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Systematic review and meta-analysis to examine intrapartum interventions, and maternal and neonatal outcomes following immersion in water during labour and waterbirth

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ABSTRACT

Objectives Water immersion during labour using a birth pool to achieve relaxation and pain relief during the first and possibly part of the second stage of labour is an increasingly popular care option in several countries. It is used particularly by healthy women who experience a straightforward pregnancy, labour spontaneously at term gestation and plan to give birth in a midwifery led care setting. More women are also choosing to give birth in water. There is debate about the safety of intrapartum water immersion, particularly waterbirth. We synthesised the evidence that compared the effect of water immersion during labour or waterbirth on intrapartum interventions and outcomes to standard care with no water immersion. A secondary objective was to synthesise data relating to clinical care practices and birth settings that women experience who immerse in water and women who do not.

Design Systematic review and meta-analysis.

Data sources A search was conducted using CINAHL, Medline, Embase, BioMed Central and PsycINFO during March 2020 and was replicated in May 2021.

Eligibility criteria for selecting studies Primary quantitative studies published in 2000 or later, examining maternal or neonatal interventions and outcomes using the birthing pool for labour and/or birth.

Data extraction and synthesis Full-text screening was undertaken independently against inclusion/exclusion criteria in two pairs. Risk of bias assessment included review of seven domains based on the Robbins-I Risk of Bias Tool. All outcomes were summarised using an OR and 95% CI. All calculations were conducted in Comprehensive Meta-Analysis V.3, using the inverse variance method. Results of individual studies were converted to log OR and SE for synthesis. Fixed effects models were used when I^2 was less than 50%, otherwise random effects models were used. The fail-safe N estimates were calculated to determine the number of studies necessary to change the estimates. Begg's test and Egger's regression risk assessed risk of bias across studies. Trim-and-fill analysis was used to estimate the magnitude of effect of the bias. Meta-regression was completed when at least 10 studies provided data for an outcome.

Results We included 36 studies in the review, (N=157 546 participants). Thirty-one studies were conducted in an obstetric unit setting (n=70 393), four studies were conducted in midwife led settings (n=61 385) and one study was a mixed setting (OU and homebirth) (n=25 768). Midwife led settings included planned home and freestanding midwifery unit (k=1), alongside midwifery units (k=1), planned homebirth (k=1), a freestanding midwifery unit and an alongside midwifery unit (k=1) and an alongside midwifery unit (k=1). For water immersion, 25 studies involved women who planned to have/had a waterbirth (n=151 742), seven involved water immersion for labour only (1901), three studies reported on water immersion during labour and waterbirth (n=3688) and one study was unclear about the timing of water immersion (n=215).

Water immersion significantly reduced use of epidural (k=7, n=10 993; OR 0.17 95% CI 0.05 to 0.56), injected opioids (k=8, n=27 391; OR 0.22 95% CI 0.13 to 0.38), episiotomy (k=15, n=36 558; OR 0.16; 95% CI 0.10 to 0.27), maternal pain (k=8, n=1200; OR 0.24 95% CI 0.12 to 0.51) and postpartum haemorrhage (k=15, n=63 891; OR 0.69 95% CI 0.51 to 0.95). There was an increase in maternal satisfaction (k=6, n=4144; OR 1.95 95% CI 1.28 to 2.96) and odds of an intact perineum (k=17, n=59 070; OR 1.48; 95% CI 1.21 to 1.79) with water immersion. Waterbirth was associated with increased odds of cord avulsion (OR 1.94 95% CI 1.30 to 2.88), although the

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ This study incorporated meta-regression, using covariates identified a priori, to identify sources of heterogeneity in previous studies.
⇒ This study included cumulative meta-analysis and fail-safe analysis to provide estimates of the stability of the findings.
⇒ Inconsistency of reporting on birth setting, care practices, interventions and outcomes prevented us from achieving our secondary objective to account for intrapartum care variation.
⇒ Meta-regression was only possible for three outcomes: intact perineum, episiotomy and postpartum haemorrhage.
⇒ Few studies were conducted in midwifery-led settings.

absolute risk remained low (4.3 per 1000 vs 1.3 per 1000). There were no differences in any other identified neonatal outcomes.

Conclusions This review endorses previous reviews showing clear benefits resulting from intrapartum water immersion for healthy women and their newborns. While most included studies were conducted in obstetric units, to enable the identification of best practice regarding water immersion, future birthing pool research should integrate factors that are known to influence intrapartum interventions and outcomes. These include maternal parity, the care model, care practices and birth setting.

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INTRODUCTION

Immersion in a birthing pool offers women a non-pharmacological option of pain relief during labour, which also enhances their sense of control. Resting and labouring in water can reduce fear, anxiety and pain perception; it helps optimise the physiology of childbirth through the release of endogenous endorphins and oxytocin. Evidence from randomised controlled trials (RCTs) showed that labouring in water reduces the need for epidural analgesia while identifying no adverse maternal or neonatal effects.[1] In the UK, most birthing pool use occurs in midwifery-led birth settings: these include alongside midwifery units (colocated with a maternity hospital setting) and freestanding midwifery units (in the community setting) and home birth.[2] The outcomes of birthing pool use may be different in midwifery-led settings compared with an obstetric setting because healthy women experience fewer interventions and operative birth when the birth occurs in a midwifery-led setting compared with an obstetric setting.[3]

Variations in care between waterbirth services may contribute to the differences in outcomes with water immersion, particularly variations in use of labour augmentation, hands on/off the perineum for the birth, pushing position, use of active management of third stage of labour and placenta birth in the water.[3–9] It is likely that women who use water immersion for labour and birth experience different care practices than women who have standard birth care. Though prior evidence has found no increased risk of adverse events for newborns born in water, heterogeneity in outcomes and limited reporting of the clinical guidance used for water immersion make implementation of evidence-based guidelines difficult.[10–12] There is a need to understand which clinical practices, when performed as part of water immersion care, result in the optimum outcomes for mother and newborn. It has been argued that an international RCT would be desirable.[13 14] However, an RCT proposal is likely to encounter ethical and recruitment challenges due to increasing acknowledgement of the importance of enabling women to take an active part in decision making during labour. Additionally, an unblinded trial and expected uneven crossover carry an inevitable limitation.[15]

Water immersion in a birth pool during labour and birth can be divided into two distinct but overlapping categories. Water immersion during labour involves using a birth pool to achieve relaxation and pain relief during the first and possibly part of the second stage of labour but exiting the pool for the birth. With this practice, the infant emerges into air to breathe. With waterbirth, the woman remains in the birth pool for the birth of the baby. The infant emerges into the water and is brought to the surface to initiate breathing.

The primary objective of this systematic review was to compare intrapartum interventions and outcomes for water immersion during labour/waterbirth to standard care with no water immersion. The secondary objective was to analyse data reported for clinical care practices and birth settings experienced by women who use water and women who do not.

Review questions

What interventions do women experience with water immersion for labour and birth?

What are the maternal and newborn outcomes following water immersion during labour and waterbirth compared with similar women who labour and/or give birth on land?

METHODS

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guideline was followed for conducting this work.[16]

Patient and public involvement

Patients were not involved in the development of the research question, study design or selection of outcome measures.

Eligibility criteria included:

1. Studies using any primary quantitative study design published in peer-reviewed journal or unpublished thesis.
2. Studies that examined maternal or neonatal interventions and/or outcomes when using the birthing pool for labour and/or birth.
3. Studies published in 2000 or later.
4. Studies conducted in any language if it could be translated into English using Google Translate.

A search was conducted using CINAHL, Medline, Embase, BioMed Central (BMC) and PsycINFO during March 2020. The search was replicated in May 2021. A predesigned search strategy was designed using the PICOT/PEOT framework to develop search terms[17]:

- Population: women in labour and early post partum.
- Intervention/Exposure: water immersion during labour and/or birth.
- Comparison: no water immersion during labour or birth.
- Outcomes: Maternal: artificial rupture of the membranes, need for labour augmentation, epidural analgesia, opioid injection, planned and actual place of birth, reason for transfer to an obstetric setting, mode of birth, perineal trauma, third-stage management,

postpartum haemorrhage (PPH)/blood transfusion, infection, breastfeeding initiation. Newborn: APGAR score, resuscitation, admission to a neonatal intensive care unit (NICU), infection, breastfeeding at 6 weeks.
- Time: labour and early puerperium.

A tested, sensitive and reproducible search strategy was developed with the specialist healthcare librarian, VF.[18] The refined search terms and strategy with Boolean operators are provided in online supplemental file 1. These were adapted for specific database architecture. Additional searches were carried out via referencing, checking all included studies with no further records found. Publication alerts were set up via BMC updates that alerted CF_1 to a new publication that met our inclusion/exclusion criteria. A final search to determine if any additional papers were published after analysis was conducted by VF in May 2021.

Study selection

Records were deduplicated in Zotero and collated into Rayyan systematic review software.[19] Initial screening (title/abstract) was carried out blind by HTC, CF_1, CF_2 against the inclusion/exclusion criteria. Consensus meetings were held to discuss and resolve disagreements. Full-text screening was carried out independently against the inclusion/exclusions criteria and in pairs: JV and CF_1, EB and PJH. Disagreements were resolved by consensus meeting. In the case of duplication of a sample across multiple papers, the paper which provided the largest sample for each outcome provided the data for synthesis.

Data collection was completed using pilot tested forms created in REDCap data collection software. Researchers worked in teams of two (JV and EB, JV and PJH) to individually abstract data for each study, identify discrepancies and reach consensus when needed. Data collected included the study type; sample characteristics, care practices for water immersion, if it was a midwifery-led setting; rates of interventions including amniotomy, labour induction, augmentation, fetal monitoring, epidural, injected opioid, episiotomy and active management of third stage; and outcome data including mode of birth, level of pain, maternal satisfaction, intact perineum, obstetric anal sphincter injury (OASI), shoulder dystocia, maternal infection defined by symptoms and positive test, primary PPH, manual removal of the placenta, 5 min APGAR, newborn resuscitation, transient tachypnoea of the newborn, respiratory distress of the newborn, neonatal intensive unit admission within the first 24 hours and lasting for 48 hours, death in neonatal period, newborn infection defined by both symptoms and positive test, cord avulsion and breastfeeding initiation.

Risk of bias assessment

Risk of bias assessment included review of seven domains based on the Robbins-I Risk of Bias Tool.[20] The domains included bias due to confounding, bias in selection of participants, bias in measurement of intervention, bias due to departures of intended treatment, bias in measurement of outcomes, bias due to missing data, bias in selection of reported results. Bias due to departure of intended treatment was modified to track studies that did not provide information about water immersion use for the control group. Risk of bias assessment was completed independently by two researchers (JV and EB, JV and PJH). Disagreements were resolved by consensus meeting.

Summary measures and synthesis of results

All outcomes were summarised using an OR and 95% CI. All calculations were conducted in Comprehensive Meta-Analysis V.3, using the inverse variance method.[21] Results of individual studies were converted to log OR and SE for synthesis. Fixed effects models were used when I^2 was less than 50%, otherwise random effects models were used. This decision was made because (1) the population eligible for water immersion is restricted to women at low risk of birth complications and (2) the goal of the analysis was to determine if variations in care practices result in changes in outcomes. Outcomes without adequate heterogeneity in estimates were considered unlikely to be affected by care practices and so a fixed effects model was appropriate for analysis. When possible, subgroup analysis was conducted to determine effect of the birth setting and parity on the estimate. In addition, analysis limited to studies published within the past 10 years was conducted when possible. Per protocol, we intended to conduct subgroup analysis by maternal age, maternal body mass index (BMI), prior caesarean, and pool type, however, the data did not allow for these analyses. Cumulative meta-analysis was used to identify the stability of the estimates over time.[22] The fail-safe N estimates were calculated to determine the number of studies necessary to change the estimates.[23] Forest plots were created in RevMan V.5.4.1.[24]

Additional analyses

Begg's test and Egger's Regression Risk assessed risk of bias across studies.[25] Trim-and-fill analysis was used to estimate the magnitude of effect of the bias.[26] Meta-regression was completed when at least 10 studies provided data for an outcome when I^2 >50%.[26–28] Tested covariates included the sample characteristics and care practices identified a priori as the structure and process variables likely to be responsible for heterogeneity in the outcomes. Directed acyclic graphs of the covariates and their role are available in online supplemental file 2.[29] For continuous covariates, the rate of a covariate (eg, the induction rate in the sample) were used for regression. Categorical covariates were coded as dichotomous (eg, described appropriate birth pool or did not describe the immersion receptacle).

Certainty assessment

The fail-safe N estimates were calculated to determine the number of studies necessary to change the estimates.[23] Fail-safe calculates the number of studies needed to change the estimate. Cumulative meta-analysis was used to identify the stability of the estimates over time.[22] Assessment of certainty with GRADE criteria was considered

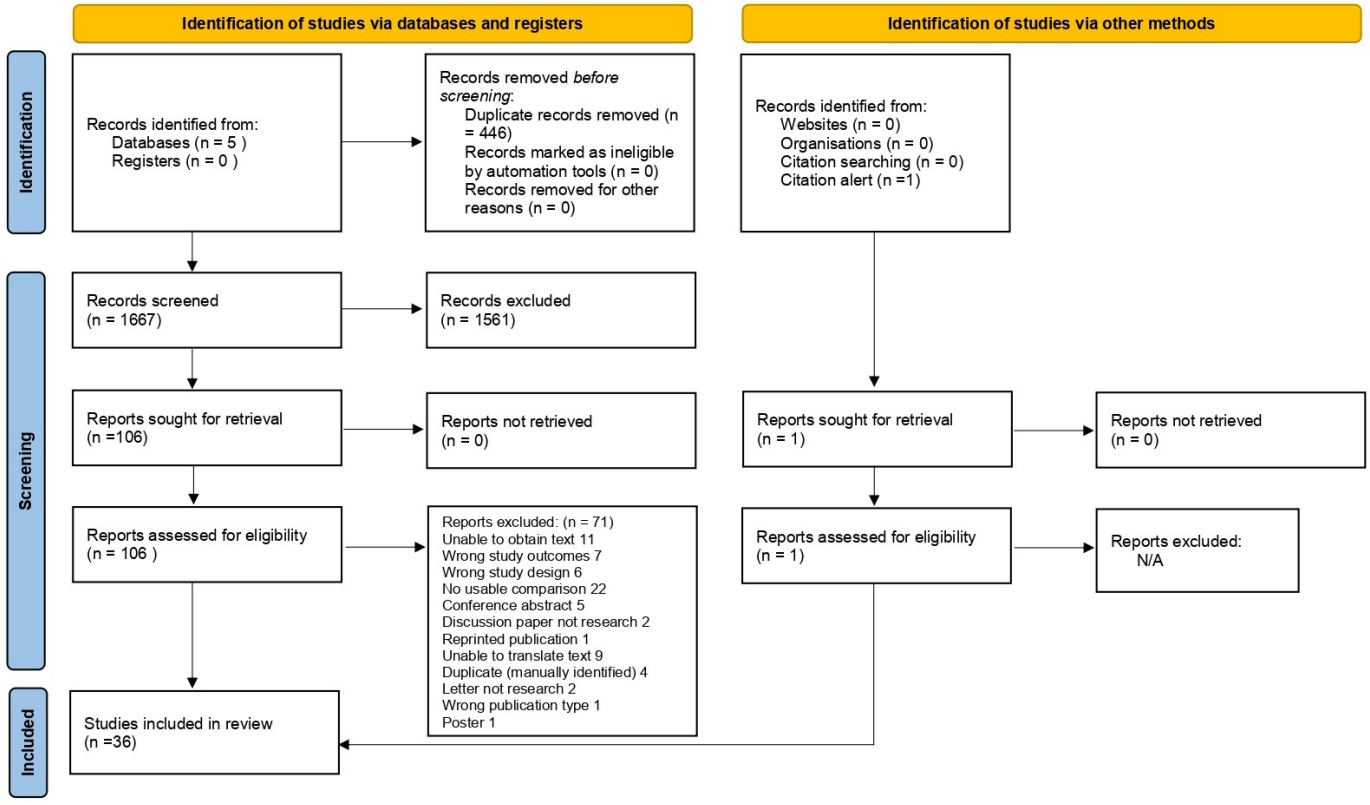

Figure 1 PRISMA 2020 flow diagram for new systematic reviews which included searches of databases, registers and other sources. PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

inappropriate for this review because the goal of this study was to identify variations between reports of outcomes with water immersion that contribute to inconsistency, imprecision, variations and confounding—three assessments made when considering certainty of evidence. However, the authors recognise the importance of a standardised GRADE assessment for readers. The individual assessments made in this review were prepared in a table outlining scores per standard Grade criteria as online supplemental file 3.

RESULTS

Study selection

The searches generated 2113 hits, reduced to 1667 after duplicates were removed; n=1561 records were discarded at the initial screening stage. Of 106 records that were full-text screened, n=71 records did not meet the criteria. See online supplemental file 4 for the list of excluded studies and the reasons. One additional study was found via BMC updates, therefore, k=36 papers reporting on outcomes for 157 546 women were included into the review.[13 30–65] Figure 1 illustrates the study selection process.[16]

Study description

Most studies (k=31) were conducted in an obstetric setting or did not adequately report the setting, while four studies were conducted in midwife-led settings; two included planned home and birth centre births,[33 58] one that involved a birth centre (not explicitly described as freestanding) and an alongside midwifery unit (co-located in an obstetric unit).[32] Studies included RCTs (k=6; n=1862), prospective studies (k=13; n=28 226), retrospective studies (k=16; n=127 477), and one pre–post study (n=11). Studies reported on waterbirth (k=25; n= 151 742), water immersion for labour (k=7; n=1901), both (k=3; n=3688

) and one whose timing of immersion could not be determined (n=215). Full information is available in table 1.

Few studies provided sample characteristics beyond parity (see table 2). Eleven studies reported the sample was restricted to persons in spontaneous labour while seven included the rate of labour induction for each group. Two studies excluded participation based on BMI while six provided weight or BMI distributions in the sample characteristics. Most studies (k=19; n=77 180) excluded multiple pregnancies, the rest did not address this characteristic. Prior caesarean was excluded by seven studies (n=2292) and reported as a sample characteristic for five studies (n=22 439).

