*Title Page (including author details and affiliations)

Midwifery and nurse staffing of inpatient maternity services – a systematic scoping review of associations with outcomes and quality of care

Corresponding Author
Lesley Turner
Senior Teaching Fellow
University of Southampton, School of Health Sciences
Highfield Campus, Southampton SO17 1BJ
lyt1g19@soton.ac.uk

Co-authors
Professor Peter Griffiths
Chair of Health Services Research,
University of Southampton, School of Health Sciences
National Institute for Health Research Applied Research Centre (Wessex)
Highfield Campus, Southampton SO17 1BJ
Peter.Griffiths@soton.ac.uk

Dr Ellen Kitson-Reynolds
Principal Teaching Fellow
University of Southampton, School of Health Sciences
Highfield Campus, Southampton SO17 1BJ
e.l.kitson-reynolds@soton.ac.uk

CRediT roles

Lesley Turner	Conceptualisation, Methodology, Investigation, Writing – original draft
Professor Peter Griffiths	Conceptualisation, Methodology, Writing – review and editing
Dr Ellen Kitson-Reynolds	Validation, Writing – review and editing

(1) Conflict of Interest – See uploaded documents from each author

Each author (corresponding author and co-author's) are required to upload their completed Conflict of Interest checklist from the ICMJE website - http://icmje.org/conflicts-of-interest/

(2) Ethical Approval – Scoping review so not applicable

(3) Funding Sources –

Peter Griffiths receives support from a Senior Investigator award made by the National Institute for Health Research and the National Institute for Health Research Applied Research Centre (Wessex).

This research was part funded by the National Institute for Health Research's Health Services & Delivery Research programme (Award ID : NIHR128056)

(4) Acknowledgements

The views expressed are those of the author(s) and not necessarily those of the National Institute for Health Research, the Department of Health and Social Care, 'arms-length' bodies or other government departments.

Highlights

Studies have mainly focused on the outcomes of labour care

There is evidence of improved patient outcomes with more midwifery staff

Impact of staffing on workforce wellbeing needs further study

No evidence of improved outcomes with more assistant staff

Limitations of current studies makes implications for staffing policy uncertain

Midwifery and nurse staffing of inpatient maternity services – a systematic scoping review of associations with outcomes and quality of care

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 were 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

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 2 patients in active labour to 1 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, 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 (UNFPA, 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 (Manktelow et al., 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?

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 1 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 outcome for mother baby, or 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.

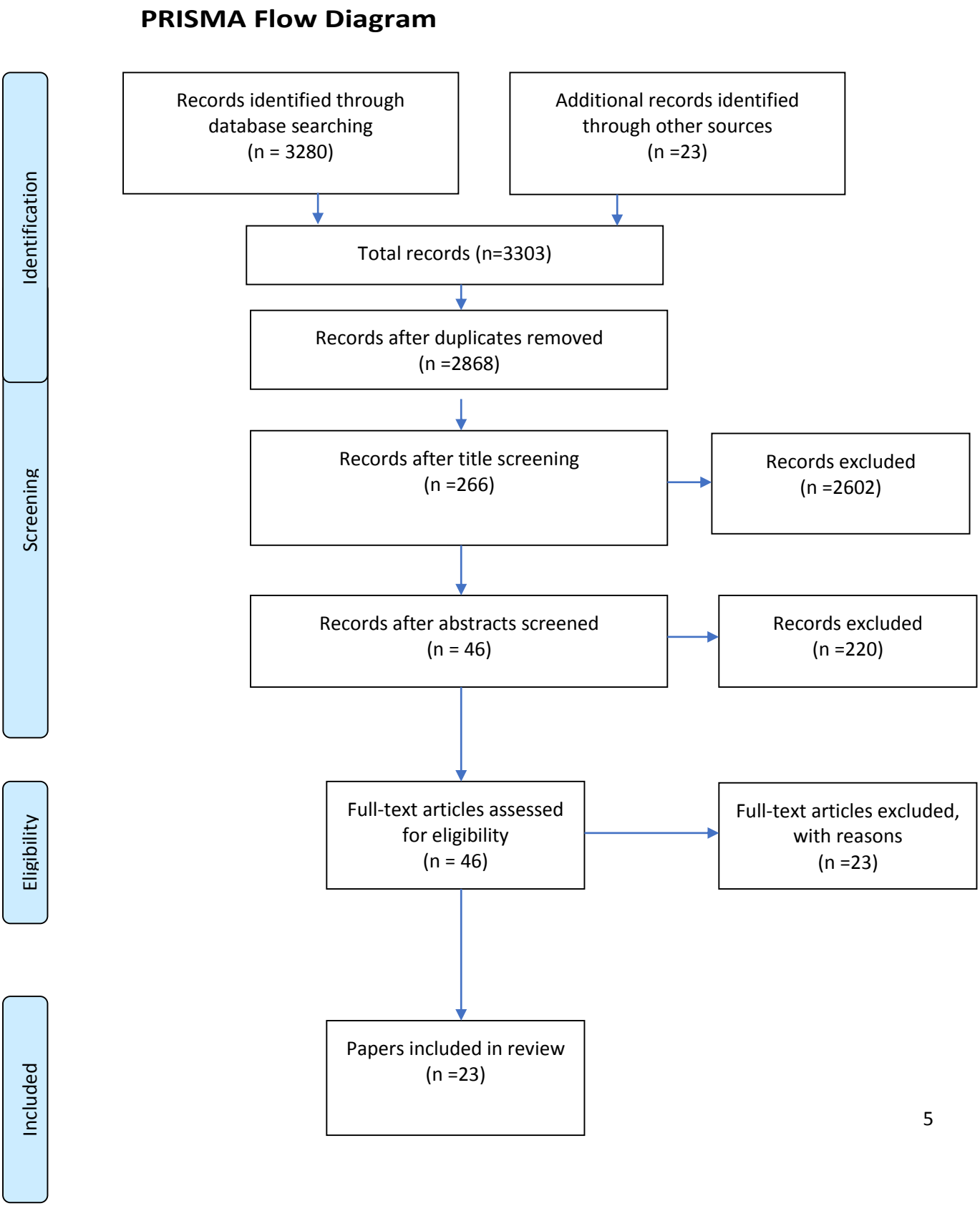
Staffing in any or all inpatient settings were considered including ante-natal, labour/delivery and post-natal care. Studies based in neonatal units and midwifery community settings were excluded.

