https://doi.org/10.1002/nur.20361

Martin, E., Blythe, R., Kularatna, S. and Carter, H. (2020) 'The role of health economics', *Health Promotion in the 21st Century: New approaches to achieving health for all*. Oxford: Routledge.

Marzalik, P., Feltham, K., Jefferson, K. and Pekin, K. (2018) 'Midwifery education in the US-Certified Nurse-Midwife, Certified Midwife and Certified Professional Midwife', *Midwifery,* 60, pp. 9-12. Available at: https://doi.org/10.1016/j.midw.2018.01.020

Maternity and Newborn Safety Investigations (2024) *National learning report: Factors affecting the delivery of safe care in midwifery units*. Available at: https://mnsi-2zor10x7-media.s3.amazonaws.com/production-assets/documents/20240508-MNSI-Delivering-safe-care-in-midwifery-units.pdf?utm_source=The%20King%27s%20Fund%20newsletters%20%28main%20account%29&utm_medium=email&utm_campaign=14473156_NEWSL_HMP_Library%202024-05-10&dm_i=21A8,8M7K4,1PGOCE,ZQ6J2,1 (Accessed: 10th May 2024).

Maxwell, S. (2000) 'Sample size and multiple regression analysis', *Psychol Methods,* 5(4), pp. 434-58. Available at: https://doi.org/10.1037/1082-989x.5.4.434

MBRRACE-UK (2020) 'MBRRACE-UK Perinatal Mortality Surveillance Report for births in 2018'. Available at: https://www.npeu.ox.ac.uk/assets/downloads/mbrrace-uk/reports/perinatal-surveillance-report-2018/MBRRACE-UK_Perinatal_Surveillance_Report_2018_-_final_v2.pdf (Accessed: 10th Jan 2021)

MBRRACE-UK (2021) *Saving Lives, Improving Mothers' Care – Lessons learned to inform maternity care from the UK and Ireland Confidential Enquiries into Maternal Deaths and Morbidity 2017-19*. Available at: https://www.npeu.ox.ac.uk/assets/downloads/mbrrace-uk/reports/maternal-report-2021/MBRRACE-UK_Maternal_CORE_Report_2021_-_FINAL.pdf (Accessed: 24th Apr 2022)

MBRRACE-UK (2022) *Saving Lives, Improving Mothers' Care - Lessons learned to inform maternity care from the UK and Ireland Confidential Enquiries into Maternal Deaths and Morbidity 2018-20*. Available at: https://www.npeu.ox.ac.uk/mbrrace-uk/reports (Accessed: 11th Aug 2023).

MBRRACE-UK (2023a) *MBRRACE-UK Perinatal Mortality Surveillance UK perinatal deaths for births from 1 January 2021 to 31 December 2021*. Available at: https://timms.le.ac.uk/mbrrace-uk-perinatal-mortality/surveillance/ (Accessed: 1st Oct 2023).

MBRRACE-UK (2023b) *MBRRACE-UK Saving Lives Improving Mothers' Care - Lessons learned to inform maternity care from the UK and Ireland Confidential Enquiries into Maternal Deaths and Morbidity 2019-21*. Available at: https://www.npeu.ox.ac.uk/assets/downloads/mbrrace-uk/reports/maternal-report-2023/MBRRACE-UK_Maternal_Compiled_Report_2023.pdf (Accessed: 21st Jan 2024)

MBRRACE-UK (2017) *MBRRACE-UK Perinatal Mortality Surveillance Report. UK Perinatal Deaths for Births from January to December 2014.* . Available at: https://www.npeu.ox.ac.uk/downloads/files/mbrrace-uk/reports/MBRRACE-UK-PMS-Report-2014.pdf.

McCourt, C., Olander, E., Wiseman, O., Uddin, N., Plachcinski, R., Rayment, J., Lazar, J., Ross-Davie, M. and Grollman, C. (2023) *Independent evaluation of the implementation of midwifery continuity of carer*. Available at: https://bpb-eu-w2.wpmucdn.com/blogs.city.ac.uk/dist/e/2879/files/2024/05/MCoC-evaluation-final-report-20.5.24.pdf (Accessed: 25th May 2024).

McDougall, L., Campbell, O. and Wendy, G. (2016) 'Maternal health an executive summary for the Lancet Series :every woman, every newborn, everywhere has the right to good quality care', *The Lancet,* 388, pp. 8. Available at:

https://www.thelancet.com/pb/assets/raw/Lancet/stories/series/maternal-health-2016/mathealth2016-exec-summ.pdf (Accessed: 22nd May 2024)

McHugh, M., Aiken, L., Sloane, D., Windsor, C., Douglas, C. and Yates, P. (2021) 'Effects of nurse-to-patient ratio legislation on nurse staffing and patient mortality, readmissions, and length of stay: a prospective study in a panel of hospitals', *The Lancet,* 397(10288), pp. 1905-1913. Available at: https://doi.org/10.1016/S0140-6736(21)00768-6

McHugh, M., Berez, J. and Small, D. (2013) 'Hospitals with higher nurse staffing had lower odds of readmissions penalties than hospitals with lower staffing', *Health Affairs,* 32(10), pp. 1740-1747. Available at: https://doi.org/10.1377/hlthaff.2013.0613

McLachlan, H., Forster, D., Yelland, J., Rayner, J. and Lumley, J. (2008) 'Is the organisation and structure of hospital postnatal care a barrier to quality care? Findings from a state-wide review in Victoria, Australia', *Midwifery,* 24(3), pp. 358-370. Available at: https://doi.org/10.1016/j.midw.2006.10.006

McLeish, J., Harvey, M., Redshaw, M. and Alderdice, F. (2021) 'A qualitative study of first time mothers' experiences of postnatal social support from health professionals in England', *Women and Birth,* 34(5), pp. e451-e460. Available at: https://doi.org/10.1016/j.wombi.2020.10.012

McLeish, J., Harvey, M., Redshaw, M., Henderson, J., Malouf, R. and Alderdice, F. (2020) 'First-time mothers' expectations and experiences of postnatal care in England', *Qual Health Res,* 30(12), pp. 1876-1887. Available at: https://doi.org/10.1177/1049732320944141

McLeish, J. and Redshaw, M. (2019) 'Maternity experiences of mothers with multiple disadvantages in England: a qualitative study', *Women and Birth,* 32(2), pp. 178-184. Available at: https://doi.org/10.1016/j.wombi.2018.05.009

McNeill, M. and Kitson-Reynolds, E. (2024) 'Student midwives' experiences of clinical placement and the decision to enter the professional register', *British Journal of Midwifery,* 32(1), pp. 14-20. Available at: https://doi.org/doi.org/10.12968/bjom.2024.32.1.14

Mercer, B. (2016) 'Delivery volume, nurse staffing and adverse perinatal outcomes', *Obstetrics & Gynecology,* 127(Supplement 1), pp. 36S-37S. Available at: https://doi.org/10.1097/01.AOG.0000483388.39624.3d

Merkow, R., Chung, J., Slota, J., Barnard, Hall, A., Ramsey, K. and Bilimoria, K. (2022) 'Correlation of the US news and world report-calculated nurse staffing index with actual hospital-reported nurse staffing', *J Nurs Care Qual,* 37(3), pp. 195-198. Available at: https://doi.org/10.1097/NCQ.0000000000000619

Miller, S., Abalos, E., Chamillard, M., Ciapponi, A., Colaci, D., Comande, D., Diaz, V., Geller, S., Hanson, C., Langer, A., Manuelli, V., Millar, K., Morhason-Bello, I., Castro, C., Pileggi, V., Robinson, N., Skaer, M., Souza, J., Vogel, J. and Althabe, F. (2016) 'Beyond too little, too late and too much, too soon: a pathway towards evidence-based, respectful maternity care worldwide', *The Lancet,* 388(10056), pp. 2176-2192. Available at: https://doi.org/10.1016/S0140-6736(16)31472-6

Min, A. and Scott, L. (2016) 'Evaluating nursing hours per patient day as a nurse staffing measure', *Journal of Nursing Management,* 24(4), pp. 439-448. Available at: https://doi.org/10.1111/jonm.12347

Moncrieff, G., Cheyne, H., Downe, S. and Hunter, B. (2023) 'Factors that influence midwives' leaving intentions: a moral imperative to intervene', *Midwifery,* 125, pp. 103793. Available at: https://doi.org/10.1016/j.midw.2023.103793

Morrow, J., McLachlan, H., Forster, D., Davey, M. A. and Newton, M. (2013) 'Redesigning postnatal care: exploring the views and experiences of midwives', *Midwifery,* 29(2), pp. 159-66. Available at: https://doi.org/10.1016/j.midw.2011.11.006

Mosadeghrad, A. M. (2014) 'Factors influencing healthcare service quality', *Int J Health Policy Manag,* 3(2), pp. 77-89. Available at: https://doi.org/10.15171/ijhpm.2014.65

Mugford, M., Szczepura, A., Lodwick, A. and Stilwell, J. (1988) 'Factors affecting the outcome of maternity care. II. Neonatal outcomes and resources beyond the hospital of birth', *J Epidemiol Community Health,* 42(2), pp. 170-6. Available at: https://doi.org/10.1136/jech.42.2.170

Mumsnet (2017) *Our survey: what women told us about care on postnatal wards*. Available at: https://www.mumsnet.com/campaigns/our-survey-what-women-told-us-about-care-on-postnatal-wards (Accessed: 8th Apr 2021).