Few studies provided descriptions of the care practices used with water immersion and water birth (see table 3). The description of the immersion receptacle used was adequate to determine the woman had freedom of movement in seven studies (n=3273). Method of induction was not reported. Sixteen studies reported a fetal heart

Table 1 Characteristics of included studies; meta-analysis of water immersion for labour and birth

Author	Study type	Setting	Immersion exposure	Sample Size	Interventions and outcomes reported
Bailey *et al*[30]	RO	Obstetric	Waterbirth	2422	1, 5, 10, 11, 13, 17
Barry *et al*[31]	PO	Obstetric	Both	380	8, 10, 11, 13, 17, 23
Benfield *et al*[32]	Pre-Post	Obstetric	Labour	11	4, 7
Bovbjerg *et al*[33]	RO	Midwifery	Waterbirth	18355	10, 11, 12, 17, 21
Cluett *et al*[34]	RCT	Obstetric	Labour	99	2, 6, 7, 8, 15, 16
da Silva *et al*[35]	RCT	Obstetric	Labour	108	2, 4, 7, 10, 12, 17
Eckert *et al*[36]	RCT	Obstetric	Labour	274	1, 5, 6, 7, 8, 11, 12, 16, 17, 18
Geisbuehler *et al*[38]	PO	Obstetric	Waterbirth	5584	12, 20
Geissbuehler *et al*[39]	PO	Obstetric	Waterbirth	9518	5, 9, 10, 11, 13, 15, 17
Geissbühler and Eberhard[37]	PO	Obstetric	Waterbirth	7508	6, 16
Haslinger *et al*[40]	RO	Obstetric	Waterbirth	7832	11, 12
Henderson *et al*[41]	PO	Obstetric	Both	3078	2, 3, 8, 10, 12, 13, 14, 18
Hodgson *et al*[42]	RO	Mixed	Waterbirth	25768	4, 11, 17, 18
Jacoby *et al*[43]	RO	Obstetric	Waterbirth	23036	11, 13, 15, 17, 18, 20, 21, 23
Lathrop *et al*[44]	PO	Obstetric	Waterbirth	198	13, 16
Lim *et al*[45]	RO	Obstetric	Waterbirth	236	4, 9, 10, 12, 13, 14, 17, 19
Liu *et al*[46]	PO	Obstetric	Labour	108	4, 7, 8, 13
Mallen-Perez *et al*[47]	PO	Obstetric	Unclear	215	7
Menakaya *et al*[49]	RO	Obstetric	Waterbirth	438	9, 10, 11, 12, 13, 17, 18
Mollamahmutoglu *et al*[50]	PO	Obstetric	Waterbirth	602	1, 7, 10, 12, 13
Neiman *et al*[51]	RO	Obstetric	Both	230	4, 8, 9, 10, 12, 13, 17, 22, 23
Ohlsson *et al*[52]	RCT	Obstetric	Labour	1237	6, 8, 11, 14, 19, 20
Otigbah *et al*[53] -	RO	Obstetric	Waterbirth	602	1, 4, 5, 9, 10, 11, 12, 13
Pagano *et al*,[13] -	RO	Obstetric	Waterbirth	220	10, 17
Peacock *et al*,[54] -	RO	Obstetric	Waterbirth	3507	17
Preston *et al*[55] -	RO	Midwifery	Waterbirth	15734	5, 9, 11
Ros[56] -	PO	Obstetric	Waterbirth	54	17
Sert *et al*[57] -	RCT	Obstetric	Labour	64	17
Snapp *et al*[58] -	RO	Midwifery	Waterbirth	26684	9, 10, 13, 17, 21, 23
Thoeni *et al*[59] -	RO	Obstetric	Waterbirth	1600	10, 11, 12
Torkamani *et al*[60] --	PO	Obstetric	Waterbirth	100	5, 7, 12
Ulfsdottir *et al*[61]-	RO	Midwifery	Waterbirth	612	1, 2, 3, 4, 6, 10, 11, 12, 13, 14, 16, 17, 23, 24
Woodward and Kelly[62] 2004	RCT	Obstetric	Waterbirth	80	4, 5, 6, 8, 10, 17, 24
Zanetti-Dällenbach *et al*[63] 2006	PO	Obstetric	Waterbirth	513	2, 3, 6, 9, 12
Zanetti-Dallenbach *et al*[64] 2007	PO	Obstetric	Waterbirth	368	4, 5, 10, 11, 13, 14, 17
Ziolkowski *et al*[65] 2009	RO	Obstetric	Waterbirth	171	16, 17

Interventions amd Outcomes Key: (1) Labour Induction (2) Amniotomy (3) Augmentation (4) Fetal Monitoring (5) Opioids (6) Epidural (7) Pain (8) Caesarean Delivery (9) Shoulder Dystocia (10) Intact Perineum (11) OASI (12) Episiotomy (13) Postpartum Haemorrhage (14) Manual Removal of Placenta (15) Maternal Infection (16) Maternal Satisfaction (17) 5 min APGAR (18) Newborn Resuscitation (19) Transient Tachypnoea of the Newborn (20) Respiratory Distress of the Newborn (21) Neonatal Death (22) Infection in newborn period (23) Cord Avulsion (24) Breastfeeding Initiation.
No studies provided comparison data for third-stage management.
No studies met the definition used for neonatal intensive care unit admission.
OASI, obstetric anal sphincter injury; PO, prospective observational; RCT, randomised controlled trial; RO, retrospective observational.

Table 2 Reported characteristics of study samples abstracted from inclusion and exclusion criteria or sample descriptions

Author	Excludes multiparous	Excludes induced labour	Excludes for BMI	Excludes multiples	Excludes prior Caesarean
Bailey *et al*[30]	Yes	No	No	Yes	No
Barry *et al*[31]	Yes	Yes	>30	Yes	n.d.
Benfield *et al*[32]	Yes	n.d.	n.d.	n.d.	n.d.
Bovbjerg *et al*[33]	Yes	n.d.	n.d.	Yes	No
Cluett *et al*[34]	Yes	Yes	n.d.	n.d.	n.d.
da Silva *et al*[35]	Yes	n.d.	n.d.	Yes	n.d.
Eckert *et al*[36]	Yes	No	n.d.	Yes	n.d.
Geisbuehler *et al*[38]	Yes	n.d.	n.d.	n.d.	n.d.
Geissbuehler *et al*[39]	Yes	n.d.	>40	n.d.	n.d.
Geissbuhler *et al*[38]	Yes	n.d.	n.d.	n.d.	n.d.
Haslinger *et al*[40]	Yes	n.d.	n.d.	Yes	n.d.
Henderson *et al*[41]	Yes	No	n.d.	n.d.	No
Hodgson *et al*[42]	Yes	n.d.	n.d.	Yes	n.d.
Jacoby *et al*[43]	Yes	Yes	n.d.	Yes	n.d.
Lathrop *et al*[44]	Yes	n.d.	n.d.	Yes	n.d.
Lim *et al*[45]	Yes	n.d.	n.d.	Yes	No
Liu *et al*[46]	No	n.d.	No	Yes	Yes
Mallen-Perez *et al*[48]	Yes	Yes	No	Yes	n.d.
Menakaya *et al*[49]	Yes	Yes	n.d.	Yes	n.d.
Mollamahmutoglu *et al*[50]	Yes	No	No	n.d.	Yes
Neiman *et al*[51]	Yes	Yes	n.d.	Yes	Yes
Ohlsson *et al*[52]	Yes	n.d.	n.d.	Yes	n.d.
Otigbah *et al*[53]	Yes	No	n.d.	n.d.	n.d.
Pagano *et al*[13]	Yes	n.d.	n.d.	n.d.	n.d.
Peacock *et al*[54]	Yes	Yes	n.d.	n.d.	n.d.
Preston *et al*[55]	Yes	Yes	No	n.d.	n.d.
Ros *et al*[56]	Yes	n.d.	n.d.	Yes	Yes
Sert *et al*[57]	Yes	Yes	n.d.	n.d.	Yes
Snapp *et al*[58]	Yes	n.d.	n.d.	n.d.	n.d.
Thoeni *et al*[59]	No	n.d.	n.d.	Yes	Yes
Torkamani *et al*[60]	Yes	n.d.	n.d.	n.d.	n.d.
Ulfsdottir *et al*[61]	Yes	Yes	No	n.d.	No
Woodward and Kelly[62]	Yes	Yes	n.d.	n.d.	Yes
Zanetti-Dällenbach *et al*[63]	Yes	n.d.	n.d.	Yes	n.d.
Zanetti-Dallenbach *et al*[64]	Yes	n.d.	n.d.	Yes	n.d.
Ziolkowski *et al*[65] 2009	No	n.d.	n.d.	n.d.	n.d.

n.d. This item was not described in the paper; it was neither listed as an inclusion/exclusion criteria nor in the description of the sample.
BMI, body mass index.

monitoring method as either intermittent auscultation (k=10; n=50 846), continuous monitoring (k=5; n=967) or a mix of methods (k=1; n=367). Six studies reported using 'hands-off' (k=4; n=5595) or 'hands-on' (k=2; n=6463) the perineum. Third-stage management was reported by six studies (n=5595), all indicating that active management was used. Three studies indicated whether the placenta and membranes were delivered in the birth pool (k=1; n=513) or out of the birth pool (k=2; n=1396).

Risk of bias assessment

Overall risk of bias is presented in figure 2. Domain 3, bias due to comparability of the groups, was most often identified in retrospective studies that did not provide

Table 3 Description of care practices reported in included studies

Author	Appropriate pool described	Induction method	Intermittent auscultation	Perineum method	Third-stage management	Placenta and membranes
Bailey *et al*[30]	No	n.d.	n.d.	n.d.	Active	Out of Pool
Barry *et al*[31]	Yes	None	Mixed	Hands Off	Active	n.d.
Benfield *et al*[32]	No	n.d.	No	n.d.	n.d.	n.d.
Bovbjerg *et al*[33]	No	n.d.	n.d.	n.d.	n.d.	n.d.
Cluett *et al*[34]	Yes	None	n.d.	n.d.	n.d.	n.d.
da Silva *et al*[35]	No	n.d.	No	n.d.	n.d.	n.d.
Eckert *et al*[36]	Yes	n.d.	n.d.	n.d.	n.d.	n.d.
Geisbuehler *et al*[38]	No	n.d.	Yes	n.d.	n.d.	n.d.
Geissbuehler *et al*[39]	No	n.d.	Yes	n.d.	n.d.	n.d.
Geissbuhler *et al*[38]	No	n.d.	Yes	n.d.	n.d.	n.d.
Haslinger *et al*[40]	No	n.d.	n.d.	Hands On	n.d.	n.d.
Henderson *et al*[41]	No	n.d.	n.d.	Hands Off	Active	n.d.
Hodgson *et al*[42]	No	n.d.	Yes	n.d.	n.d.	n.d.
Jacoby *et al*[43]	No	None	n.d.	n.d.	n.d.	n.d.
Lathrop *et al*[44]	No	n.d.	n.d.	n.d.	n.d.	n.d.
Lim *et al*[45]	No	n.d.	No	n.d.	n.d.	n.d.
Liu *et al*[46]	No	n.d.	Yes	n.d.	n.d.	n.d.
Mallen-Perez *et al*[48]	Yes	None	n.d.	n.d.	n.d.	n.d.
Menakaya *et al*[49]	Yes	None	n.d.	n.d.	n.d.	n.d.
Mollamahmutoglu *et al*[50]	Yes	n.d.	Yes	Hands Off	Active	n.d.
Neiman *et al*[51]	No	None	Yes	n.d.	n.d.	n.d.
Ohlsson *et al*[52]	No	n.d.	n.d.	n.d.	n.d.	n.d.
Otigbah *et al*[53]	Yes	n.d.	Yes	Hands Off	Active	Out of Pool
Pagano *et al*[13]	No	n.d.	n.d.	n.d.	n.d.	n.d.
Peacock *et al*[54]	No	None	n.d.	n.d.	n.d.	n.d.
Preston *et al*[55]	No	None	n.d.	n.d.	n.d.	n.d.
Ros *et al*[56]	No	n.d.	n.d.	n.d.	n.d.	n.d.
Sert *et al*,[57]	Yes	None	n.d.	n.d.	n.d.	n.d.
Snapp *et al*[58]	No	n.d.	n.d.	n.d.	n.d.	n.d.
Thoeni *et al*[59]	No	n.d.	n.d.	Hands On	n.d.	n.d.
Torkamani *et al*[60]	No	n.d.	n.d.	n.d.	n.d.	n.d.
Ulfsdottir *et al*[61]	Yes	None	No	n.d.	n.d.	n.d.
Woodward and Kelly[62]	No	None	Yes	n.d.	n.d.	n.d.
Zanetti-Dällenbach *et al*[63]	No	n.d.	No	n.d.	Active	In Pool
Zanetti-Dallenbach *et al*[64]	No	n.d.	No	n.d.	n.d.	n.d.
Ziolkowski *et al*[65]	No	n.d.	Yes	n.d.	n.d.	n.d.

n.d. Care practice not described in the paper in methods or results.

adequate sample restriction to ensure comparability. Domain 4, bias due to departure from intended treatment, had the highest potential for bias because studies did not provide information about if or why the comparison group included persons who used water in labour but not during birth. Bias in measurement of outcomes was rare because most outcomes were standard medical record items. However, measurement for pain and maternal satisfaction was not consistently described. Individual study results and risk of bias for each outcome are provided in the forest plots found in figures 3–24.

Labour induction

Three studies provided data on labour induction (n=2008), all conducted after 2010. Overall, this analysis found no difference between use of labour induction with

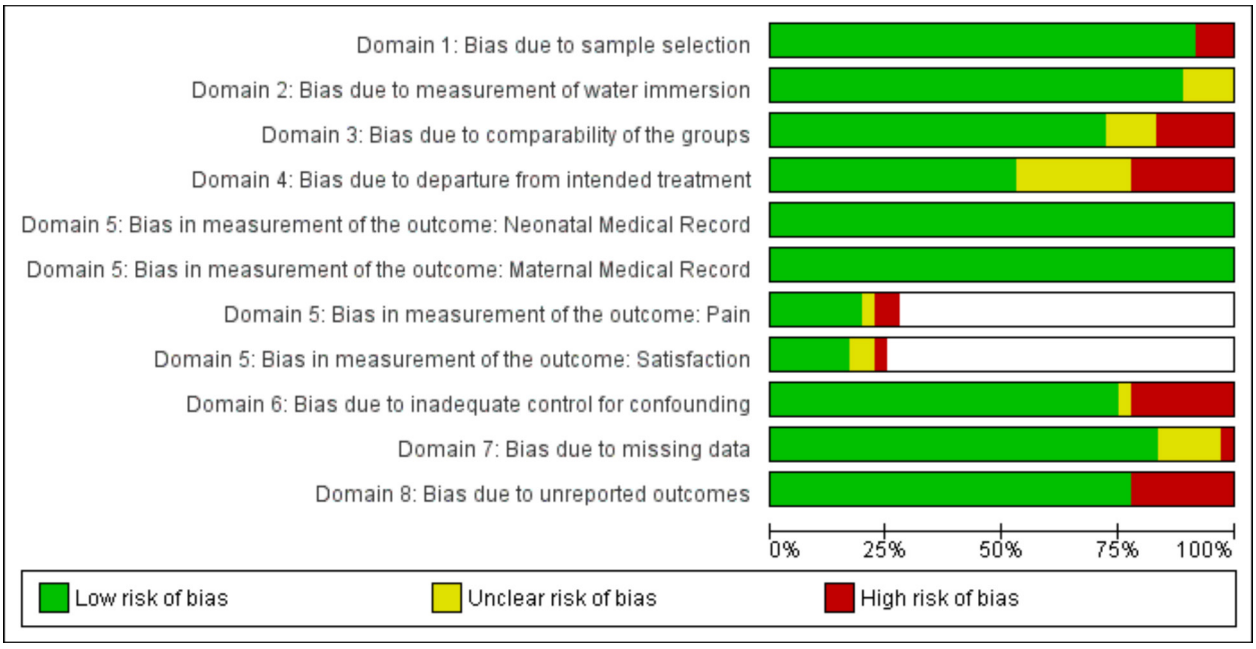

Figure 2 Risk of bias assessment.

water immersion and standard care (OR 0.43; 95% CI 0.16 to 1.16; random effects; Q=20.7 p<0.001; I^2=90%). Subgroup analysis of studies reporting in an obstetric setting remained no difference. Results of the subgroup analyses are in table 4. Three studies were too few for cumulative meta-analysis. Two additional studies indicated there was no difference but did not provide data to synthesise.[36 53]

Amniotomy

Five studies provided data on amniotomy (n=1627). Overall, this analysis found no difference (OR 0.71; 95% CI 0.37 to 1.39; random effects; Q=23.9 p<0.001; I^2=83%). Cumulative meta-analysis indicated the available evidence has consistently indicated no difference in the rate of amniotomy. Subgroup analysis of studies reporting in an obstetric setting and the most recent studies remained no difference.

Augmentation

Three studies provided data to compare augmentation of labour (n=1420). This analysis favoured water immersion (OR 0.30; 95% CI 0.10 to 0.92; random effects; Q=19.2 p<0.001; I^2=90%). Subgroup analysis of studies reporting in an obstetric setting and the most recent studies remained no difference. Fail-safe analysis estimated 34 additional studies finding no difference would be needed to change the estimate to no difference. Three studies were too few for cumulative meta-analysis.

Fetal monitoring

No studies provided data to compare the use of intermittent or continuous fetal monitoring during immersion to standard care.

Opioid use

Eight studies provided data on opioid use (n=27 391), all were conducted in an obstetric setting. Overall, this analysis found reduced use of opioids with water immersion (OR 0.22 95% CI 0.13 to 0.38; random effects; Q=96.1 p<0.001; I^2=93%). Subgroup analysis of the most recent studies remained no difference. Cumulative meta-analysis indicated the available evidence consistently favoured water immersion. Fail-safe analysis estimated

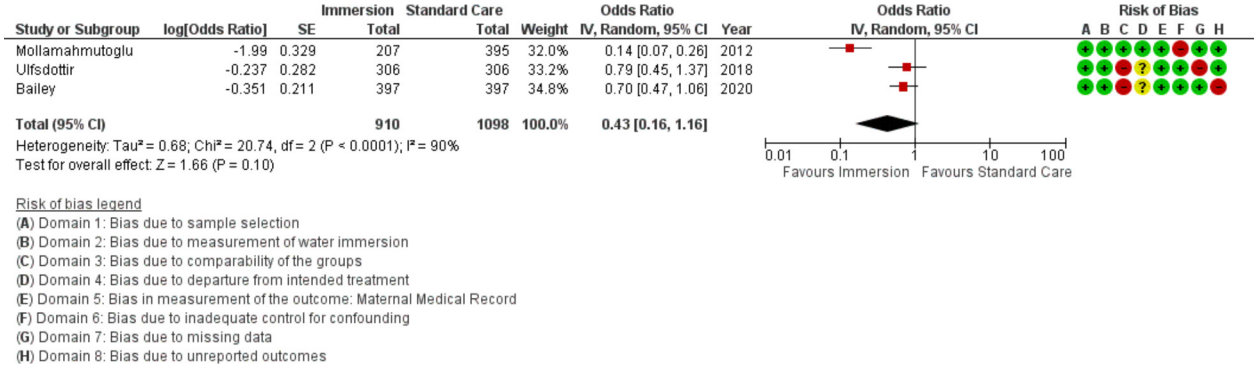

Figure 3 Forest plot of synthesis of labour induction. IV, inverse variance.

