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A 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

Objective: To compare water immersion for labour and birth to standard care, accounting for differences in clinical practice experienced by women who use water and women who do not.

Design: Systematic Review and Meta-Analysis

Setting: Obstetric and midwifery-led settings

Participants: 36 papers reporting on outcomes for 153,236 participants

Interventions: Water immersion during labour and waterbirth

Primary and secondary outcome measures: Labour interventions included augmentation, opioids, epidural, episiotomy. Maternal outcomes included mode of birth, intact perineum, obstetric anal sphincter injury (OASI), pain, satisfaction, postpartum haemorrhage, infection, breastfeeding initiation. Newborn outcomes included APGAR score, resuscitation, respiratory distress, transient tachypnea, admission to a neonatal intensive care unit (NICU), infection.

Results: Use of epidural (OR 0.17 95% CI 0.05 – 0.56), injected opioids (OR 0.22 95% CI 0.13 – 0.38), episiotomy (OR 0.16; 95% CI 0.10 – 0.27), maternal pain, and postpartum hemorrhage (OR 0.69 95% CI 0.51 – 0.95) were significantly reduced with water immersion. Maternal satisfaction (OR 1.95 95% CI 1.28 – 2.96) and odds of an intact perineum (OR 1.48; 95% CI 1.21 – 1.79) were significantly increased with water immersion. Waterbirth was associated with increased odds of cord avulsion (OR 1.94 95% CI 1.30 – 2.88), although the absolute risk remained low (4.3 per 1,000 vs 1.3 per 1,000). There were no differences in any identified neonatal outcomes.

Conclusions: Water immersion during labour and waterbirth have clear benefits for healthy women and their newborns and reduce risk when conducted in the obstetric unit setting.

Strengths and Limitations of the 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
- This meta-analysis was limited to studies published in any language if it could be translated into English using Google Translate, and published in 2000 or later.
- Few studies were conducted in midwifery-led settings.

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.[3] Evidence from randomised controlled trials (RCTs) showed that labouring in water reduces the need for epidural analgesia whilst identifying no adverse maternal or neonatal effects.[37] In the UK, most birthing pool use occurs in midwifery-led birth settings: these include alongside midwifery units (co-located with a maternity hospital setting) and freestanding midwifery units
(FMU) (in the community setting) and home birth.[38] The outcomes of birthing pool use may be different in midwifery-led settings compared to an obstetric setting because healthy women experience fewer interventions and operative birth when delivery occurs in a midwifery-led setting compared to an obstetric setting.[38]

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 delivery, pushing position, use of active management of third stage of labour, and placenta delivery in the water.[39-45] It is likely that woman who use water immersion for labour and birth experience different care practices than women who have standard delivery 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.[46-48] 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.[49,50] However, a RCT proposal is likely to encounter ethical and recruitment challenges due to increasing acknowledgment 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.[51]

The objective of this systematic review was to compare water immersion for labour and birth to standard care, accounting for the differences in care practices 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

A protocol for the review was published in the International Prospective Register of Systematic Reviews PROSPERO2019 CRD42019147001 prior to completion of the searches and updated in July 2020. The PRISMA 2020 guideline was followed for conducting this work.[52]

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 delivery.
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. A predesigned search strategy was designed using the PICOT/PEOT framework to develop search terms:[53]

- Population: women in labour and early postpartum
- 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/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.[54] The refined search terms and strategy with Boolean operators are provided in Supplement 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 de-duplicated in Zotero and collated into Rayyan systematic review software.[55] 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 PH. 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 Process & Data Items

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 PH) 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 delivery, level of pain, maternal satisfaction, intact perineum, obstetric anal sphincter injury, shoulder dystocia, maternal infection defined by symptoms and positive test, primary postpartum haemorrhage, manual removal of the placenta, 5-minute 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 7 domains based on the Robbins-I Risk of Bias Tool.[56] 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 PH). Disagreements were resolved by consensus meeting.

Summary Measures & Synthesis of Results

All outcomes were summarised using an odds ratio (OR) and 95% confidence interval (CI). All calculations were conducted in Comprehensive Meta-Analysis Version 3, using the inverse variance method.[57] Results of individual studies were converted to log odds ratio and standard error for synthesis. Fixed effects models were used when I^2 was less than 50%, otherwise random effects models were used. 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 BMI, prior cesarean, 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.[58] The fail-safe N estimates was calculated to determine the number of studies necessary to change the estimates.[59] Forest plots were created in RevMan v5.4.1.[60]

Additional Analyses

Begg's Test and Egger's Regression Risk assessed risk of bias across studies.[61] Trim & Fill analysis was used to estimate the magnitude of effect of the bias.[62] Meta-regression was completed when at least ten studies provided data for an outcome when I^2 >50%.[63,64] 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 (DAG) of the covariates and their role are available in Supplement 2.[65] For continuous covariates, the rate of a covariate (e.g. the induction rate in the sample) were used for regression.

Categorical covariates were coded as dichotomous (e.g. described appropriate birth pool or did not describe the immersion receptacle).

Patient and Public Involvement

No patient involved.

Results

Study Selection

The searches generated 2,113 hits, reduced to 1,667 after duplicates were removed; n=1,561 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 Supplement 3 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 153,236 women were included into the review. Figure 1 PRISMA diagram illustrates the study selection process.[52]

[Figure 1 here]

Study Description

Most studies (k=32) 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 4, 29, 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 randomised controlled trials (k=7; n=2,666), prospective studies (k=13; n=30,085), retrospective studies (k=15; 120,474), and one pre-post study (n=11). Studies reported on waterbirth (k=25; n=146,499), water immersion for labour (k=7; 1,901), both (k=3; 4,621) and one whose timing of immersion could not be determined (n=215). Full information is available in Table 1.

