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Review Article

Maternal and perinatal outcomes by planned place of birth among women with low-risk pregnancies in high-income countries: A systematic review and meta-analysis

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ABSTRACT

Background: The comparative safety of different birth settings is widely debated. Comparing research across high-income countries is complex, given differences in maternity service provision, data discrepancies, and varying research techniques and quality. Studies of births planned at home or in birth centres have reported both better and poorer outcomes than planned hospital births. Previous systematic reviews have focused on outcomes from either birth centres or home births, with inconsistent attention to quality appraisal. Few have attempted to synthesise findings.

Objective: To compare maternal and perinatal outcomes from different places of birth via a systematic review of high-quality research, and meta-analysis of appropriate data (Prospero registration CRD42016042291).

Design: Reviewers searched CINAHL, Embase, Maternity and Infant Care, Medline and PsycINFO databases to identify studies comparing selected outcomes by place of birth among women with low-risk pregnancies in high-income countries. They critically appraised identified studies using an instrument specific to birth place research and then combined outcome data via meta-analysis, using RevMan software.

Findings: Twenty-eight articles met inclusion criteria, yielding comparative data on perinatal mortality, mode of birth, maternal morbidity and/or NICU admissions. Meta-analysis indicated that women planning hospital births had statistically significantly lower odds of normal vaginal birth than in other planned settings. Women experienced severe perineal trauma or haemorrhage at a lower rate in planned home births than in obstetric units. There were no statistically significant differences in infant mortality by planned place of birth, although

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most studies had limited statistical power to detect differences for rare outcomes. Differences in location, context, quality and design of identified studies render results subject to variation.

Conclusions and implications for practice: High-quality evidence about low-risk pregnancies indicates that place of birth had no statistically significant impact on infant mortality. The lower odds of maternal morbidity and obstetric intervention support the expansion of birth centre and home birth options for women with low-risk pregnancies.

Introduction

The universal importance of maternal and newborn well-being is unquestioned. However, the impact of place of birth on safety and well-being is widely debated globally. Debate is fuelled by divergent conclusions from research on planned place of birth (de Vries et al., 2013) and is further complicated by national and regional variation in provision of maternity care across birth places.

Women are increasingly seeking greater choice in birth place, including options other than hospitals that offer fewer interventions and greater autonomy (Vedam et al., 2017b). Yet, researchers vary in their conclusions about outcomes from different places of birth. Consequently, there is keen interest in reliable research evidence comparing maternal and perinatal outcomes by place of birth, especially amongst clinicians, policy-makers, and childbearing women and their families. There is particular attention devoted to home as a safe place of birth. Study findings must take account not only of whether the mother and infant *survive* but also how well mother and infant *thrive* in different birthplaces. Diverse study designs and methods, and contradictory research findings create difficulty in synthesising outcomes to inform clinical decisions. Accordingly, government policy and professional guidelines in different countries vary in their support for birth centres and home births. Variation reflects differing beliefs about autonomy, safety, risk and childbirth, together with differing interpretations of the body of existing research (Roome and Welsh 2015).

Variation in birth setting

In many high-income countries, most women give birth in hospital. Access to alternative birth places varies within and between countries, although usually limited. In the Netherlands approximately 20% of births take place at home; elsewhere the proportion of planned home births in high-income countries ranges between 0.3% in Australia (Hilder et al., 2014) and 3.3% in New Zealand (Shaw et al., 2016). Similarly, the rate of births in midwife-led birth centres (a term encompassing various models) varies from approximately 0.5% in the United States (MacDorman and Declercq 2016) to over 10% in New Zealand and the Netherlands (Shaw et al., 2016) and 11% in England (National Audit Office 2013). Variation in birthplace options is affected by the status, scope and role of the midwife in different jurisdictions, licensing and insurance issues, the extent of integration between maternity care options, funding issues and other sociocultural factors (Benoit et al., 2005; De Vries et al., 2002; Vedam et al., 2018).

The debate on safety

Several recent studies in high-income regions compared outcomes from births planned in hospitals and at home. They found no significant difference in risk of adverse perinatal outcomes for planned home births among women with low-risk pregnancies (de Jonge et al., 2015; de Jonge et al., 2009; Hutton et al., 2016; Janssen et al., 2009) and among low-risk parous women (Birthplace in England Collaborative, 2011; Homer et al., 2014). Similarly, studies found no significant differences in adverse outcomes between births planned in labour wards and in birth centres (Birthplace in England Collaborative, 2011; Gottvall et al., 2005; Homer et al., 2014; Laws et al., 2010). Further, many studies identified lower rates of intervention and/or maternal morbidity in births planned in birth centres and at home, compared with hospital births.

However, other investigators reported higher rates of adverse perinatal outcomes in planned home births than in planned hospital births (Grunebaum et al., 2014; Pang et al., 2002; Snowden et al., 2015; Wax et al., 2010). Some of these findings were reported in countries where skilled birth attendants are not universally integrated across birth settings into regional health systems (e.g. Chang and MacOnes 2011; Kennare et al., 2010; Snowden et al., 2015). Other results were from population-based studies that combined pregnancies with different levels of risk or used unreliable data sources for the reported outcome (e.g. Cheng et al., 2013; Evers et al., 2010; Grunebaum et al., 2013; Kennare et al., 2010; Pang et al., 2002; Wax et al., 2010). Others combined data from births with skilled and unskilled birth attendants (e.g. Chang and MacOnes 2011; Malloy 2010). A large English study reported a small but statistically significant increase in adverse results on a composite primary perinatal outcome (including both mortality and morbidity) among nulliparous women planning home births compared with those planning a hospital birth (Birthplace in England Collaborative Group 2011).

Variation in the design and quality of research on place of birth inhibits the development of universally acceptable recommendations for provision of services across settings (Gyte et al., 2009; Michal et al., 2011; Nove et al., 2012b; Vedam, 2003; Vedam et al., 2013).

Methodological challenges in research about place of birth

Researchers have delineated and discussed the unique features of studies into place of birth (Declercq, 2013; Leslie and Romano, 2007; Nove et al., 2012b; Olsen and Clausen, 2012; Vedam, 2003; Zielinski et al., 2015). These features include appropriately identifying intended (as distinct from actual) birth place, ensuring equivalence of risk status, controlling for confounding and mediating factors, dealing with adverse events that would have occurred regardless of setting (especially related to congenital abnormalities), and accounting for different providers in countries with different models of maternity provision.

When comparing outcomes across places of birth, consistent, standardised inclusion criteria across cohorts, reliable sampling methods, and relevant outcome measures are all imperative. For example, some research on place of birth is compromised by amalgamating data from unplanned home births (without skilled birth attendants) and from planned births at home within integrated maternity systems (Gyte et al., 2010; Kirby and Frost, 2011; Michal et al., 2011). All these factors, as well as the limits to randomisation, complicate appraisals of research quality and risk of bias (Nove et al., 2012b; Vedam et al., 2017a).

Further, adequate sample sizes are essential to allow for comparisons between settings, especially when exploring rare outcomes such as mortality and severe morbidity. Relatively small numbers of women choose to give birth in birth centres or at home in most high-income countries. Typically, datasets with sufficient power can only be generated by large population-based studies conducted over several years, notwithstanding the limitations of using registry-based data (de Jonge et al., 2017), or through meta-analysis, where possible. Some studies have utilised a 'composite outcome' to group data on uncommon adverse outcomes to improve statistical power (Birthplace in England Collaborative Group et al., 2011). Finally, the diverse context of maternity provision in different countries generates inconsistencies in data availability, inclusion criteria and key definitions, further complicating research in this field.

Table 1
Inclusion and exclusion criteria for articles in systematic review.