Munier, T. and Porter, S. (2014) 'The struggle for safe staffing levels in the USA: a political economy of evidence-based practice', *Journal of Research in Nursing,* 19(7-8), pp. 592-603. Available at: https://doi.org/10.1177/1744987114557108

Musca, S. C., Kamiejski, R., Nugier, A., Méot, A., Er-Rafiy, A. and Brauer, M. (2011) 'Data with hierarchical structure: impact of intraclass correlation and sample size on type-I error', *Frontiers in psychology,* 2, pp. 1-6. Available at: https://doi.org/10.3389/fpsyg.2011.00074

Musy, S., Endrich, O., Leichtle, A., Griffiths, P., Nakas, C. and Simon, M. (2020) 'Longitudinal study of the variation in patient turnover and patient-to-nurse ratio: descriptive analysis of a Swiss university hospital', *J Med Internet Res,* 22(4), pp. e15554. Available at: https://doi.org/10.2196/15554

Nahasaram, S., Ramoo, V. and Lee, W. (2021) 'Missed nursing care in the Malaysian context: A cross-sectional study from nurses' perspective', *J Nurs Manag,* 29(6), pp. 1848-1856. Available at: https://doi.org/10.1111/jonm.13281

National Health Service (2019) *The NHS Long Term Plan*. Available at: https://www.longtermplan.nhs.uk/publication/nhs-long-term-plan/ (Accessed: 28th Apr 2022).

National Institute for Health and Care Excellence (2015) *Safe midwifery staffing for maternity settings Appendix 1: Evidence to recommendations tables*. Available at: https://www.nice.org.uk/guidance/ng4/evidence/appendix-1-pdf-5278573 (Accessed: 31st March 2024).

National Institute for Health and Care Excellence (2021) *Caesarean birth*. Available at: https://www.nice.org.uk/guidance/ng192 (Accessed: 3rd Jul 2021).

National Institute for Health and Care Excellence (2015) *Safe midwifery staffing for maternity settings*. Available at: https://www.nice.org.uk/guidance/ng4/resources/safe-midwifery-staffing-for-maternity-settings-pdf-51040125637 (Accessed: 13th Oct 2020).

National Institute for Health and Care Excellence (2023) *Intrapartum care*. Available at: https://www.nice.org.uk/guidance/ng235/resources/intrapartum-care-pdf-66143897812933 (Accessed: 16th Feb 2024)

National Institute for Health Research (2019) *Staffing on wards : making decisions about healthcare staffing,improving effectiveness and supporting staff to care well*. Available at: https://content.nihr.ac.uk/nihrdc/themedreview-03553-SW/FINAL-Ward-Staffing-for-WEB.pdf (Accessed: 22nd Nov 2021).

National Maternity and Perinatal Audit (2019a) *National Maternity and Perinatal Audit: Clinical Report 2019. Based on births in NHS maternity services between 1 April 2016 and 31 March 2017*. Available at: https://maternityaudit.org.uk/FilesUploaded/NMPA%20Clinical%20Report%202019.pdf (Accessed: 8th Dec 2020)

National Maternity and Perinatal Audit (2019b) *Organisational Report 2019. A snapshot of NHS maternity and neonatal services in England, Scotland and Wales in January 2019*: Healthcare Quality Improvement Partnership. Available at: https://maternityaudit.org.uk/FilesUploaded/NMPA%20organisational%20report%202019.pdf (Accessed: 2nd Feb 2024)

National Maternity and Perinatal Audit (2021) *Ethnic and Socio-economic Inequalities in NHS Maternity and Perinatal Care for Women and their Babies*. Available at: https://maternityaudit.org.uk/FilesUploaded/Ref%20308%20Inequalities%20Sprint%20Audit%20Report%202021_FINAL.pdf (Accessed: 3rd Jun 2022).

National Maternity and Perinatal Audit (2022) *Clinical Report 2022. Based on births in NHS maternity services in England and Wales between 1 April 2018 and 31 March 2019*. Available at: https://maternityaudit.org.uk/FilesUploaded/Ref%20336%20NMPA%20Clinical%20Report_2022.pdf (Accessed: 28th Jul 2022)

National Maternity Review (2016) *Better births; improving outcomes of maternity services in England*. NHS England, London. Available at: https://www.england.nhs.uk/wp-content/uploads/2016/02/national-maternity-review-report.pdf (Accessed:21th April 2022)

National Quality Board (2016) *Supporting NHS providers to deliver the right staff, with the right skills, in the right place at the right time: safe, sustainable and productive staffing*: National Quality Board (NQB). Available at: https://www.england.nhs.uk/wp-content/uploads/2013/04/nqb-guidance.pdf (Accessed: 13th Oct 2020)

National Quality Board (2018) *Safe, sustainable and productive staffing. An improvement resource for adult inpatient wards in acute hospitals*. Available at: https://improvement.nhs.uk/documents/584/FINAL_Adult_In-patient_Safe_Staffing.pdf (Accessed: 13th Oct 2020).

Naughton, S., Harvey, C. and Baldwin, A. (2021) 'Providing woman-centred care in complex pregnancy situations', *Midwifery,* 102(103060). Available at: https://doi.org/10.1016/j.midw.2021.103060

Needleman, J., Liu, J., Shang, J., Larson, E. and Stone, P. (2020) 'Association of registered nurse and nursing support staffing with inpatient hospital mortality', *BMJ Quality & Safety,* 29(1), pp. 10-18. Available at: https://doi.org/10.1136/bmjqs-2018-009219

NHS (2022) 'NHS Staff Survey'. Available at: https://www.nhsstaffsurveys.com/ (Accessed: 2nd Mar 2024)

NHS Confederation (2023) *NHS leaders facing impossible choices on which services to cut unless government provides urgent cash injection*. Available at: https://www.nhsconfed.org/news/nhs-leaders-facing-impossible-choices-which-services-cut-unless-government-provides-urgent (Accessed: 2nd April 2024)

NHS Digital (2018a) *DCB3066 Digital Maternity Record Standard*. Available at: https://digital.nhs.uk/data-and-information/information-standards/information-standards-and-data-collections-including-extractions/publications-and-notifications/standards-and-collections/dcb3066-digital-maternity-record-standard#current-release (Accessed: 5th Mar 2024)

NHS Digital (2018b) *Hospital Episode Statistics (HES)*. Available at: https://digital.nhs.uk/data-and-information/data-tools-and-services/data-services/hospital-episode-statistics (Accessed: 3rd May 2021).

NHS Digital (2018c) *NHS Workforce statistics*. Available at: https://digital.nhs.uk/data-and-information/publications/statistical/nhs-workforce-statistics (Accessed: 9th May 2021)

NHS Digital (2019a) *Hospital Episode Statistics (HES)*. Available at: https://digital.nhs.uk/data-and-information/data-tools-and-services/data-services/hospital-episode-statistics (Accessed: 3rd Oct 2020).