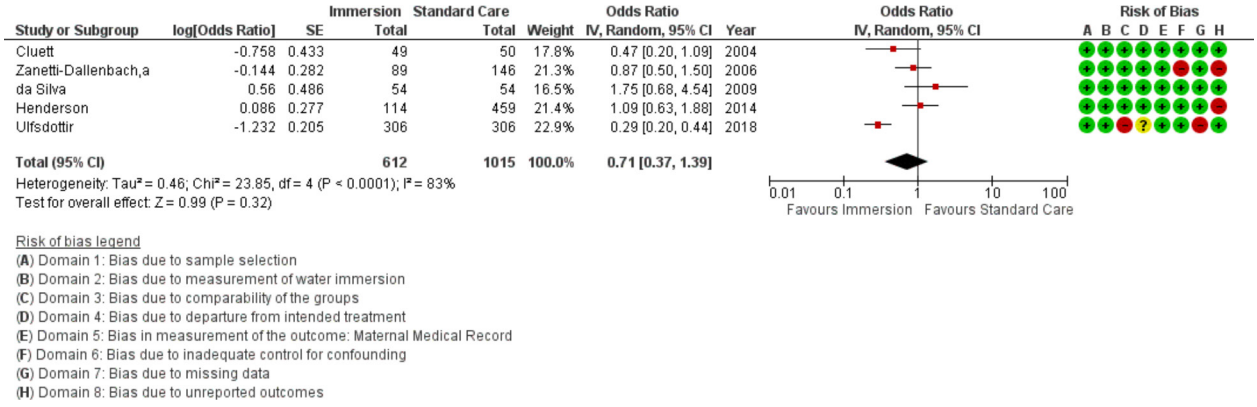

Figure 4 Forest plot of synthesis of amniotomy. IV, inverse variance.

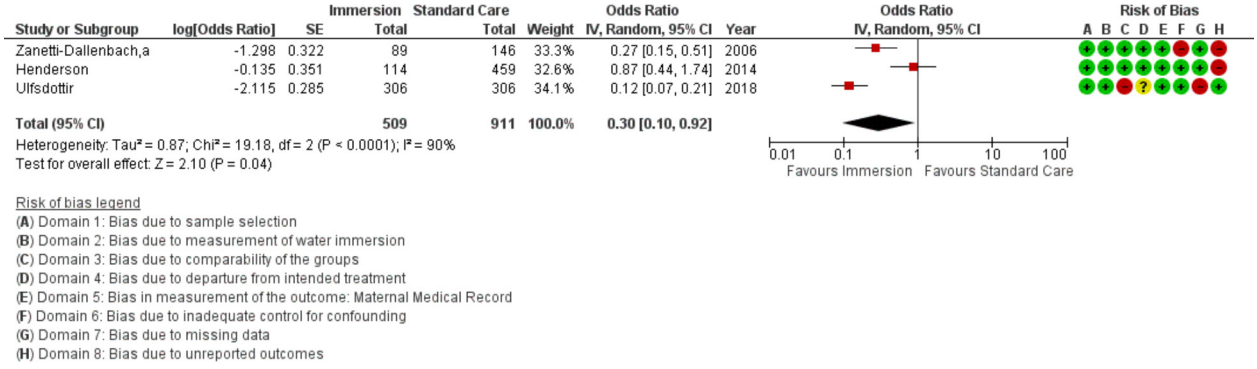

Figure 5 Forest plot of synthesis of augmentation of labour. IV, inverse variance.

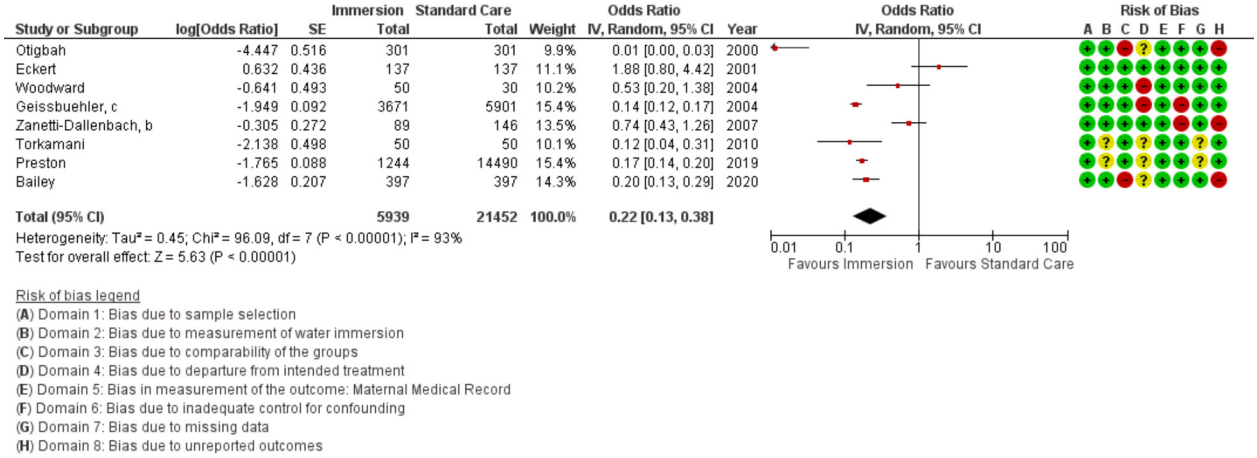

Figure 6 Forest plot of synthesis of opioid use. IV, inverse variance.

972 additional studies would be needed to change the estimate to no difference.

Epidural use

Seven studies provided data on epidural use (n=10 993). Overall, this analysis favoured water immersion (OR 0.26 95% CI 0.08 to 0.83; random effects; Q=89.5 p<0.001; I^2=94%). Cumulative meta-analysis revealed the estimate moved from no difference to favour water immersion in 2007. Fail-safe analysis indicated 100 additional studies would be needed to change the estimate to no difference. Subgroup analysis revealed the use of epidural was reduced with water immersion in an obstetric setting.

Pain

Eight studies provided data for analysis of pain (n=1200), all were conducted in an obstetric setting. Because these studies varied in their measurement timing and scale, they were combined with a random effects model for an overall score and the results were stratified by timing of measurement in the forest plot. Overall, the results indicated reduced pain with water immersion (OR 0.24 95% CI 0.12 to 0.51; random effects; Q=76.7 p<0.001; I^2=91%). One additional study reported in favour of water immersion but did not provide the data in a way that allowed synthesis.[31] Subgroup analysis of the most

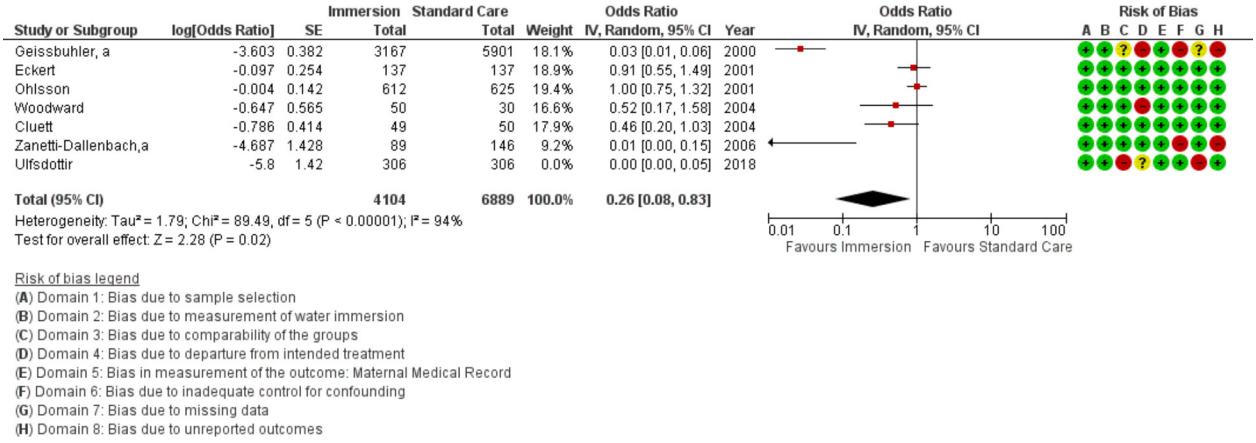

Figure 7 Forest plot of synthesis of epidural use. IV, inverse variance.

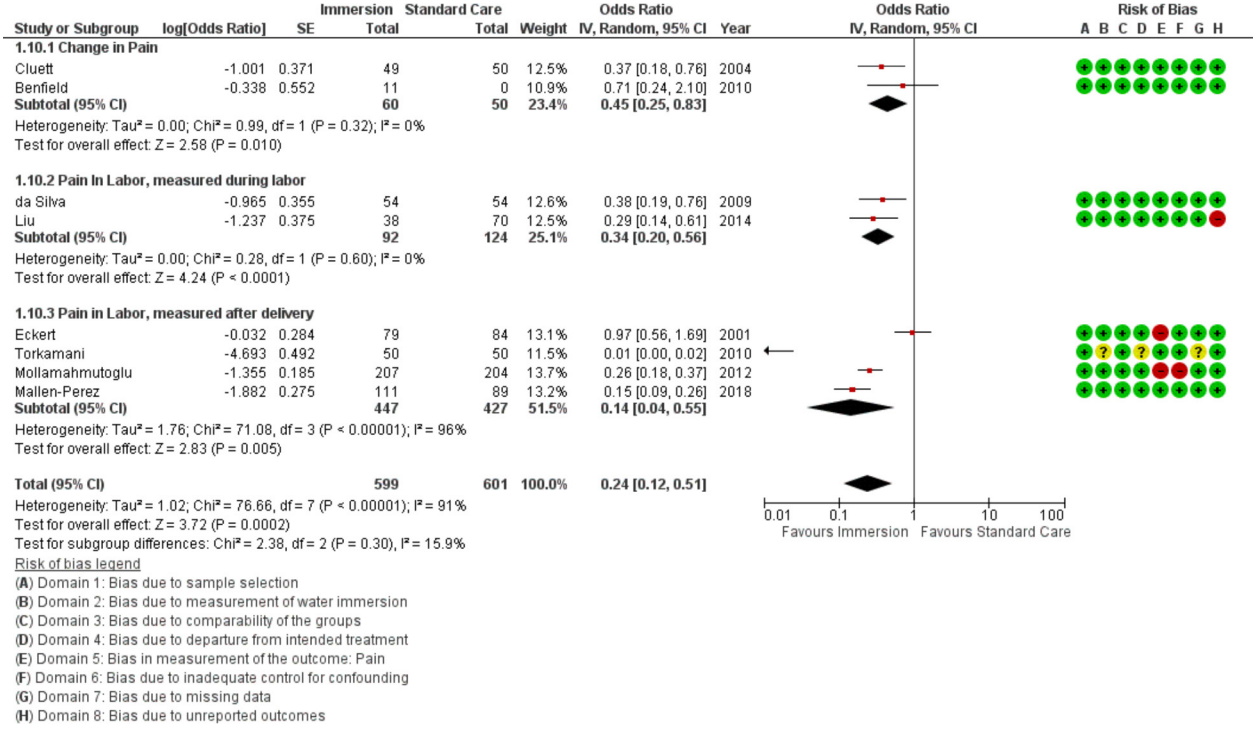

Figure 8 Forest plot of synthesis of pain. IV, inverse variance.

recent studies indicated reduced reports of pain with water immersion. Cumulative meta-analysis indicated the available evidence moved from no difference to favour water immersion in 2009 and has been stable since. Fail-safe analysis estimated 279 studies finding no difference would be necessary to change the estimate from favouring water to no difference.

Caesarean birth

Eight studies provided data on mode of birth comparing water immersion (n=1190) vs standard care (n=1575), all were conducted in an obstetric setting. All but one study reported on the difference in caesarean with water immersion during labour; the final study was an RCT that analysed using intention to treat. The meta-analysis indicated no difference between water immersion and standard care for caesarean birth (OR 0.92 95% CI 0.58 to 1.48; fixed effects; Q=9.0 p=0.249; I^2=23%). Subgroup analysis of studies reporting by year of publication remained no difference. Cumulative meta-analysis indicated this result has been stable at no difference since the first time the outcome was reported in 2001.

Shoulder dystocia

Seven studies provided data that could be synthesised for shoulder dystocia (n=53 367). One additional study reported zero events in the sample and could not be included in the synthesis.[16] There was no difference between water immersion and standard care (OR 0.88 95% CI 0.46 to 1.69; random effects; Q=16 p=0.012; I^2=63%). The subgroup analysis of studies in an obstetric setting and the most recent studies

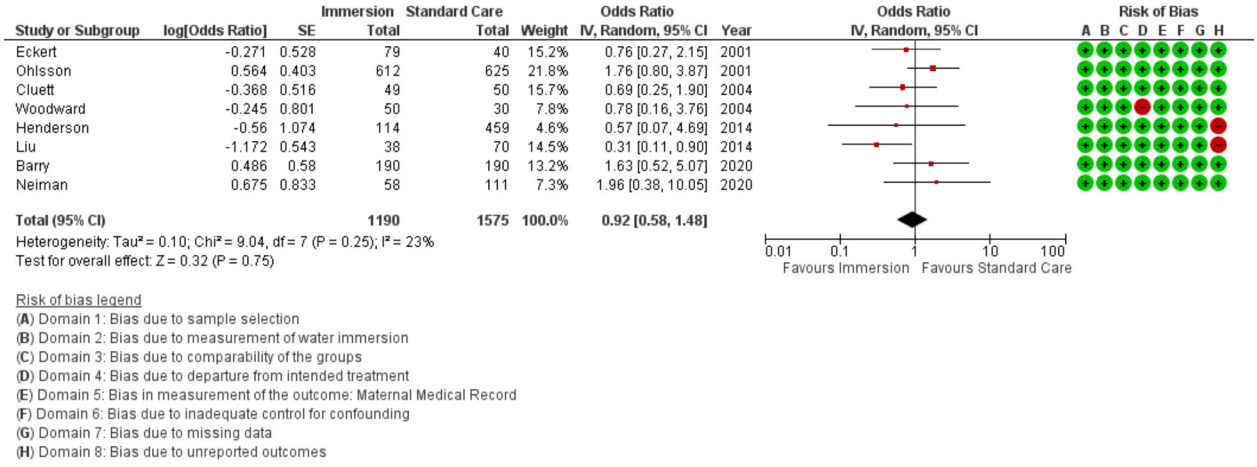

Figure 9 Forest plot of synthesis of caesarean delivery. IV, inverse variance.

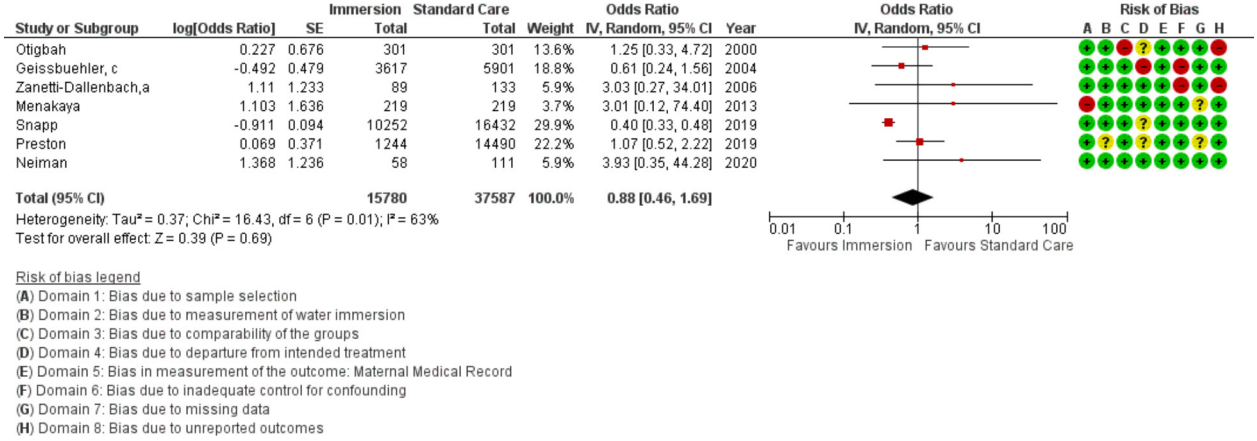

Figure 10 Forest plot of synthesis of shoulder dystocia. IV, inverse variance.

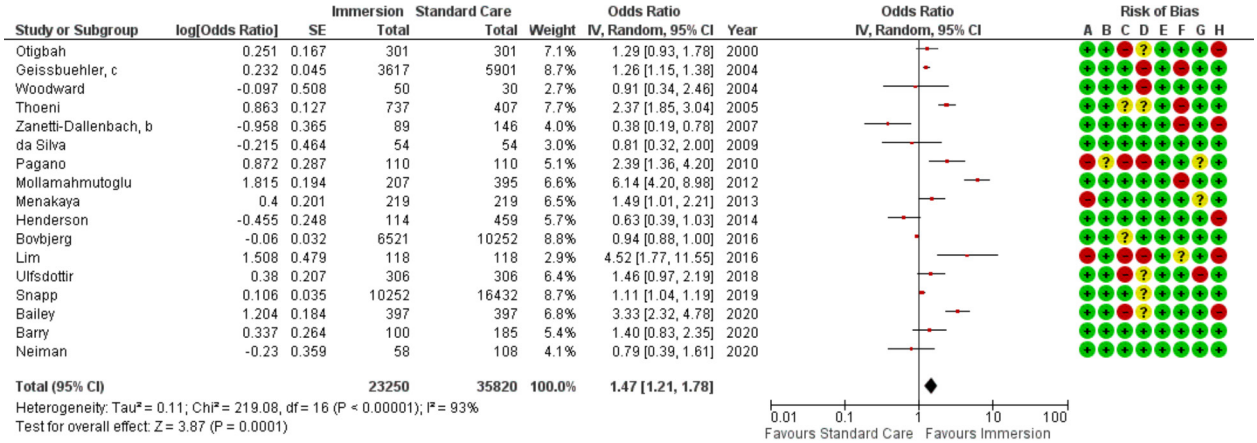

Figure 11 Forest plot of synthesis of intact perineum. IV, inverse variance.