Inclusion criteria	Exclusion examples
Participants	
Healthy women with low-risk pregnancies, assessed by the researchers using clear consistent criteria.	• Non-human participants. • Women with known antenatal risk factors e.g. twins, non-vertex presentation, previous caesarean section, pre-term labour, elective caesarean section, gestational diabetes, hypertension. • Risk self-rated by study participants. • Risk factors not comparable in all study cohorts.
Women giving birth in a high-income country.	• Women in low- or medium-income countries. • Women in two or more high-income countries, where outcomes may be affected by variation. between jurisdictions rather than place of birth.
Intervention	
Intended place of birth, determined at or close to the onset of labour.	• Model of care or provider type rather than birth place. • Actual place of birth, regardless of intention. • Intended birth place determined at booking, not close to onset of labour. • Cohorts including births without skilled attendants. • Cohorts including unplanned home births. • Studies where intended place of birth is a comparator rather than the independent variable. • Comparison of specific antenatal, intrapartum or postnatal interventions or management approaches.
Comparison	
Comparison of two or more intended birth settings – home birth, birth in hospital obstetric unit or birth centre (including, where relevant, free-standing and alongside midwifery units).	• Studies of outcomes in one birth setting i.e. just home births or birth centres, without comparison cohort.
	• Studies of modified rooms within hospital obstetric unit. • (Meta-analysis excluded studies comparing birth centres with home births as the meta-analysis uses hospital births as referent.)
Outcomes	
Maternal or neonatal outcomes related to labour and birth, specifically: • Perinatal mortality – intraparum stillbirth and early neonatal mortality (0–7 days postpartum). • Admission to NICU. • Mode of birth – normal vaginal birth, instrumental birth, caesarean section. • Perineal status – intact perineum, 3rd/4th degree perineal trauma. • Postpartum haemorrhage ≥1000 mL. Many studies also investigated other outcomes not addressed here, as indicated in Table S1.	• Articles presenting study protocols rather than outcomes. • Studies with place of birth as outcome. • Articles which do not include data on at least one of these outcomes. • Psycho-social outcomes only. • Cost-related or other economic outcomes. • Studies which only report satisfaction or other qualitative results.
Study design	
Original research comparing outcomes from two or more birth place cohorts, prospectively or retrospectively determined.	• Studies which don't compare outcomes from two or more places of birth. • Opinion pieces, reports, case-studies, commentaries etc. • Systematic reviews and/or meta-analyses (individual studies may be included). • Studies not reported in peer-reviewed journals published between 2000 and 2016.

Synthesising research findings

There have been few Cochrane reviews of place of birth outcomes. Olsen and Clausen attempted a systematic review comparing planned home versus hospital birth (2012) and were able to identify only one small study ($n = 11$) that met inclusion criteria. Noting difficulties with recruiting women who will consent to randomisation, their discussion highlighted the importance of well-designed population-based observational studies. Another Cochrane review (Hodnett et al., 2012) incorporated 10 trials comparing 'alternative settings for birth' with conventional hospital labour wards, of which five examined alongside midwifery units. This review found no impact on adverse outcomes for mothers or infants across included settings, but women allocated to alternative settings had higher rates of spontaneous vaginal births and breastfeeding at six to eight weeks, and lower rates of obstetric intervention than women giving birth in hospital units (Hodnett et al., 2012).

Other research syntheses about outcomes by place of birth have involved largely narrative analysis. Some compared data from hospital births with home births (Elder et al., 2016; Fullerton et al., 2007; Leslie and Romano, 2007; McIntyre, 2012; Stotland and Declercq, 2002; Zielinski et al., 2015); others compared births in hospitals with birth centres (Alliman and Phillippi, 2016; Dixon et al., 2012; McIntyre, 2012; Muthu and Fischbacher, 2004; Stewart et al., 2005; Stotland and Declercq, 2002; Walsh and Downe, 2004).

The varying quality of research has been a recurring theme in reviews (Campbell and MacFarlane, 1986; Elder et al., 2016; McIntyre, 2012; Olsen, 1997; Vedam et al., 2013). Some authors have specifically concluded that the limited quality or comparability of studies precludes undertaking meta-analysis (Blix et al., 2014; Stewart et al., 2005; Walsh and Downe, 2004). Some systematic reviews indicate methods used to assess potential bias in selected studies (Alliman and Phillippi, 2016; Blix et al., 2014; Stewart et al., 2005; Walsh and Downe, 2004), although other reviews do not indicate how quality was determined. One systematic review and meta-analysis comparing planned home births and hospital births (Wax et al., 2010) reported that study quality was evaluated using a published instrument (Zaza et al., 2000) but did not report on the quality assessment of included studies. This meta-analysis has been widely criticised for methodological flaws (Gyte et al., 2010; Kirby and Frost, 2011; Michal et al., 2011).

We did not identify any systematic review or meta-analysis that examined outcomes from studies across three places of birth (home, birth centre, hospital), using a validated rating tool to appraise the quality of included studies.

Objectives

This systematic review addressed the question: are perinatal and maternal outcomes significantly different from births planned at home, in birth centres or hospitals, for women with low-risk pregnancies? We

reviewed original research from high-income countries (World Bank, 2016) using a birthplace-specific quality appraisal instrument (Vedam et al., 2017a), and undertook meta-analysis of outcome data where possible.

Methods

The review examined the effect of *birth place* as distinct from model of maternity care, although often closely linked. The definition of place of birth varied between studies, depending on data availability, regional differences in provision and study design. We registered our protocol with Prospero international register of systematic reviews (http://www.crd.york.ac.uk/PROSPERO/) in July 2016 (CRD42016042291). This paper follows the PRISMA guidelines for reporting systematic reviews and meta-analyses (Moher et al., 2010).

Eligibility criteria

The systematic review included articles:

- published in peer-reviewed journals between 2000 and 2016;
- comparing outcomes from two or more places of birth;
- written in English.

We included articles which provided evidence on one or more of nine outcomes addressing important dimensions of perinatal mortality and morbidity, mode of birth and maternal morbidity (regardless of other outcomes examined):

1. intrapartum stillbirth
2. early neonatal mortality 0–7 days
3. admission to neonatal intensive care unit (NICU)
4. normal vaginal birth
5. instrumental birth
6. caesarean section
7. intact perineum after vaginal birth
8. severe perineal trauma (3rd or 4th degree tear) after vaginal birth
9. postpartum haemorrhage (PPH) ≥ 1000 mL.

Table 1 indicates inclusion criteria following a framework comprising population, intervention, comparisons, outcomes and study design (PICOS) (Moher et al., 2010), giving examples of excluded study types.

Information sources

We searched five databases during May 2016: CINAHL, Embase, Maternity and Infant Care, Medline and PsycINFO. We further scrutinised reference lists manually to identify other potential articles, and set up alerts from the databases used to receive notification of relevant articles published after the main data extraction. We updated the search in January 2017, to fully cover the period 2000–2016.

Search strategy

The review used a combination of search terms (Box 1) encompassing different concepts. The 'birth place terms' in column A were all combined with the Boolean term OR, as were all 'outcome terms' in column B. The resulting searches A and B were then combined with AND.

Box 1. Review search terms.

A	B
General birth place terms	***Outcome-related terms***
Birth place OR birthplace	Outcomes + CV2[##]
Place of birth	Safety + CV2
Birth setting	Risk + CV2
Birth site OR site of birth	Mortality + CV2
Out-of-hospital + CV1[#]	Morbidity + CV2
Model of care[1] + CV1	Death + CV2
Midwife-led	Loss + CV2
Midwifery-led	Stillbirth
	Death in childbirth
	Complications + CV1
Specific birth place terms[2]	Birth injuries
Home birth OR Homebirth	Perineal trauma
Home childbirth OR child birth	Perineal tear
Childbirth at home	Episiotomy
Alternative birth cent*	Postpartum h(a)emorrhage
Birthing cent*	Transfer + CV1
Birth cent* OR birthcent*	Neonatal intensive care
Domiciliary birth	Special care nursery
Alongside unit	Psycho-social outcomes + CV1
Freestanding unit	Trauma + CV1
Alternative birth setting	Stress + CV1
	PTSD + CV1
	Postpartum mood
	Postnatal depression
	Fear of childbirth
	Apgar
	Breast feeding
	Transfer + CV1
	Neonatal intensive care
	Special care nursery
[#] *CV1 = Childbirth Variable 1* Child birth OR Childbirth OR Maternity OR Midwife OR Obstetric	
[##] *CV2 = Childbirth Variable 2* Perinatal OR Neonatal OR Maternal OR Newborn OR Pregnancy OR Obstetric OR F(o)etal OR Infant	
1. Although model of care was not the focus of this review, we used it as a search term as some studies of alternate models of care also report outcomes by place of birth.	
2. Because the review focuses on comparisons between different birth places, it was not necessary to use search terms related only to hospital-based births (delivery suite, labour ward, obstetric unit etc). Searching using terms related to home births and birth centres (as above) identified studies comparing these with hospital-based births, thus reducing the search time involved.	