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.

Figure 1 : Outcome of search strategy



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 in Appendix 2. Data were 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 patients all receiving one to one care in labour with usual staffing levels, although all had some limitations. Hodnett et al. (2002) excluded patients 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 patients. The study by Clark et al. (2014) was conducted in a select patient 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 (Kpéa 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 that 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 1). 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 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 1 : 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 2). 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 2 : 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 3). 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 1:1 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 1 caesarean section was achieved within 15 mins for 81/82 (99%) cases where staffing was 1:1 or better, compared to 34/40 (85%) when the ratio fell below this target.

Table 3 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 4). The results were mixed, and no patterns emerged favouring more or less staff.

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 4 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

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 three 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, 2018; 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., 2019).

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 be 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, 2016) 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 1 : 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 2 : 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 ($p<0.001$).

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).

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 r99atio. 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.

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 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).

Author and date	Design	Participants and Setting	Measurement of staffing	Outcome measures	Potential confounders measured and included in analysis	Results
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.
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

Author and date	Design	Participants and Setting	Measurement of staffing	Outcome measures	Potential confounders measured and included in analysis	Results
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).
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.

Author and date	Design	Participants and Setting	Measurement of staffing	Outcome measures	Potential confounders measured and included in analysis	Results
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.
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

Author and date	Design	Participants and Setting	Measurement of staffing	Outcome measures	Potential confounders measured and included in analysis	Results
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 were available for 30 of the 36 obstetric units. Staffing and activity logs completed twice daily by midwives during data collection for the cohort study. Not linked to individual women.	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 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.	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 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).

Author and date	Design	Participants and Setting	Measurement of staffing	Outcome measures	Potential confounders measured and included in analysis	Results
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). 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).

Author and date	Design	Participants and Setting	Measurement of staffing	Outcome measures	Potential confounders measured and included in analysis	Results
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 were 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)
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)

References

Aiken, L., Sloane, D., Bruyneel, L., et al., 2014. Nurse staffing and education and hospital mortality in nine European countries: a retrospective observational study. *Lancet, 383*(9931), 1824-1830.

Aiken, L., Sloane, D., Griffiths, P., et al., 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), 559-568.

Ashcroft, B., Elstein, M., Boreham, N., et al., 2003. Prospective semistructured observational study to identify risk attributable to staff deployment, training, and updating opportunities for midwives. *Bmj, 327*(7415), 584.

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*, 131-134.

Australian Nursing Midwifery Foundation, 2015. *Nurse/Midwife: Patient ratios-It's a matter of saving lives*. Available from https://www.anmfvic.asn.au/~/media/f06f12244fbb4522af619e1d5304d71d.

Bailey, S., Wilson, G., & 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), 787-792.

Ball, J., & Washbrook, M., 2015. Safe staffing in midwifery care: Gathering data and learning lessons with Birthrate Plus. *The Health Foundation*. https://improve.bmj.com/sites/default/files/resources/3.safe_staffing_in_midwifery_care-v3.pdf.

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 from https://www.nice.org.uk/guidance/ng4/evidence/evidence-review-2-pdf-5134718.

Bick, D. E., Sandall, J., Furuta, M., et al., 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), 1140-1146.

Bohren, M. A., Hofmeyr, G. J., Sakala, C., et al., 2017. Continuous support for women during childbirth. *Cochrane database of systematic reviews*(7), DOI: 10.1002/14651858.CD14003766.pub14651856.

Callander, E., Sidebotham, M., Lindsay, D., et al., 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), 56-60.

Cerbinskaite, A., Malone, S., McDermott, J., et al., 2011. Emergency caesarean section: influences on the decision-to-delivery interval. *Journal of pregnancy, 2011*, doi:10.1155/2011/640379.

Clapp, M. A., James, K. E., Bates, S. V., et al., 2019. Unexpected term NICU admissions: a marker of obstetrical care quality? *American journal of obstetrics and gynecology, 220*(4), 395. e391-395. e312.

Clark, S. L., Saade, G. A., Meyers, J. A., et al., 2014. The clinical and economic impact of nurse to patient staffing ratios in women receiving intrapartum oxytocin. *American journal of perinatology, 31*(2), 119-124.

Coffman, J. M., Seago, J. A., & Spetz, J., 2002. Minimum nurse-to-patient ratios in acute care hospitals in California. *Health Affairs, 21*(5), 53-64.

Cookson, G., Jones, S., van Vlymen, J., et al., 2014. The Cost-Effectiveness of Midwifery Staffing and Skill Mix on Maternity Outcomes. *A Report for the National Institute for Health and Care Excellence*. https://www.nice.org.uk/guidance/ng4/evidence/economicevaluation-%20report-5277277.

Dani, C., Papini, S., Iannuzzi, L., et al., 2020. Midwife-to-newborn ratio and neonatal outcome in healthy term infants. *Acta Paediatrica, 00*(1-4). DOI: 10.1111/apa.15180.

Dietz, H. P., & Campbell, S., 2016. Toward normal birth–but at what cost? *American journal of obstetrics and gynecology, 215*(4), 439-444.

Gagnon, A. J., Waghorn, K., & Covell, C., 1997. A randomized trial of one-to-one nurse support of women in labor. *Birth, 24*(2), 71-77.

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, Retrieved from 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

Gerova, V., Griffiths, P., Jones, S., et al., 2010. The association between midwifery staffing and outcomes in maternity units in England: observational study using routinely collected data. https://eprints.soton.ac.uk/168511/.

Griffin, R., Richardson, M., & Morris-Thompson, T., 2012. An evaluation of the impact of maternity support workers. *British Journal of Midwifery, 20*(12), 884-889.

Griffiths, P., Ball, J., Bloor, K., et al., 2018. Nurse staffing levels, missed vital signs and mortality in hospitals: retrospective longitudinal observational study. *NIHR Journals Library, 6*, ISSN 2050-4349.