Table 1: Characteristics of included studies; Meta-analysis of water immersion for Labour and delivery

Author	Study Type	Setting	Immersion Exposure[a]	Sample Size	Interventions and Outcomes Reported
Bailey, 2019	RCT	Obstetric	Waterbirth	794	1, 5, 10, 11, 13, 17
Barry, 2020	PO	Obstetric	Both	367	8, 10, 11, 13, 17, 23
Benfield, 2010	Pre-Post	Obstetric	Labour	11	4, 7
Bovbjerg, 2016	RO	Midwifery	Waterbirth	16,773	10, 11, 12, 17, 21
Cluett, 2004	RCT	Obstetric	Labour	99	2, 6, 7, 8, 15, 16
da Silva, 2009	RCT	Obstetric	Labour	108	2, 4, 7, 10, 12, 17
Eckert, 2001	RCT	Obstetric	Labour	274	1, 5, 6, 7, 8, 11, 12, 16, 17, 18
Geisbuehler, 2002	PO	Obstetric	Waterbirth	5584	12, 20
Geissbuehler, 2004	PO	Obstetric	Waterbirth	9518	5, 9, 10, 11, 13, 15, 17
Geissbuhler, 2000	PO	Obstetric	Waterbirth	8434	6, 16
Haslinger, 2015	RO	Obstetric	Waterbirth	5319	11, 12
Henderson, 2014	PO	Obstetric	Both	4024	2, 3, 8, 10, 12, 13, 14, 18
Hodgson, 2020	RO	Obstetric	Waterbirth	25,768	4, 11, 17, 18
Jacoby, 2019	RO	Obstetric	Waterbirth	23,036	11, 13, 15, 17, 18, 20, 21, 23
Lathrop, 2018	PO	Obstetric	Waterbirth	198	13, 16
Lim, 2016	RO	Obstetric	Waterbirth	236	4, 9, 10, 12, 13, 14, 17, 19
Liu, 2014	PO	Obstetric	Labour	108	4, 7, 8, 13
Mallen-Perez, 2018	PO	Obstetric	Unclear	215	7
Menakaya, 2013	RO	Obstetric	Waterbirth	438	9, 10, 11, 12, 13, 17, 18
Mollamahmutoglu, 2012	PO	Obstetric	Waterbirth	602	1, 7, 10, 12, 13
Neiman, 2020	RO	Obstetric	Both	230	4, 8, 9, 10, 12, 13, 17, 22, 23
Ohlsson, 2001	RCT	Obstetric	Labour	1237	6, 8, 11, 14, 19, 20
Otigbah, 2000	RO	Obstetric	Waterbirth	602	1, 4, 5, 9, 10, 11, 12, 13
Pagano, 2010	RO	Obstetric	Waterbirth	220	10, 17
Peacock, 2018	RO	Obstetric	Waterbirth	3507	17
Preston, 2019	RO	Obstetric	Waterbirth	15734	5, 9, 11
Ros, 2009	PO	Obstetric	Waterbirth	54	17

Sert, 2019	RCT	Obstetric	Labour	64	17
Snapp, 2019	RO	Midwifery	Waterbirth	26,684	9, 10, 13, 17, 21, 23
Thoeni, 2005	RO	Obstetric	Waterbirth	1,144	10, 11, 12
Torkamani, 2010	PO	Obstetric	Waterbirth	100	5, 7, 12
Ulfsdottir, 2018	RO	Midwifery	Waterbirth	612	1, 2, 3, 4, 6, 10, 11, 12, 13, 14, 16, 17, 23, 24
Woodward, 2004	RCT	Obstetric	Waterbirth	90	4, 5, 6, 8, 10, 17, 24
Zanetti-Dallenbach, 2006	PO	Obstetric	Waterbirth	513	2, 3, 6, 9, 12
Zanetti-Dallenbach, 2007	PO	Obstetric	Waterbirth	368	4, 5, 10, 11, 13, 14, 17
Ziolkowski, 2009	RO	Obstetric	Waterbirth	171	16, 17

Study Type Key: RCT, Randomized Controlled Trial; PO, Prospective Observational; RO, Retrospective Observational
Interventions & Outcomes Key: 1) Labour Induction 2) Amniotomy 3) Augmentation 4) Fetal Monitoring 5) Opioids 6) Epidural 7) Pain 8) Cesarean Delivery 9) Shoulder Dystocia 10) Intact Perineum 11) OASI 12) Episiotomy 13) Postpartum Hemorrhage 14) Manual Removal of Placenta 15)

Few studies provided sample characteristics beyond parity (See Table 2). Eleven studies reported the sample was restricted to persons in spontaneous labor 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) excluded multiple pregnancies, the rest did not address this characteristic. Prior caesarean was excluded by seven studies and reported as a sample characteristic for five studies.

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, 2019	Yes	No	No	Yes	No
Barry, 2020	Yes	Yes	>30	Yes	n.d.
Benfield, 2010	Yes	n.d.	n.d.	n.d.	n.d.
Bovbjerg, 2016	Yes	n.d.	n.d.	Yes	No
Cluett, 2004	Yes	Yes	n.d.	n.d.	n.d.
da Silva, 2009	Yes	n.d.	n.d.	Yes	n.d.
Eckert, 2001	Yes	No	n.d.	Yes	n.d.
Geisbuehler, 2002	Yes	n.d.	n.d.	n.d.	n.d.
Geissbuehler, 2004	Yes	n.d.	>40	n.d.	n.d.
Geissbuhler, 2000	Yes	n.d.	n.d.	n.d.	n.d.
Haslinger, 2015	Yes	n.d.	n.d.	Yes	n.d.
Henderson, 2014	Yes	No	n.d.	n.d.	No
Hodgson, 2020	Yes	n.d.	n.d.	Yes	n.d.
Jacoby, 2019	Yes	Yes	n.d.	Yes	n.d.
Lathrop, 2018	Yes	n.d.	n.d.	Yes	n.d.
Lim, 2016	Yes	n.d.	n.d.	Yes	No
Liu, 2014	No	n.d.	No	Yes	Yes
Mallen-Perez, 2018	Yes	Yes	No	Yes	n.d.
Menakaya, 2013	Yes	Yes	n.d.	Yes	n.d.
Mollamahmutoglu, 2012	Yes	No	No	n.d.	Yes
Neiman, 2020	Yes	Yes	n.d.	Yes	Yes
Ohlsson, 2001	Yes	n.d.	n.d.	Yes	n.d.
Otigbah, 2000	Yes	No	n.d.	n.d.	n.d.
Pagano, 2010	Yes	n.d.	n.d.	n.d.	n.d.
Peacock, 2018	Yes	Yes	n.d.	n.d.	n.d.
Preston, 2019	Yes	Yes	No	n.d.	n.d.
Ros, 2009	Yes	n.d.	n.d.	Yes	Yes