Study selection

Two researchers searched electronic databases and screened the results for eligibility. We removed duplicates, screened titles to remove those clearly out of scope and then reviewed abstracts to assess eligibility. Both then read the remaining 86 articles to further determine eligibility, and resolved any disagreement about inclusion by discussion. In ensuring that selected studies contained relatively comparable risk levels, we excluded those including women with even one previous caesarean section (CS) (Hutton et al., 2016; Janssen et al., 2009). Supplementary Table S1 indicates reasons for excluding 58 articles from the systematic review following this close reading. Fig. 1 illustrates the study selection process.

Study appraisal (risk of bias)

We assessed study quality using the Birth Place Research Quality (ResQu) Index (see Supplementary Fig . S19), a newly developed critical appraisal system. This instrument was developed specifically to appraise studies that compare different birth settings, and takes account of the unique characteristics of place of birth research. Development and content validation by an international panel of experts are described elsewhere (Vedam et al., 2017a). The instrument provides a quantitative summary score based on 27 criteria to rate the quality of research evidence at study level: high (scores of 75% and above), moderate (65–74%) and low (less than 65%).

Two researchers read the remaining 28 articles and rated them using the ResQu Index, discussing any diverging scores until reaching consensus. During meta-analysis, sensitivity analyses eliminated studies that scored less than 75% to explore the impact of research quality on identified outcomes.

Data items

Box 2 defines the data items.

Box 2. Definition of data terms.

Birth Place (= Birth Setting = Place of Birth)

Birth centre: a separate area designated to provide midwife-led primary-level care in a home-like setting with no routine involvement of medical staff. Birth centres may be located as part of a hospital (Alongside Midwifery Unit – AMU) or a Freestanding Midwifery Unit (FMU). Access to specialist obstetric, anaesthetic or paediatric consultation requires transfer to a hospital obstetric unit. Birth centres may be publicly or privately funded.

Planned home birth: where a woman intends to give birth outside a formal health facility, usually in her home, and plans to receive care from one or more qualified birth attendants (midwife or doctor recognised in their country as competent to provide care). Home birth may be funded publicly or privately.

Hospital birth: births planned to take place in a hospital obstetric unit (OU) which is staffed by qualified midwives, nurses and doctors. Hospitals provide access to anaesthetic, surgical and neonatal facilities and may be public or privately-funded.

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High-income country: as defined by the World Bank for the 2016 fiscal year (World Bank, 2016).

Intended place of birth: recorded as close as possible to the onset of care in labour and preserving integrity of cohorts by taking account of intrapartum or postpartum transfers from home or birth centre to hospital. We approximate intention-to-treat by including the outcomes of the place of birth determined at (or close to) the start of labour.

Low-risk pregnancy: definitions may vary by country or by study. However, it is critical that studies specify the criteria utilised, the source of their definition and apply the same criteria to different birth place cohorts to maximise comparability. Ideally studies use recognised guidelines for determining low obstetric risk (e.g. NICE guidelines). In addition to specifying term, vertex, singleton pregnancies, studies should also indicate clearly what other maternal factors are eliminated from the dataset, e.g. hypertension, pre-existing medical conditions. For simplicity, this paper refers to 'low-risk pregnancies' and acknowledges variation in definitions in selected studies.

Mode of birth: Normal vaginal birth, instrumental birth (forceps or vacuum extraction) or non-elective caesarean section. Elective caesarean sections are correctly excluded from samples of women with low-risk pregnancies.

NICU admission: admission of newborn after birth to a neonatal intensive care unit

Normal vaginal birth is defined variously by study authors. The meta-analysis groups results for births other than caesarean sections or instrumental birth. However, we also conducted sensitivity analyses based on a more rigorous definition i.e. births other than caesarean sections or instrumental birth, specifically stating there was no induction of labour, epidural or spinal analgesia or episiotomy; vertex presentation.

Outcomes: measurable results for mother and/or infant with an emphasis on items related to safety as commonly defined by clinical studies. We focused on outcomes resulting from care in labour and birth, rather than the processes of that care, and did not include data on interventions such as induction, analgesia, anaesthesia, and episiotomy. Similarly we do not review data about Apgar scores because of the subjective nature of this measure and the variety of thresholds reported in the literature.

Our analysis principally focuses on nine outcomes: perinatal mortality (intrapartum stillbirth and early neonatal mortality 0–7 days), NICU admission, mode of birth (normal vaginal birth, instrumental birth, caesarean section), perineal status (intact perineum and severe perineal trauma) and post-partum haemorrhage $\geq$ 1000 mL. Many studies investigated additional outcomes (see Table S3).

Perinatal mortality: data on intrapartum death of a fetus known to be alive at the onset of labour (stillbirth) and early neonatal death (0–7 days). Sensitivity analyses group data from studies specifically excluding deaths resulting from known congenital abnormalities.

Perineal status: This review reports results on either intact perineum (no lacerations and no episiotomy) or severe perineal trauma (third or fourth degree lacerations).

Postpartum haemorrhage (PPH): blood loss of greater than 1000 mL.

Research quality: refers to a study's score on the ResQu Index (Vedam et al., 2017a)

1. High quality evidence –75% or above
2. Moderate – 65–74%
3. Low – below 65%

Spontaneous vaginal birth: see *Normal vaginal birth*.

Data collection process

Two researchers independently extracted the raw data for the nine outcomes from the 28 articles, ensuring consistency with our definitions (Box 2). These were recorded on a specifically-developed extraction form (Supplementary Table S2). We endeavoured to locate additional data for this systematic review, including seeking supplementary tables. At times, the extracted data differed from the published rates; for instance, for studies examining perineal outcomes, we ensured that the denominator included only vaginal births. We resolved any discrepancies by careful discussion of the studies' methodology and results.

Summary measures

Selected studies presented outcome data in different ways, most commonly (adjusted) odds ratios (OR) but also relative risk or as percentages. Supplementary Table S3 presents further detail on the statistical techniques and findings from the selected studies on outcomes relevant to this review.

Synthesis of results (meta-analysis)

Data on the nine outcomes (where available) were entered into the RevMan software (The Nordic Cochrane Centre, 2014) to calculate estimated ORs for each outcome, with a 95% confidence interval (CI). This used the random effects statistical model given the varying study designs and heterogeneity in findings. Few individual studies included in