Griffiths, P., Maruotti, A., Recio Saucedo, A., et al., 2019. Nurse staffing, nursing assistants and hospital mortality: retrospective longitudinal cohort study. *BMJ Qual Saf, 28*(8), 609-617.

Haftu, M., Girmay, A., Gebremeskel, M., et al., 2019. Commonly missed nursing cares in the obstetrics and gynecologic wards of Tigray general hospitals; Northern Ethiopia. *Plos One, 14*(12).

Health Education England, 2019. *Maternity Workforce Strategy – Transforming the Maternity Workforce*. Available from https://www.hee.nhs.uk/sites/default/files/document/MWS_Report_Web.pdf.

Heinen, M. M., van Achterberg, T., Schwendimann, R., et al., 2013. Nurses' intention to leave their profession: a cross sectional observational study in 10 European countries. *International journal of nursing studies, 50*(2), 174-184.

Hodnett, E. D., Gates, S., Hofmeyr, G. J., et al., 2013. Continuous support for women during childbirth. *Cochrane database of systematic reviews*(7), DOI: 10.1002/14651858.CD14003766.pub14651855.

Hodnett, E. D., Lowe, N. K., Hannah, M. E., et al., 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), 1373-1381.

Hunter, B., Fenwick, J., Sidebotham, M., et al., 2019. Midwives in the United Kingdom: Levels of burnout, depression, anxiety and stress and associated predictors. *Midwifery, 79*, 102526.

International Labour Office, 2012. International standard classification of occupations ISCO-08 https://www.ilo.org/wcmsp5/groups/public/---dgreports/---dcomm/---publ/documents/publication/wcms_172572.pdf.

Joyce, R., Webb, R., & Peacock, J., 2002. Predictors of obstetric intervention rates: case-mix, staffing levels and organisational factors of hospital of birth. *Journal of Obstetrics and Gynaecology, 22*(6), 618-625.

Joyce, R., Webb, R., & 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), F51-F56.

Karimi, F., Ebrahimipour, H., Hooshmand, E., et al., 2016. Medication Errors and its Contributing Factors among Midwives. *Journal of Midwifery and Reproductive Health, 4*(4), 748-756.

Kashanian, M., Javadi, F., & Haghighi, M. M., 2010. Effect of continuous support during labor on duration of labor and rate of cesarean delivery. *International Journal of Gynecology & Obstetrics, 109*(3), 198-200.

Kennedy, H. P., Balaam, M. C., Dahlen, H., et al., 2020. The role of midwifery and other international insights for maternity care in the United States: An analysis of four countries. *Birth, 47*(4), 332-345.

Kim, S. J., Han, K.-T., Lee, H. J., et al., 2016. Positive effects of medical staffing on readmission within 30 days after discharge: a retrospective analysis of obstetrics and gynecology data. *The European Journal of Public Health, 26*(6), 935-939.

Kirkup, B., 2015. *The report of the Morecambe Bay investigation. Morecambe Bay Investigation*. Available from https://www.gov.uk/government/publications/morecambe-bay-investigation-report.

Knape, N., Mayer, H., Schnepp, W., et al., 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*(14), 300.

Kpéa, L., Bonnet, M.-P., Le Ray, C., et al., 2015. Initial Preference for Labor Without Neuraxial Analgesia and Actual Use: Results from a National Survey in France. *Anesthesia And Analgesia, 121*(3), 759-766.

Laliotis, I., & Cooksona, G., 2018. Labour productivity and skill mix in maternity services: Evidence from the English NHS. https://www.surrey.ac.uk/sites/default/files/2018-09/dp-no-11-labour-productiviy-skill-mix-maternity-NHS.pdf.

Levac, D., Colquhoun, H., & O'Brien, K. K., 2010. Scoping studies: advancing the methodology. *Implementation science, 5*(1), 69.

Lilford, R. J., Brown, C. A., & Nicholl, J., 2007. Use of process measures to monitor the quality of clinical practice. *Bmj, 335*(7621), 648-650.

Lopes, S. C., Guerra-Arias, M., Buchan, J., et al., 2017. A rapid review of the rate of attrition from the health workforce. *Human resources for health, 15*(1), 1-9.

Makhfudli, M., Efendi, F., Kurniati, A., et al., 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, In Press.*

Manktelow, B., Smith, L., & Seaton, S., 2017. *MBRRACE-UK Perinatal Mortality Surveillance Report. UK Perinatal Deaths for Births from January to December 2014.* . Available from https://www.npeu.ox.ac.uk/downloads/files/mbrrace-uk/reports/MBRRACE-UK-PMS-Report-2014.pdf.

Mark, B. A., & Harless, D. W., 2010. Nurse staffing and post-surgical complications using the present on admission indicator. *Research in nursing & health, 33*(1), 35-47.

Martin, E., Blythe, R., Kularatna, S., et al. (2020). The role of health economics. In *Health Promotion in the 21st Century: New approaches to achieving health for all*. Oxford: Routledge.

Marzalik, P. R., Feltham, K. J., Jefferson, K., et al., 2018. Midwifery education in the US-Certified Nurse-Midwife, Certified Midwife and Certified Professional Midwife. *Midwifery, 60*, 9-12.

McDougall, L., Campbell, O., & Wendy, G., 2016. Maternal Health An Executive Summary for The Lancet's Series :Every woman, every newborn, everywhere has the right to good quality care. *The Lancet, 388*, 8.

Mercer, B. M., 2016. Delivery volume, nurse staffing and adverse perinatal outcomes. *Obstetrics and Gynecology, 127*(Supplement 1), 36S-37S.

National Institute for Health and Care Excellence, 2015. Safe midwifery staffing for maternity settings. *NICE, London*. https://www.nice.org.uk/guidance/ng4/resources/safe-midwifery-staffing-for-maternity-settings-pdf-51040125637.

Orkin, F. K., 2010. Risk stratification, risk adjustment, and other risks. *The Journal of the American Society of Anesthesiologists, 113*(5), 1001-1003.