Sert, 2019	Yes	Yes	n.d.	n.d.	Yes
Snapp, 2019	Yes	n.d.	n.d.	n.d.	n.d.
Thoeni, 2005	No	n.d.	n.d.	Yes	Yes
Torkamani, 2010	Yes	n.d.	n.d.	n.d.	n.d.
Ulfsdottir, 2018	Yes	Yes	No	n.d.	No
Woodward, 2004	Yes	Yes	n.d.	n.d.	Yes
Zanetti-Dallenbach, 2006	Yes	n.d.	n.d.	Yes	n.d.
Zanetti-Dallenbach, 2007	Yes	n.d.	n.d.	Yes	n.d.
Ziolkowski, 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.

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. Method of induction was not reported. Sixteen studies reported a fetal heart monitoring method as either intermittent auscultation (k=10), continuous monitoring (k=5) or a mix of methods (k=1). Six studies reported using "hands-off" (k=4) or "hands-on" (k=2) the perineum. Third stage management was reported by six studies, all indicating that active management was used. Three studies indicated whether the placenta and membranes were delivered in the birth pool (k=1) or out of the birth pool (k=2).

Table 3: Description of care practices reported in included studies

Author	Appropriate Pool Described	Induction Method	Intermittent Auscultation	Perineum Method	3rd Stage Management	Placenta & Membranes
Bailey, 2019	No	n.d.	n.d.	n.d.	Active	Out of Pool
Barry, 2020	Yes	None	Mixed	Hands Off	Active	n.d.
Benfield, 2010	No	n.d.	No	n.d.	n.d.	n.d.
Bovbjerg, 2016	No	n.d.	n.d.	n.d.	n.d.	n.d.
Cluett, 2004	Yes	None	n.d.	n.d.	n.d.	n.d.
da Silva, 2009	No	n.d.	No	n.d.	n.d.	n.d.
Eckert, 2001	Yes	n.d.	n.d.	n.d.	n.d.	n.d.
Geisbuehler, 2002	No	n.d.	Yes	n.d.	n.d.	n.d.
Geissbuehler, 2004	No	n.d.	Yes	n.d.	n.d.	n.d.
Geissbuhler, 2000	No	n.d.	Yes	n.d.	n.d.	n.d.
Haslinger, 2015	No	n.d.	n.d.	Hands On	n.d.	n.d.
Henderson, 2014	No	n.d.	n.d.	Hands Off	Active	n.d.
Hodgson, 2020	No	n.d.	Yes	n.d.	n.d.	n.d.
Jacoby, 2019	No	None	n.d.	n.d.	n.d.	n.d.
Lathrop, 2018	No	n.d.	n.d.	n.d.	n.d.	n.d.
Lim, 2016	No	n.d.	No	n.d.	n.d.	n.d.
Liu, 2014	No	n.d.	Yes	n.d.	n.d.	n.d.
Mallen-Perez, 2018	Yes	None	n.d.	n.d.	n.d.	n.d.
Menakaya, 2013	Yes	None	n.d.	n.d.	n.d.	n.d.
Mollamahmutoglu, 2012	Yes	n.d.	Yes	Hands Off	Active	n.d.
Neiman, 2020	No	None	Yes	n.d.	n.d.	n.d.
Ohlsson, 2001	No	n.d.	n.d.	n.d.	n.d.	n.d.
Otigbah, 2000	Yes	n.d.	Yes	Hands Off	Active	Out of Pool
Pagano, 2010	No	n.d.	n.d.	n.d.	n.d.	n.d.
Peacock, 2018	No	None	n.d.	n.d.	n.d.	n.d.
Preston, 2019	No	None	n.d.	n.d.	n.d.	n.d.
Ros, 2009	No	n.d.	n.d.	n.d.	n.d.	n.d.

Sert, 2019	Yes	None	n.d.	n.d.	n.d.	n.d.
Snapp, 2019	No	n.d.	n.d.	n.d.	n.d.	n.d.
Thoeni, 2005	No	n.d.	n.d.	Hands On	n.d.	n.d.
Torkamani, 2010	No	n.d.	n.d.	n.d.	n.d.	n.d.
Ulfsdottir, 2018	Yes	None	No	n.d.	n.d.	n.d.
Woodward, 2004	No	None	Yes	n.d.	n.d.	n.d.
Zanetti-Dallenbach, 2006	No	n.d.	No	n.d.	Active	In Pool
Zanetti-Dallenbach, 2007	No	n.d.	No	n.d.	n.d.	n.d.
Ziolkowski, 2009	No	n.d.	Yes	n.d.	n.d.	n.d.

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

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 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 delivery. 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.