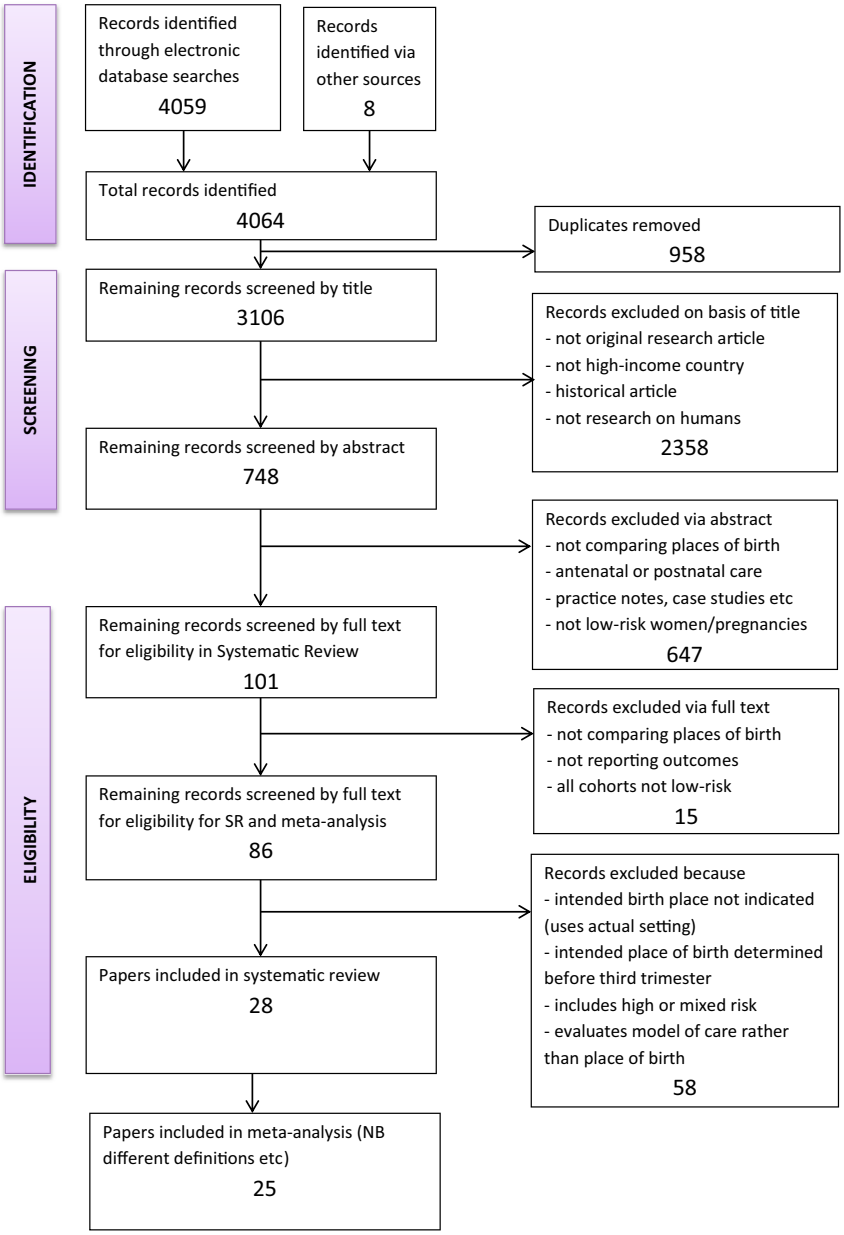

Fig. 1. Flow diagram of systematic review process.

the meta-analyses had sample sizes of sufficient power to detect meaningful differences in rare outcomes such as perinatal mortality (de Jonge et al., 2015; van der Kooy et al., 2011).

Where there were zero events reported in a study, individual odds ratios are not calculable, but these data are included in the pooled denominator to calculate the overall odds ratio for that outcome. Occasionally we have included studies which did not define mortality variables fully but where zero events in both cohorts (Gaudineau et al., 2013; Halfdansdottir et al., 2015; Homer et al., 2000; Overgaard et al., 2011) meant that a specific definition (e.g. neonatal death) was not required as the result would have been zero regardless of the actual definition.

Some articles reported data from the same study or utilise the same (or overlapping) datasets. For instance, several studies use data from the Netherlands Perinatal Registry for intersecting periods (de Jonge et al., 2013; van der Kooy et al., 2011; Wiegerinck et al., 2015). Similarly, two New Zealand studies used data from the same dataset for the years 2006–2007 (Davis et al., 2011; Dixon et al., 2014). We only used one source in each meta-analysis. Two selected studies were not included in any meta-analysis because they used data which overlapped other studies (Overgaard et al., 2012; van der Kooy et al., 2011). Another study did not present raw data from the lowest-risk cohorts (Pang et al., 2002). Other studies were excluded from specific meta-analyses because they used different definitions from ours on individual variables. For instance regarding perinatal mortality, the Birthplace in England study used a composite neonatal outcome rather than stillbirth or early neonatal death (Birthplace in England Collaborative Group, 2011). Others presented data on neonatal death up to 28 days rather than seven (Davis et al., 2011; Laws et al., 2010) or combined data on intrapartum stillbirth and neonatal death (Dixon et al., 2014; van der Kooy et al., 2011). Some studies did not provide sufficient specificity on critical terms, such as 'stillbirth' (Burns et al., 2012; Dixon et al., 2014; Laws et al., 2010). A number of studies were excluded from the PPH meta-analysis because they only presented data on blood loss over 500 mL (Blix et al., 2012; Gaudineau et al., 2013; Miller and Skinner 2012; Prelec et al., 2014) or over 300 mL (Byrne et al., 2000).

Additional analyses

To address the unavoidable heterogeneity of the selected studies, we conducted sensitivity analyses, excluding studies that achieved less than 75% in the ResQu Index. The results of the sensitivity analyses are reported beside the main findings. For perinatal outcomes, we also eliminated data from studies that did not specifically exclude known congenital abnormalities and conducted further analysis by parity when data were available from studies of planned home births. Data on planned births in birth centre were insufficient to stratify by parity.) In assessing birth centre outcomes, separate analyses compared data from FMUs and AMUs. In studies of birth centres in Australia (Homer et al., 2014; Laws et al., 2010), the meta-analysis assumed these to be AMUs. However, it is possible that data include a small number of FMU births during the periods studied; there are very few FMUs in Australia and some units closed during the study period (Monk et al., 2013).

Results

Study selection

Initial searching identified 4059 records across five databases and another eight manually. Fig. 1 illustrates the process of screening and reviewing articles to meet inclusion criteria. In the final stage, two reviewers read the remaining 86 articles and excluded 58 (Supplementary Table 1).

Study characteristics

Twenty-eight eligible articles from 26 studies remained, published 2000–2016. Table 2 summarises PICOS with further detail in Supplementary Table 2. Five studies originated in Australia (Byrne et al., 2000; Homer et al., 2000; Homer et al., 2014; Laws et al., 2010; Ryan and Roberts 2005), five in the Netherlands (Bolten et al., 2016; de Jonge et al., 2015; de Jonge et al., 2013; van der Kooy et al., 2011; Wiegerinck et al., 2015), three in the United Kingdom (Birthplace in England Collaborative Group, 2011; Burns et al., 2012; Nove et al., 2012a), six in Nordic countries (Bernitz et al., 2011; Blix et al., 2012; Eide et al., 2009; Halfdansdottir et al., 2015; Overgaard et al., 2012; Overgaard et al., 2011), two in other European countries (Gaudineau et al., 2013; Prelec et al., 2014), four in New Zealand (Davis et al., 2012; Davis et al., 2011; Dixon et al., 2014; Miller and Skinner 2012), two in the USA (Pang et al., 2002; Thornton et al., 2017) and one in Japan (Hiraizumi and Suzuki 2013). Research design included two randomised controlled trials (both of AMUs), 21 retrospective studies (4 with matched data), and five prospective studies. Eighteen were rated as providing high quality evidence.

Despite all meeting eligibility criteria, the articles varied considerably in rigour, study design and outcomes investigated. In addition to the nine outcomes under review (Table 2 and Box 2), studies examined various interventions (induction, augmentation, episiotomy, fetal monitoring, third stage management), pain management, duration of labour, birth positions, breastfeeding, transfer, maternal satisfaction and/or psychological well-being. Several investigated infants' Apgar scores. Table 2 also includes a rating of research quality (risk of bias, summarised as high, moderate or low, Box 2).

Results and synthesis of selected outcomes

The results from meta-analyses of data from 25 studies across nine outcome variables are summarised in Tables 3 and 4, showing comparisons of planned hospital births with births planned at home and in birth centres. Forest plots from each meta-analysis are included in Supplementary Figs. S1–S18, including separate results from AMUs and FMUs in birth centre analysis.

Tables 3 and 4 also report sensitivity analyses for selected outcomes repeating the meta-analysis using only the studies rated as high quality (i.e. ≥ 75% on the ResQu Index). The description of infant mortality reports sensitivity analyses limited to studies which specifically excluded infants with known congenital abnormalities. We also repeated the meta-analyses of perinatal data from studies of planned home births, stratifying by parity where possible.

Infant outcomes

There was no significant difference in the odds of intrapartum stillbirth according to place of birth. This was true for meta-analyses combining data from studies of planned home birth (Table 3 and Fig. S1) and births planned in birth centres (Table 3 and Fig. S2). This finding did not change when low and medium quality studies were removed from the analysis (Table 3). Limiting the analysis to studies where known congenital abnormalities were specifically excluded also yielded non-significant odds ratios (home births: OR = 0.98 [95% CI: 0.66–1.46]; birth centres OR = 0.65 [95% CI: 0.31–1.34]). Further analysis by parity indicated that there were no significant differences in the odds of stillbirth between births planned in hospitals and at home for either nulliparous and multiparous women (Table 3 and Fig. S1a).