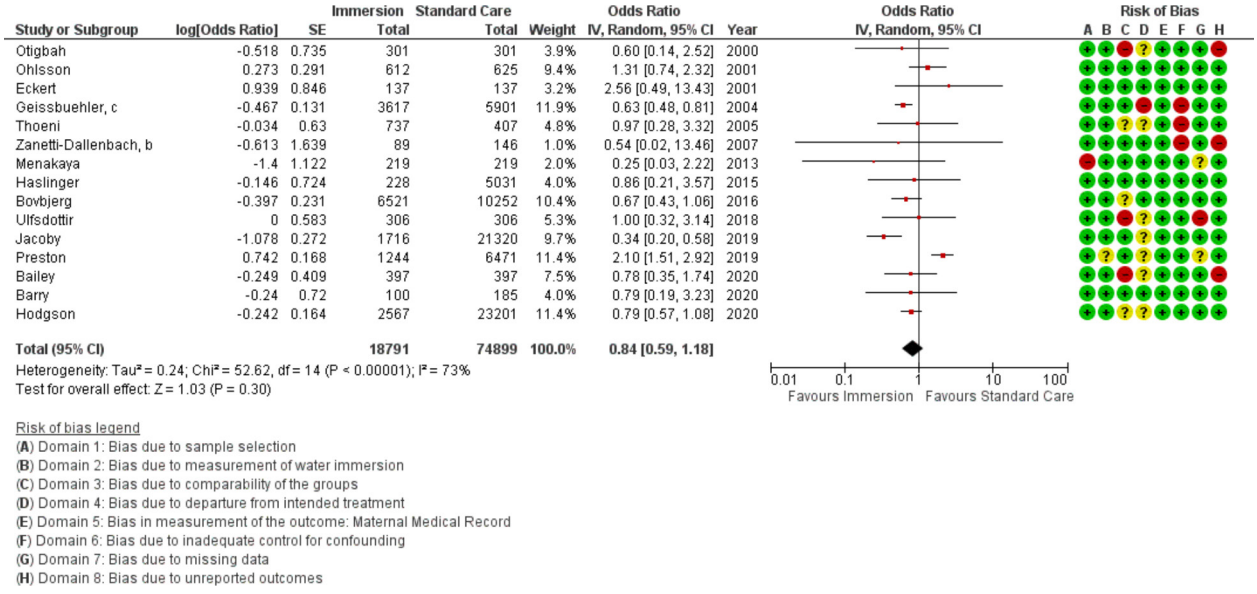

Figure 12 Forest plot of synthesis of obstetric anal sphincter injuries. IV, inverse variance.

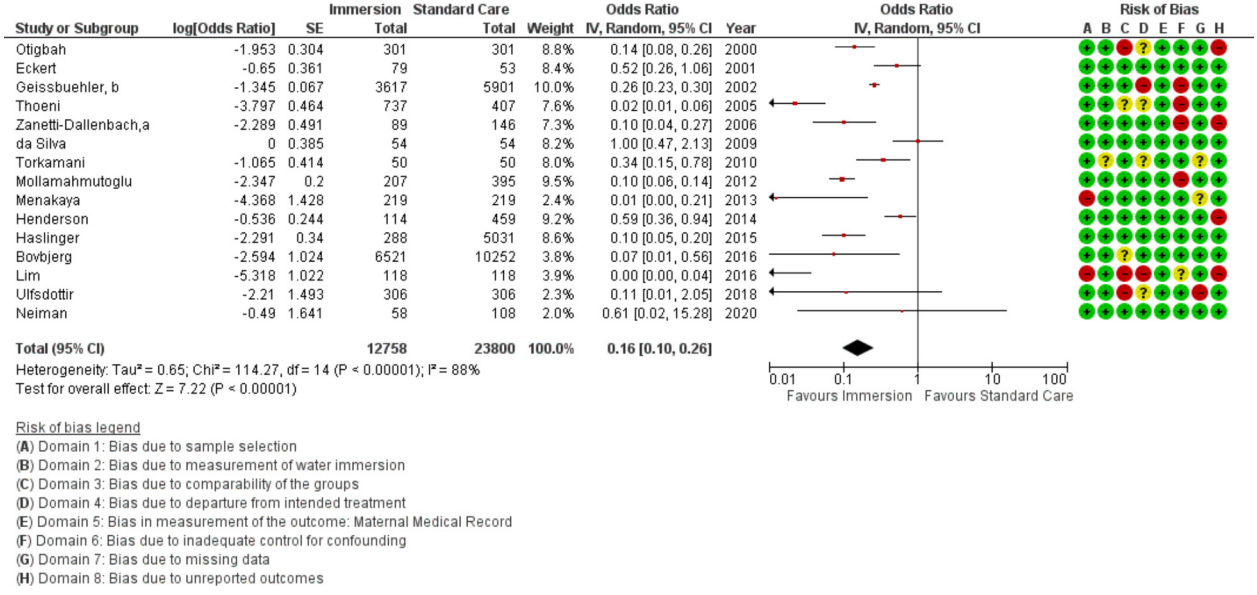

Figure 13 Forest plot of synthesis of episiotomy. IV, inverse variance.

remained no difference. Cumulative meta-analysis indicated there has consistently been no difference.

Intact perineum

Seventeen studies provided data on intact perineum (n=59 070). This analysis favoured water immersion (OR 1.47; 95% CI 1.21 to 1.78; random effects; Q=219.1 p<0.001; I^2=93%). Note the direction of effect for figure 11 reflects that intact perineum is a positive outcome. Subgroup analysis revealed no difference in odds of intact perineum in midwifery-led settings, in studies that compare waterbirth to no immersion. Subgroup analysis revealed higher odds of intact perineum with water immersion in an obstetric setting and in the most recent studies. Cumulative meta-analysis indicated the available evidence has consistently indicated no difference or favoured water immersion, with evidence stable at favouring water immersion since 2016. Fail-safe analysis estimated 358 additional studies finding no difference would be necessary to change the estimate from favouring water to no difference. Subgroup analysis revealed no difference in odds of intact perineum in midwifery-led settings and in favour of water immersion in an obstetric setting.

Meta-regression identified the episiotomy rate (p<0.001) and the proportion of nulliparas in the sample (p=0.001) accounted for the variation in odds of an intact perineum (R^2=1.00). Though only six studies provided the necessary data to test this association, the statistically significant result indicated the analysis was adequately powered to find this association. After accounting for these variables, the result was in favour of water immersion (OR 3.03 95% CI 1.52 to 6.04; random effects; Q=2 p=0.504 I^2=0%).

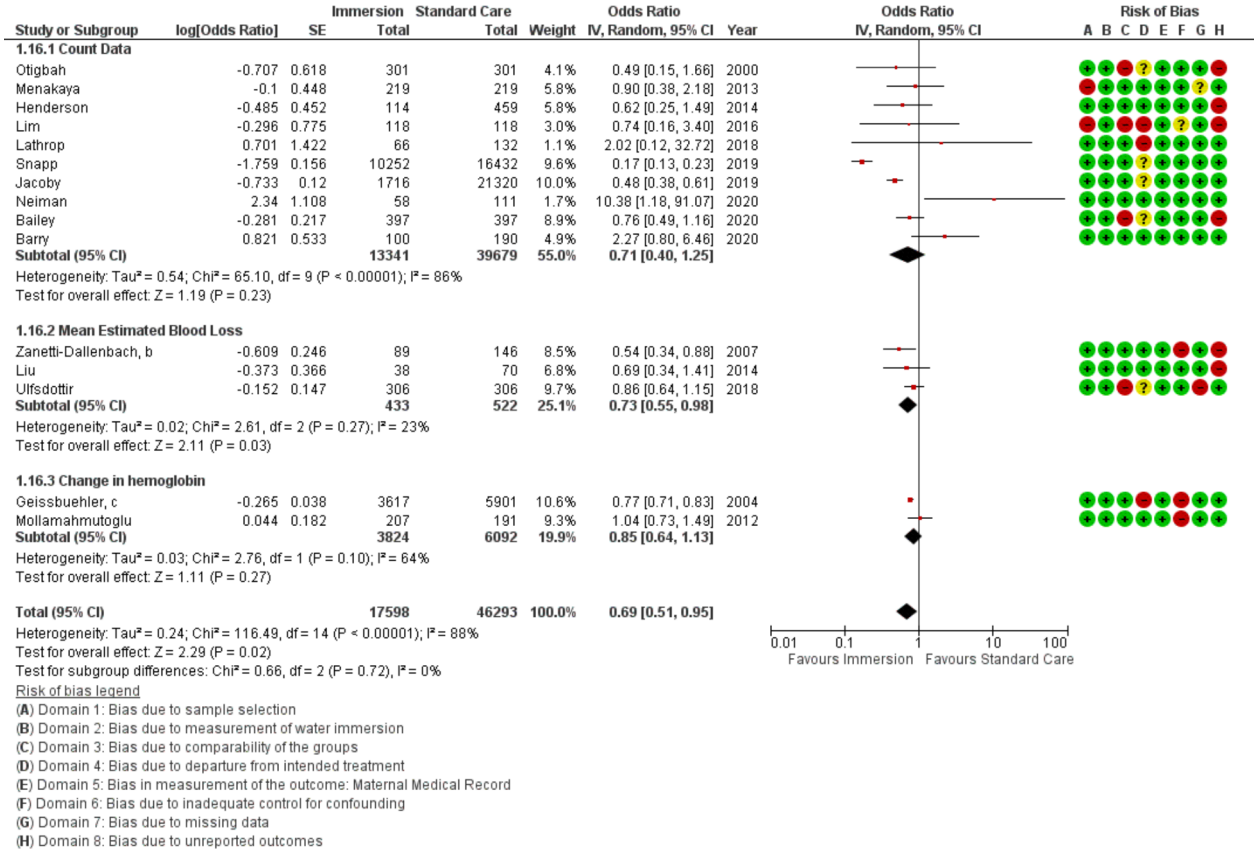

Figure 14 Forest plot of synthesis of postpartum haemorrhage.

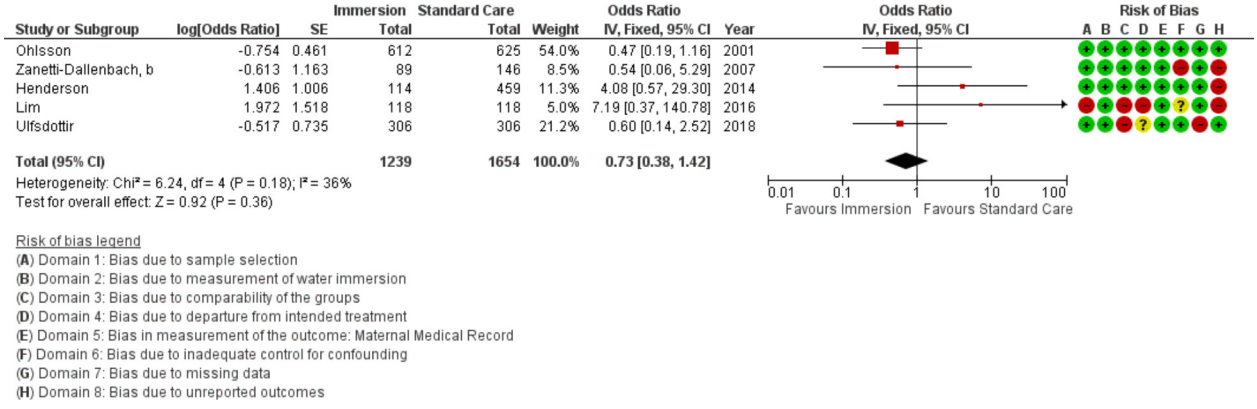

Figure 15 Forest plot of synthesis of manual removal of the placenta. IV, inverse variance.

Obstetric anal sphincter injury

Fifteen studies provided data on OASI (n=93 690). This analysis found no difference (OR 0.84 95% CI 0.59 to 1.18; random effects; Q=52.6 p<0.001; I^2=73%). Cumulative meta-analysis indicated the estimate has moved between no difference and favouring water, with the most recent change to no difference occurring in 2019. Analysis of subgroups by setting found consistent results of no difference in both settings. Meta-regression of the studies with the a priori selected control variables was not able to reduce the heterogeneity.

Episiotomy

Fifteen studies provided data on use of episiotomy (n=36 558). This analysis found reduced use of episiotomy with water immersion (OR 0.16; 95% CI 0.10 to 0.26; random effects; Q=114.3 p<0.001; I^2=88%). Subgroup analysis revealed a reduction with water immersion in an obstetric setting, for nulliparas, and in the most recent studies. Cumulative meta-analysis indicated the available evidence has consistently favoured water immersion. Fail-safe analysis estimated 1525 additional studies finding no difference would be necessary to change the estimate from favouring water to no difference.

Meta-regression of the studies in an obstetric setting indicated the proportion of nulliparas in the sample accounted for some of the variance (R^2=0.76; p=0.001; seven studies). Though this analysis was limited to seven studies, the finding of an association indicates the analysis had adequate power to identify the association. After accounting for the variation

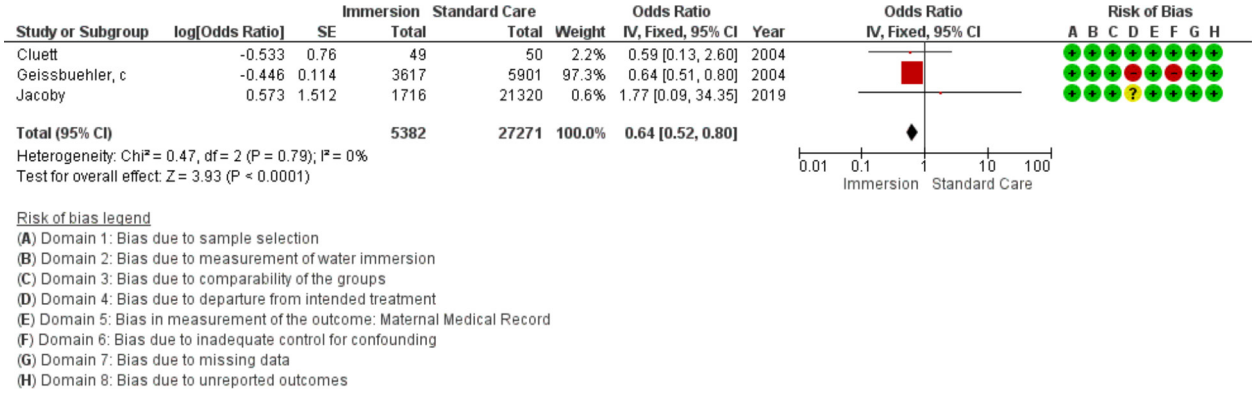

Figure 16 Forest plot of synthesis for maternal infection. IV, inverse variance.

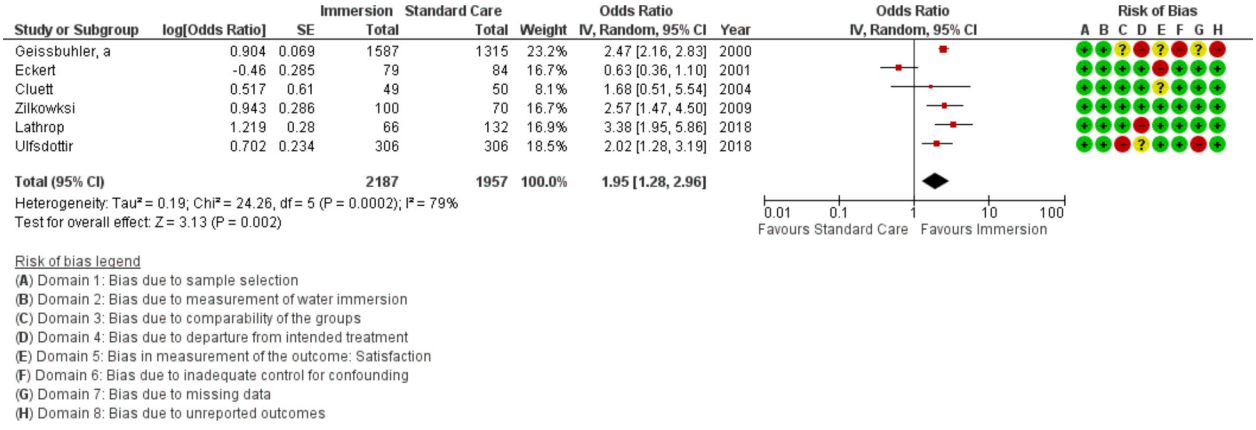

Figure 17 Forest plot of synthesis of maternal satisfaction measures. IV, inverse variance.