NHS Digital (2019b) *Indicator supporting documentation. Summary Hospital-level Mortality Indicator (SHMI)*. Available at: https://www.nice.org.uk/Media/Default/Standards-and-indicators/National-Library-of-Quality-Indicators/IAP00385%20supporting%20documentation.docx (Accessed: 3rd Jan 2024)

NHS Digital (2019c) *NHS Maternity Statistics, England 2019-20*. Available at: https://digital.nhs.uk/data-and-information/publications/statistical/nhs-maternity-statistics/2019-20 (Accessed: 3rd Aug 2021)

NHS Digital (2020) *Safety thermometer - maternity dashboard*. Available at: https://digital.nhs.uk/data-and-information/data-collections-and-data-sets/data-sets/maternity-services-data-set (Accessed: 6th Oct 2020).

NHS Digital (2022a) *Emergency readmissions to hospital within 30 days of discharge by diagnosis*. Available at: https://digital.nhs.uk/data-and-information/publications/statistical/compendium-emergency-readmissions/current/emergency-readmissions-to-hospital-within-30-days-of-discharge (Accessed: 7th May 2023)

NHS Digital (2022b) *NHS Workforce Statistics*. Available at: https://digital.nhs.uk/data-and-information/publications/statistical/nhs-workforce-statistics (Accessed: 8th Oct 2021).

NHS Digital (2023a) 'Deliveries over time'. Available at: https://digital.nhs.uk/data-and-information/publications/statistical/nhs-maternity-statistics/2022-23/deliveries---time-series#:~:text=Spontaneous%20method%20of%20onset%20is,%2D13%20to%202022%2D23. (Accessed: 4th April 2024)

NHS Digital (2023b) *Hospital Episode Statistics (HES)*. Available at: https://digital.nhs.uk/data-and-information/publications/statistical/nhs-maternity-statistics/2022-23 (Accessed: 18th Jan 2024)

NHS Digital (2023c) *Maternity Services Data Set (MSDS)*. Available at: https://digital.nhs.uk/data-and-information/data-collections-and-data-sets/data-sets/maternity-services-data-set/about-the-maternity-services-data-set (Accessed: 6th Oct 2020).

NHS Digital (2023d) *NHS Workforce Statistics*. Available at: https://digital.nhs.uk/data-and-information/publications/statistical/nhs-workforce-statistics (Accessed: 2nd Feb 2024).

NHS Digital (2023e) *Summary Hospital-level Mortality Indicator (SHMI)*. Available at: https://digital.nhs.uk/data-and-information/publications/ci-hub/summary-hospital-level-mortality-indicator-shmi (Accessed: 23rd Apr 2023)

NHS England (2014) *Hard truths commitments regarding the publishing of staffing data*. Available at: https://www.england.nhs.uk/wp-content/uploads/2014/04/staff-data-faqs-0414.pdf (Accessed: 4th April 2024)

NHS England (2018) *The fifteen steps for maternity - quality from the perspective of people who use maternity services*. Available at: https://www.england.nhs.uk/wp-content/uploads/2018/05/15-steps-maternity-toolkit-v9-1.pdf (Accessed: 21st Jan 2022).

NHS England (2020) *Better Births four years on: a review of progress*. . Available at: https://www.england.nhs.uk/wp-content/uploads/2020/03/better-births-four-years-on-progress-report.pdf (Accessed: 15th Apr 2021).

NHS England (2021a) *NMC emergency standards*. Available at: https://www.england.nhs.uk/coronavirus/documents/nmc-emergency-standards/ (Accessed: 15th Mar 2024)

NHS England (2021b) *Personalised care and support planning guidance*. Available at: https://www.england.nhs.uk/wp-content/uploads/2021/03/B0423-personalised-care-and-support-planning-guidance-for-lms.pdf (Accessed: 6th May 2024).

NHS England (2022) *NHS announces £127 million maternity boost for patients and families*. Available at: https://www.england.nhs.uk/2022/03/nhs-announces-127m-maternity-boost-for-patients-and-families/ (Accessed: 21st Apr 2022)

NHS England (2023a) ''How to' guide: a resource pack to support implementing the core competency framework version 2'. Available at: https://www.england.nhs.uk/wp-content/uploads/2023/05/PRN00239i-how-to-guide-core-competency-framework.pdf (Accessed: 21st May 2024)

NHS England (2023b) *NHS data model and dictionary*. Available at: https://www.datadictionary.nhs.uk/supporting_information/healthcare_resource_group.html (Accessed: 12th Jan 2024)

NHS England (2023c) *NHS long term workforce plan*. Available at: https://www.england.nhs.uk/wp-content/uploads/2023/06/nhs-long-term-workforce-plan-v1.2.pdf (Accessed: 12th Aug 2023).

NHS England (2024a) *Maternity support worker implementation and mapping toolkit*. Available at: https://www.england.nhs.uk/long-read/maternity-support-worker-implementation-and-mapping-toolkit/ (Accessed: 27th May 2024).

NHS England (2024b) 'The Model Health System'. Available at: https://www.england.nhs.uk/applications/model-hospital/ (Accessed: 25th May 2024)

NHS Health Education England (2020) 'Maternity support worker level 3 apprenticeship training and competency manual'. Available at: https://healtheducationengland.sharepoint.com/:w:/r/Comms/Digital/_layouts/15/Doc.aspx?sourcedoc=%7B7DEDE5B0-F4B3-477A-880D-32A5C0D03A73%7D&file=01.%20MSW%20Skills%20Passport.docx&action=default&mobileredirect=true (Accessed: 29th Feb 2024)

NHS Improvement (2018) *Care hours per patient day (CHPPD): guidance for acute and acute specialist trusts*. Available at: https://www.england.nhs.uk/care-hours-patient-day-chppd-data/ (Accessed: 9th Nov 2020).

NHS Improvement (2021) *Care hours per patient day (CHPPD): guidance for acute and acute specialist trusts*. Available at: https://www.england.nhs.uk/wp-content/uploads/2021/03/B0473-care-hours-per-patient-day-chppd-guidance-for-all-inpatient-trusts-updated-march-2021.pdf (Accessed: 22nd Nov 2021).

NHS Resolution (2020) 'Maternity incentive scheme – year three. Ten maternity safety actions with technical guidance'. Available at: https://resolution.nhs.uk/services/claims-management/clinical-schemes/clinical-negligence-scheme-for-trusts/maternity-incentive-scheme/ (Accessed: 10th Dec 2020)

NHS Resolution (2023) *Annual report and accounts 2022/23*. Available at: https://resolution.nhs.uk/wp-content/uploads/2023/07/4405-NHSR-Annual-Report-and-Accounts_Rollout_A_Access2.pdf (Accessed: 6th Aug 2023).

Nilsen Mørch, M., Sommerseth, E. and Dahl, B. (2019) 'Perceptions of postnatal care after emergency caesarean sections', *Norwegian Journal of Clinical Nursing,* 14 (76793). Available at: https://doi.org/10.4220/Sykepleienf.2019.76793

Nove, A., Friberg, I., de Bernis, L., McConville, F., Moran, A., Najjemba, M., Ten Hoope-Bender, P., Tracy, S. and Homer, C. S. (2021) 'Potential impact of midwives in preventing and reducing maternal and neonatal mortality and stillbirths: a Lives Saved Tool modelling study', *The Lancet Global Health,* 9(1), pp. e24-e32. Available at: https://doi.org/10.1016/S2214-109X(20)30397-1

Nuffield Trust (2023) *Inequalities in midwifery continuity of care during pregnancy*. Available at: https://www.nuffieldtrust.org.uk/news-item/inequalities-in-midwifery-continuity-of-care-during-pregnancy#:~:text=Although%20the%20national%20average%20of,its%20peak%20in%20September%202021. (Accessed: 2nd Feb 2024)

Nuffield Trust (2024) *What health and care need from the next government: #1 – NHS staffing*. Available at: https://www.nuffieldtrust.org.uk/resource/what-health-and-care-need-from-the-next-government-1-nhs-staffing (Accessed: 9th Mar 2024)

Nursing and Midwifery Council (2019) *Standards of proficiency for midwives*. Available at: https://www.nmc.org.uk/standards/standards-for-midwives/standards-of-proficiency-for-midwives/ (Accessed: 13th Oct 2020).

O'Brien, R. (2007) 'A caution regarding rules of thumb for variance inflation factors', *Quality & quantity,* 41, pp. 673-690. Available at: https://doi.org/10.1007/s11135-006-9018-6

Ockenden, D. (2022) *Final report of the Ockenden Review*. Available at: https://www.gov.uk/government/publications/final-report-of-the-ockenden-review (Accessed: 3rd Apr 2022).