There were no significant differences in the odds for early neonatal death (0–7 days) in relation to birth place, regardless of study quality (Figs. S3 and S4). Studies of planned home births that specifically excluded congenital abnormalities also showed a non-significant difference (OR = 0.99 [95% CI: 0.77–1.26]). Studies of birth centres that excluded infants with congenital abnormalities had a non-significant OR of 0.99 [95% CI: 0.34–2.86]. Similarly, there were no significant differences in early neonatal death by parity between births planned at home and in hospital (Table 3 and Fig. S3a).

Meta-analysis of four studies of planned home births identified significantly lower odds of NICU admission than for planned hospital births, as did the three high quality studies (Davis et al., 2011; de Jonge et al., 2015; Halfdansdottir et al., 2015). Babies of multiparous women had significantly lower odds of NICU admission if they planned a home birth rather than a hospital birth, although there was no significant difference by birth place among nulliparous women on this outcome (Figs. S5 and S5a). Combining data from studies of planned birth centre births showed no significant difference in odds of NICU admission regardless of study quality (Table 3 and Fig. S6).

Maternal outcomes – mode of birth

Women planning home births were nearly three times more likely to have a normal (non-instrumental) vaginal birth than women planning a hospital birth. The odds were higher when analysis was restricted to high quality studies (Table 4 and Fig. S7) and to studies using a more specific definition of non-instrumental vaginal birth without induction of labour, epidural, spinal or general anaesthesia (Birthplace in England Collaborative Group et al. 2011; Burns et al., 2012; Homer et al., 2014) (OR = 5.62 [95% CI: 1.30–24.24]). Women planning home births had significantly lower odds of either caesarean section or instrumental birth (approximately one third of those for women planning a hospital birth), regardless of study quality.

Women planning a birth centre birth had nearly twice the odds of having normal vaginal births compared with women planning hospital births – with higher odds identified amongst higher quality studies (Table 4) and planned FMU births (Fig. S8). Sensitivity analysis using the stricter definition found that women planning birth centre births had significantly higher odds of normal vaginal births without other interventions ($n = 3$, OR = 2.12 [95% CI: 1.54–2.92]). The odds of instrumental birth and caesarean section were also significantly lower for women planning to give birth in birth centres, regardless of type of birth centre or quality of the study (Figs. S10 and S12).

Table 2
Summary of studies included in systematic review (N = 28).

	First author. Publication date. Country	Study design	Source of data. Year/s	Population – eligibility criteria	Intervention – Planned place of birth	Comparator – Planned place of birth	Outcome measures – relevant to current review outcomes	Quality rating
1	Bernitz 2011. Norway	RCT	Admin data 2004–2010	1111 women with low-risk pregnancies = AMU eligibility.	MW-led AMU $N = 412$	Normal birth unit (NU) $N = 417$. Special birth unit (SU) $N = 282$.	Operative birth, PPH, sphincter injuries, NICU admission	High
2	Birthplace in England Collaborative 2011. England	Prospective cohort study	Data collection forms. 2008–2010	64,538 women with low-risk pregnancies as per NICE guidelines. *Additional analysis of 57,127 women without complicating conditions at labour onset.*	Planned HB $N = 16,840$ AMU $N = 16,710$ FMU $N = 11,282$	Obstetric Unit (OU) $N = 19,706$	Composite PO = perinatal mortality + major intrapartum morbidity (defined). SO: 'normal birth' (SVB without IOL; anaesthesia; or episiotomy)	High
3	Blix 2012. Norway	Retrospective cohort study	Patient files + registry data. 1990–2007	17,941 low-risk pregnancies	Planned HB $N = 1631$	Planned hospital birth $N = 16,310$	PO: PPH > 500 mL. SO: perinatal and neonatal death rates	High
4	Bolten 2016. Netherlands	Prospective cohort study	Perinatal database + participant questions 2009–2011	3495 women with low-risk pregnancies in MW care at onset of labour	Planned HB $N = 2050$.	MW-led OU birth $N = 1445$	PO: SVB and perineal outcomes, PPH.	High
5	Burns 2012. England, Scotland, Northern Ireland	Prospective cohort study	Data collection forms. 2000–2008	8924 women "low risk" as per RCOG water immersion joint statement.	Water immersion in a birth pool in AMU $N = 2100$. Combined FMU/HB (=community) $N = 2694$.	Water immersion in a birth pool in OU $N = 4130$	Maternal: mode of birth, perineal trauma, PPH. Neonatal: NICU admission, mortality	High
6	Byrne 2000. Australia	RCT	Case notes + participant questions 1993–1995	201 women with normal uncomplicated pregnancies.	Birth centre AMU. $N = 100$	Hospital delivery suite $N = 101$	CS, blood loss ≥ 300 mL, SCN admission	High
7	Davis 2011. New Zealand	Comparative descriptive study	Perinatal database 2006–2007	16,210 women with low risk pregnancies	Primary Unit (PU, like FMU) $N = 2877$	Planned HB $N = 1830$, Secondary hospital (SU) $N = 7380$, Tertiary hospital (TU) $N = 4123$	Mode of birth, perineal trauma (not defined), PPH ≥ 1000 mL, NICU admission	High
8	Davis 2012 New Zealand	Retrospective cohort study	Perinatal database 2006–2007	16,210 women with low risk pregnancies	Planned PU birth $N = 2877$	Planned HB $N = 1830$ SU $N = 7308$ TU $N = 4123$	PPH ≥ 1000 mL	High
9	de Jonge, 2013. Netherlands	Linked cohort study	Perinatal database + LEMMoN study data 2004–2006	146,752 women with low risk pregnancies.	Planned HB $N = 92,333$	Planned OU birth $N = 54,419$.	PO: Severe acute maternal morbidity (defined). SO: PPH ≥ 1000mL	High

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Table 2 (*continued*)

	First author. Publication date. Country	Study design	Source of data. Year/s	Population – eligibility criteria	Intervention – Planned place of birth	Comparator – Planned place of birth	Outcome measures – relevant to current review outcomes	Quality rating
10	de Jonge 2015. Netherlands	Retrospective cohort study	Linked national registry data. 2000–2009	743,070 women with low risk pregnancies in MW-led care	Planned HB $N = 466,112$	Planned hospital birth (including AMU) $N = 276,958$	Intrapartum and neonatal death, NICU admission	High
11	Dixon 2014. New Zealand	Retrospective cohort (aim to replicate BPiE in NZ)	NZ College Midwives Research Data. 2006–2010	61,072 women defined as low-risk using BPiE criteria	Planned HB $N = 4921$ Primary unit (PU) $N = 10,158$	Hospital birth in either SU ($N = 29,027$) or TU ($N = 16,966$)	Perinatal mortality, NICU admission.	Moderate
12	Eide 2009. Norway	Prospective observational cohort study	Hospital data. 2001–2002	453 *nulliparous* women with low-risk pregnancies = MLW eligibility	MLW $N = 252$	Conventional delivery ward (CDW) $N = 201$	PPH, perineal trauma, mode of birth	High
13	Gaudineau 2012. France	Retrospective case-control study	Hospital data. 2005–2008	1206 women with low risk pregnancies.	Home-like BC $N = 316$	Traditional labour ward (TLW) $N = 890$	Mode of delivery, perineal trauma, PPH (≥500 mL), adverse neonatal outcomes (including neonatal death).	Moderate
14	Halfdansdottir 2015. Iceland	Retrospective cohort study – matched. Two methods	Hospital data + registry data. 2005–2009	*Method 1*: 1228 all HB + matched hospital births *Method 2:* 1112 women with no contraindications.	Planned HB 1) $N = 307$ 2) $N = 278$.	Matched planned hospital birth (including AMU) 1) $N = 921$ 2) $N = 834$.	Operative birth, PPH, anal sphincter injury, NICU admission	High
15	Hiraizumi 2013. Japan	Retrospective cohort study	?Medical records. 2007–2011	508 women with low risk pregnancies	Planned HB under MW-led care $N = 168$	Planned OU birth under MW ($N = 123$) or under obstetrician ($N = 217$).	Mode of birth, perineal trauma, PPH ≥ 1000mL	Moderate
16	Homer 2000. Australia	Retrospective cohort study	Hospital data. 1995.	734 women with low-risk pregnancies	Birth centre $N = 367$	Hospital labour ward $N = 367$	Mode of birth, perineal trauma, neonatal outcomes.	Moderate
17	Homer 2014. Australia	Retrospective population- based cohort study (similar to BPiE)	Linked registry + hospital data. 2000–2008	258,161 women with low risk pregnancies. *Additional analysis for 235,611 women without complications at start of labour*	Planned HB $N = 742$ BC $N = 14,483$	Hospital labour ward $N = 242,936$	PO: primary neonatal outcome (see BPiE Collaboration). SO: stillbirth + NND, mode of birth, perineal trauma, 'normal labour and birth' (defined)	High