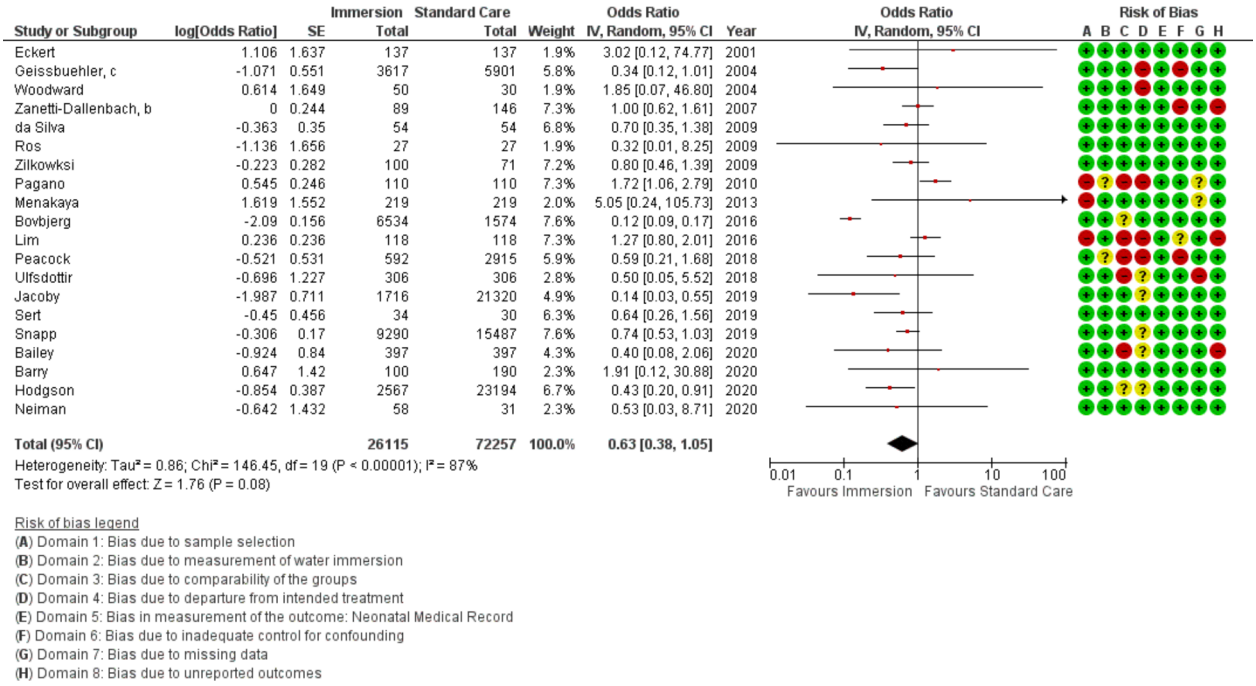

Figure 18 Forest plot of synthesis of 5 min APGAR. IV, inverse variance.

in proportion of nulliparas, the result remained in favour of water immersion (OR 0.04 95% CI 0.01 to 0.13; random effects; Q=12 p=0.038; I^2=57%).

Third-stage management

No studies provided comparison data for third-stage management.

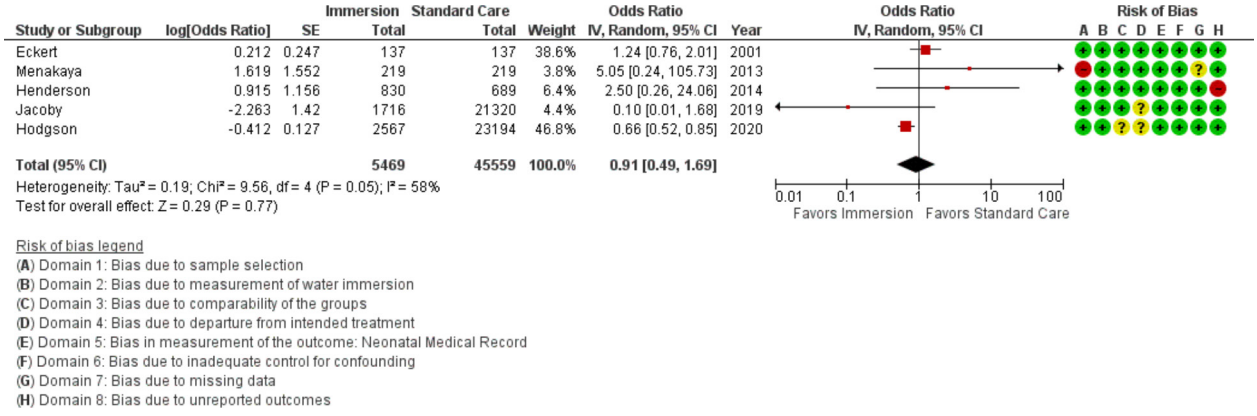

Figure 19 Forest plot of synthesis of neonatal resuscitation. IV, inverse variance.

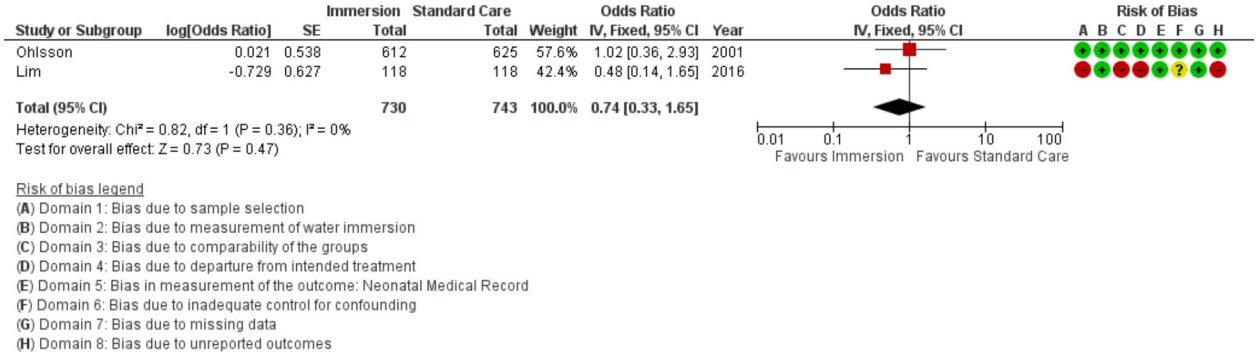

Figure 20 Forest plot of synthesis of transient tachypnoea of the newborn. IV, inverse variance.

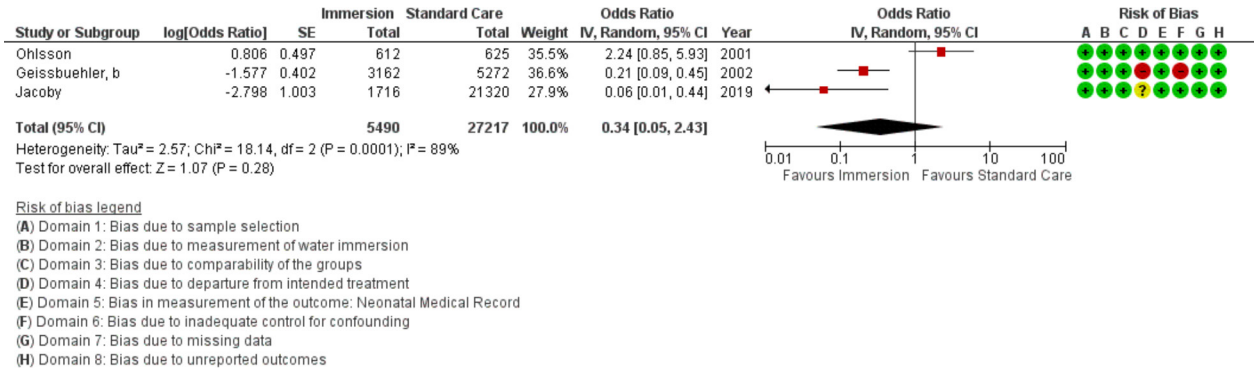

Figure 21 Forest plot of synthesis of respiratory distress. IV, inverse variance.

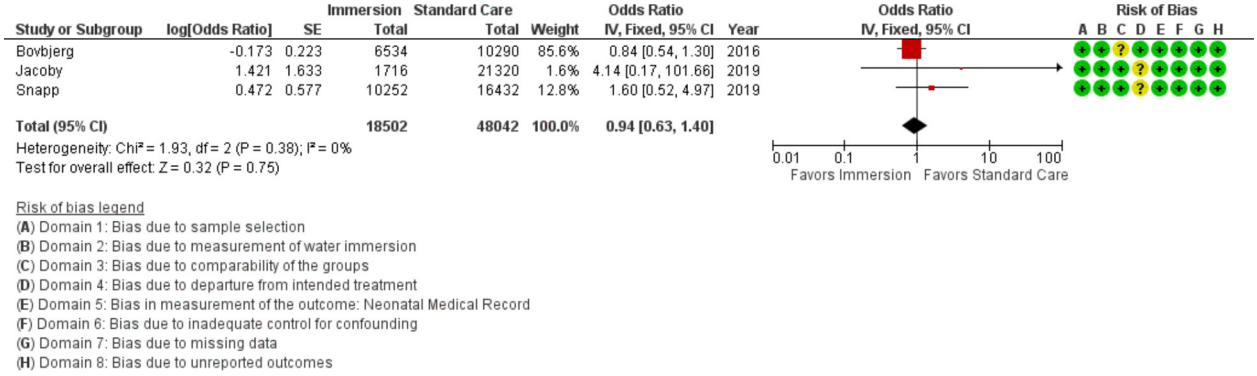

Figure 22 Forest plot of synthesis of neonatal death. IV, inverse variance.

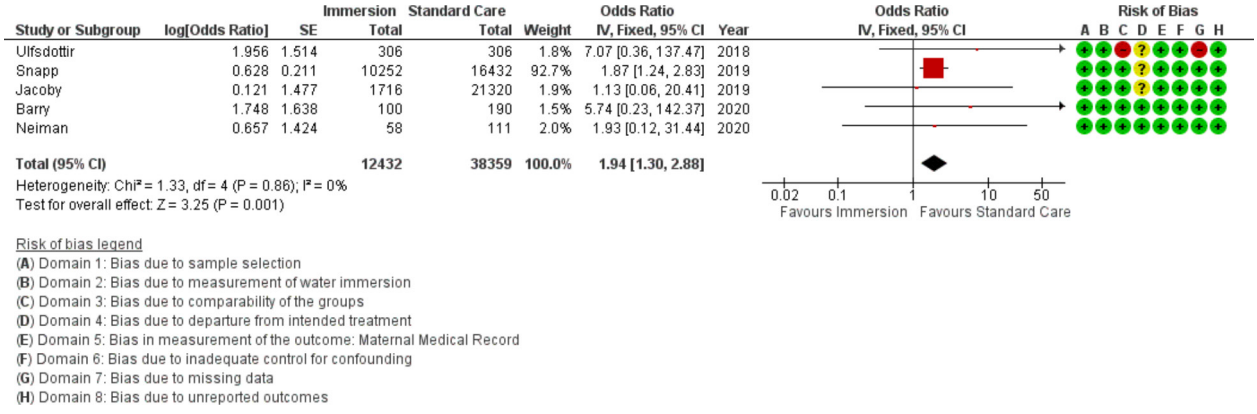

Figure 23 Forest plot of synthesis of cord avulsion. IV, inverse variance.

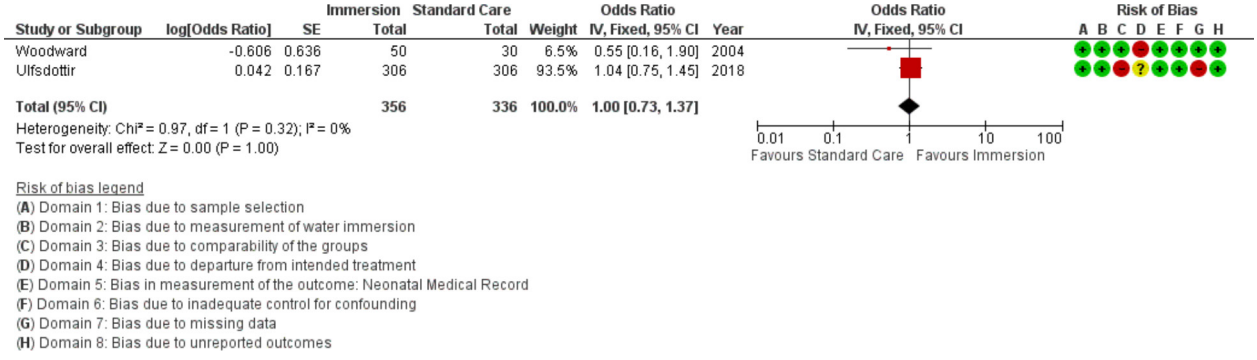

Figure 24 Forest plot of synthesis of breastfeeding initiation. IV, inverse variance.

Postpartum haemorrhage

Fifteen studies provided data about PPH (n=63 891) using three different measures: count of PPH defined as >500 mL blood loss, mean estimated blood loss, and change in haemoglobin. Overall, this analysis favoured water immersion (OR 0.69 95% CI 0.51 to 0.95; random effects; Q=116.5 p<0.001; I^2=88%). Subgroup analysis revealed no difference in odds of PPH in midwife-led settings, in studies comparing waterbirth to no water use, and the most recent studies. Subgroup analysis revealed a reduction with water immersion in an obstetric setting. Cumulative meta-analysis of the random effects model found the available evidence has consistently indicated no difference. Fail-safe analysis estimated 198 additional studies finding no difference would be necessary to change the estimate from favouring water to no difference.

Meta-regression of the studies in an obstetric setting identified no association with induction rate (R^2=0; p=0.777; nine studies). Too few studies provided the data necessary to determine the effect of active management of third stage or the birth of the placenta and membranes into the water.

Manual removal of the placenta

Five studies provided data to assess risk for manual removal of the placenta (n=2893). This analysis indicated no difference (OR 0.73 95% CI 0.38 to 1.42; fixed effects; Q=6.2 p=0.181; I^2=36%). Cumulative meta-analysis indicated there has consistently been no difference in manual removal of the placenta. Subgroup analysis revealed no difference in an obstetric setting and in the most recent studies.

Maternal infection

Three studies provided data about maternal infection (n=32 653), all were conducted in an obstetric setting. This analysis favoured water immersion (OR 0.64 95% CI 0.52 to 0.80; fixed effects; Q=0.5 p=0.792; I^2=0%), however, one study carried 97% of the weight for this synthesis. Fail-safe analysis estimated two additional studies finding no difference would be necessary to change the estimate from favouring water to no difference. Three studies were too few for cumulative meta-analysis.

Maternal satisfaction

Six studies provided data on a measure of maternal satisfaction (n=4144). Due to heterogeneity in measurement tool, this analysis used random effects modelling and results were stratified by measurement tool in the forest plot. This analysis indicated increased satisfaction with water immersion (OR 1.95 95% CI 1.28 to 2.96; random effects; Q=24.3 p<0.001; I^2=33%). Note the direction of effect for figure 17 reflects that maternal satisfaction is a positive outcome. Subgroup analysis revealed increased satisfaction with water immersion in an obstetric setting and in the most recent studies. Cumulative meta-analysis indicated the available evidence moved from no difference to favoured water immersion in 2018. Fail-safe analysis estimated 133 additional studies finding no difference

Table 4 Results of subgroup analysis of interventions on outcomes of water immersion for labour and waterbirth compared with standard care

Outcome	Studies	Sample	Effect OR (95% CI) model	Heterogeneity Q (p) I^2%
Labour Induction*				
Obstetric units	2	604 Immersion 792 Standard care	0.32 (0.06 to 1.58) Random effects	18 (<0.01) 94
Amniotomy*				
Obstetric units	4	306 Immersion 709 Standard care	0.95 (0.62 to 1.46) Random effects	5 (0.17) 40
2010 and earlier	3	192 Immersion 250 Standard care	0.87 (0.46 to 1.64) Random effects	4 (0.13) 51
2011 and later	2	420 Immersion 765 Standard care	0.56 (0.15 to 2.02) Random effects	14 (<0.01) 93
Augmentation*				
Obstetric units	2	203 Immersion 605 Standard care	0.48 (0.16 to 1.51) Random effects	6 (0.02) 83
2011 and later	2	420 Immersion 765 Standard care	0.32 (0.05 to 2.24) Random effects	19 (<0.01) 95
Opioid use				
2010 and earlier	6	4298 Immersion 6565 Standard care	0.23 (0.08 to 0.70) Random effects	95 (<0.01) 95
2011 and later	2	1641 Immersion 14 887 Standard care	0.17 (0.15 to 0.20) Fixed effects	0 (0.54) 0
Epidural*				
Obstetric units	6	4104 Immersion 6889 Standard care	0.26 (0.08 to 0.83) Random effects	89 (<0.01) 94
2010 and earlier	6	4104 Immersion 6889 Standard care	0.26 (0.08 to 0.83) Random effects	89 (<0.01) 94
Pain				
2010 and earlier	3	182 Immersion 188 Standard care	0.53 (0.27 to 1.03) Random effects	6 (0.05) 68
2011 and later	5	417 Immersion 413 Standard care	0.15 (0.06 to 0.42) Random effects	48 (<0.01) 92
Caesarean delivery				
2010 and earlier	4	790 Immersion 745 Standard care	1.05 (0.63 to 1.74) Fixed effects	3 (0.43) 0
2011 and later	4	400 Immersion 830 Standard care	0.84 (0.32 to 2.23) Fixed effects	6 (0.12) 48
Shoulder dystocia				
Obstetric units	6	5528 Immersion 21 155 Standard care	1.06 (0.64 to 1.74) Fixed effects	4 (0.60) 0
2010 and earlier	3	4007 Immersion 6335 Standard care	0.88 (0.42 to 1.83) Fixed effects	2 (0.39) 0
2011 and later	4	11 773 Immersion 31 252 Standard care	0.87 (0.33 to 2.26) Random effects	11 (0.01) 73
Intact perineum				
Obstetric units	14	6170 Immersion 8866 Standard care	1.55 (1.12 to 2.16) Random effects	147 (<0.01) 91
Midwifery-led units	3	17 079 Immersion 23 249 Standard care	1.07 (0.91 to 1.26) Random effects	15 (<0.01) 87