Patrician, P. A., Loan, L., McCarthy, M., et al., 2011. The association of shift-level nurse staffing with adverse patient events. *J Nurs Adm, 41*(2), 64-70.

Prapawichar, P., Ratinthorn, A., Utriyaprasit, K., et al., 2020. Maternal and health service predictors of postpartum hemorrhage across 14 district, general and regional hospitals in Thailand. *BMC Pregnancy and Childbirth, 20*(1).

Renfrew, M. J., McFadden, A., Bastos, M. H., et al., 2014. Midwifery and quality care: findings from a new evidence-informed framework for maternal and newborn care. *The Lancet, 384*(9948), 1129-1145.

Romanzi, L. J., 2014. Natural Childbirth: A Global Perspective. *AMA Journal of Ethics, 16*(10), 835-841.

Rowe, R. E., Townend, J., Brocklehurst, P., et al., 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), e005551.

Royal College of Midwives, 2016. *RCM guidance on implementing the NICE safe staffing guideline on midwifery staffing in maternity settings*. Available from 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 from https://www.rcm.org.uk/media/2374/the-gathering-storm-england-s-midwifery-workforce-challenges.pdf.

Royal College of Obstetricians and Gynaecologists, 2007. *Safer Childbirth: Minimum standards for the organisation and delivery of care in labour*: RCOG.

Rubbo, B., Griffiths, P., Saville, C., et al., 2021. Associations between healthcare professional staffing levels and mortality in acute hospitals, a systematic review. *PROSPERO*. https://www.crd.york.ac.uk/prospero/display_record.php?RecordID=219869.

Sandall, J., Murrells, T., Dodwell, M., et al., 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).

Sharma, G., Mathai, M., Dickson, K. E., et al., 2015. Quality care during labour and birth: a multi-country analysis of health system bottlenecks and potential solutions. *BMC Pregnancy and Childbirth, 15*(2), 1-19.

Simpson, K. R., & Lyndon, A., 2017. Consequences of delayed, unfinished, or missed nursing care during labor and birth. *The Journal of perinatal & neonatal nursing, 31*(1), 32-40.

Simpson, K. R., Lyndon, A., & Ruhl, C., 2016. Consequences of inadequate staffing include missed care, potential failure to rescue, and job stress and dissatisfaction. *Journal of Obstetric, Gynecologic & Neonatal Nursing, 45*(4), 481-490.

Smith, A. H. K., Dixon, A. L., & Page, L. A., 2009. Health-care professionals' views about safety in maternity services: a qualitative study. *Midwifery, 25*(1), 21-31

Staggs, V. S., Knight, J. E., & Dunton, N., 2012. Understanding unassisted falls: effects of nurse staffing level and nursing staff characteristics. *J Nurs Care Qual, 27*(3), 194-199.

Stilwell, J., Szczepura, A., & Mugford, M., 1988. Factors affecting the outcome of maternity care. 1. Relationship between staffing and perinatal deaths at the hospital of birth. *Journal of Epidemiology & Community Health, 42*(2), 157-169.

Tucker, J., Parry, G., Penney, G., et al., 2003. Is midwife workload associated with quality of process of care (continuous electronic fetal monitoring [CEFM]) and neonatal outcome indicators? A prospective study in consultant-led labour wards in Scotland. *Paediatric and perinatal epidemiology, 17*(4), 369-377.

UNFPA, 2021. The State of The World's Midwifery. https://www.unfpa.org/sites/default/files/resource-pdf/21-038-UNFPA-SoWMY2021-FastFacts-ENv4302.pdf.

World Health Organization, 2012. *Optimizing health worker roles for maternal and newborn health* Available from https://www.who.int/reproductivehealth/publications/maternal_perinatal_health/978924504843/en/.

World Health Organization, 2017. Optimizing the contributions of the nursing and midwifery workforce to achieve universal health coverage and the Sustainable Development Goals through education, research and practice. https://www.who.int/hrh/resources/health-observer22/en/.

World Health Organization, 2018. *WHO recommendations on intrapartum care for a positive childbirth experience*: World Health Organization.

World Health Organization, 2019. *Evaluating the quality of care for severe pregnancy complications. The WHO near-miss approach for maternal health*. Available from https://www.who.int/reproductivehealth/topics/maternal_perinatal/nmconcept/en/.

Yao, J., Zhu, X., & Lu, H., 2016. Assessing the midwifery workforce demand: Utilising Birthrate Plus in China. *Midwifery, 42*, 61-66.

Zbiri, S., Rozenberg, P., Goffinet, F., et al., 2018. Cesarean delivery rate and staffing levels of the maternity unit. *PLoS ONE], 13*(11), e0207379.

Zhu, J., Dy, S. M., Wenzel, J., et al., 2018. Association of Magnet Status and Nurse Staffing With Improvements in Patient Experience With Hospital Care, 2008-2015. *Med Care, 56*(2), 111-120. https://www.ncbi.nlm.nih.gov/pubmed/29271818.

Midwifery and nurse staffing of inpatient maternity services – a systematic scoping review of associations with outcomes and quality of care

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 ~~registered~~ midwives, nurse midwives or equivalent, and assistant staff working under the supervision of ~~registered~~ 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 were 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~~support staff~~ 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 ~~care~~ assistants and other staff groups.

Keywords

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

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.
~~In order to inform workforce planning, managers need evidence based guidelines to inform their staffing decisions. One such guideline from the UK is the recommendation that women should receive dedicated care from one midwife during labour (Royal College of Obstetricians and Gynaecologists, 2007; Simpson et al., 2019).~~

Guidelines differ across ~~in other parts of~~ the world, and California was one of the first states to mandate a staffing ratio of no more than 2 patients in active labour to 1 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, 2007). Evidence underpinning such specific recommendations is sometimes ~~was~~ sparse ~~at this time,~~ although a ~~later~~ 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). ~~A large number of women still receive labour care by a core team of midwives, who also deliver care in the antenatal and postnatal wards of the hospital. This is despite mounting evidence to support the roll out of continuity of carer which offers benefits in terms of reduced rates of stillbirth, premature births and medical interventions.~~

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 (UNFPA, 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 ~~reported in the UK from 2015-2017~~ (Manktelow et al., 2017).