[Figure 2]

Labour Induction. Three studies provided data on labour induction (n=2,008), all conducted after 2010. Overall, this analysis found no difference between use of labour induction with water immersion and standard care (OR 0.43; 95% CI 0.16 – 1.16; random effects; Q=20.75 p<.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.[7,23]

[Figure 3]

Table 4: Results of subgroup analysis of interventions on outcomes of water immersion for Labour and delivery compared to standard care.

Outcome	Studies	Sample	Effect OR (95% CI) Model	Heterogeneity Q (p) I^2%
Labour Induction[a]				
Obstetric Units	2	604 Immersion 792 Standard Care	0.32 (0.06 – 1.58) Random Effects	18 (<.01) 94%
Amniotomy[a]				
Obstetric Units	4	306 Immersion 709 Standard Care	0.95 (0.62 – 1.46) Random Effects	5 (.17) 40%
2011 and Later	2	420 Immersion 765 Standard care	0.56 (0.15 – 2.02) Random Effects	14 (<.01) 93%
Augmentation[a]				
Obstetric Units	2	203 Immersion 605 Standard Care	0.48 (0.16 – 1.51) Random Effects	6 (.02) 83%
2011 and Later	2	420 Immersion 765 Standard care	0.32 (0.05 – 2.24) Random Effects	19 (<.01) 95%
Opioid Use				
2011 and Later	2	1,641 Immersion 14,887 Standard care	0.17 (0.15 – 0.20) Fixed Effects	0 (.54) 0%
Epidural[a]				
Obstetric Units	6	4,104 Immersion 6,889 Standard Care	0.26 (0.08 – 0.83) Random Effects	89 (<.01) 94%
Pain				
2011 and Later	5	417 Immersion 413 Standard Care	0.15 (0.06 – 0.42) Random Effects	48 (<.01) 92%
Caesarean Delivery				
2011 and Later	4	400 Immersion 830 Standard Care	0.84 (0.32 – 2.23) Fixed Effects	6 (.12) 48%
Shoulder Dystocia				
Obstetric Units	6	5,528 Immersion 21,155 Standard Care	1.06 (0.64 – 1.74) Fixed Effects	4 (.60) 0%
2011 and Later	4	11,773 Immersion 31,252 Standard Care	0.87 (0.33 – 2.26) Random Effects	11 (.01) 73%
Intact Perineum				
Obstetric Units	14	6,170 Immersion 8,866 Standard care	1.55 (1.12 – 2.16) Random Effects	147 (<.01) 91%
Midwifery-led Units	3	17,079 Immersion 23,249 Standard care	1.07 (0.91 – 1.26) Random Effects	15 (<.01) 87%
Nulliparas	5	1,065 Immersion 894 Standard care	1.59 (1.01 – 2.50) Random Effects	12 (.01) 68%
Waterbirth vs No Water	8	954 Immersion 1696 Standard care	1.35 (0.67 – 2.72) Random Effects	83 (<.01) 92%
2011 and Later	10	18,292 Immersion 28,871 Standard Care	1.59 (1.22 – 2.07) Random Effects	156 (<.01) 94%
OASI				
Obstetric Units	13	10,720 Immersion 57,870 Standard care	0.85 (0.57 – 1.30) Random Effects	51 (<.001)) 77%

Midwifery-led Units	2	6,827 Immersion 10,558 Standard care	0.71 (0.47 – 1.08) Fixed Effects	0 (.527) 0%
Nulliparas	2	870 Immersion 540 Standard care	1.25 (0.42 – 3.71) Fixed Effects	1 (.385) 0%
Waterbirth vs No Water	3	408 Immersion 550 Standard care	0.57 (0.19 – 1.69) Fixed Effects	1 (.681) 0%
2011 and Later	9	13,298 Immersion 67,382 Standard Care	0.78 (0.48 – 1.28) Random Effects	42 (<.01) 81%
Episiotomy[a]				
Obstetric Units	14	6177 Immersion 13,548 Standard care	0.17 (0.11 – 0.28) Random Effects	109 (<.001) 88%
Nulliparas	3	886 Immersion 582 Standard care	0.10 (0.02 – 0.60) Random Effects	14 (<.001) 86%
Waterbirth vs No Water	5	691 Immersion 1022 Standard care	0.63 (0.02 – 0.20) Random Effects	14 (.008) 71%
2011 and Later	8	7,831 Immersion 16,888 Standard Care	0.09 (0.03 – 0.25) Random Effects	53 (<.01) 87%
Postpartum Hemorrhage				
Obstetric Units	13	7,040 Immersion 29,555 Standard care	0.75 (0.60 – 0.94) Random Effects	30 (.002) 60%
Midwifery-led Units	2	10,558 Immersion 16,738 Standard care	0.39 (0.08 – 1.86) Random Effects	56 (<.001) 98%
Waterbirth vs No Water	5	758 Immersion 1,177 Standard care	1.02 (0.76 – 1.36) Fixed Effects	4 (.439) 0%
2011 and Later	12	13,591 Immersion 39,945 Standard Care	0.76 (0.48 – 1.20) Random Effects	97 (<.01) 89%
Manual Removal of Placenta				
Obstetric Units	4	1,239 Immersion 1,654 Standard care	0.78 (0.37 – 1.64) Fixed Effects	6 (.105) 51%
2011 and Later	3	538 Immersion 883 Standard Care	1.48 (0.50 – 4.38) Fixed Effects	4 (.16) 45%
Maternal Satisfaction				
Obstetric Units	5	1,802 Immersion 1,568 Standard care	2.02 (1.28 – 3.19) Random Effects	24 (<.01) 83%
2011 and Later	2	372 Immersion 438 Standard Care	2.55 (1.54 – 4.23) Random Effects	2 (.16) 50%
APGAR				
Obstetric Units	18	10,286 Immersion 54,361 Standard care	0.85 (0.66 – 1.08) Random Effects	29 (.047) 38%
Midwifery-led Units	3	17,092 Immersion 18,31 Standard care	0.33 (0.07 – 1.54) Random Effects	57 (<.001) 96%
Waterbirth vs No Water	6	614 Immersion 655 Standard care	1.07 (0.76 – 1.51) Fixed Effects	3 (.643) 0%
2011 and Later	12	21,931 Immersion 65,781 Standard care	0.52 (0.25 – 1.05) Random Effects	101 (<.001) 89%
Neonatal Death				
Midwifery-led units	2	16,786 Immersion 26,722 Standard care	0.91 (0.61 – 1.34) Fixed Effects	1 (.297) 8%
Cord Avulsion				
Obstetric Units	3	1,874 Immersion	2.18 (0.34 – 11.97)	1 (.757)