Continued

Table 4 Continued

Outcome	Studies	Sample	Effect OR (95% CI) model	Heterogeneity Q (p) I^2%
Nulliparas	5	1065 Immersion 894 Standard care	1.59 (1.01 to 2.50) Random effects	12 (0.01) 68
Waterbirth versus no water	8	954 Immersion 1696 Standard care	1.35 (0.67 to 2.72) Random effects	83 (<0.01) 92
2010 and earlier	7	4958 Immersion 6949 Standard care	1.28 (0.90 to 1.82) Random effects	39 (<0.01) 85
2011 and later	10	18292 Immersion 28871 Standard care	1.59 (1.22 to 2.07) Random effects	156 (<0.01) 94
OASI				
Obstetric units	13	10720 Immersion 57870 Standard care	0.85 (0.57 to 1.30) Random effects	51 (<0.001) 77
Midwifery-led units	2	6827 Immersion 10558 Standard care	0.71 (0.47 to 1.08) Fixed effects	0 (0.527) 0
Nulliparas	2	870 Immersion 540 Standard care	1.25 (0.42 to 3.71) Fixed effects	1 (0.385) 0
Waterbirth versus no water	3	408 Immersion 550 Standard care	0.57 (0.19 to 1.69) Fixed effects	1 (0.681) 0
2010 and earlier	6	5493 Immersion 7517 Standard care	0.73 (0.58 to 0.91) Fixed effects	8 (0.16) 37
2011 and later	9	13298 Immersion 67382 Standard care	0.78 (0.48 to 1.28) Random effects	42 (<0.01) 81
Episiotomy*				
Obstetric units	14	6177 Immersion 13548 Standard care	0.17 (0.11 to 0.28) Random effects	109 (<0.001) 88
Nulliparas	3	886 Immersion 582 Standard care	0.10 (0.02 to 0.60) Random effects	14 (<0.001) 86
Waterbirth versus no water	5	691 Immersion 1022 Standard care	0.63 (0.02 to 0.20) Random effects	14 (0.008) 71%
2010 and earlier	7	4927 Immersion 6912 Standard care	0.21 (0.11 to 0.41) Random effects	52 (<0.01) 88
2011 and later	8	7831 Immersion 16888 Standard care	0.09 (0.03 to 0.25) Random effects	53 (<0.01) 87
Postpartum faemorrhage				
Obstetric units	13	7040 Immersion 29555 Standard care	0.75 (0.60 to 0.94) Random effects	30 (0.002) 60
Midwifery-led units	2	10558 Immersion 16738 Standard care	0.39 (0.08 to 1.86) Random effects	56 (<0.001) 98
Waterbirth versus no mater	5	758 Immersion 1177 Standard care	1.02 (0.76 to 1.36) Fixed effects	4 (0.439 0
2010 and earlier	3	4007 Immersion 6348 Standard care	0.72 (0.59 to 0.88) Random effects	2 (0.30) 17
2011 and later	12	13591 Immersion 39945 Standard care	0.76 (0.48 to 1.20) Random effects	97 (<0.01) 89
Manual removal of placenta				
Obstetric units	4	1239 Immersion 1654 Standard care	0.78 (0.37 to 1.64) Fixed effects	6 (0.105) 51
2010 and earlier	2	701 Immersion 771 Standard care	0.48 (0.21 to 1.11) Fixed effects	0 (0.91) 0
2011 and later	3	538 Immersion 883 Standard care	1.48 (0.50 to 4.38) Fixed effects	4 (0.16) 45

Continued

Table 4 Continued

Outcome	Studies	Sample	Effect OR (95% CI) model	Heterogeneity Q (p) I^2%
Maternal satisfaction				
Obstetric units	5	1802 Immersion 1568 Standard care	2.02 (1.28 to 3.19) Random effects	24 (<0.01) 83
2010 and earlier	4	1815 Immersion 1519 Standard care	1.64 (0.83 to 3.24) Random effects	22 (<0.01) 86
2011 and later	2	372 Immersion 438 Standard care	2.55 (1.54 to 4.23) Random effects	2 (0.16) 50
APGAR				
Obstetric units	18	10286 Immersion 54361 Standard care	0.85 (0.66 to 1.08) Random effects	29 (0.047) 38
Midwifery-led units	3	17092 Immersion 18,31 Standard care	0.33 (0.07 to 1.54) Random effects	57 (<0.001) 96
Waterbirth versus no water	6	614 Immersion 655 Standard care	1.07 (0.76 to 1.51) Fixed effects	3 (0.643) 0
2010 and earlier	8	4184 Immersion 6476 Standard care	1.00 (0.77 to 1.29) Fixed effects	7 (0.120) 39
2011 and later	12	21931 Immersion 65781 Standard care	0.52 (0.25 to 1.05) Random effects	101 (<0.001) 89
Neonatal death				
Midwifery-led units	2	16786 Immersion 26722 Standard care	0.91 (0.61 to 1.34) Fixed effects	1 (0.297) 8
Cord avulsion				
Obstetric units	3	1874 Immersion 21621 Standard care	2.18 (0.34 to 11.97) Fixed effects	1 (0.757) 0
Midwifery-led units	2	10649 Immersion 16829 Standard care	1.92 (1.28 to 2.89) Fixed effects	1 (0.386) 0

*Random effects models were used for intervention (labour induction, amniotomy, augmentation, epidural, and episiotomy) models because variation in use of these procedures is dependent on practice habits of the provider which are not otherwise controlled.
OASI, obstetric anal sphincter injury.

would be necessary to change the estimate from favouring water to no difference.

Five min APGAR

Twenty-one studies provided data for 5 min APGAR (n=98 372). This analysis found no difference (OR 0.63 95% CI 0.38 to 1.05; random effects; Q=146.5 p<0.001; I^2=87%). Three additional studies reported on 5 min APGAR but did not provide data in a usable format; two found no difference[47 52] and one reported in favour of water immersion.[60] Analysis of subgroups found consistent results of no difference. Cumulative meta-analysis indicated the available evidence has consistently demonstrated no difference.

Meta-regression indicated that study setting accounted for some between-study variance (R^2=0.85; p=0.001; nine studies). After accounting for setting the analysis favoured water immersion (OR 0.14 95% CI 0.06 to 0.36; random effects; Q=20 p=0.034; I^2=50%).

Newborn resuscitation

Five studies provided data on newborn resuscitation (n=51 028), all were conducted in an obstetric setting. This analysis found no difference (OR 0.91; 95% CI 0.49 to 1.69; random effects; Q=9.6 p=0.048; I^2=58%. Cumulative meta-analysis indicated this outcome has been stable at no difference since first reported.

Transient tachypnoea of the newborn

Two studies provided data on transient tachypnoea of the newborn (n=1473), both were conducted in an obstetric setting. This analysis found no difference (OR 0.74; 95% CI 0.33 to 1.65; fixed effects; Q=0.8 p=0.364; I^2=0%). Too few studies were available to conduct cumulative meta-analysis and subgroup analysis.

Respiratory distress of the newborn

Three studies provided data on respiratory distress of the newborn (n=32 707), all were conducted in an obstetric setting. This analysis indicated no difference (OR 0.34; 95% CI 0.05 to 2.43; random effects; Q=18.1 p<0.001;

I^2=89%). Three studies were too few for cumulative meta-analysis.

NICU admission

No studies met the definition for NICU admission.

Neonatal death

Three studies provided data on neonatal death (n=66 544), all were published after 2010. This analysis indicated no difference (OR 0.94; 95% CI 0.63 to 1.40; fixed effects; Q=1.9 p=0.381; I^2=0%). Subgroup analysis by setting revealed no difference in midwifery-led settings. Three studies were too few for cumulative meta-analysis.

Infection in newborn period

Only one study met the definition for reporting newborn infection; it reported no difference.

Cord avulsion

Five studies provided data on cord avulsion (n=50 791), all were published after 2010. This analysis favoured standard care (OR 1.94 95% CI 1.30 to 2.88; fixed effects; Q=1.3 p=0.856; I^2=0%). One study was responsible for 92.7% of the weight of this analysis, when that study was removed the result became no difference (OR 2.92 95% CI 0.67 to 12.77). Subgroup analysis by setting found no difference in an obstetric setting, but increased odds of cord avulsion in midwifery-led settings. Cumulative meta-analysis indicated the estimate moved from no difference to favour standard care in 2019. Fail-safe analysis estimated five additional studies would be needed to change the estimate to no difference.

Breastfeeding initiation

Two studies provided data on breastfeeding initiation (n=692). This analysis found no difference (OR 1.00 95% CI 0.73 to 1.37; fixed effects; Q=1.0 p=0.325; I^2=0%). Note the direction of effect for figure 24 reflects that breastfeeding initiation is a positive outcome. Two studies were too few for cumulative meta-analysis and subgroup analysis.

Risk of bias across studies

Risk of bias analysis results are available in table 5. Begg's test has moderate power with 25 studies, so is underpowered to find publication bias for this review. Egger's regression identified risk for publication bias in three outcomes: epidural, intact perineum and shoulder dystocia. In each case, trim-and-fill estimates of the magnitude of bias indicate the magnitude was too small to affect the results.

DISCUSSION

The main findings of this systematic review and meta-analysis are that labouring and/or giving birth in water has clear benefits to women in the obstetric setting. These findings are interesting because, in general, healthy women are more likely to experience interventions and adverse outcomes in this setting compared with midwifery-led settings and this has been reported for women who labour and/or give birth in water.[3 66–68] Given that globally, most births take place in the obstetric setting, this review shows that water immersion can significantly increase the likelihood of an intact perineum and reduce episiotomy; an intervention which offers no perineal or fetal benefit, can increase postnatal pain, anxiety and impact negatively on a woman's birth experience.[69 70] Furthermore, labouring and/or giving birth in water does not increase the likelihood of OASI, which corroborates previous waterbirth research.[7 71 72] A significant PPH reduction was another important finding, which is also supported in the literature.[73]

In this study, there was no difference in caesarean birth rate between those who used water and those who did not. Interestingly, the caesarean rate in these studies was 3.6%, with all but two studies reporting a caesarean birth rate of less than 10% for the study participants. Given the low caesarean rates reported by most studies, these results should not be generalised to settings with a caesarean rate higher than 10% for women considered low risk. The study with a caesarean rate of 19% is not generalisable to settings with a low-risk caesarean birth rate higher than 10% because it compared the use of water immersion to medical augmentation for women with a stalled labour.[34] One study with a caesarean rate of 26% is generalisable to settings with a higher low-risk caesarean birth rate.[46]

Our results for newborns mirror those reported in three substantial newborn specific systematic reviews.[10–12] Additionally, this study improved on prior research, which was limited by variations in definition for reporting newborn infection and NICU admission. The more rigorous definitions used for this study reveals limited reporting of serious complications. Given the lack of association with poor newborn outcomes between this study and prior analyses, it is unlikely that differences in prevalence of serious complications between water immersion and standard care exist.

More cord avulsions were reported for waterbirths and may relate to possible undue traction on the umbilical cord as the newborn is brought up out of the water.[3 74] The incidence of cord avulsion was 4.3 per 1000 births in water compared with 1.3 per 1000 births with standard care. Interestingly, the incidence of cord avulsion varied from 0.2 per 1000 to 11.8 per 1000 in the five studies that reported this outcome, suggesting individual practice characteristics are more relevant to the incidence of cord avulsion than whether the birth occurs in water. A review of case reports of poor newborn outcomes found that when reported, cord avulsion was easily managed by the midwife with no consequences for the newborn.[75]

Our results show that water immersion has the potential to make a meaningful contribution to the global agenda towards promoting physiological birth.[76–80] Labouring and/or giving birth in water can reduce maternal pain with no increased risk of an adverse event, and without the risk introduced by epidural and opioids.[81–84] Differences between birth settings in intact perineum and PPH

Table 5 Analysis of risk of bias across studies comparing water immersion for labour and waterbirth to standard care

Outcome	K	Begg's test rank correlation S-statistic (P)	Egger's regression Intercept (P)	Trim-and-fill direction of bias* OR (95% CI)
Amniotomy	5	4 (0.164)	5.04 (0.129)	Standard care 0.43 (0.34 to 0.53)
Induction	3	−3 (0.059)	−10 (0.238)	–
Augmentation	3	3 (0.59)	28.96 (0.057)	Standard care 0.12 (0.09 to 0.16)
Opioid	8	−2 (0.402)	2.13 (0.197)	Standard care 0.17 (0.15 to 0.19)
Epidural	7	−9 (0.088)	−4.51 (0.039)	Immersion 0.67 (0.54 to 0.83)
Caesarean	8	−2 (0.402)	−0.74 (0.327)	–
Pain	8	0 (0.500)	−1.67 (0.339)	Standard care 0.16 (0.07 to 0.37)
Satisfaction	6	−5 (0.174)	−1.26 (0.216)	Immersion 1.73 (1.13 to 2.64)
Intact perineum	14	−10 (0.340)	2.13 (0.045)	Standard care 1.71 (1.40 to 2.10)
Episiotomy	13	−11 (0.274)	−1.27 (0.121)	Immersion 0.20 (0.13 to 0.32)
OASI	14	3 (0.435)	0.40 (0.234)	Standard care 0.64 (0.50 to 0.82)
Shoulder dystocia	7	5 (0.226)	1.85 (0.001)	Standard care 0.68 (0.38 to 1.21)
Maternal infection	3	–	0.34 (0.290)	–
Postpartum haemorrhage	13	9 (0.328)	−0.23 (0.412)	Standard care 0.52 (0.39 to 0.71)
Retained placenta	5	6 (0.071)	2.11 (0.068)	Standard care 0.76 (0.29 to 2.03)
APGAR	16	−34 (0.179)	0.86 (0.209)	Standard care 0.59 (0.36 to 0.96)
Neonatal resuscitation	5	2 (0.312)	0.69 (0.282)	–
Transient tachypnoea	2	–	–	–
Respiratory distress	3	1 (0.301)	−1.77 (0.426)	–
Neonatal death	3	1 (0.301)	1.34 (0.078)	Standard care 0.84 (0.53 to 1.33)
Cord avulsion	5	6 (0.071)	0.36 (0.182)	Standard care 1.86 (1.26 to 2.75)
Breastfeeding initiation	2	–	–	–

*Trim-and-fill analysis conducted with random effects model and indicates ORs and 95% CI estimate if bias were corrected.
OASI, obstetric anal sphincter injury.

suggest water immersion in an obstetric setting may result in outcomes similar to those achieved in midwifery-led settings. This interpretation is supported by the results of subgroup analysis of studies in an obstetric setting that episiotomy is reduced with water immersion, and maternal satisfaction is increased. Given these results, water immersion for labour and waterbirth is an intervention that can be used to achieve physiological birth and improve the quality of care in the obstetric setting.

One major issue that hindered the potential of this review was that only four studies were conducted in midwifery-led settings. None of the included studies described the care model in operation where the study participants laboured. Healthy women who give birth in a midwifery-led setting are more likely to experience fewer interventions and adverse outcomes compared with those who give birth in an obstetric setting, particularly nullipara.[2 3] There is strong evidence showing that the

relational element of care matters to service users, and continuity of carer/care is linked to fewer interventions and adverse outcomes when compared with fragmented care models.[84] This is important because birth pool use is most prevalent in midwifery-led settings.[3] Evidence-based practice of water immersion requires research that reflects the context of care provision.

Few studies provided information generally considered to be relevant to the outcomes reported or controlled for potential confounders. Just over half the studies (k=20, 55%) included some description of the birth pool(s), resulting in uncertainty about whether all participants could move around and adopt different positions with ease. Furthermore, studies did not specify the type of fetal monitoring. Since intermittent auscultation does not inhibit mobility, and continuous electronic fetal monitoring typically does, this could present a confounder. Few studies stratified for parity, even when the outcomes reported occur at higher rates among nullipara. Only six studies (17%) mentioned inclusion of induction of labour while five studies included women with a prior caesarean. Only eight studies (22%) provided birth pool eligibility criteria regarding raised BMI. These studies did not include BMI as a characteristic in their analysis for interventions or outcomes. However, their inclusion in the study populations suggest that water immersion is not considered to be harmful for women who have raised BMI but are otherwise healthy. No studies provided data for the management of the third stage of labour in the studies, to enable examination for any associations between active or physiological management and PPH. Improvements in reporting standards would enable expansion of populations considered appropriate for water immersion and identify best practice for birth pool use.

Strengths and limitations of this work

This was the first substantial systematic review to attempt to include birth setting as an analytic variable. A broad search strategy was developed and all review processes were conducted by at least two reviewers. This study incorporated meta-regression, using covariates identified a priori, to reduce the effect of sources of heterogeneity. The inclusion of analyses of the stability of the results, cumulative meta-analysis and fail-safe, add value to the synthesis by identifying which outcomes may be considered sufficiently researched. The results are further strengthened by use of a trim-and-fill analysis to identify the direction of any potential publication bias.

This review was limited to studies published during or after 2000 or later because earlier studies may not be generalisable to current water immersion practices. This review did not include grey literature, and was limited by language; the search was conducted in English using English-language indices. This analysis was limited to a priori variables for meta-regression. Additional variables, not tested in this study, may contribute to heterogeneity. Inconsistency of reporting on birth setting, care practices, interventions and outcomes prevented us from achieving our secondary objective to account for intrapartum care variation. Meta-regression was only possible for three outcomes: intact perineum, episiotomy and PPH.

Clinical implications

Water immersion provides benefits for the mother and newborn when used in the obstetric setting, making water immersion a low-tech intervention for improving quality and satisfaction with care. In addition, water immersion during labour and waterbirth alter clinical practice resulting in less augmentation, episiotomy and requirements for pharmacological analgesia. Water immersion is an effective method to reduce pain in labour, without increasing risk. Clinicians should be mindful to avoid putting undue traction on the umbilical cord when bringing the newborn to the surface of the water.

Research implications

Water immersion during labour and birth is a low-tech yet complex, nuanced intervention. We suggest that studies incorporate the following fundamentals to advance the evidence: birth pool description, clearly described maternal and obstetric characteristics, the birth setting, the care model and use of standardised definitions. Studies should report potential confounders such as hands-on or hands-off the perineum and third-stage management. When appropriate for the outcome, results should be stratified by maternal parity. The study population should reflect all those now using a birth pool, not just the healthy women who experience an uncomplicated pregnancy. There is a need for additional research conducted in midwifery-led settings to establish best practice.

CONCLUSION

Water immersion during labour and birth, while low-tech, is a complex, nuanced intervention. Importantly it has clear benefits for healthy women and their newborns when in the obstetric unit setting where the majority of women give birth, and may have benefits for populations previously excluded from water immersion. To enable the identification of best practice regarding water immersion, future birthing pool research should integrate factors that are known to influence intrapartum interventions and outcomes. These include maternal parity, the care model, care practices, birth setting and a clear description of the water immersion receptacle.