~~Poor staffing has been implicated in a number of error reviews and reports of near-misses in maternity care (Ashcroft et al., 2003; Karimi et al., 2016). The cost of litigation in maternity care is soaring, and the human cost of poor outcomes is immeasurable. Complexity in maternity cases is increasing(McDougall et al., 2016), so here is likely to be sustained demand for complex inpatient maternity care, requiring the expertise of core staff in these areas. (Sharma et al., 2015)~~

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 ~~significant~~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. ~~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.~~

A further driver for interest in this area is the training and development of~~-~~ assistant staff~~maternity support workers~~. 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).~~, although t~~They~~re~~ is~~ expressed concern about the quality of the underpinning data on effectiveness, due to the use of aggregate ~~data to~~ 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 ~~registered~~ 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~~registered staff~~ to assistants~~support workers~~ varies?

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 1 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 outcome for mother baby, or 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 ~~registered~~ midwives, nurse midwives or equivalent, and assistant staff working under the supervision of ~~registered~~ professionals. Studies reporting a quantitative measure of subjective staffing adequacy were included but purely qualitative studies were excluded.

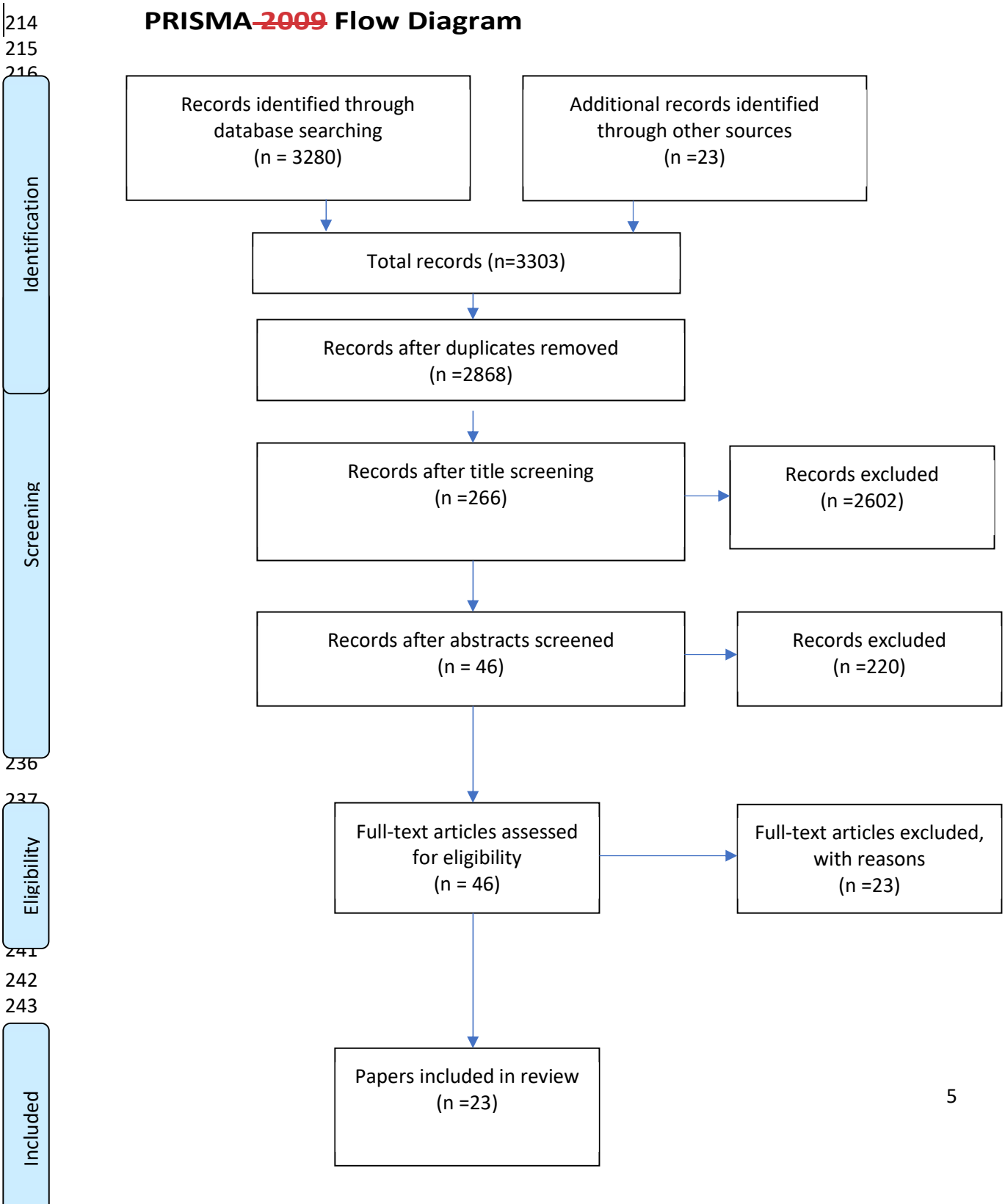
Staffing in any or all inpatient settings were considered including ante-natal, labour/delivery and post-natal care. Studies ~~which were~~ based in neonatal units and midwifery community settings were excluded.

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.

Figure 1 : Outcome of search strategy



Results

Summary of included studies

The online searches yielded a total of 3280 records. The PRISMA flow diagram is shown in Figure 1 ~~below~~. Twenty one separate studies ~~were identified which were~~ published from 1988 -2020 were identified. These studies are tabulated in detail in Appendix 2. Data were 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 ~~health care~~ assistant~~/support worker~~ 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 patients all receiving one to one care in labour with usual staffing levels, although all had some limitations. Hodnett et al. (2002) excluded patients 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 patients. The study by Clark et al. (2014) was conducted in a select patient 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 (Kpéa 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 that 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 1). 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 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 1 : 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 2). 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 2 : 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 3). 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 1:1 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 1 caesarean section was achieved within 15 mins for 81/82 (99%) cases where staffing was 1:1 or better, compared to 34/40 (85%) when the ratio fell below this target.