Office for National Statistics (2020) *Provisional births in England and Wales*. Available at: https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/livebirths/articles/provisionalbirthsinenglandandwales/2020#live-births-by-place-of-occurrence (Accessed: 13th Jun 2021)

Office for National Statistics (2023) *Birth characteristics in England and Wales: 2021*. Available at: https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/livebirths/bulletins/birthcharacteristicsinenglandandwales/2021 (Accessed: 18th Jan 2024)

Olley, R., Edwards, I., Avery, M. and Cooper, H. (2018) 'Systematic review of the evidence related to mandated nurse staffing ratios in acute hospitals', *Australian Health Review,* 43(3), pp. 288-293. Available at: https://doi.org/10.1071/AH16252

Orkin, F. (2010) 'Risk stratification, risk adjustment, and other risks', *The Journal of the American Society of Anesthesiologists,* 113(5), pp. 1001-1003. Available at: https://doi.org/10.1097/ALN.0b013e3181f7ab17.

Osborne, K. (2017) 'Are specially trained midwives the right professionals to perform the newborn physical examination?', *British Journal of Midwifery,* 25(3), pp. 174-179. Available at: https://doi.org/10.12968/bjom.2017.25.3.174

Paddison, C., Elliott, M., Parker, R., Staetsky, L., Lyratzopoulos, G., Campbell, J. and Roland, M. (2012) 'Should measures of patient experience in primary care be adjusted for case mix? Evidence from the English General Practice Patient Survey', *BMJ Quality & Safety,* 21(8), pp. 634-640. Available at: https://doi.org/10.1136/bmjqs-2011-000737

Panda, S., Begley, C. and Daly, D. (2016) 'Readmission following caesarean section: outcomes for women in an Irish maternity hospital', *British Journal of Midwifery,* 24(5), pp. 322-328. Available at: https://doi.org/10.12968/bjom.2016.24.5.322

Park, S., Blegen, M., Spetz, J., Chapman, S. and De Groot, H. (2012) 'Patient turnover and the relationship between nurse staffing and patient outcomes', *Research in nursing & health,* 35(3), pp. 277-288. Available at: https://doi.org/10.1002/nur.21474

Park, S., Dunton, N. and Blegen, M. (2016) 'Comparison of unit-level patient turnover measures in acute care hospital settings', *Res Nurs Health,* 39(3), pp. 197-203. Available at: https://doi.org/10.1002/nur.21715

Parkin, E. and Balogun, B. (2023) *Quality and safety of maternity care (England). Research Briefing*: House of Commons Library. Available at: https://researchbriefings.files.parliament.uk/documents/CBP-9815/CBP-9815.pdf.

Parra, C., Bertizzolo, L., Schroter, S., Dechartres, A. and Goetghebeur, E. (2021) 'Consistency of causal claims in observational studies: a review of papers published in a general medical journal', *BMJ Open,* 11(5), pp. e043339. Available at: https://doi.org/10.1136/bmjopen-2020-043339

Patrician, P., Loan, L., McCarthy, M., Fridman, M., Donaldson, N., Bingham, M. and Brosch, L. (2011) 'The association of shift-level nurse staffing with adverse patient events', *J Nurs Adm,* 41(2), pp. 64-70. Available at: https://doi.org/10.1097/NNA.0b013e31820594bf

Pervez, S., Sharawi, N., Blake, L., Habib, A., Brookfield, K. and Carvalho, B. (2021) 'Impact of enhanced recovery after caesarean delivery on maternal outcomes: A systematic review and meta-analysis', *Anaesthesia, Critical Care & Pain Medicine,* 40(100935), pp. 1-11. Available at: https://doi.org/10.1016/j.accpm.2021.100935

Pittrof, R., Campbell, O. and Filippi, V. (2002) 'What is quality in maternity care? An international perspective', *Acta Obstet Gynecol Scand,* 81(4), pp. 277-283. Available at: https://doi.org/10.1034/j.1600-0412.2002.810401.x

Pokharel, A., Kiriya, J., Shibanuma, A., Silwal, R. and Jimba, M. (2023) 'Association of workload and practice of respectful maternity care among the healthcare providers, before and during the early phase of COVID-19 pandemic in South Western Nepal: a cross-sectional study', *BMC Health Serv Res,* 23(1), pp. 538. Available at: https://doi.org/10.1186/s12913-023-09561-x

Prapawichar, P., Ratinthorn, A., Utriyaprasit, K. and Viwatwongkasem, C. (2020) 'Maternal and health service predictors of postpartum hemorrhage across 14 district, general and regional hospitals in Thailand', *BMC Pregnancy Childbirth,* 20(1), pp. 172. Available at: https://doi.org/10.1186/s12884-020-2846-x

Price, C. (2019) 'Legal and ethical considerations for midwives performing the neonatal infant physical examination', *British Journal of Midwifery,* 27(1), pp. 54-58. Available at: https://doi.org/10.12968/bjom.2019.27.1.54

Public Health England (2016) *Health matters: giving every child the best start in life*. Available at: https://www.gov.uk/government/publications/health-matters-giving-every-child-the-best-start-in-life/health-matters-giving-every-child-the-best-start-in-life (Accessed: 26th Nov 2023).

Queensland Government (2023) *Queensland to introduce nation-leading midwife ratios for mums and bubs*. Available at: https://statements.qld.gov.au/statements/99278#:~:text=A%20minimum%20ratio%20of%20one,%2C%20highest%2Dquality%20care%20possible. (Accessed: 28th Jan 2024)

Quigley, D., Qureshi, N., Rybowski, L., Shaller, D., Edgman-Levitan, S., Cleary, P., Ginsberg, C. and Hays, R. (2022) 'Summary of the 2020 AHRQ research meeting on advancing methods of implementing and evaluating patient experience improvement using consumer assessment of healthcare providers and systems surveys', *Expert Rev Pharmacoecon Outcomes Res,* 22(6), pp. 883-890. Available at: https://doi.org/10.1080/14737167.2022.2064848

Rae, P., Pearce, S., Greaves, P., Dall'Ora, C., Griffiths, P. and Endacott, R. (2021) 'Outcomes sensitive to critical care nurse staffing levels: A systematic review', *Intensive Crit Care Nurs,* 67, pp. 103110. Available at: https://doi.org/10.1016/j.iccn.2021.103110

Rafferty, A. and Leary, A. (2023) 'Nursing notes on a scandal', *Future Healthc J,* 10(1), pp. 3-6. Available at: https://doi.org/10.7861/fhj.2023-FR102

Rai, S., van Teijlingen, E., Regmi, P., Wood, J., Dangal, G. and Dhakal, K. (2021) 'Caesarean section for non-medical reasons: A rising public health issue', *Journal of Karnali Academy of Health Sciences,* 4(2). Available at: https://eprints.bournemouth.ac.uk/38791/1/Sulochana%20et%20al%20non-med%20reasons%20CS%202021%20JKAHS.pdf (Accessed: 11th Apr 2024)

Ranger, N. (2023) *Safety critical red lines*. Royal College of Nursing,. Available at: https://www.rcn.org.uk/news-and-events/Blogs/safety-critical-red-lines-151223 (Accessed: 2nd April 2024)

Rayment, J., McCourt, C., Scanlon, M., Culley, L., Spiby, H., Bishop, S. and de Lima, L. (2020) 'An analysis of media reporting on the closure of freestanding midwifery units in England', *Women and Birth,* 33(1), pp. e79-e87. Available at: https://doi.org/10.1016/j.wombi.2018.12.012

Renfrew, M., McFadden, A., Bastos, M., Campbell, J., Channon, A., Cheung, N., Silva, D., Downe, S., Kennedy, H., Malata, A., McCormick, F., Wick, L. and Declercq, E. (2014) 'Midwifery and quality care: findings from a new evidence-informed framework for maternal and newborn care', *The Lancet,* 384(9948), pp. 1129-45. Available at: https://doi.org/10.1016/S0140-6736(14)60789-3

Robertson, K., Hardingham, I., D'Arcy, R., Reddy, A. and Clacey, J. (2021) 'Delay in the induction of labour process: a retrospective cohort study and computer simulation of maternity unit workload', *BMJ Open,* 11(9), pp. e045577. Available at: https://doi.org/10.1136/bmjopen-2020-045577

Romanzi, L. (2014) 'Natural childbirth: a global perspective', *AMA Journal of Ethics,* 16(10), pp. 835-841. Available at: https://doi.org/10.1001/virtualmentor.2014.16.10.oped1-1410.