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Supplement 1 Search Information

Pre-designed search terms

Population	Primip* OR nullip* OR multip* OR term gestation* OR intra?partum OR birth* OR childbirth OR labo?r* OR parturition OR planned place birth* OR childbearing wom?n OR expectant wom?n OR expectant mother* OR labo?ring wom?n OR wom?n in labo?r
Intervention/Exposure water	Water OR water?birth OR water birth OR water immersion OR hydrotherapy OR birth* pool OR birth in water OR birth in pool
Interventions during labour	Rupture membrane* OR spontaneous* OR artificial* OR augment*OR induc* OR epidural* OR oxytocin infusion OR opioid injection* OR transfer* OR transfer obstetric unit* OR electronic monitor* OR EFM OR cardiotocograph* OR auscultat* OR intermediate auscultate* OR physiological third stage OR expectant third stage OR physiological 3rd stage OR expectant 3rd stage OR managed third stage OR managed 3rd stage OR active third stage OR active 3rd stage OR placenta delivery OR delivery of the placenta
Outcomes Maternal	spontaneous vaginal birth* OR spont* delivery OR perine* OR perineal OR trauma* OR anal sphincter OR OASIS OR obstetric anal sphincter injur* OR episiotom* OR postpartum h?emorrhage* OR PPH OR h?emorrhage* OR blood transfusion* OR blood product* OR red blood cell* OR infection* OR sepsis OR admission* OR readmission* OR pain OR numerical rating scales OR NRS OR visual analog scales OR VAS OR maternal health OR wom?n health
Outcomes Neonatal	birthweight* OR gestation* OR Apgar score* OR resus* OR resuscitation OR ventilation* OR respiratory OR distress* OR transfer* OR transfer obstetric unit* OR paed* OR neonat* OR neonatal unit OR special care unit* OR antibiotic* OR admission* OR readmission* OR breastfeeding OR infection* OR sepsis OR antibiotic* OR new?born health OR neonat* health
Time	Intrapartum OR intra?partum OR birth* OR child?birth OR labo?r* OR post?natal OR post?partum OR puerperium*

Pilot Search Terms

Population: Primip* OR nullip* OR multip* OR parturient OR birth* wom?n
Exposure : Water OR waterbirth OR water birth OR water immersion OR immersion OR hydrotherapy OR birth* pool OR tub
Time: Intrapartum OR intra-partum OR birth* OR childbirth OR labour* OR labor* OR parturition OR dilatation OR expulsion OR delivery of the placenta OR first stage OR second stage OR third stag

Librarian Search Term Input

BNI (via Proquest)
S1 ab(Intrapartum OR intra-partum OR labor OR laboring OR labour OR labouring OR deliver* OR childbirth* OR birth* OR parturition) OR ti(Intrapartum OR intra-partum OR labor OR laboring OR labour OR labouring OR deliver* OR childbirth* OR birth* OR parturition) 98,180
S2 MAINSUBJECT.EXACT("Childbirth & labor") 12,308
S3 S1 OR S2 100,458
S4 ab((Water N/3 birth) OR waterbirth OR water-birth OR (birth* N/3 tub) OR (birth*N/3 pool*) OR (water N/3 immersion)) OR ti((Water N/3 birth) OR waterbirth OR water-birth OR (birth* N/3 tub) OR (birth* N/3 pool*) OR (water N/3 immersion)) 501
S5 S3 AND S4 424

CINAHL (via Ebscohost)
S1 TI (Intrapartum OR intra-partum OR labor OR laboring OR labour OR labouring OR deliver* OR childbirth* OR birth* OR parturition) OR AB (Intrapartum OR intra-partum OR labor OR laboring OR labour OR labouring OR deliver* OR childbirth* OR birth* OR parturition) 252,840
S2 (MH "Childbirth+") OR (MH "Labor+") 36,176
S3 S1 OR S2 263,207
S4 TI ((Water N3 birth) OR waterbirth OR water-birth OR (birth* N3 tub) OR (birth* N3 pool*) OR (water N3 immersion)) OR AB ((Water N3 birth) OR waterbirth OR water-birth OR (birth* N3 tub) OR (birth* N3 pool*) OR (water N3 immersion)) 1,264
S5 (MH "Water Birth") 600
S6 S4 OR S5 1,572
S7 S3 AND S6 824

PsycInfo (via Ebscohost)
S1 TI (Intrapartum OR intra-partum OR labor OR laboring OR labour OR labouring OR deliver* OR childbirth* OR birth* OR parturition) OR AB (Intrapartum OR intra-partum OR labor OR laboring OR labour OR labouring OR deliver* OR childbirth* OR birth* OR parturition) 187,428
S2 DE "Intrapartum Period" OR DE "Birth" OR DE "Labor (Childbirth)" OR DE "Natural Childbirth" OR DE "Premature Birth" 14,070
S3 S1 OR S2 190,598
S4 TI ((Water N3 birth) OR waterbirth OR water-birth OR (birth* N3 tub) OR (birth* N3 pool*) OR (water N3 immersion)) OR AB ((Water N3 birth) OR waterbirth OR water-birth OR (birth* N3 tub) OR (birth* N3 pool*) OR (water N3 immersion)) 461
S5 S3 AND S4 68

Medline (via Ebscohost)
S1 TI (Intrapartum OR intra-partum OR labor OR laboring OR labour OR labouring OR deliver* OR childbirth* OR birth* OR parturition) OR AB (Intrapartum OR intra-partum OR labor OR laboring OR labour OR labouring OR deliver* OR childbirth* OR birth* OR parturition) 971,137

S2 (MH "Parturition+") OR (MH "Labor, Obstetric+") 60,186

S3 S1 OR S2 989,569

S4 TI ((Water N3 birth) OR waterbirth OR water-birth OR (birth* N3 tub) OR (birth* N3 pool*) OR (water N3 immersion)) OR AB ((Water N3 birth) OR waterbirth OR water-birth OR (birth* N3 tub) OR (birth* N3 pool*) OR (water N3 immersion)) 6,075

S5 S3 AND S4 892

CINAHL Search

Accessibility Information and TipsRevised Date: 07/2015

Print Search History

Monday, March 09, 2020 9:20:23 AM

#	Query	Limiters/Expanders	Last Run Via	Results
S8	((MH water birth) OR (S4 OR S5)) AND (S3 AND S6)	Limiters - Published Date: 20000101-20201231 Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	719
S7	((MH water birth) OR (S4 OR S5)) AND (S3 AND S6)	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	826

S6	(MH water birth) OR (S4 OR S5)	Expanders - Apply equivalent subjects	Interface - EBSCOhost Research Databases	1,577
		Search modes - Boolean/Phrase	Search Screen - Advanced Search	
			Database - CINAHL	
S5	MH water birth	Expanders - Apply equivalent subjects	Interface - EBSCOhost Research Databases	602
		Search modes - Boolean/Phrase	Search Screen - Advanced Search	
			Database - CINAHL	
S4	TI water N3 birth OR TI (waterbirth or water-birth) OR TI birth* N3 tub OR TI birth* N3 pool* OR TI water N3 immersion OR AB water N3 birth OR AB (waterbirth or water-birth) OR AB birth* N3 tub OR AB birth* N3 pool* OR AB water N3 immersion	Expanders - Apply equivalent subjects	Interface - EBSCOhost Research Databases	1,270
		Search modes - Boolean/Phrase	Search Screen - Advanced Search	
			Database - CINAHL	
S3	(((MH childbirth+ OR MH labor+) OR (S1 OR S2)) AND (S1 OR S2)) AND (S1 OR S2)	Expanders - Apply equivalent subjects	Interface - EBSCOhost Research Databases	263,754
		Search modes - Boolean/Phrase	Search Screen - Advanced Search	
			Database - CINAHL	
S2	MH childbirth+ OR MH labor+	Expanders - Apply equivalent subjects	Interface - EBSCOhost Research Databases	36,225
		Search modes - Boolean/Phrase	Search Screen - Advanced Search	

			Database - CINAHL	
S1	TI (intrapartum or intra-partum or labor or laboring or labour or labouring or deliver* or childbirth* or birth* or parturition) OR AB (intrapartum or intra-partum or labor or laboring or labour or labouring or deliver* or childbirth* or birth* or parturition)	Expanders - Apply equivalent subjects	Interface - EBSCOhost Research Databases	253,388
		Search modes - Boolean/Phrase	Search Screen - Advanced Search	
			Database - CINAHL	

Psychinfo Search

Accessibility Information and TipsRevised Date: 07/2015

Print Search History

Monday, March 09, 2020 9:59:32 AM

#	Query	Limiters/Expanders	Last Run Via	Results
S5	(TI water N3 birth OR TI (waterbirth or water-birth) OR TI birth* N3 tub OR TI birth* N3 pool OR TI water N3 immersion OR AB water N3 birth OR AB (waterbirth or water-birth) OR AB birth* N3 tub OR AB birth* N3 pool OR AB water N3 immersion) AND (S3 AND S4)	Expanders - Apply equivalent subjects	Interface - EBSCOhost Research Databases	58
		Search modes - Boolean/Phrase	Search Screen - Advanced Search	
			Database - APA PsycInfo	
S4	TI water N3 birth OR TI (waterbirth or water-birth) OR TI birth* N3 tub OR TI birth* N3 pool OR TI water N3 immersion OR AB water N3 birth OR AB (waterbirth or water-birth) OR AB birth* N3 tub OR AB birth* N3 pool OR AB water N3 immersion	Expanders - Apply equivalent subjects	Interface - EBSCOhost Research Databases	451
		Search modes - Boolean/Phrase	Search Screen - Advanced Search	

			Database - APA PsycInfo	
S3	(((MM "Intrapartum Period") OR (MM "Birth" OR MM "Birth Weight" OR MM "Caesarean Birth" OR MM "Labor (Childbirth)" OR MM "Natural Childbirth" OR MM "Premature Birth")) OR (MM "Labor (Childbirth)" OR MM "Caesarean Birth" OR MM "Intrapartum Period")) OR (S1 OR S2)	Expanders - Apply equivalent subjects	Interface - EBSCOhost Research Databases	190,277
		Search modes - Boolean/Phrase	Search Screen - Advanced Search	
			Database - APA PsycInfo	
S2	((MM "Intrapartum Period") OR (MM "Birth" OR MM "Birth Weight" OR MM "Caesarean Birth" OR MM "Labor (Childbirth)" OR MM "Natural Childbirth" OR MM "Premature Birth")) OR (MM "Labor (Childbirth)" OR MM "Caesarean Birth" OR MM "Intrapartum Period")	Expanders - Apply equivalent subjects	Interface - EBSCOhost Research Databases	12,875
		Search modes - Boolean/Phrase	Search Screen - Advanced Search	
			Database - APA PsycInfo	
S1	TI (intrapartum or intra-partum or labor or laboring or labour or labouring or deliver* or childbirth* or birth* or parturition) OR AB (intrapartum or intra-partum or labor or laboring or labour or labouring or deliver* or childbirth* or birth* or parturition)	Expanders - Apply equivalent subjects	Interface - EBSCOhost Research Databases	187,669
		Search modes - Boolean/Phrase	Search Screen - Advanced Search	
			Database - APA PsycInfo	

Medline Search

Accessibility Information and TipsRevised Date: 07/2015

Print Search History

Monday, March 09, 2020 11:32:22 AM

#	Query	Limiters/Expanders	Last Run Via	Results
S5	(TI Water N3 birth OR TI (waterbirth or water-birth) OR TI birth N3 tub OR TI birth N3 pool OR TI water N3 immersion OR AB Water N3 birth OR AB (waterbirth or water-birth) OR AB birth N3 tub OR AB birth N3 pool OR AB water N3 immersion) AND (S3 AND S4)	Expanders - Apply equivalent subjects	Interface - EBSCOhost Research Databases	697
		Search modes - Boolean/Phrase	Search Screen - Advanced Search	
			Database - MEDLINE with Full Text	
S4	TI Water N3 birth OR TI (waterbirth or water-birth) OR TI birth N3 tub OR TI birth N3 pool OR TI water N3 immersion OR AB Water N3 birth OR AB (waterbirth or water-birth) OR AB birth N3 tub OR AB birth N3 pool OR AB water N3 immersion	Expanders - Apply equivalent subjects	Interface - EBSCOhost Research Databases	5,881
		Search modes - Boolean/Phrase	Search Screen - Advanced Search	
			Database - MEDLINE with Full Text	
S3	(MH Parturition+ OR MH Labor, Obstetric+) OR (S1 OR S2)	Expanders - Apply equivalent subjects	Interface - EBSCOhost Research Databases	988,860
		Search modes - Boolean/Phrase	Search Screen - Advanced Search	
			Database - MEDLINE with Full Text	

S2	MH Parturition+ OR MH Labor, Obstetric+	Expanders - Apply equivalent subjects	Interface - EBSCOhost Research Databases	60,125
		Search modes - Boolean/Phrase	Search Screen - Advanced Search	
			Database - MEDLINE with Full Text	
S1	TI (intrapartum or intra-partum or labor or laboring or labour or labouring or deliver* or childbirth* or birth* or parturition) OR AB (intrapartum or intra-partum or labor or laboring or labour or labouring or deliver* or childbirth* or birth* or parturition)	Expanders - Apply equivalent subjects	Interface - EBSCOhost Research Databases	970,439
		Search modes - Boolean/Phrase	Search Screen - Advanced Search	
			Database - MEDLINE with Full Text	

Embase Search

# ▼	Searches	Results	Type	Actions	Annotations
7	3 and 6	552	Advanced	Display Results More	
6	4 or 5	55859	Advanced	Display Results More	
5	exp labor/	34388	Advanced	Display Results More	
4	exp childbirth/	55859	Advanced	Display Results	

				More
3	1 and 2	39342	Advanced	Display Results
				More
2	(water or waterbirth or water birth or water immersion or hydrotherapy or birth* pool).ti. or (water or waterbirth or water birth or water immersion or hydrotherapy or birth* pool).ab.	883990	Advanced	Display Results
1	(intrapartum or intra-partum or labor or laboring or labour or labouring or deliver* or childbirth* or birth* or parturition).ti. or (intrapartum or intra-partum or labor or laboring or labour or labouring or deliver* or childbirth* or birth* or parturition).ab.	1283598	Advanced	Display Results

Cochrane Central Search

Search Name: water
Date Run: 3/9/2020 4:18:27 PM
Comment:

ID	Search	Hits
#1	intrapartum or intra-partum or labor or laboring or labour or labouring or deliver* or childbirth* or birth* or parturition	109154
#2	MeSH descriptor: [Labor, Obstetric] explode all trees	2298
#3	MeSH descriptor: [Parturition] explode all trees	408
#4	#1 or #2 or #3	109322
#5	(water NEAR birth):ti,ab,kw OR (water NEAR immersion):ti,ab,kw OR (waterbirth* or water-birth*):ti,ab,kw OR (birth* NEAR tub):ti,ab,kw OR (birth* NEAR pool):ti,ab,kw	788
#6	#4 AND #5	87

Results

Database	**Number of hits**
CINAHL	719
pyshinfo	58
MEDLINE	697
EMBASE	552

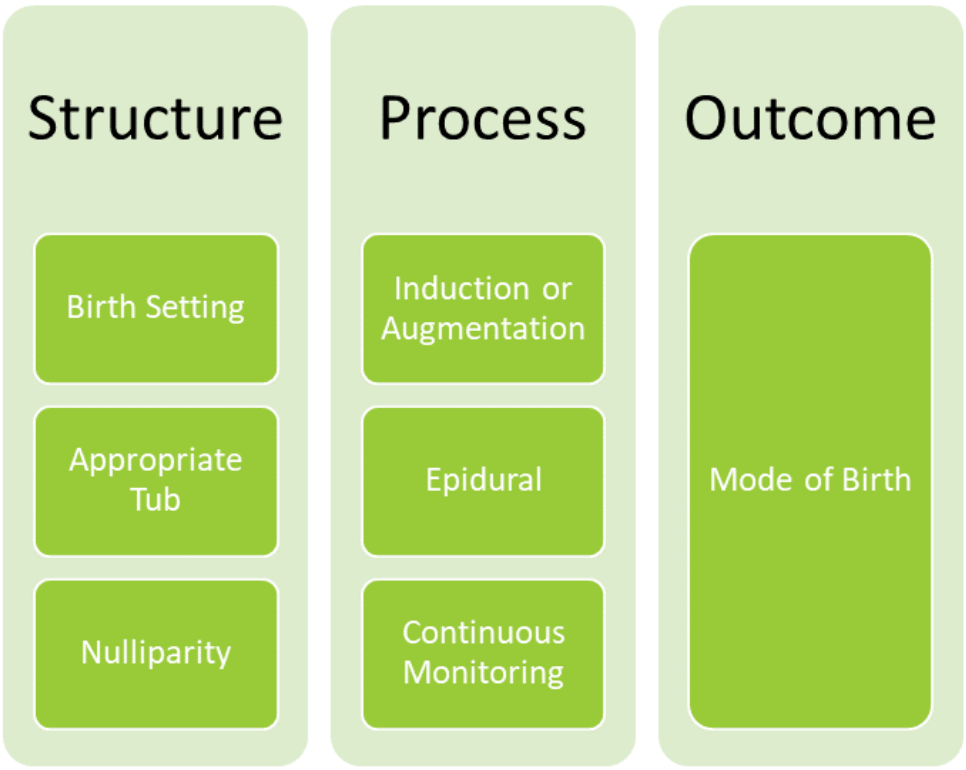
COCHRANE	87	
	2113	
Duplicates removed	446	
	1667	
Screened		
title/abstract	1667	
Excluded	1561	
Included for full text	**106**	
Full text EXCLUDED	49	
Full text INCLUDED	**57**	
BMC update	1	
	58	INCLUDED

Excluded Reasons

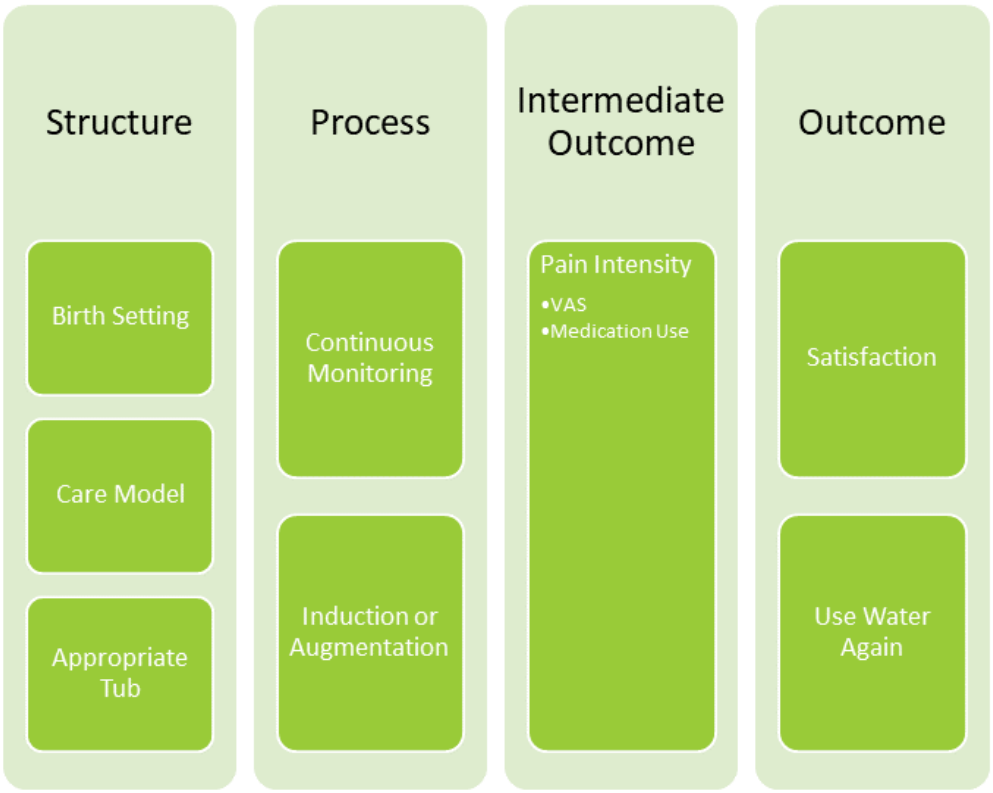
Reasons for exclusions	**Number**
Unable to obtain text	11
Wrong study outcomes	7
Wrong study design	6
Conference abstract	5
Discussion paper not research	2
Reprinted publication	1
Unable to translate text	9
Duplicate	4
Letter not research	2
Wrong publication type	1
Poster	1
	49

Supplement 2: Directed Acyclic Graphs to identify assumptions of covariates likely to cause heterogeneity in the outcomes.