		21,621 Standard care	Fixed Effects	0%
Midwifery-led Units	2	10,649 Immersion 16,829 Standard care	1.92 (1.28 – 2.89) Fixed Effects	1 (.386) 0%

a. 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.

Amniotomy. Five studies provided data on amniotomy (n=1,627). Overall, this analysis found no difference (OR 0.72 ; 95% CI 0.37 – 1.41; random effects; Q=25 p<.001; I^2=84%). 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.

[Figure 4]

Augmentation. Three studies provided data to compare augmentation of labour (n=2,230). This analysis favoured water immersion (OR 0.30; 95% CI 0.10 – 0.92; random effects; Q=20 p<.001; I^2=89%). 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.

[Figure 5]

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 – 0.38; random effects; Q=107 p<.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 972 additional studies would be needed to change the estimate to no difference.

[Figure 6]

Epidural use. Seven studies provided data on epidural use (n=12,055). Overall, this analysis favoured water immersion (OR 0.17 95% CI 0.05 – 0.56; random effects; Q=104 p<.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.

[Figure 7]

Pain. Eight studies provided data for analysis of pain (n=1,200), 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 0.23 95% CI 0.12 – 0.51; random effects; Q=76.7 p<.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 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.

[Figure 8]

Caesarean Delivery. 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. The meta-analysis indicated no difference between water immersion and standard care for cesarean delivery (OR 0.95 95% CI 0.63 – 1.42; fixed effects; Q=9.05 p=.249; I^2=22.6%). 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.

[Figure 9]

Shoulder Dystocia. Seven studies provided data that could be synthesized 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 – 1.69; random effects; Q=16 p=.012; I^2=63%). The subgroup analysis of studies in an obstetric setting and the most recent studies remained no difference. Cumulative meta-analysis indicated there has consistently been no difference.

[Figure 10]

Intact Perineum. Seventeen studies provided data on intact perineum (n=59,070). This analysis favoured water immersion (OR 1.48; 95% CI 1.21 – 1.79; random effects; Q=227 p<.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<.001) and the proportion of nullipara in the sample (p=.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 – 6.04; random effects; Q=2 p=.504 I^2=0%).

[Figure 11]

OASI. Fifteen studies provided data on obstetric anal sphincter injuries (n=93,690)**.** This analysis found no difference (OR 0.84 95% CI 0.60 – 1.18; random effects; Q=52 p<.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.

[Figure 12]

Episiotomy. Fifteen studies provided data on use of episiotomy (n=36,498). This analysis found reduced use of episiotomy with water immersion (OR 0.16; 95% CI 0.10 – 0.27; random effects; Q=110 p<.001; I^2=87%). 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 primiparas in the sample accounted for some of the variance (R^2=.76; p=.001; 7 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 in proportion of primiparas, the result remained in favour of water immersion (OR 0.04 95% CI 0.01 – 0.13; random effects; Q=12 p=.038; I^2=57%).

[Figure 13]

Third Stage Management. No studies provided comparison data for third stage management.

Postpartum Hemorrhage. Fifteen studies provided data about postpartum hemorrhage (n=63,891) using three different measures: count of postpartum hemorrhage defined as >500 ml blood loss, mean estimated blood loss, and change in hemoglobin. Overall, this analysis favoured water immersion (OR 0.69 95% CI 0.51 – 0.95;

random effects; Q=117 p<.001; I^2=88%). Subgroup analysis revealed no difference in odds of postpartum hemorrhage 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; 9 studies). Too few studies provided the data necessary to determine the effect of active management of third stage or the delivery of the placenta and membranes into the water.

[Figure 14]

Manual removal of the placenta. Five studies provided data to assess risk for manual removal of the placenta (n=2,893). This analysis indicated no difference (OR 0.73 95% CI 0.38-1.42; fixed effects; Q=6 p=.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.

[Figure 15]

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 – 0.80; fixed effects; Q=0.5 p=.792; I^2=0%), however one study carried 97% of the weight for this synthesis. Fail-safe analysis estimated 2 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.

[Figure 16]

Maternal Satisfaction. Six studies provided data on a measure of maternal satisfaction (n=4,144). Due to heterogeneity in measurement tool, this analysis used random effects modeling 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 – 2.96; random effects; Q=7.5 p=.184; 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 would be necessary to change the estimate from favouring water to no difference.

[Figure 17]

5-Minute APGAR. Twenty-one studies provided data for 5-minute APGAR (n=100,881). This analysis found no difference (OR 0.67 95% CI 0.43 – 1.04; random effects; Q=160 p<.001; I^2=87%). Three additional studies reported on 5-minute APGAR but did not provide data in a usable format; two found no difference[18,22] and one reported in favor of water immersion.[31] 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=.85; p=.001; 9 studies). After accounting for setting the analysis favoured water immersion (OR 0.14 95% CI 0.06 – 0.36; random effects; Q=20 p=.034; I^2=50%).

[Figure 18]

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 – 1.69; random effects; Q=10 p=.048; I^2=58. Cumulative meta-analysis indicated this outcome has been stable at no difference since first reported.