Rowe, R., Townend, J., Brocklehurst, P., Knight, M., Macfarlane, A., McCourt, C., Newburn, M., Redshaw, M., Sandall, J., Silverton, L. and Hollowell, J. (2014) 'Service configuration, unit characteristics and variation in intervention rates in a national sample of obstetric units in England: an exploratory analysis', *BMJ Open,* 4(5), pp. e005551. Available at: https://doi.org/10.1136/bmjopen-2014-005551

Royal College of Midwives (2009) *Guidance Paper on Staffing Standard in Midwifery Services*, London: Royal College of Midwives.

Royal College of Midwives (2016a) *Getting the midwifery workforce right*. Available at: https://www.rcm.org.uk/media/2368/getting-the-midwifery-workforce-right.pdf (Accessed: 18th Jan 2024).

Royal College of Midwives (2016b) *RCM guidance on implementing the NICE safe staffing guideline on midwifery staffing in maternity settings*. Available at: https://www.rcm.org.uk/media/2369/rcm-guidance-on-implementing-the-nice-safe-staffing-guideline-on-midwifery-staffing-in-maternity-settings.pdf.

Royal College of Midwives (2017) *The gathering storm: England's midwifery workforce challenges*. Available at: https://www.rcm.org.uk/media/2374/the-gathering-storm-england-s-midwifery-workforce-challenges.pdf (Accessed: 13th Oct 2020).

Royal College of Midwives (2019) *RCM Pay Review Body Evidence* Available at: https://www.rcm.org.uk/media/3155/royal-college-of-midwives-pay-review-body-evidence-2019.pdf (Accessed: 4th Sept 2021).

Royal College of Midwives (2021) *RCM warns of midwife exodus as maternity staffing crisis grows*. Available at: https://www.rcm.org.uk/media-releases/2021/september/rcm-warns-of-midwife-exodus-as-maternity-staffing-crisis-grows/ (Accessed: 24th Jul 2022).

Royal College of Midwives (2022a) *Care outside guidance : Caring for those women seeking choices that fall outside guidance*. Available at: https://www.rcm.org.uk/media/5941/care_outside_guidance.pdf (Accessed: 6th May 2024).

Royal College of Midwives (2022b) *Maternity underfunding means care based on what trusts can afford not on women's safety and needs says RCM*. Available at: https://www.rcm.org.uk/media-releases/2022/february/maternity-underfunding-means-care-based-on-what-trusts-can-afford-not-on-women-s-safety-and-needs-says-rcm/ (Accessed: 17th May 2024)

Royal College of Midwives (2022c) *RCM evidence to the NHS Pay Review Body*. Available at: https://www.rcm.org.uk/media/5784/rcm-pay-review-body-evidence-2022.pdf#:~:text=The%20Royal%20College%20of%20Midwives%20%28RCM%29%20welcomes%20the,and%20maternity%20support%20workers%20%28MSWs%29%20in%20the%20UK. (Accessed: 23rd Apr 2022)

Royal College of Midwives (2024) *How to become a maternity support worker*. Available at: https://www.rcm.org.uk/promoting/education-hub/become-maternity-support-worker/ (Accessed: 2nd Feb 2024)

Royal College of Midwives and Kings College London (2017) *The deployment, education and development of maternity support workers in England*. Available at:

https://www.rcm.org.uk/media/2347/the-deployment-education-and-development-of-maternity-support-workers-in-england.pdf (Accessed: 13th Oct 2020)

Royal College of Nursing (2019) *Nurses in maternity care*, London. Available at: https://www.rcn.org.uk/professional-development/publications/pub-007640 (Accessed: 13th Oct 2020).

Royal College of Nursing (2023) *Impact of staffing levels on safe and effective patient care literature review*. Available at: https://www.rcn.org.uk/Professional-Development/publications/impact-of-staffing-levels-on-safe-and-effective-patient-care-uk-pub-010-665 (Accessed: 16th Feb 2024).

Royal College of Obstetricians and Gynaecologists (2017) *Maternal mental health – women's voices*. Available at: https://www.rcog.org.uk/globalassets/documents/patients/information/maternalmental-healthwomens-voices.pdf (Accessed: 2nd May 2021).

Royal College of Obstetricians and Gynaecologists (2021) 'Each baby counts'. Available at: https://rcog.org.uk/media/a4eg2xnm/ebc-2020-final-progress-report.pdf (Accessed: 26th Jul 2022)

Royal College of Obstetricians and Gynaecologists (2022) *RCOG workforce report 2022*. Available at: https://www.rcog.org.uk/media/fdtlufuh/workforce-report-july-2022-update.pdf (Accessed: 24th Jul 2022)

Royal College of Obstetricians and Gynaecologists, Royal College of Midwives, Royal College of Paediatrics and Child Health and Royal College of Anaesthetists (2007) *Safer childbirth: minimum standards for the organisation and delivery of care in labour*: RCOG. Available at: https://www.rcog.org.uk/en/guidelines-research-services/guidelines/safer-childbirth-minimum-standards-for-the-organisation-and-delivery-of-care-in-labour/ (Accessed: 17th Jan 2024).

Rubbo, B., Griffiths, P., Saville, C., Dall'Ora, C. and Turner, L. (2021) 'Associations between healthcare professional staffing levels and mortality in acute hospitals, a systematic review', *PROSPERO*. Available at: https://www.crd.york.ac.uk/prospero/display_record.php?RecordID=219869

Rubbo, B., Saville, C., Dall'Ora, C., Turner, L., Jones, J., Ball, J., Culliford, D. and Griffiths, P. (2023) 'Staffing levels and hospital mortality in England: a national panel study using routinely collected data', *BMJ Open,* 13(5), pp. e066702. Available at: https://doi.org/10.1136/bmjopen-2022-066702

Rudman, A. and Waldenstrom, U. (2007) 'Critical views on postpartum care expressed by new mothers', *BMC Health Serv Res,* 7(178), pp. 178. Available at: https://doi.org/10.1186/1472-6963-7-178

Russell, S. (2021) 'Eradicating racism From maternity care begins with addressing implicit bias', *Nurs Womens Health,* 25(3), pp. 167-169. Available at: https://doi.org/10.1016/j.nwh.2021.03.005

Rydon-Grange, M. (2018) 'Psychological perspective on compassion in modern healthcare settings', *J Med Ethics,* 44(11), pp. 729-733. Available at: https://doi.org/10.1136/medethics-2017-104698

Sandall, J., Fernandez Turienzo, C., Devane, D., Soltani, H., Gillespie, P., Gates, S., Jones, L., Shennan, A. and Rayment-Jones, H. (2024) *Midwife continuity of care models versus other models of care for childbearing women*. Cochrane Database of Systematic Reviews. Available at: https://www.cochranelibrary.com/cdsr/doi/10.1002/14651858.CD004667.pub6/epdf/full (Accessed: 11th April 2024)

Sandall, J., Murrells, T., Dodwell, M., Gibson, R., Bewley, S., Coxon, K., Bick, D., Cookson, G., Warwick, C. and Hamilton-Fairley, D. (2014) 'The efficient use of the maternity workforce and the implications for safety and quality in maternity care: a population-based, cross-sectional study', *Health Services and Delivery Research.,* 2 (38). Available at: https://doi.org/10.3310/hsdr02380

Sandall, J., Taylor, C. and Rayment-Jones, H. (2017) *Evidence Review - maternity safe staffing improvement resource*. Available at: https://improvement.nhs.uk/documents/1355/Evidence_Review_-_maternity_safe_staffing_improvement_resource__Report_v2_website.pdf (Accessed: 13th Oct 2020)

Sanders, J., Simonsen, S., Porucznik, C., Hammoud, A., Smith, K. and Stanford, J. (2022) 'Fertility treatments and the risk of preterm birth among women with subfertility: a linked-data retrospective cohort study', *Reproductive Health,* 19(1), pp. 1-10. Available at: https://doi.org/10.1186/s12978-022-01363-4