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Table 2 (*continued*)

	First author. Publication date. Country	Study design	Source of data. Year/s	Population – eligibility criteria	Intervention – Planned place of birth	Comparator – Planned place of birth	Outcome measures – relevant to current review outcomes	Quality rating
18	Laws 2010. Australia	Retrospective population-based study	Perinatal database. 2001–2005	822,955 women. *Additional analysis of 498,023 women with term, low-risk pregnancies*	Planned BC birth *N* = 22,222	Intended OU birth *N* = 800,733 Low-risk group: *N* = 475,791	Perinatal mortality, mode of birth, severe perineal trauma, SCN admission	Moderate
19	Miller 2012. New Zealand	Retrospective matched case control study	Questionnaires to MW. 2006–2007	225 *nulliparous* women with low-risk pregnancies.	Planned HB *N* = 109	Planned OU birth with same MW as HB group *N* = 116	Type of birth, perineal status, PPH ≥ 500ml	Moderate
20	Nove 2012. UK	Observational study	Secondary analysis of maternity data. 1998–2000	273,872 women. Exclude high risk pregnancies (NICE guidelines)	Planned HB *N* = 5998	Planned hospital birth *N* = 267,874	PPH ≥ 1000ml	High
21	Overgaard 2011. Denmark	Cohort study with matched control.	Patient records and admin data. 2004–2008.	1678 women with low risk pregnancies (NICE guidelines) + healthy multips with uncomplicated obstetric history regardless of age and BMI.	Planned FMU birth. *N* = 839	Hospital birth, women matched on 9 key factors. *N* = 839	PO: CS. SO: NICU admission, perineal status, type of birth, PPH ≥ 500 ml, perinatal mortality	High
22	Overgaard 2012 Denmark	Cohort study with matched control.	Secondary analysis of data from Overgaard 2011	1678 women as above, stratified by educational disadvantage. *[460 women without post-secondary education]*	Planned FMU birth. *N* = 839 *[Women without post-secondary education N = 230]*	Hospital birth *N* = 839 *[Women without post-secondary education N = 230]*	Composite optimal birth outcome (uncomplicated SVB with good maternal and fetal outcomes), SVB, CS, NICU admission, perineal status.	High
23	Pang 2002. USA	Retrospective population-based cohort study	Birth registry data, linked with death records. 1989–1996	Singleton birth 34/40 + with no recorded complications (defined) *N* = 16,726 women. *Additional analysis used infants 2500 g + or 37/40 + N = 16,253.*	HB with health professional as attendant or certifier (not 'planned HB') *N* = 5854 + attempted HB transferred to hospital *N* = 279. *Secondary analysis N = 6052*	Hospital birth *N* = 10,593. *Secondary analysis N = 10,347*	Neonatal death, PPH (not defined)	Low

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Table 2 (*continued*)

	First author. Publication date. Country	Study design	Source of data. Year/s	Population – eligibility criteria	Intervention – Planned place of birth	Comparator – Planned place of birth	Outcome measures – relevant to current review outcomes	Quality rating
24	Prelec 2014. Slovenia	Prospective case-control study	Hospital data 2013	497 low-risk *nulliparous* pregnancies (NICE guidelines).	MW-managed births in MLU *N* = 154	OU births *N* = 343	PO: CS SO: SVB, PPH ≥ 500 mL, perineal status, NICU admission	Moderate
25	Ryan 2005. Australia	Retrospective cohort study	Hospital records. 1995–1996	3683 women all with BC eligibility.	Planned BC birth *N* = 720	Planned hospital labour ward (LW) *N* = 2963	Type of labour and birth, perineal status, PPH ≥ 600 mL, perinatal death, SCN admission	Low
26	Thornton 2016. USA	Retrospective cohort study using prospective study data	Secondary analysis of data from AABC. 2006–2011	11,303 women attending BC for antenatal care, who chose hospital or BC birth.	FMU birth *N* = 8776	Hospital birth *N* = 2527	PO: Type of birth. SO: PPH, composite of severe newborn outcomes	High
27	Van der Kooy 2011. Netherlands	Population-based cohort –2 methods	Perinatal Registry data. 2000–2007	679,952 women with low risk pregnancies in MW care. *[602,331 excluding labour < 37/40 or > 41/40, or earlier intrauterine death]*	Planned HB with MW 1) *N* = 402,912 2) *N* = 363,568	Planned hospital birth 1) *N* = 219,105 2) *N* = 190,098 OR unclear planned BP 1) *N* = 57,935 2) *N* = 48,665	Combined intrapartum death, neonatal death up to 24/24, neonatal death from 1–7 days.	High
28	Wiegerinck, 2015. Netherlands	Retrospective cohort study	Linked admin + Registry data. 2005–2008	Main study 83,289 women with singleton term pregnancies no elective CS, congenital abnormality or fetal death, at all risk levels. *Additional data on 52,629 women with low-risk pregnancies*	Planned HB following MW-led care *N* = 23,323	Planned hospital birth after MW-led care (*n* = 18,675) + obstetrician-led care of low-risk pregnancies (*n* = 10,631) Total *N* = 29,306	PO: Perinatal mortality SO: mode of birth, perineal trauma, PPH, admission to NICU	Moderate

Abbreviations:
AABC = American Association of Birth Centers; AMU = Alongside Midwifery Unit; BC = birth centre; BMI = Body Mass Index; BP = birth place; BPiE = Birthplace in England (Collaboration Group); CDW = conventional delivery ward; CLU = consultant led unit; CS = Caesarean section; FMU = Freestanding (stand-alone) Midwifery Unit; HB = home birth; HELLP = haemolysis, elevated liver enzymes, low platelet count; IOL = induction of labour; ITT = intention to treat; LW = labour ward; mL = millilitres; MLU = Midwifery Led Unit; MW = midwife; N = number in cohort; NICU = Neonatal Intensive Care Unit; NICE = National Institute for Health and Care Excellence; NND = neonatal death; NS = not significant; NU = normal unit; NZ = New Zealand; OU = hospital (obstetric unit); PO = primary outcome; PPH = postpartum haemorrhage;PU = primary unit; RCOG = Royal College of Obstetricians and Gynaecologists; RCT = randomised controlled trial; SCN = special care nursery; signif = significant; SO = secondary outcome; SU = special/secondary unit; SVB = spontaneous vaginal birth; TLW = traditional labour ward; TU = tertiary unit

Table 3
Meta-analysis of infant outcomes.