[Figure 19]

Transient tachypnea of the newborn. Two studies provided data on transient tachypnea of the newborn (n=1,473), both were conducted in an obstetric setting. This analysis found no difference (OR 0.74; 95% CI 0.34-1.65; fixed effects; Q=1 p=.364; I^2=0%). Too few studies were available to conduct cumulative meta-analysis and subgroup analysis.

[Figure 20]

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 – 2.43; random effects; Q=18 p<.001; I^2=88%). Three studies were too few for cumulative meta-analysis.

[Figure 21]

Neonatal intensive care unit 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 – 1.40; fixed effects; Q=2 p=.381; I^2=3%). Subgroup analysis by setting revealed no difference in midwifery-led settings. Three studies were too few for cumulative meta-analysis.

[Figure 22]

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 – 2.88; fixed effects; Q=1 p=.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 – 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 5 additional studies would be needed to change the estimate to no difference.

[Figure 23]

Breastfeeding Initiation. Two studies provided data on breastfeeding initiation (n=692). This analysis found no difference (OR 1.00 95% CI 0.73 – 1.37; fixed effects; Q=1 p=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.

[Figure 24]

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 & fill estimates of the magnitude of bias indicate the magnitude was too small to affect the results.

Table 5: Analysis of risk of bias across studies comparing water immersion for labor and delivery to standard care.

Outcome	k	Begg's Test Rank Correlation S-statistic (*p*)	Egger's Regression Intercept (*p*)	Trim & Fill Direction of Bias[a] OR (95% CI)
Amniotomy	5	4 (.164)	5.04 (.129)	Standard Care 0.43 (0.34 – 0.53)
Induction	3	-3 (0.059)	-10 (.238)	--
Augmentation	3	3 (0.59)	28.96 (.057)	Standard Care 0.12 (0.09 – 0.16)
Opioid	8	-2 (.402)	2.13 (.197)	Standard Care 0.17 (0.15 – 0.19)
Epidural	7	-9 (.088)	-4.51 (.039)	Immersion 0.67 (0.54 – 0.83)
Cesarean	8	-2 (.402)	-0.74 (.327)	--
Pain	8	0 (.500)	-1.67 (.339)	Standard Care 0.16 (0.07 – 0.37)

Satisfaction	6	-5 (.174)	-1.26 (.216)	Immersion 1.73 (1.13 – 2.64)
Intact Perineum	14	-10 (.340)	2.13 (.045)	Standard Care 1.71 (1.40 – 2.10)
Episiotomy	13	-11 (.274)	-1.27 (.121)	Immersion 0.20 (0.13 – 0.32)
OASI	14	3 (.435)	0.40 (.234)	Standard Care 0.64 (0.50 – 0.82)
Shoulder Dystocia	7	5 (.226)	1.85 (.001)	Standard Care 0.68 (0.38 – 1.21)
Maternal Infection	3	--	0.34 (.290)	--
Postpartum Hemorrhage	13	9 (.328)	-0.23 (.412)	Standard Care 0.52 (0.39 – 0.71)
Retained Placenta	5	6 (.071)	2.11 (.068)	Standard Care 0.76 (0.29 – 2.03)
APGAR	16	-34 (.179)	0.86 (.209)	Standard Care 0.59 (0.36 – 0.96)
Neonatal Resuscitation	5	2 (.312)	0.69 (.282)	--
Transient Tachypnea	2	--	--	--
Respiratory Distress	3	1 (.301)	-1.77 (.426)	--
Neonatal Death	3	1 (.301)	1.34 (.078)	Standard Care 0.84 (0.53 – 1.33)
Cord Avulsion	5	6 (.071)	0.36 (.182)	Standard Care 1.86 (1.26 – 2.75)
Breastfeeding Initiation	2	--	--	--

a. Confidence Interval estimate if bias were corrected.

Trim & Fill analysis conducted with random effects model and indicates OR and 95%

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 to midwifery-led settings and this has been reported for women who labour and/or give birth in water.[44,66-68] 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 obstetric anal sphincter injury (OASI),

which corroborates previous waterbirth research.[71,72] A significant postpartum haemorrhage (PPH) reduction was another important finding, which is also supported in the literature.[73]

In this study, there was no difference in caesarean delivery rate between those who used water and those who did not. Interestingly, the cesarean rate in these studies was 3.6%, with all but two studies reporting a cesarean delivery 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 cesarean delivery rate higher than 10% because it compared the use of water immersion to medical augmentation for women with a stalled labour.[5] One study with a caesarean rate of 26% is generalisable to settings with a higher low risk cesarean delivery rate.[17]

Our results for newborns mirror those reported in three substantial newborn specific systematic reviews.[46-48] 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.[44,74] The incidence of cord avulsion was 4.3 per 1,000 births in water compared to 1.3 per 1,000 births with standard care. Interestingly, the incidence of cord avulsion varied from 0.2 per 1,000 to 11.8 per 1,000 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 toward promoting physiologic birth.[84-88] 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.[77,78,80] Differences between birth settings in intact perineum and postpartum haemorrhage 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 labour induction and episiotomy are reduced with water immersion, while maternal satisfaction is increased. Given these results, water immersion for labour and birth is a tool that can be used to achieve physiologic birth and improve the quality of care in the obstetric setting.

One major issue that hindered the potential of this review was that only three 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.[38,44] 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 to fragmented care models.[89] This is important because birth pool use is most prevalent in midwifery-led settings.[38] 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. 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 cesarean. Only eight studies (22%) provided birth pool eligibility criteria regarding BMI. These studies did not include separate analysis of outcomes for women generally excluded from water immersion, however their inclusion in the study populations suggest water immersion is not harmful. 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 postpartum haemorrhage. 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 & fill analysis to identify the direction of any potential publication bias.