Santos-Pereira, J., Gruenwald, L. and Bernardino, J. (2022) 'Top data mining tools for the healthcare industry', *Journal of King Saud University-Computer and Information Sciences,* 34(8), pp. 4968-4982. Available at: https://doi.org/10.1016/j.jksuci.2021.06.002

Saptari, A., Leau, J. and Mohamad, N. (2015) *The effect of time pressure, working position, component bin position and gender on human error in manual assembly line*. 2015 Proceedings of the International Conference on Industrial Engineering and Operations Management. March 3 – 5, 2015

Saville, C. and Griffiths, P. (2021a) 'Ward staffing guided by a patient classification system: A multi-criteria analysis of "fit" in three acute hospitals', *J Nurs Manag,* 29(7), pp. 2260-2269. Available at: https://doi.org/10.1111/jonm.13341

Saville, C., Monks, T., Griffiths, P. and Ball, J. E. (2021b) 'Costs and consequences of using average demand to plan baseline nurse staffing levels: a computer simulation study', *BMJ Quality & Safety,* 30(1), pp. 7-16. Available at: https://doi.org/10.1136/bmjqs-2019-010569

Schreiber-Gregory, D. (2018) *Logistic and linear regression assumptions: violation recognition and control*. Henry M Jackson Foundation. Available at: https://www.researchgate.net/publication/341354759_Logistic_and_Linear_Regression_Assumptions_Violation_Recognition_and_Control (Accessed: 3rd May 2021)

Scottish Government (2019a) *Health and Care (Staffing) (Scotland) Act 2019*. Available at: https://www.gov.scot/publications/health-and-care-staffing-scotland-act-2019-overview/ (Accessed: 7th Mar 2024)

Scottish Government (2019b) *Maternity care survey 2018: national results*. Available at: https://www.gov.scot/publications/maternity-care-survey-2018-national-results/ (Accessed: 3rd Nov 2020).

Sharif, S., Yap, W., Fun, W., Yoon, E., Razak, N., Sararaks, S. and Lee, S. (2021) 'Midwifery qualification in selected countries: a rapid review', *Nursing Reports,* 11(4), pp. 859-880. Available at: https://doi.org/10.3390/nursrep11040080

Sharma, G., Mathai, M., Dickson, K. E., Weeks, A., Hofmeyr, G., Lavender, T., Day, L. T., Mathews, J., Fawcus, S. and Simen-Kapeu, A. (2015) 'Quality care during labour and birth: a multi-country analysis of health system bottlenecks and potential solutions', *BMC Pregnancy Childbirth,* 15(2), pp. 1-19. Available at: https://doi.org/10.1186/1471-2393-15-S2-S2

Sharvit, M., Rubinstein, T., Ravid, D., Shechter-Maor, G., Fishman, A. and Biron-Shental, T. (2014) 'Patients with high-risk pregnancies and complicated deliveries have an increased risk of maternal postpartum readmissions', *Archives of Gynecology and Obstetrics,* 290, pp. 629-633. Available at: https://doi.org/10.1007/s00404-014-3255-z

Sheen, J., Wright, J., Goffman, Kern-Goldberger, A., Booker, W., Siddiq, Z., D'Alton, M. and Friedman, A. (2018) 'Maternal age and risk for adverse outcomes', *Am J Obstet Gynecol,* 219(4), pp. 390 e1-e15. Available at: https://doi.org/10.1016/j.ajog.2018.08.034

Shekelle, P. (2013) 'Nurse–patient ratios as a patient safety strategy: a systematic review', *Annals of internal medicine,* 158(5_Part_2), pp. 404-409. Available at: https://doi.org/10.7326/0003-4819-158-5-201303051-00007

Shimonovich, M., Pearce, A., Thomson, H., Keyes, K. and Katikireddi, S. (2021) 'Assessing causality in epidemiology: revisiting Bradford Hill to incorporate developments in causal thinking', *Eur J Epidemiol,* 36(9), pp. 873-887. Available at: https://doi.org/10.1007/s10654-020-00703-7

Shrestha, N. (2020) 'Detecting multicollinearity in regression analysis', *American Journal of Applied Mathematics and Statistics,* 8(2), pp. 39-42. Available at: https://doi.org/10.12691/ajams-8-2-1

Shu, X. and Ye, Y. (2023) 'Knowledge discovery: methods from data mining and machine learning', *Social Science Research,* 110, pp. 102817. Available at: https://doi.org/10.1016/j.ssresearch.2022.102817

Simpson, K. (2020) 'Measuring nurses' contribution to care and outcomes is a patient safety issue', *MCN: The American Journal of Maternal/Child Nursing,* 45(5), pp. 316. Available at: https://doi.org/10.1097/NMC.0000000000000654

Simpson, K. and Lyndon, A. (2017) 'Consequences of delayed, unfinished, or missed nursing care during labor and birth', *J Perinat Neonatal Nurs,* 31(1), pp. 32-40. Available at: https://doi.org/10.1097/JPN.0000000000000203

Simpson, K., Lyndon, A. and Ruhl, C. (2016) 'Consequences of inadequate staffing include missed care, potential failure to rescue, and job stress and dissatisfaction', *J Obstet Gynecol Neonatal Nurs,* 45(4), pp. 481-90. Available at: https://doi.org/10.1016/j.jogn.2016.02.011

Simpson, K., Lyndon, A., Spetz, J., Gay, C. and Landstrom, G. (2020) 'Missed nursing care during labor and birth and exclusive breast milk feeding during hospitalization for childbirth', *MCN: The American Journal of Maternal/Child Nursing,* 45(5), pp. 280-288. Available at: https://doi.org/10.1097/NMC.0000000000000644

Simpson, K., Lyndon, A., Wilson, J. and Ruhl, C. (2012) 'Nurses' perceptions of critical issues requiring consideration in the development of guidelines for professional registered nurse staffing for perinatal units', *J Obstet Gynecol Neonatal Nurs,* 41(4), pp. 474-82. Available at: https://doi.org/10.1111/j.1552-6909.2012.01383.x

Sinha, S., Peach, G., Poloniecki, J., Thompson, M. and Holt, P. (2013) 'Studies using English administrative data (Hospital Episode Statistics) to assess health-care outcomes--systematic review and recommendations for reporting', *Eur J Public Health,* 23(1), pp. 86-92. Available at: https://doi.org/10.1093/eurpub/cks046

Sizmur, S., Graham, C. and Walsh, J. (2015) 'Influence of patients' age and sex and the mode of administration on results from the NHS Friends and Family Test of patient experience', *J Health Serv Res Policy,* 20(1), pp. 5-10. Available at: https://doi.org/10.1177/1355819614536887

Smith, A., Ayanian, J., Covinsky, K., Landon, B., McCarthy, E., Wee, C. and Steinman, M. (2011) 'Conducting high-value secondary dataset analysis: an introductory guide and resources', *J Gen Intern Med,* 26(8), pp. 920-9. Available at: https://doi.org/10.1007/s11606-010-1621-5

Smith, A., Dixon, A. and Page, L. (2009) 'Health-care professionals' views about safety in maternity services: a qualitative study', *Midwifery,* 25(1), pp. 21-31 Available at: https://doi.org/10.1016/j.midw.2008.11.004

Smith, E. (2024) 'Threat to low-risk birth environments', *British Journal of Midwifery,* 32(6), pp. 328-331. Available at: https://doi.org/10.12968/bjom.2024.32.6.328

Society for Maternal-Fetal Medicine Safety Health Policy Committees, Bailit, J., Gregory, K., Srinivas, S., Westover, T., Grobman, W. and Saade, G. (2016) 'Society for Maternal-Fetal Medicine (SMFM) Special Report: Current approaches to measuring quality of care in obstetrics', *Am J Obstet Gynecol,* 215(3), pp. B8-B16. Available at: https://doi.org/10.1016/j.ajog.2016.06.048

Song, M., Lin, F., Ward, S. and Fine, J. (2013) 'Composite variables: when and how', *Nursing Research,* 62(1), pp. 45-49. Available at: https://doi.org/10.1097/NNR.0b013e3182741948

Spetz, J., Chapman, S., Herrera, C., Kaiser, J., Seago, J. and Dower, C. (2009) *Assessing the impact of California's nurse staffing ratios on hospitals and patient care*. Available at: https://www.chcf.org/wp-content/uploads/2017/12/PDF-AssessingCANurseStaffingRatios.pdf (Accessed: 6th Mar 2024)