Infant outcomes – planned homebirth vs hospital	Fig.	No. of studies	Planned home birth n/N	Planned hospital birth n/N	Estimated odds ratio	95% confidence interval	Sensitivity analysis – High quality studies only		
							No. of studies	Est odds ratio	95% CI
Stillbirth	S1	6[a]	206/486,035	280/542,374	0.94	0.76–1.17	6	0.94	0.76–1.17
Stillbirth – nulliparous	*S1a*	*3*	*113/198,948*	*87/144,273*	*1.20*	*0.32–4.51*			
Stillbirth – multiparous	*S1a*	*3*	*87/269,031*	*45/149,866*	*1.04*	*0.73–1.50*			
Early neonatal death	S3	6[b]	171/484,165	166/534,878	1.00	0.78–1.27	6	1.00	0.78–1.27
ENND – nulliparous	*S3a*	*3*	*95/198,845*	*69/144,193*	*0.99*	*0.73–1.36*			
ENND – multiparous	*S3a*	*3*	*72/268,949*	*42/149,823*	*1.03*	*0.69–1.54*			
Admission to NICU	S5	4[c]	1123/472,914	2694/335,202	0.71	0.55–0.92	3	0.79	0.63–0.98
NICU admission – nulliparous	*S5a*	*2*	*656/198,476*	*499/137,280*	*1.11*	*0.65–1.89*			
NICU admission – multiparous	*S5a*	*2*	*337/267,687*	*272/140,426*	*0.74*	*0.62–0.87*			
Infant outcomes - planned birth in birth centre (BC) vs hospital	Fig.	No of studies	Planned BC birth n/N	Planned hospital birth n/N	Estimated odds ratio	95% confidence interval			
Stillbirth	S2	7[d]	9/44,750	151/253,294	0.66	0.32–1.34	4	0.65	0.31–1.34
Early neonatal death	S4	6[e]	4/20,609	54/230,245	0.87	0.29–2.61	3	0.82	0.25–2.63
Admission to NICU	S6	6[f]	387/16,540	2073/63,507	0.82	0.62–1.08	4	0.88	0.59–1.32

Included studies:

[a] Birthplace in England Collaborative Group 2011; Blix et al., 2012; Davis et al., 2011; de Jonge et al. 2015; Halfdansdottir et al., 2015; Homer et al., 2014. Parity data not available for two studies: Davis et al., 2011; Homer et al., 2014

[b] Birthplace in England Collaborative Group 2011; Blix et al., 2012; Burns et al., 2012; de Jonge et al. 2015; Halfdansdottir et al., 2015; Homer et al., 2014. Parity data not available for two studies: Burns et al., 2012; Homer et al., 2014

[c] Davis et al., 2011; de Jonge et al. 2015; Dixon et al., 2014; Halfdansdottir et al., 2015. Parity data not available for Davis et al., 2011; Dixon et al., 2014

[d] Birthplace in England Collaborative Group 2011; Davis et al., 2011; Gaudineau et al., 2013; Homer et al., 2000; Homer et al., 2014; Overgaard et al., 2011; Ryan & Roberts 2005). Parity data only available for two studies with nil events for either cohort (Gaudineau et al., 2013; Overgaard et al., 2011

[e] Birthplace in England Collaborative Group 2011; Burns et al., 2012; Gaudineau et al., 2013; Homer et al., 2000; Homer et al., 2014; Overgaard et al., 2011; Ryan & Roberts 2005. Parity data only available for one study with nil events for either cohort Gaudineau et al., 2013

[f] Bernitz et al., 2011; Davis et al., 2011; Dixon et al., 2014; Overgaard et al., 2011; Prelec et al., 2014. AMU data only for Burns et al., 2012 as FMU data merged with homebirth data.

Maternal outcomes – perineal status

Only two studies investigated the likelihood of an intact perineum amongst women planning home births, reporting significantly higher odds (Fig. S13). The six studies investigating this variable in planned birth centre births found no significant difference in odds compared with planned hospital births, regardless of study quality (Table 4 and Fig. S14).

The odds of severe perineal trauma were significantly lower amongst planned home births, regardless of study quality (Fig. S15) and among higher-quality studies of births planned in birth centres (Table 4).

Maternal outcomes – PPH

Severe PPH (≥1000 mL) was significantly less likely in planned home births than in planned hospital births (Fig. S17). However, there was no significant difference in the odds identified in studies of planned birth centre births, regardless of the type of birth centre (Fig. S18) or the rating of study quality (Table 4).

Discussion

Principal findings

This review examined whether there were significant differences between different planned birth places in critical maternal and perinatal outcomes, to help women make informed decisions about where to give birth. It is unique in including data from both birth centres and home births.

Limiting data to outcomes from low-risk pregnancies, we endeavoured to compare planned birth place cohorts across nine relevant outcomes. Combined maternal data from the selected studies indicated significantly lower odds of intervention and maternal morbidity, and significantly higher odds of normal vaginal births among planned home births compared to planned hospital births (Table 4). This is consistent with conclusions from other syntheses of research on planned home births (not all of which included comparative data) (Fullerton et al., 2007; Leslie and Romano 2007; McIntyre 2012; Stotland and Declercq 2002; Zielinski et al., 2015) and with Olsen's early meta-analysis (1997). Further, women planning birth centre births had nearly twice the odds of a normal vaginal birth compared to women planning a hospital birth, with correspondingly lower rates of caesarean section or instrumental births. This is consistent with findings from other reviews (Alliman and Phillippi 2016; Dixon et al., 2012; Hodnett et al., 2012; McIntyre 2012; Muthu and Fischbacher 2004). Our results found no significant difference in rates of severe perineal trauma or PPH between planned birth centre and hospital births.

While many authors have identified favourable maternal outcomes in planned birth centre and home births, including outcomes not addressed in this review, results regarding infant outcomes from different places of birth are more controversial. Our meta-analysis found no significant difference between the cohorts in the odds of stillbirth or early neonatal death (Table 3), albeit by combining several studies with limited statistical power to detect differences in such rare outcomes. This was consistent for studies of births planned in birth centres and at home, regardless of study quality. Moreover, the odds of perinatal mortality did not differ between births planned in hospital and at home, among both nulliparous and multiparous women. The absolute numbers of adverse events were still very small (Olsen and Clausen 2012). There were signif-

Table 4
Meta-analysis of maternal outcomes.

Maternal outcomes – planned homebirth vs hospital	Fig.	No. of studies	Planned home birth n/N	Planned hospital birth n/N	Estimated odds ratio	95% confidence interval	Sensitivity analysis – High quality studies only		
							No. of studies	Estimated odds ratio	95% confidence interval
Normal vaginal birth	S7	9[a]	41,473/45,777	163,523/300,507	2.93	2.13–4.03	6	3.25	1.97–5.38
Caesarean section	S9	9[b]	1006/46,935	31,209/322,166	0.35	0.27–0.46	6	0.36	0.24–0.53
Instrumental birth	S11	9[c]	2682/46,935	46,157/322,166	0.37	0.24–0.58	6	0.33	0.21–0.51
Intact perineum	S13	2[d]	1632/3720	5284/12,079	1.15	1.06–1.25	2	1.15	1.06–1.25
Severe perineal trauma	S15	9[e]	920/44,625	9333/290,389	0.57	0.40–0.81	6	0.49	0.30–0.81
PPH ≥ 1000mL	S17	6[f]	2853/102,663	5231/336,330	0.73	0.55–0.96	5	0.68	0.52–0.89
Maternal outcomes – planned birth in birth centre vs hospital	Fig.	No. of studies	Planned BC birth n/N	Planned hospital birth n/N	Estimated odds ratio	95% confidence interval	No. of studies	Estimated odds ratio	95% confidence interval
Normal vaginal birth	S8	11[g]	53,108/63,443	322,132/521,925	1.92	1.59–2.32	7	2.05	1.60–2.63
Caesarean section	S10	15[h]	4061/81,697	136,964/782,157	0.48	0.39–0.60	9	0.54	0.42–0.70
Instrumental birth	S12	14[i]	5731/72,921	97,916/780,066	0.61	0.52–0.71	8	0.58	0.46–0.72
Intact perineum	S14	6[j]	2517/6912	7014/19,361	1.20	0.98–1.47	3	1.04	0.82–1.30
Severe perineal trauma	S16	11[k]	1852/68,328	14,429/621,185	1.01	0.96–1.07	7	0.93	0.87–0.99
PPH ≥ 1000mL	S18	5[l]	77/6378	238/17,309	0.87	0.67–1.14	4	0.83	0.63–1.09

Included studies:

[a] Birthplace in England Collaborative Group 2011; Blix et al., 2012; Bolten et al., 2016; Davis et al., 2011; Halfdansdottir et al., 2015; Hiraizumi & Suzuki 2013; Homer et al., 2014; Miller & Skinner 2012; Wiegerinck et al., 2016

[b] Birthplace in England Collaborative Group 2011; Blix et al., 2012; Bolten et al., 2016; Davis et al., 2011; Halfdansdottir et al., 2015; Hiraizumi & Suzuki 2013; Homer et al., 2014; Miller & Skinner 2012; Wiegerinck et al., 2016