This review was limited to studies published in 2000 or later because earlier studies may not be generalisable to current water immersion practices. This review 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. This review did not include grey literature.

Clinical Implications

Water immersion provides benefits for the mother and newborn when used in the obstetric setting, making water immersion a tool for improving quality and satisfaction with care. In addition, water immersion for labour and waterbirth alters clinical practice resulting in less augmentation, episiotomy, and requirements for pharmacologic 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 -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. It has clear benefits for healthy women and their newborns when conducted in an obstetric setting and may have benefits for populations previously excluded from water immersion. Future research should focus on implementing water immersion in all birth settings and identification of best practice.

Author Contributions

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Figures

1. PRISMA flow diagram
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3. Synthesis of Labour Induction
4. Synthesis of Amniotomy
5. Synthesis of labour Augmentation
6. Synthesis of Opioid use
7. Synthesis of Epidural use
8. Synthesis of Maternal pain
9. Synthesis of Caesarean section delivery
10. Synthesis of Shoulder dystocia
11. Synthesis of Intact perineum
12. Synthesis of Obstetric Anal Sphincter Injury (OASI)
13. Synthesis of Episiotomy
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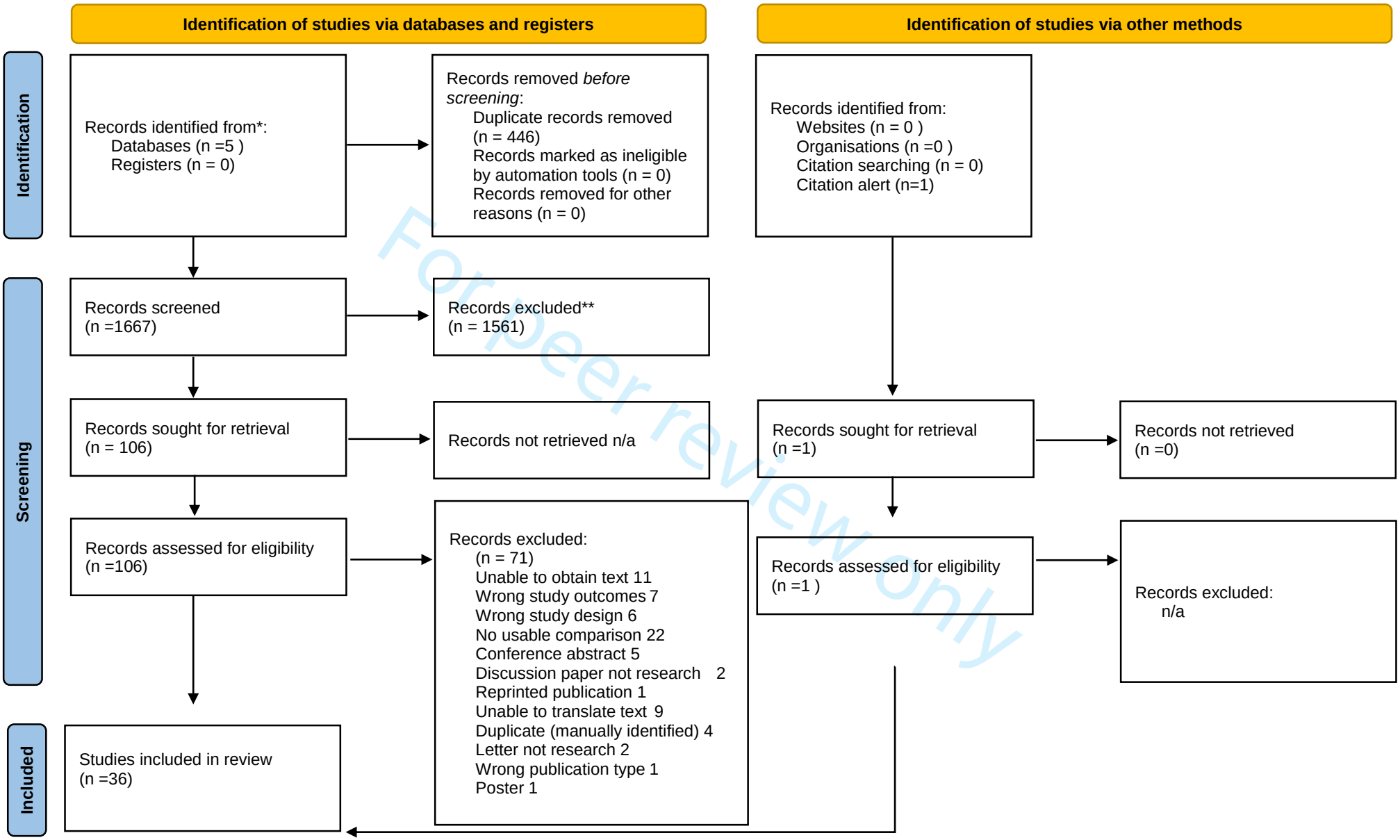
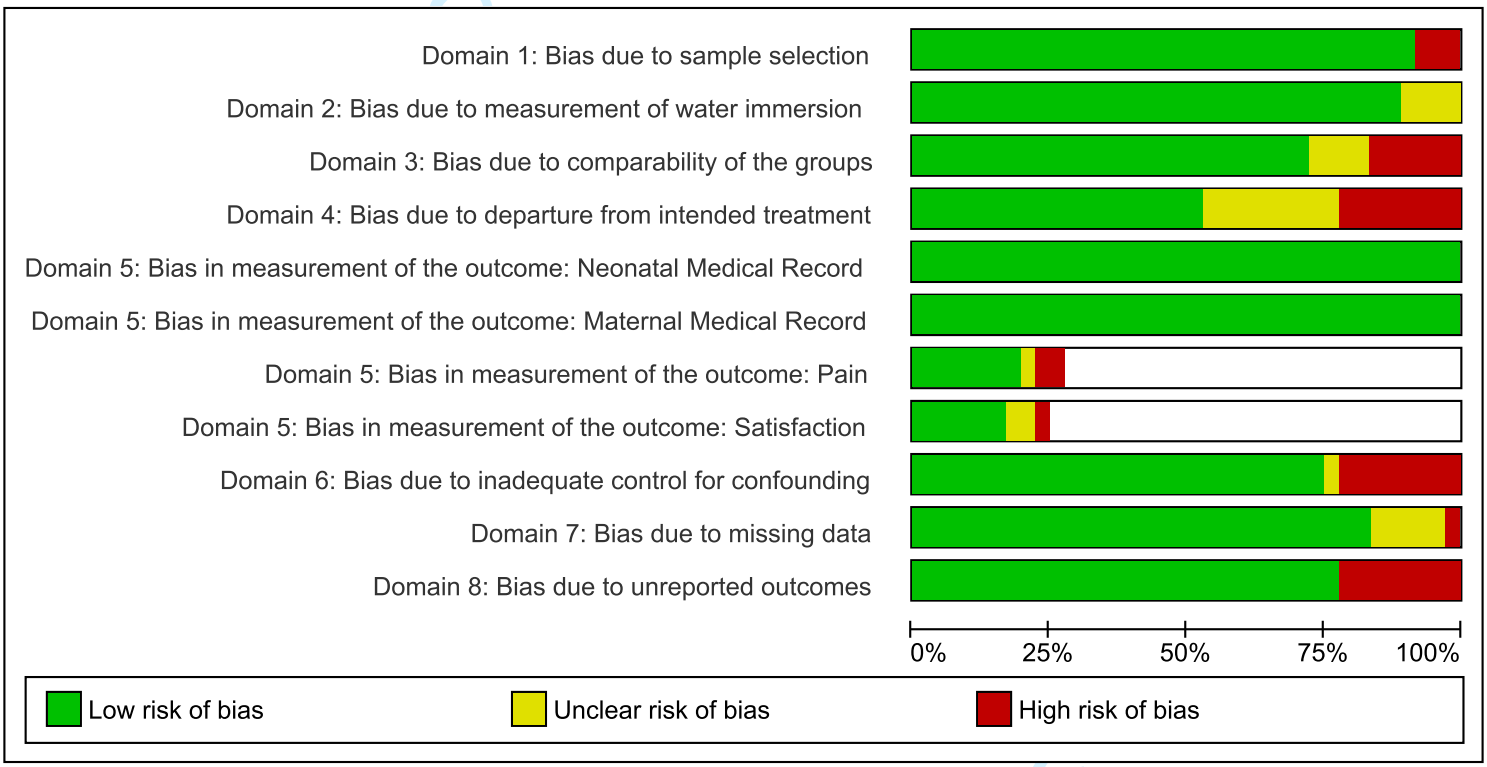
24. Synthesis of Breastfeeding initiation