Staggs, V., Knight, J. and Dunton, N. (2012) 'Understanding unassisted falls: effects of nurse staffing level and nursing staff characteristics', *J Nurs Care Qual,* 27(3), pp. 194-9. Available at: https://doi.org/10.1097/NCQ.0b013e318241da2d

Stapleton, S., Wright, J. and Jolles, D. (2020) 'Improving the experience of care: results of the American Association of Birth Centers strong start client experience of care registry pilot program, 2015-2016', *J Perinat Neonatal Nurs,* 34(1), pp. 27-37. Available at: https://doi.org/10.1097/JPN.0000000000000454

Stilwell, J., Szczepura, A. and Mugford, M. (1988) 'Factors affecting the outcome of maternity care. 1. Relationship between staffing and perinatal deaths at the hospital of birth', *J Epidemiol Community Health,* 42(2), pp. 157-69. Available at: https://doi.org/10.1136/jech.42.2.157

Stockdale, M. (2023) *Seeing both sides: wellbeing in maternity services post COVID-19.* Bangor University (United Kingdom) [Online] Available at: https://research.bangor.ac.uk/portal/files/59885598/2023_Stockdale_MJ_DClinPsy.pdf (Accessed: 29th Mar 2024)

Szafrańska, M., Begley, C., Carroll, M. and Daly, D. (2020) 'Factors associated with maternal readmission to hospital, attendance at emergency rooms or visits to general practitioners within three months postpartum', *European Journal of Obstetrics & Gynecology and Reproductive Biology,* 254, pp. 251-258. Available at: https://doi.org/10.1016/j.ejogrb.2020.09.018

Taylor, B., Cross-Sudworth, F., Rimmer, M., Quinn, L., Morris, R. K., Johnston, T., Morad, S., Davidson, L., Kenyon, S. and UK Audit Research Collaborative in Obstetrics Gynaecology Members (2024) 'Induction of labour care in the UK: A cross-sectional survey of maternity units', *Plos one,* 19(2), pp. e0297857. Available at: https://doi.org/10.1371/journal.pone.0297857

Taylor, B., Henshall, C., Goodwin, L. and Kenyon, S. (2018) 'Task shifting midwifery support workers as the second health worker at a home birth in the UK: A qualitative study', *Midwifery,* 62, pp. 109-115. Available at: https://doi.org/10.1016/j.midw.2018.03.003

Taylor, C., Mattick, K., Carrieri, D., Cox, A. and Maben, J. (2022) ''The WOW factors': comparing workforce organization and well-being for doctors, nurses, midwives and paramedics in England', *British Medical Bulletin,* 141(1), pp. 60-79. Available at: https://doi.org/10.1093/bmb/ldac003

The Health and Social Care Act 2008 (Regulated Activities) Regulations (2014). Available at: https://www.legislation.gov.uk/uksi/2014/2936 (Accessed: 9th Mar 2024)

The Health Foundation (2016) 'Person-centred care made simple : What everyone should know about person-centred care'. Available at: https://www.health.org.uk/sites/default/files/PersonCentredCareMadeSimple.pdf (Accessed: 6th April 2024)

The Institute for Fiscal Studies (2017) *Under pressure? NHS maternity services in England*. Available at: https://www.ifs.org.uk/uploads/publications/bns/BN215.pdf (Accessed: 13th Oct 2020)

The Kings Fund (2023) *Key facts and figures about the NHS*. Available at: https://www.kingsfund.org.uk/insight-and-analysis/data-and-charts/key-facts-figures-nhs (Accessed: 9th Mar 2024).

The National Federation of Women's Institutes and National Childbirth Trust (2017) *Support Overdue: Women's experiences of maternity services*. Available at: https://www.thewi.org.uk/data/assets/pdf_file/0009/187965/NCT-nct-WI-report-72dpi.pdf (Accessed: 13th Oct 2020).

The Society for Acute Medicine (2011) *Workforce planning considerations for acute medical units*. Available at: https://www.acutemedicine.org.uk/wp-content/uploads/samworkforceplanningforamustoolkitaug2011.pdf (Accessed: 9th May 2024)

Trenner, M., Eckstein, H., Kallmayer, M., Reutersberg, B. and Kühnl, A. (2019) 'Secondary analysis of statutorily collected routine data', *Gefässchirurgie,* 24(3), pp. 220-227. Available at: https://doi.org/10.1007/s00772-019-0524-y

Tubbs-Cooley, H., Cimiotti, J., Silber, J., Sloane, D. and Aiken, L. (2013) 'An observational study of nurse staffing ratios and hospital readmission among children admitted for common conditions', *BMJ Quality & Safety,* 22(9), pp. 735-742. Available at: https://doi.org/10.1136/bmjqs-2012-001610

Tucker, J., Parry, G., Penney, G., Page, M. and Hundley, V. (2003) 'Is midwife workload associated with quality of process of care (continuous electronic fetal monitoring and neonatal outcome indicators? A prospective study in consultant-led labour wards in Scotland', *Paediatric and perinatal epidemiology,* 17(4), pp. 369-377. Available at: https://doi.org/10.1046/j.1365-3016.2003.00524.x

Turner, L., Ball, J., Culliford, D., Kitson-Reynolds, E. and Griffiths, P. (2022a) 'Exploring the relationship between women's experience of postnatal care and reported staffing measures: an observational study', *PLoS One,* 17(e0266638). Available at: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0266638

Turner, L., Ball, J., Meredith, P., Kitson-Reynolds, E. and Griffiths, P. (2024a) 'The association between midwifery staffing and reported harmful incidents: a cross-sectional analysis of routinely collected data', *BMC Health Serv Res,* 24, pp. 1-8. Available at: https://doi.org/10.1186/s12913-024-10812-8

Turner, L., Culliford, D., Ball, J., Kitson-Reynolds, E. and Griffiths, P. (2022b) 'The association between midwifery staffing levels and the experiences of mothers on postnatal wards: cross sectional analysis of routine data', *Woman and Birth,* 35, pp. e583–e589. Available at: https://doi.org/https://doi.org/10.1016/j.wombi.2022.02.005

Turner, L., Griffiths, P. and Kitson-Reynolds, E. (2021) 'Midwifery and nurse staffing of inpatient maternity services – a systematic scoping review of associations with outcomes and quality of care', *Midwifery,* 103, pp. 103118. Available at: https://doi.org/10.1016/j.midw.2021.103118

Turner, L., Saville, C., Ball, J., Culliford, D., Dall'Ora, C., Jones, J., Kitson-Reynolds, E., Meredith, P. and Griffiths, P. (2024b) 'Inpatient midwifery staffing levels and postpartum readmissions – a retrospective multi-centre longitudinal study', *BMJ Open,* 14:e077710. Available at: https://doi.org/10.1136/bmjopen-2023-077710

Twigg, D. and Duffield, C. (2009) 'A review of workload measures: a context for a new staffing methodology in Western Australia', *Int J Nurs Stud,* 46(1), pp. 131-9. Available at: https://doi.org/10.1016/j.ijnurstu.2008.08.005

Twigg, D., Kutzer, Y., Jacob, E. and Seaman, K. (2019) 'A quantitative systematic review of the association between nurse skill mix and nursing-sensitive patient outcomes in the acute care setting', *J Adv Nurs,* 75(12), pp. 3404-3423. Available at: https://doi.org/10.1111/jan.14194

UK Data Service (2021) *Data catalogue*. Available at: https://ukdataservice.ac.uk/ (Accessed: 14th Jan 2021)

United Nations Population Fund (2021) *The State of The World's Midwifery*. Available at: https://www.unfpa.org/sites/default/files/resource-pdf/21-038-UNFPA-SoWMY2021-FastFacts-ENv4302.pdf (Accessed: 11th May 2021)

Van den Heede, K., Cornelis, J., Bouckaert, N., Bruyneel, L., Van de Voorde, C. and Sermeus, W. (2020) 'Safe nurse staffing policies for hospitals in England, Ireland, California, Victoria and Queensland: A discussion paper', *Health Policy,* 124(10), pp. 1064-1073. Available at: https://doi.org/10.1016/j.healthpol.2020.08.003

Vanderlaan, J. (2023) 'Midwifery workforce density moderates the association between independent practice and pregnancy outcomes', *J Midwifery Womens Health,* 68(5), pp. 588-595. Available at: https://doi.org/10.1111/jmwh.13500

VanVoorhis, C. and Morgan, B. (2007) 'Understanding power and rules of thumb for determining sample sizes', *Tutorials in quantitative methods for psychology,* 3(2), pp. 43-50. Available at: https://doi.org/10.20982/tqmp.03.2.p043

Vaughan, L. and Edwards, N. (2020) 'The problems of smaller, rural and remote hospitals: Separating facts from fiction', *Future Healthc J,* 7(1), pp. 38-45. Available at: https://doi.org/10.7861/fhj.2019-0066

Vest, J., Gamm, L., Oxford, B., Gonzalez, M. and Slawson, K. (2010) 'Determinants of preventable readmissions in the United States: a systematic review', *Implement Sci,* 5(1), pp. 88. Available at: https://doi.org/10.1186/1748-5908-5-88

Vincent, C., Taylor-Adams, S. and Stanhope, N. (1998) 'Framework for analysing risk and safety in clinical medicine', *BMJ,* 316(7138), pp. 1154-1157. Available at: https://doi.org/10.1136/bmj.316.7138.1154.