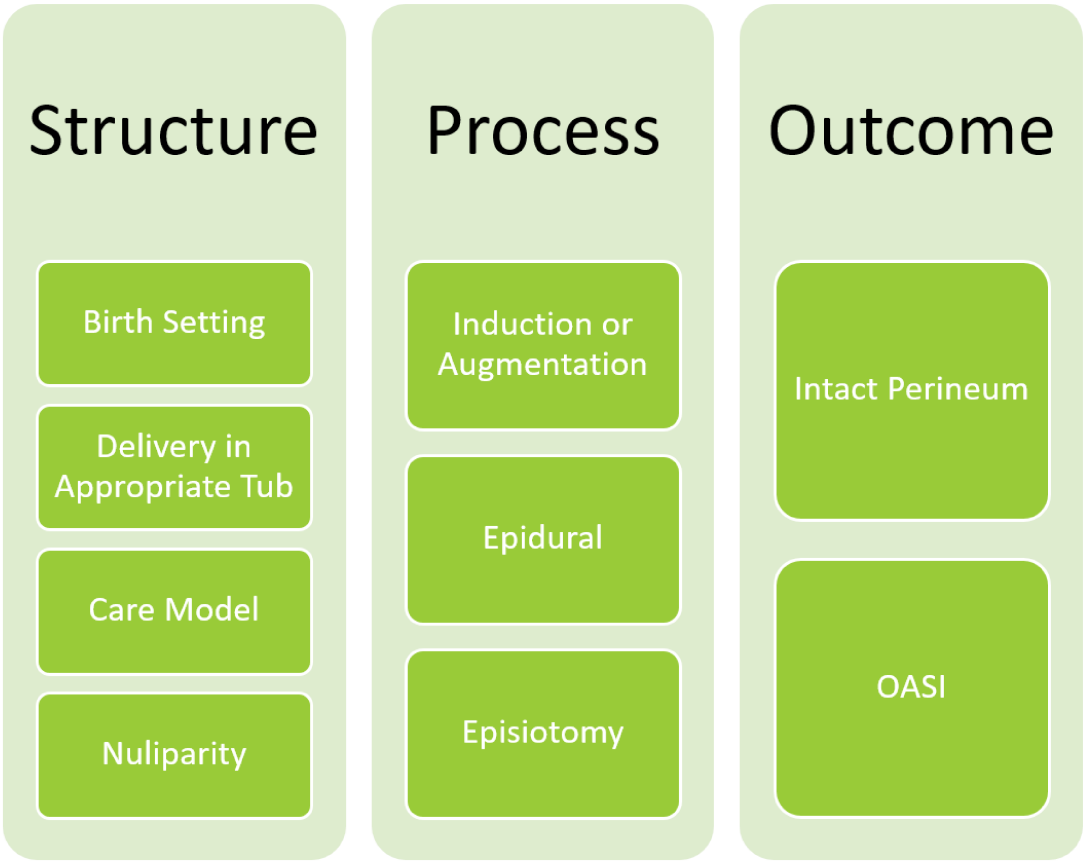
DAG 1: Assumptions about variables associated with variation in mode of birth.



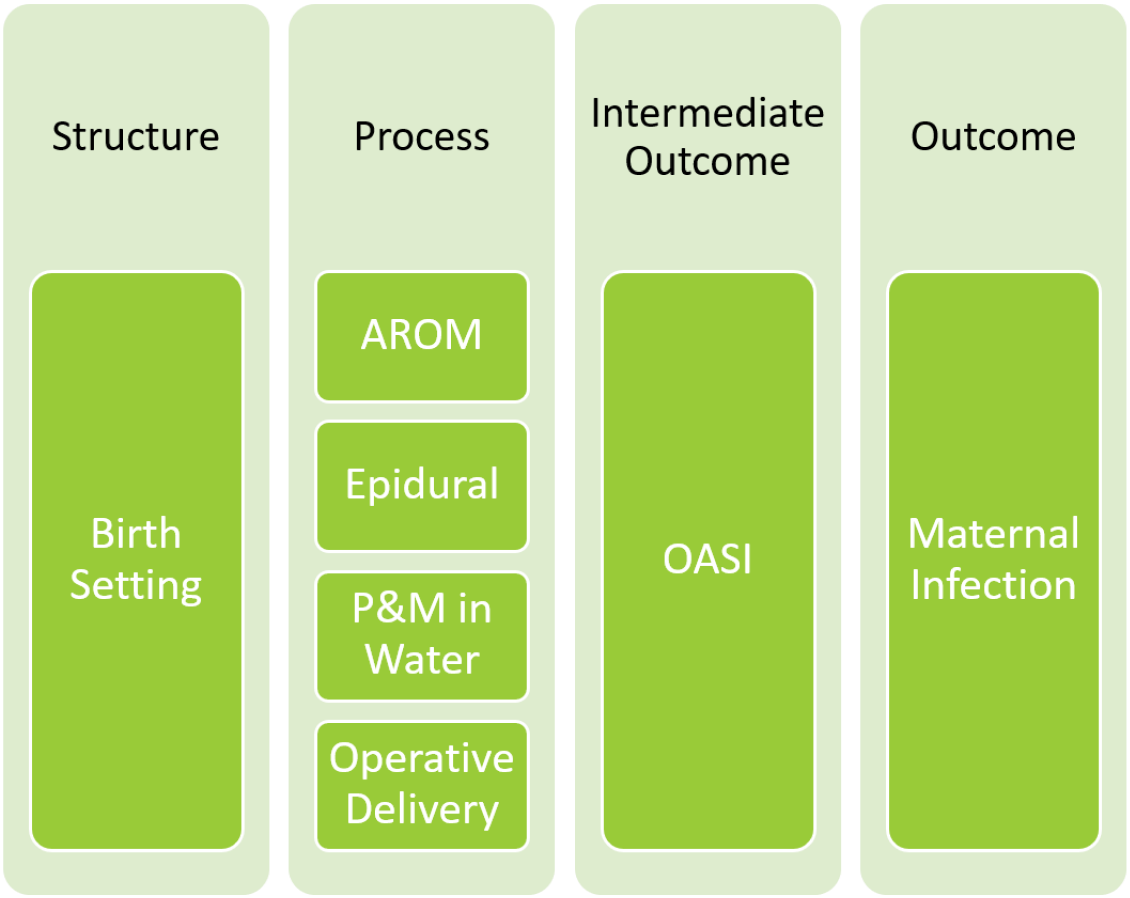
DAG 2: Assumptions about variables associated with variation in maternal satisfaction



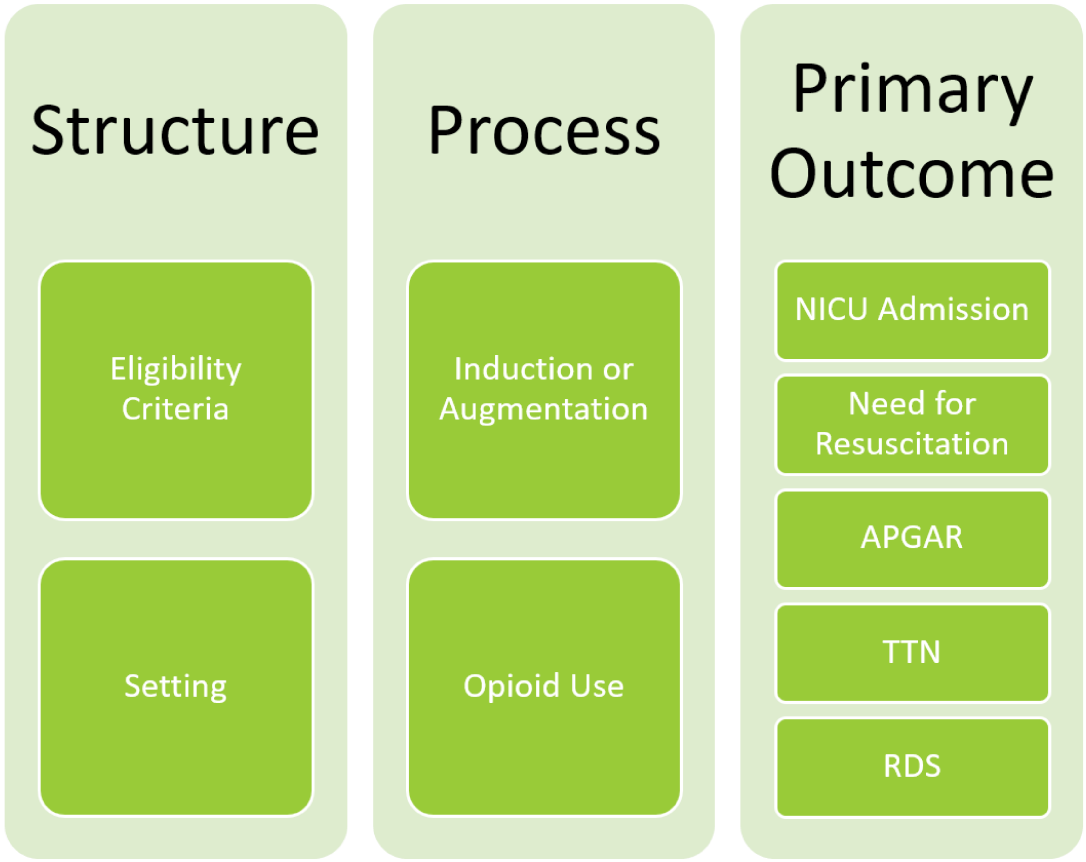
DAG 3: Assumptions about variables associated with variation in perineal outcomes.



DAG 4: Assumptions about variables associated with variation in maternal infection.



DAG 5: Assumptions about variables associated with variation in neonatal outcomes.



Supplement 3: Certainty of Estimates using GRADE Criteria

Challenges of Applying GRADE to Water Immersion

When using the GRADE Criteria for water immersion, the certainty of the evidence for all outcomes begins at the level of "low" because most water immersion research is conducted as prospective observational studies. GRADE scores observational studies as less certain than randomized controlled trials. Unfortunately, randomized controlled trials of water immersion do not automatically reduce bias because of the nature of the intervention. Blinding of the care provider and participants is not possible and there is no control that can act as a placebo. This increases the risks for performance bias, detection bias, and reporting bias. Uneven attrition is expected as women randomized to water have many legitimate reasons for exiting the water, such as to use the bathroom or to facilitate fetal monitoring. In contrast, women randomized to standard care are unlikely to be asked to enter the water. This attrition bias causes challenges with intention to treat analyses, especially for outcomes that are only relevant if the birth occurs in water. A further challenge occurs in recruiting a sample willing to be randomized. Women who desire water immersion are less willing to be randomized. This selection bias produces a sample that does not represent the population that chooses water immersion for pain control. Given these limitations, randomized controlled trials reduce as much bias as a well-controlled prospective study.

The GRADE criteria assume a study is assessing the superiority of one intervention over another. However, most water immersion studies are interested in equivalency of outcomes. GRADE criteria allow upgrading for large magnitude of effect, but this is not possible when the purpose of a study is to demonstrate no increased risk of poor outcomes. GRADE criteria also allow upgrading for demonstration of a dose-effect. However there is no dose of water immersion; instead women enter and leave the pool at will and the length of immersion is determined by the length of labor. This leaves only one category of upgrading available to studies of water immersion – plausible confounding.

Understanding the limitations of applying the GRADE criteria to water immersion, we recommend readers interpret the results of the GRADE assessment with caution. A GRADE of "low" certainty for water immersion does not necessarily indicate a need for more research. We point to the example of postpartum hemorrhage. Thirteen studies reporting on 63,891 participants have been synthesized to demonstrate there is no increased risk of postpartum hemorrhage with water immersion. Grade assessment indicates the level of certainty is low, but fail-safe analysis indicated an additional 198 studies are needed to change the results to no difference. Fail-safe N is only calculated when the result favors water immersion or the standard care, so these comparisons are not available for outcomes reporting no difference.

Description of Assessment Criteria

Risk of Bias in individual studies are provided in the forest plots for each outcome. Grade criteria reduce certainty of an estimate if an outcome had serious limitations likely to result in a biased estimate, including accounting for the weight of each study to the final estimate.

Inconsistency of estimates between studies was expected as part of this review, as the purpose was to identify reasons for heterogeneity. Because the eligibility criteria for this study reflect intentionally seeking papers in different settings, inconsistency is not a criteria to assess the certainty of the estimate.

Indirectness of the evidence reduces certainty when the population studied is not the population for the intended review. The study of water immersion is limited to women at low risk of birth complications, so this criterion does not affect the certainty of the evidence.

Imprecision of the estimate for a systematic review is generally measuring the ability of the evidence to find a statistically significant result, however one purpose of studies of water immersion is to demonstrate no increased risk of harm. For the purposes of GRADE assessment, certainty was downgraded for imprecision when the sample available for meta-analysis had less than 2000 participants.

Publication bias reduces certainty because it assumes studies with negative results are left unpublished. Prior studies have found publication bias that favors standard care over water immersion. This means the outcome is likely more favorable of water immersion than the estimate suggests and we can be more certain that water immersion is safe. To accommodate the standard Grade format, certainty of a result will be downgraded when the trim and fill test indicate the potential publication bias is enough to change the results.

Certainty of evidence is upgraded when the magnitude of effect is large, using standard risk ratios to define large and very large. For rare outcomes, such as those reported with water immersion, the OR becomes equivalent to the risk ratio, allowing this study to use the standard Grade Criteria for large effect (RR >2 or <0.5) and very large (RR >5 or <0.2) for most outcomes.

Certainty of evidence is upgraded when the evidence suggests a dose-effect. Water immersion does not have defined doses, instead women enter and exit the tub at will. In general, the length of immersion is determined by the length of labor.

Certainty of evidence is upgraded when controlling for potential sources of confounding are likely to result in a more favorable outcome for water immersion. For this table, studies are upgraded if the result from meta-regression was more favorable than the main analysis.

Supplement 4 Table 1: GRADE Criteria for interventions and outcomes with water immersion for labor and delivery.

			Reduce Grade					Increase Grade					
Outcome	**Studies**	**Sample Size**	**Risk of Bias**	**Inconsistency**	**Indirectness**	**Imprecision**	**Publication Bias**	**Magnitude**	**Dose-Effect**	**Plausible Confounding**	**Final Grade**	**Importance**	**Fail-safe N**
Induction	3	2,008	-	n.d.	-	-	-	-	n.d.	-	Low	Limited	-
Amniotomy	5	1,627	-	n.d.	-	↓	-	-	n.d.	-	Low	Limited	-
Augmentation	3	1,420	-	n.d.	-	↓	-	↑	n.d.	-	Low	Important	-
Fetal Monitoring	0	0	-	n.d.	-	-	-	-	n.d.	-	NONE	Limited	-
Opioid	8	27,391	-	n.d.	-	-	-	↑	n.d.	-	Moderate	Important	972
Epidural	7	10,993	-	n.d.	-	-	-	↑	n.d.	-	Moderate	Important	100
Pain	8	1,200	-	n.d.	-	↓	-	↑	n.d.	-	Low	Important	279
Cesarean	8	1,575	-	n.d.	-	↓	-	-	n.d.	-	Very Low	Critical	-
Shoulder Dystocia	7	53,367	-	n.d.	-	-	-	-	n.d.	-	Low	Critical	-
Intact Perineum	14	59,070	-	n.d.	-	-	-	-	n.d.	↑	Moderate	Limited	358
OASI	14	93,690	-	n.d.	-	-	-	-	n.d.	-	Low	Important	-
Episiotomy	13	36,498	-	n.d.	-	-	-	↑↑	n.d.	↑	Very High	Important	1525
Third Stage Management	0	0	-	n.d.	-	-	-	-	n.d.	-	NONE	Limited	-
Postpartum Hemorrhage	13	63,891	-	n.d.	-	-	-	-	n.d.	-	Low	Critical	198
Manual Removal of Placenta	5	2,893	-	n.d.	-	-	-	-	n.d.	-	Low	Critical	-
Maternal Infection	3	32,653	-	n.d.	-	-	-	-	n.d.	-	Low	Important	-
Satisfaction	6	4,144	-	n.d.	-	-	-	-	n.d.	-	Low	Important	133
APGAR	16	100,881	-	n.d.	-	-.	-	-	n.d.	↑	Moderate	Important	-
Neonatal Resuscitation	5	51,028	-	n.d.	-	-	-	-	n.d.	-	Low	Critical	-
Transient Tachypnea	2	1,473	-	n.d.	-	↓	-	-	n.d.	-	Very Low	Limited	-

Outcome	Studies	Sample Size	Reduce Grade					Increase Grade			Final Grade	Importance	Fail-safe N
			Risk of Bias	Inconsistency	Indirectness	Imprecision	Publication Bias	Magnitude	Dose-Effect	Plausible Confounding			
Respiratory Distress	3	32,707	-	n.d.	-	-	-	-	n.d.	-	Low	Critical	-
Neonatal Intensive Unit Admission	0	0	-	n.d.	-	-	-	-	n.d.	-	NONE	Critical	-
Neonatal Death	3	66,544	-	n.d.	-	-	-	-	n.d.	-	Low	Critical	-
Infection in Newborn Period	0	0	-	n.d.	-	-	-	-	n.d.	-	NONE	Important	-
Cord Avulsion	5	50,791	-	n.d.	-	-	-	-	n.d.	-	Low	Limited	5
Breastfeeding Initiation	2	692	-	n.d	-	↓	-	-	n.d.	-	Very Low	Important	-

Supplement 4: Total studies excluded following searches and during full text review; systematic review and meta-analysis of interventions and outcomes with water birth.

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