[c] Birthplace in England Collaborative Group 2011; Blix et al., 2012; Bolten et al., 2016; Davis et al., 2011; Halfdansdottir et al., 2015; Hiraizumi & Suzuki 2013; Homer et al., 2014; Miller & Skinner 2012; Wiegerinck et al., 2016

[d] Bolten et al., 2016; Davis et al., 2011

[e] Birthplace in England Collaborative Group 2011; Blix et al., 2012; Bolten et al., 2016; Davis et al., 2011; Halfdansdottir et al., 2015; Hiraizumi & Suzuki 2013; Homer et al., 2014; Miller & Skinner 2012; Wiegerinck et al., 2016

[f] Bolten et al., 2016; Davis et al., 2012; de Jonge et al. 2013; Halfdansdottir et al., 2015; Hiraizumi & Suzuki 2013; Nove et al., 2012a

[g] Bernitz et al., 2011; Birthplace in England Collaborative Group 2011; Burns et al., 2012; Davis et al., 2011; Eide et al., 2009; Gaudineau et al., 2013; Hiraizumi & Suzuki 2013; Homer et al., 2000; Homer et al., 2014; Laws et al., 2010; Overgaard et al., 2011

[h] Bernitz et al., 2011; Birthplace in England Collaborative Group 2011; Burns et al., 2012; Byrne et al., 2000; Davis et al., 2011; Eide et al., 2009; Gaudineau et al., 2013; Hiraizumi & Suzuki 2013; Homer et al., 2000; Homer et al., 2014; Laws et al., 2010; Overgaard et al., 2011; Prelec et al., 2014; Ryan & Roberts 2005; Thornton et al., 2017

[i] Bernitz et al., 2011; Birthplace in England Collaborative Group 2011; Burns et al., 2012; Byrne et al., 2000; Davis et al., 2011; Eide et al., 2009; Gaudineau et al., 2013; Hiraizumi & Suzuki 2013; Homer et al., 2000; Homer et al., 2014; Laws et al., 2010; Overgaard et al., 2011; Prelec et al., 2014; Ryan & Roberts 2005

[j] Burns et al., 2012; Davis et al., 2011; Gaudineau et al., 2013; Homer et al., 2000; Overgaard et al., 2011; Ryan & Roberts 2005

[k] Bernitz et al., 2011; Birthplace in England Collaborative Group 2011; Burns et al., 2012; Davis et al., 2011; Eide et al., 2009; Gaudineau et al., 2013; Hiraizumi & Suzuki 2013; Homer et al., 2014; Laws et al., 2010; Overgaard et al., 2011; Prelec et al., 2014

[l] Bernitz et al., 2011; Burns et al., 2012; Davis et al., 2012; Hiraizumi & Suzuki 2013; Overgaard et al., 2011

icantly lower odds of admission to NICU for babies of women planning a home birth than those of women planning hospital births.

Limitations

Given different countries of origin, the selected studies varied considerably in context: service provision, setting, models of care and the overall integration between maternity services. Thus, generalisation of findings to high-income countries with different healthcare systems requires caution. There was diversity too in the quality of the included studies, although we attempted to reduce its impact through strict eligibility criteria and appraisal with the ResQu Index. Studies explored a wide range of outcomes; even common outcomes were sometimes defined differently, limiting the extent to which we could extract comparable data. Thus not all studies addressing a given outcome contributed data to its relevant meta-analyses.

Limiting eligibility to publication in English language peer-reviewed journals may have resulted in some publication bias across studies, overlooking studies from some regions. Publication bias may have also resulted in the inclusion of studies that only reported significant differences between cohorts. However, given the controversial nature of this topic and the varying strong perspectives of different provider groups in some regions, it is likely that most good quality studies on perinatal and maternal outcomes would find an outlet. Further, for some outcomes such as mortality, a non-significant difference between places of birth is as newsworthy as one that is statistically significant.

We only conducted a few meta-analyses in terms of parity, focussing on adverse perinatal outcomes from planned home births. Although we recognise that parity is an important determinant of maternal and perinatal outcomes, many studies did not present data by parity. Further, by focusing specifically on birth setting, we did not explore the impact of provider type or model of care.

Most research into place of birth is observational. Our quality appraisal process, eligibility criteria and data extraction endeavoured to minimise bias between individual studies in design, analysis and re-

porting. However, there may have been systematic differences in confounders that could be overcome through randomisation. The rarity of perinatal mortality in high-income countries necessitates combining studies to provide sufficiently large home birth or birth centre cohorts to show meaningful results.

Another proposed systematic review and meta-analysis (Hutton et al., 2014) is in progress. It will focus on studies of home birth outcomes that stratify by parity and those in countries where home birth is well integrated with other maternity services.

Heterogeneity

Not surprisingly, several meta-analyses showed high heterogeneity scores (I^2) (Figs. S1–S18), especially for mode of birth. These scores largely reflect the variation in sample size and in the outcomes of the individual studies and are consistent with the conclusions of other reviews that have highlighted the disparities between selected observational studies. The measures generated by the software may overlook other aspects of heterogeneity in studies, such as unmeasured differences in staffing or resources between birth settings or in underlying characteristics of the women in different cohorts.

Risk status

We closely analysed the studies' definitions 'low-risk', rather than comparing them with a strict definition determined *a priori*. Most studies gave detailed criteria, including at minimum gestational age, fetal presentation, and singleton pregnancy. The descriptions of exclusion criteria varied from vaguely-defined 'pre-existing medical conditions' or 'obstetric complications', through to comprehensive lists of factors which contribute significantly to risk status. Even where they demonstrated similar levels of obstetric risk, several studies identified marked disparity in the demographic characteristics between cohorts. Most studies adjusted reported odds ratios to take account of some if not all of these demographic differences; some discussed the impact of less measurable distinctions between their cohorts (e.g. motivation, attitudes).

Quality appraisal

This paper is unique in using the ResQu Index, an innovative instrument to appraise research specifically on place of birth (Vedam et al., 2017a). Although the development of the Index included expert validation and extensive pilot-testing, this is the first known application of the tool in a systematic review. Only ten included studies scored as moderate or low in quality. This does not demonstrate that the Index is undiscriminating; rather it reflects that review inclusion criteria were strict and addressed similar considerations as the ResQu Index itself (e.g. adherence to intention-to-treat analysis or exclusion of non-comparable cohorts).

Findings from the sensitivity analyses (Tables 3 and 4) indicate that the overall odds ratios rarely changed substantially by ruling out weaker studies, which typically had smaller sample sizes. In one meta-analysis of perineal trauma among planned birth centre births, data limited to higher quality studies generated a statistically significant difference from planned hospital births whereas analysis of all studies yielded a non-significant difference.

Conclusions

By comparing and synthesising results from three distinct birth settings, this review offers valuable evidence to inform decisions about birth place. The results demonstrate that, amongst carefully selected studies of women with low-risk pregnancies in high-income countries, planned place of birth appears to have little significant impact on adverse perinatal outcomes. Moreover, women who planned to give birth in a birth centre or at home had significantly lower odds for intervention and severe morbidity in labour and birth.

These findings have important implications for healthcare costs and services. They support the expansion of birth centres and home birth options, and the systems to support them, including professional guidelines and education. The results also have ramifications for information provided to pregnant women and their families, as a means to enhance their choice and autonomy about birthplace options. They help extend existing knowledge about the risks and potential outcomes from different places of birth, and the circumstances necessary to optimise the safety and well-being of mothers and newborns.

Conflict of interest

The authors declare there is no conflict of interest.

Ethical approval

This study is a systematic review and meta-analysis. It does not require ethical approval. The wider Birthplace in Australia study has been approved by the University of Technology Sydney Human Research Ethics Committee (reference number UTS HREC Ref No. 2,012,000,167) and the ethics committees of Australian state and territory health authorities

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Clinical trial registration

Not applicable.

Registration of systematic review

The protocol for this study was submitted to Prospero, the international register of systematic reviews (https://www.crd.york.ac.uk/prospero/), Registration Number: CRD42016042291.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.midw.2018.03.024.

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