Vitner, D., Harris, K., Maxwell, C. and Farine, D. (2019) 'Obesity in pregnancy: a comparison of four national guidelines', *J Matern Fetal Neonatal Med,* 32(15), pp. 2580-2590. Available at: https://doi.org/10.1080/14767058.2018.1440546

Walters, S., Campbell, M. and Machin, D. (2021) *Medical statistics: a textbook for the health sciences.* John Wiley & Sons.

Warwick, C. (2014) 'Pressure Points: the case for better postnatal care', *Infant,* 10(4), pp. 108-109. Available at: https://www.infantjournal.co.uk/pdf/inf_058_stn.pdf (Accessed: 13th Oct 2020)

Watson, H. and Brown, D. (2021) 'Experiences of newly qualified midwives working in clinical practice during their transition period', *British Journal of Midwifery,* 29(9), pp. 524-530. Available at: https://doi.org/doi.org/10.12968/bjom.2021.29.9.524

Weiss, M., Yakusheva, O. and Bobay, K. (2011) 'Quality and cost analysis of nurse staffing, discharge preparation, and postdischarge utilization', *Health Serv Res,* 46(5), pp. 1473-94. Available at: https://doi.org/10.1111/j.1475-6773.2011.01267.x

Welsh Government (2021) 'Nurse Staffing Levels (Wales) Act 2016: statutory guidance (version 2)'. Available at: https://www.gov.wales/nurse-staffing-levels-wales-act-2016-statutory-guidance-version-2-html (Accessed: 19th Sept 2023)

Wen, T., Overton, E., Sheen, J., Attenello, F., Mack, W., D'Alton, M. and Friedman, A. (2021) 'Risk for postpartum readmissions and associated complications based on maternal age', *J Matern Fetal Neonatal Med,* 34(9), pp. 1375-1381. Available at: https://doi.org/10.1080/14767058.2019.1637411

Wen, T., Yu, V., Wright, J., Goffman, D., Attenello, F., Mack, W., D'Alton, M. and Friedman, A. (2020) 'Postpartum length of stay and risk for readmission among women with preeclampsia', *The Journal of Maternal-Fetal & Neonatal Medicine,* 33(7), pp. 1086-1094. Available at: https://doi.org/10.1080/14767058.2018.1514382

Wilkinson, E. (2022) 'Hospitals in England are told to stop using caesarean rates to assess performance'. Available at: https://doi.org/doi.org/10.1136/bmj.o446

Wilson, B. and Blegen, M. (2010) 'Labor and delivery nurse staffing as a cost-effective safety intervention', *The Journal of Perinatal & Neonatal Nursing,* 24(4), pp. 312-319. Available at: https://doi.org/10.1097/JPN.0b013e3181f32703

Wilson, B. and Butler, R. (2021) 'Identifying optimal labor and delivery nurse staffing: The case of cesarean births and nursing hours', *Nurs Outlook,* 69(1), pp. 84-95. Available at: https://doi.org/10.1016/j.outlook.2020.07.003

Winter, V., Dietermann, K., Schneider, U. and Schreyogg, J. (2021) 'Nurse staffing and patient-perceived quality of nursing care: a cross-sectional analysis of survey and administrative data in German hospitals', *BMJ Open,* 11(11), pp. e051133. Available at: https://doi.org/10.1136/bmjopen-2021-051133

World Health Organization (2012) *Optimizing health worker roles for maternal and newborn health* Available at: https://www.who.int/reproductivehealth/publications/maternal_perinatal_health/978924504843/en/.

World Health Organization (2018a) *Intrapartum care for a positive childbirth experience WHO recommendations*. Available at: www.who.int/publications/i/item/9789241550215 (Accessed: 11th April 2024)

World Health Organization (2018b) *WHO recommendations on intrapartum care for a positive childbirth experience.* : World Health Organization. Available at: https://www.who.int/publications/i/item/9789241550215 (Accessed 17th Jan 2024).

World Health Organization (2019) *Evaluating the quality of care for severe pregnancy complications. The WHO near-miss approach for maternal health*. Available at: https://www.who.int/reproductivehealth/topics/maternal_perinatal/nmconcept/en/ (Accessed: 18th Jan 2024).

World Health Organization (2021) *Quality of care*. Available at: https://www.who.int/health-topics/quality-of-care#tab=tab_1 (Accessed: 10th Dec 2023)

World Health Organization (2022) *WHO recommendations on maternal and newborn care for a positive postnatal experience*. Available at: https://apps.who.int/iris/bitstream/handle/10665/353586/9789240044074-eng.pdf?sequence=1 (Accessed: 15th Apr 2022).

World Health Organization (2023) *Global Health Observatory data repository*. Available at: https://www.who.int/data/gho (Accessed: 26th Mar 2023)

World Health Organization, United Nations Children's Fund and World Bank Group (2018) 'Nurturing care for early childhood development: a framework for helping children survive and thrive to transform health and human potential. Geneva: World Health Organization'. Available at: https://apps.who.int/iris/bitstream/handle/10665/272603/9789241514064-eng.pdf?ua=1 (Accessed: 22nd May 2024)

World Health Organization Europe (2009) *European Union standards for nursing and midwifery: information for accession countries* Available at: https://apps.who.int/iris/bitstream/handle/10665/107957/E92852.pdf (Accessed: 12th Aug 2023).

Wray, J. (2006) 'Postnatal care: is it based on ritual or a purpose? A reflective account', *British Journal of Midwifery,* 14(9), pp. 520-526. Available at: https://doi.org/10.12968/bjom.2006.14.9.21792

Yang, C., Kuebeler, M., Jiang, R., Knox, M., Wong, J., Mehta, P., Dorsey, L. and Petersen, L. (2024) 'Beyond hospital-level aggregated data: a methodology to adapt clinical data from the electronic health record for nursing unit-level research', *Medical Care,* 62, pp. 189-195. Available at: https://doi.org/10.1097/MLR.0000000000001972

Yao, J., Zhu, X. and Lu, H. (2016) 'Assessing the midwifery workforce demand: Utilising Birthrate Plus in China', *Midwifery,* 42, pp. 61-66. Available at: https://doi.org/10.1016/j.midw.2016.09.007

Zbiri, S., Rozenberg, P., Goffinet, F. and Milcent, C. (2018) 'Cesarean delivery rate and staffing levels of the maternity unit', *PLoS One,* 13(11), pp. e0207379. Available at: https://doi.org/10.1371/journal.pone.0207379

Zhu, J., Dy, S., Wenzel, J. and Wu, A. (2018) 'Association of Magnet status and nurse staffing with improvements in patient experience with hospital care, 2008-2015', *Med Care,* 56(2), pp. 111-120. Available at: https://doi.org/10.1097/MLR.0000000000000854

Zhu, W., Zhu, C., Min, H., Li, L., Wang, X., Wu, J., Zhu, X. and Gu, C. (2024) 'Status of the midwifery workforce and childbirth services and the impact of midwife staffing on birth outcomes in China: a multicentre cross-sectional study', *BMJ open,* 14(e082527). Available at: https://doi.org/10.1136/bmjopen-2023-082527