Table 3 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 4). The results were mixed, and no patterns emerged favouring more or less staff.

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 4 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

Effect of midwifery assistant~~support worker~~ staffing

Three studies (Gerova 2014, Sandall 2014, Kim 2016) reported on the addition of assistants ~~health care support workers~~ and relationship with outcomes. Gerova (2014) found that increases in ~~health care~~ 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) ~~found~~ concluded that assistant staffing levels were not statistically related to any of the three healthy mother and healthy baby indicators in the adjusted analysis. ~~no significant differences in improved outcomes for increasing support worker staff in all of their measured outcomes 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~~are~~ reduced when the number of assistants ~~support workers~~ increased, irrespective of parity (ORs range from 0.87 to 0.93). ~~Support worker~~Assistant staffing levels ~~a~~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~~support worker~~ 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 ~~o~~Oxytocin induction or augmentation ~~within the USA~~. 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~~1~~ 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, 2018; 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 ~~patient demographics,~~age, parity and clinical risk~~, or other therapeutic interventions~~ 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~~mothers~~. 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). ~~In the UK, g~~Guidance states that a systematic process ~~is~~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~~registered~~ 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 ~~support~~assistant staff to patient outcomes. Outcomes were not improved by the addition of assistants~~support workers~~, 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., 2019).

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 survey by found that in the UK~~, ~~healthcare providers were employing a variety of personnel to support midwifery services, including theatre nurses, obstetric nurses, nursery nurses, maternity care assistants and breastfeeding supporters.~~ The contribution of each of the~~se~~ staff groups towards outcomes is unclear. ~~These~~Some task shifting initiatives ~~are~~~~may~~ be driven by necessity due to shortages of professional staff (World Health Organization, 2012) ~~rather than optimal workforce planning~~.

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, 2016) 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. ~~Support worker~~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 1 : 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 2 : 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 ($p<0.001$).

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).

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 r99atio. 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.

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 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).

Author and date	Design	Participants and Setting	Measurement of staffing	Outcome measures	Potential confounders measured and included in analysis	Results
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.
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

Author and date	Design	Participants and Setting	Measurement of staffing	Outcome measures	Potential confounders measured and included in analysis	Results
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).
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.

Author and date	Design	Participants and Setting	Measurement of staffing	Outcome measures	Potential confounders measured and included in analysis	Results
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.
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

Author and date	Design	Participants and Setting	Measurement of staffing	Outcome measures	Potential confounders measured and included in analysis	Results
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 were available for 30 of the 36 obstetric units. Staffing and activity logs completed twice daily by midwives during data collection for the cohort study. Not linked to individual women.	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 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.	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 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).

Author and date	Design	Participants and Setting	Measurement of staffing	Outcome measures	Potential confounders measured and included in analysis	Results
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). 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).

Author and date	Design	Participants and Setting	Measurement of staffing	Outcome measures	Potential confounders measured and included in analysis	Results
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 were 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)
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)

References

Aiken, L., Sloane, D., Bruyneel, L., et al., 2014. Nurse staffing and education and hospital mortality in nine European countries: a retrospective observational study. *Lancet, 383*(9931), 1824-1830.

Aiken, L., Sloane, D., Griffiths, P., et al., 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), 559-568.

Ashcroft, B., Elstein, M., Boreham, N., et al., 2003. Prospective semistructured observational study to identify risk attributable to staff deployment, training, and updating opportunities for midwives. *Bmj, 327*(7415), 584.

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*, 131-134.

Australian Nursing Midwifery Foundation, 2015. *Nurse/Midwife: Patient ratios-It's a matter of saving lives*. Available from https://www.anmfvic.asn.au/~/media/f06f12244fbb4522af619e1d5304d71d.

Bailey, S., Wilson, G., & 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), 787-792.

Ball, J., & Washbrook, M., 2015. Safe staffing in midwifery care: Gathering data and learning lessons with Birthrate Plus. *The Health Foundation*. https://improve.bmj.com/sites/default/files/resources/3.safe_staffing_in_midwifery_care-v3.pdf.

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 from https://www.nice.org.uk/guidance/ng4/evidence/evidence-review-2-pdf-5134718.

Bick, D. E., Sandall, J., Furuta, M., et al., 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), 1140-1146.

Bohren, M. A., Hofmeyr, G. J., Sakala, C., et al., 2017. Continuous support for women during childbirth. *Cochrane database of systematic reviews*(7), DOI: 10.1002/14651858.CD14003766.pub14651856.

Callander, E., Sidebotham, M., Lindsay, D., et al., 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), 56-60.

Cerbinskaite, A., Malone, S., McDermott, J., et al., 2011. Emergency caesarean section: influences on the decision-to-delivery interval. *Journal of pregnancy, 2011*, doi:10.1155/2011/640379.

Clapp, M. A., James, K. E., Bates, S. V., et al., 2019. Unexpected term NICU admissions: a marker of obstetrical care quality? *American journal of obstetrics and gynecology, 220*(4), 395. e391-395. e312.

Clark, S. L., Saade, G. A., Meyers, J. A., et al., 2014. The clinical and economic impact of nurse to patient staffing ratios in women receiving intrapartum oxytocin. *American journal of perinatology, 31*(2), 119-124.

Coffman, J. M., Seago, J. A., & Spetz, J., 2002. Minimum nurse-to-patient ratios in acute care hospitals in California. *Health Affairs, 21*(5), 53-64.

Cookson, G., Jones, S., van Vlymen, J., et al., 2014. The Cost-Effectiveness of Midwifery Staffing and Skill Mix on Maternity Outcomes. *A Report for the National Institute for Health and Care Excellence*. https://www.nice.org.uk/guidance/ng4/evidence/economicevaluation-%20report-5277277.

Dani, C., Papini, S., Iannuzzi, L., et al., 2020. Midwife-to-newborn ratio and neonatal outcome in healthy term infants. *Acta Paediatrica, 00*(1-4). DOI: 10.1111/apa.15180.

Dietz, H. P., & Campbell, S., 2016. Toward normal birth–but at what cost? *American journal of obstetrics and gynecology, 215*(4), 439-444.

Gagnon, A. J., Waghorn, K., & Covell, C., 1997. A randomized trial of one-to-one nurse support of women in labor. *Birth, 24*(2), 71-77.

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, Retrieved from 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

Gerova, V., Griffiths, P., Jones, S., et al., 2010. The association between midwifery staffing and outcomes in maternity units in England: observational study using routinely collected data. https://eprints.soton.ac.uk/168511/.

Griffin, R., Richardson, M., & Morris-Thompson, T., 2012. An evaluation of the impact of maternity support workers. *British Journal of Midwifery, 20*(12), 884-889.

Griffiths, P., Ball, J., Bloor, K., et al., 2018. Nurse staffing levels, missed vital signs and mortality in hospitals: retrospective longitudinal observational study. *NIHR Journals Library, 6*, ISSN 2050-4349.

Griffiths, P., Maruotti, A., Recio Saucedo, A., et al., 2019. Nurse staffing, nursing assistants and hospital mortality: retrospective longitudinal cohort study. *BMJ Qual Saf, 28*(8), 609-617.

Haftu, M., Girmay, A., Gebremeskel, M., et al., 2019. Commonly missed nursing cares in the obstetrics and gynecologic wards of Tigray general hospitals; Northern Ethiopia. *Plos One, 14*(12).

Health Education England, 2019. *Maternity Workforce Strategy – Transforming the Maternity Workforce*. Available from https://www.hee.nhs.uk/sites/default/files/document/MWS_Report_Web.pdf.

Heinen, M. M., van Achterberg, T., Schwendimann, R., et al., 2013. Nurses' intention to leave their profession: a cross sectional observational study in 10 European countries. *International journal of nursing studies, 50*(2), 174-184.

Hodnett, E. D., Gates, S., Hofmeyr, G. J., et al., 2013. Continuous support for women during childbirth. *Cochrane database of systematic reviews*(7), DOI: 10.1002/14651858.CD14003766.pub14651855.

Hodnett, E. D., Lowe, N. K., Hannah, M. E., et al., 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), 1373-1381.

Hunter, B., Fenwick, J., Sidebotham, M., et al., 2019. Midwives in the United Kingdom: Levels of burnout, depression, anxiety and stress and associated predictors. *Midwifery, 79*, 102526.

International Labour Office, 2012. International standard classification of occupations ISCO-08 https://www.ilo.org/wcmsp5/groups/public/---dgreports/---dcomm/---publ/documents/publication/wcms_172572.pdf.

Joyce, R., Webb, R., & Peacock, J., 2002. Predictors of obstetric intervention rates: case-mix, staffing levels and organisational factors of hospital of birth. *Journal of Obstetrics and Gynaecology, 22*(6), 618-625.

Joyce, R., Webb, R., & 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), F51-F56.

Karimi, F., Ebrahimipour, H., Hooshmand, E., et al., 2016. Medication Errors and its Contributing Factors among Midwives. *Journal of Midwifery and Reproductive Health, 4*(4), 748-756.

Kashanian, M., Javadi, F., & Haghighi, M. M., 2010. Effect of continuous support during labor on duration of labor and rate of cesarean delivery. *International Journal of Gynecology & Obstetrics, 109*(3), 198-200.

Kennedy, H. P., Balaam, M. C., Dahlen, H., et al., 2020. The role of midwifery and other international insights for maternity care in the United States: An analysis of four countries. *Birth, 47*(4), 332-345.

Kim, S. J., Han, K.-T., Lee, H. J., et al., 2016. Positive effects of medical staffing on readmission within 30 days after discharge: a retrospective analysis of obstetrics and gynecology data. *The European Journal of Public Health, 26*(6), 935-939.

Kirkup, B., 2015. *The report of the Morecambe Bay investigation. Morecambe Bay Investigation*. Available from https://www.gov.uk/government/publications/morecambe-bay-investigation-report.

Knape, N., Mayer, H., Schnepp, W., et al., 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*(14), 300.

Kpéa, L., Bonnet, M.-P., Le Ray, C., et al., 2015. Initial Preference for Labor Without Neuraxial Analgesia and Actual Use: Results from a National Survey in France. *Anesthesia And Analgesia, 121*(3), 759-766. http://search.ebscohost.com/login.aspx?direct=true&db=cmedm&AN=26086620&site=ehost-live.

Laliotis, I., & Cooksona, G., 2018. Labour productivity and skill mix in maternity services: Evidence from the English NHS. https://www.surrey.ac.uk/sites/default/files/2018-09/dp-no-11-labour-productiviy-skill-mix-maternity-NHS.pdf.

Levac, D., Colquhoun, H., & O'Brien, K. K., 2010. Scoping studies: advancing the methodology. *Implementation science, 5*(1), 69.

Lilford, R. J., Brown, C. A., & Nicholl, J., 2007. Use of process measures to monitor the quality of clinical practice. *Bmj, 335*(7621), 648-650.

Lopes, S. C., Guerra-Arias, M., Buchan, J., et al., 2017. A rapid review of the rate of attrition from the health workforce. *Human resources for health, 15*(1), 1-9.

Makhfudli, M., Efendi, F., Kurniati, A., et al., 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, In Press.*

Manktelow, B., Smith, L., & Seaton, S., 2017. *MBRRACE-UK Perinatal Mortality Surveillance Report. UK Perinatal Deaths for Births from January to December 2014.* . Available from https://www.npeu.ox.ac.uk/downloads/files/mbrrace-uk/reports/MBRRACE-UK-PMS-Report-2014.pdf.

Mark, B. A., & Harless, D. W., 2010. Nurse staffing and post-surgical complications using the present on admission indicator. *Research in nursing & health, 33*(1), 35-47.

Martin, E., Blythe, R., Kularatna, S., et al. (2020). The role of health economics. In *Health Promotion in the 21st Century: New approaches to achieving health for all*. Oxford: Routledge.

Marzalik, P. R., Feltham, K. J., Jefferson, K., et al., 2018. Midwifery education in the US-Certified Nurse-Midwife, Certified Midwife and Certified Professional Midwife. *Midwifery, 60*, 9-12.

McDougall, L., Campbell, O., & Wendy, G., 2016. Maternal Health An Executive Summary for The Lancet's Series :Every woman, every newborn, everywhere has the right to good quality care. *The Lancet, 388*, 8.

Mercer, B. M., 2016. Delivery volume, nurse staffing and adverse perinatal outcomes. *Obstetrics and Gynecology, 127*(Supplement 1), 36S-37S.

National Institute for Health and Care Excellence, 2015. Safe midwifery staffing for maternity settings. *NICE, London*. https://www.nice.org.uk/guidance/ng4/resources/safe-midwifery-staffing-for-maternity-settings-pdf-51040125637.

Orkin, F. K., 2010. Risk stratification, risk adjustment, and other risks. *The Journal of the American Society of Anesthesiologists, 113*(5), 1001-1003.

Patrician, P. A., Loan, L., McCarthy, M., et al., 2011. The association of shift-level nurse staffing with adverse patient events. *J Nurs Adm, 41*(2), 64-70.

Prapawichar, P., Ratinthorn, A., Utriyaprasit, K., et al., 2020. Maternal and health service predictors of postpartum hemorrhage across 14 district, general and regional hospitals in Thailand. *BMC Pregnancy and Childbirth, 20*(1).

Renfrew, M. J., McFadden, A., Bastos, M. H., et al., 2014. Midwifery and quality care: findings from a new evidence-informed framework for maternal and newborn care. *The Lancet, 384*(9948), 1129-1145.

Romanzi, L. J., 2014. Natural Childbirth: A Global Perspective. *AMA Journal of Ethics, 16*(10), 835-841.

Rowe, R. E., Townend, J., Brocklehurst, P., et al., 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), e005551.

Royal College of Midwives, 2016. *RCM guidance on implementing the NICE safe staffing guideline on midwifery staffing in maternity settings*. Available from 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 from https://www.rcm.org.uk/media/2374/the-gathering-storm-england-s-midwifery-workforce-challenges.pdf.

Royal College of Obstetricians and Gynaecologists, 2007. *Safer Childbirth: Minimum standards for the organisation and delivery of care in labour*: RCOG.

Rubbo, B., Griffiths, P., Saville, C., et al., 2021. Associations between healthcare professional staffing levels and mortality in acute hospitals, a systematic review. *PROSPERO*. https://www.crd.york.ac.uk/prospero/display_record.php?RecordID=219869.

Sandall, J., Murrells, T., Dodwell, M., et al., 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).

Sharma, G., Mathai, M., Dickson, K. E., et al., 2015. Quality care during labour and birth: a multi-country analysis of health system bottlenecks and potential solutions. *BMC Pregnancy and Childbirth, 15*(2), 1-19.

Simpson, K. R., & Lyndon, A., 2017. Consequences of delayed, unfinished, or missed nursing care during labor and birth. *The Journal of perinatal & neonatal nursing, 31*(1), 32-40.

Simpson, K. R., Lyndon, A., & Ruhl, C., 2016. Consequences of inadequate staffing include missed care, potential failure to rescue, and job stress and dissatisfaction. *Journal of Obstetric, Gynecologic & Neonatal Nursing, 45*(4), 481-490.

Simpson, K. R., Lyndon, A., Spetz, J., et al., 2019. Adherence to the AWHONN Staffing Guidelines as Perceived by Labor Nurses. *Nursing for women's health, 23*(3), 217-223.

Smith, A. H. K., Dixon, A. L., & Page, L. A., 2009. Health-care professionals' views about safety in maternity services: a qualitative study. *Midwifery, 25*(1), 21-31

Staggs, V. S., Knight, J. E., & Dunton, N., 2012. Understanding unassisted falls: effects of nurse staffing level and nursing staff characteristics. *J Nurs Care Qual, 27*(3), 194-199.

Stilwell, J., Szczepura, A., & Mugford, M., 1988. Factors affecting the outcome of maternity care. 1. Relationship between staffing and perinatal deaths at the hospital of birth. *Journal of Epidemiology & Community Health, 42*(2), 157-169.

Tucker, J., Parry, G., Penney, G., et al., 2003. Is midwife workload associated with quality of process of care (continuous electronic fetal monitoring [CEFM]) and neonatal outcome indicators? A prospective study in consultant-led labour wards in Scotland. *Paediatric and perinatal epidemiology, 17*(4), 369-377.

UNFPA, 2021. The State of The World's Midwifery. https://www.unfpa.org/sites/default/files/resource-pdf/21-038-UNFPA-SoWMY2021-FastFacts-ENv4302.pdf.

World Health Organization, 2012. *Optimizing health worker roles for maternal and newborn health* Available from https://www.who.int/reproductivehealth/publications/maternal_perinatal_health/978924504843/en/.

World Health Organization, 2017. Optimizing the contributions of the nursing and midwifery workforce to achieve universal health coverage and the Sustainable Development Goals through education, research and practice. https://www.who.int/hrh/resources/health-observer22/en/.

World Health Organization, 2018. *WHO recommendations on intrapartum care for a positive childbirth experience*: World Health Organization.

World Health Organization, 2019. *Evaluating the quality of care for severe pregnancy complications. The WHO near-miss approach for maternal health*. Available from https://www.who.int/reproductivehealth/topics/maternal_perinatal/nmconcept/en/.

Yao, J., Zhu, X., & Lu, H., 2016. Assessing the midwifery workforce demand: Utilising Birthrate Plus in China. *Midwifery, 42*, 61-66. http://search.ebscohost.com/login.aspx?direct=true&db=cmedm&AN=27764683&site=ehost-live.

Zbiri, S., Rozenberg, P., Goffinet, F., et al., 2018. Cesarean delivery rate and staffing levels of the maternity unit. *PLoS ONE [Electronic Resource], 13*(11), e0207379.

Zhu, J., Dy, S. M., Wenzel, J., et al., 2018. Association of Magnet Status and Nurse Staffing With Improvements in Patient Experience With Hospital Care, 2008-2015. *Med Care, 56*(2), 111-120. https://www.ncbi.nlm.nih.gov/pubmed/29271818.