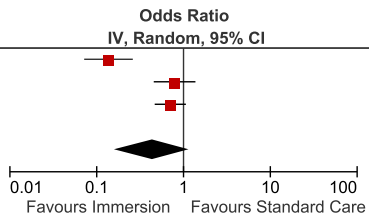
Figure 1 PRISMA 2020 flow diagram for new systematic reviews which included searches of databases, registers and other sources




Domain 1: Bias due to sample selection
Domain 2: Bias due to measurement of water immersion
Domain 3: Bias due to comparability of the groups
Domain 4: Bias due to departure from intended treatment
Domain 5: Bias in measurement of the outcome: Neonatal Medical Record
Domain 5: Bias in measurement of the outcome: Maternal Medical Record
Domain 5: Bias in measurement of the outcome: Pain
Domain 5: Bias in measurement of the outcome: Satisfaction
Domain 6: Bias due to inadequate control for confounding
Domain 7: Bias due to missing data
Domain 8: Bias due to unreported outcomes
0%
25%
50%
75%
100%
Low risk of bias
Unclear risk of bias
High risk of bias

Study or Subgroup	log[Odds Ratio]	SE	Immersion Total	Standard Care Total	Weight	Odds Ratio IV, Random, 95% CI	Year
Mollamahmutoglu	-1.99	0.329	207	395	32.0%	0.14 [0.07, 0.26]	2012
Ulfsdottir	-0.237	0.282	306	306	33.2%	0.79 [0.45, 1.37]	2018
Bailey	-0.351	0.211	397	397	34.8%	0.70 [0.47, 1.06]	2020
Total (95% CI)			**910**	**1098**	**100.0%**	**0.43 [0.16, 1.16]**	

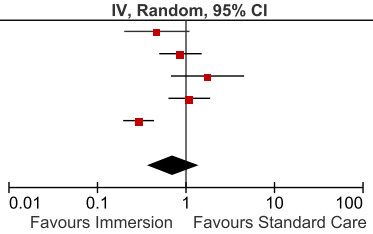
Heterogeneity: Tau² = 0.68; Chi² = 20.74, df = 2 (P < 0.0001); I² = 90%
Test for overall effect: Z = 1.66 (P = 0.10)



Risk of bias legend
(**A**) Domain 1: Bias due to sample selection
(**B**) Domain 2: Bias due to measurement of water immersion
(**C**) Domain 3: Bias due to comparability of the groups
(**D**) Domain 4: Bias due to departure from intended treatment
(**E**) Domain 5: Bias in measurement of the outcome: Maternal Medical Record
(**F**) Domain 6: Bias due to inadequate control for confounding
(**G**) Domain 7: Bias due to missing data
(**H**) Domain 8: Bias due to unreported outcomes

Study or Subgroup	log[Odds Ratio]	SE	Immersion Total	Standard Care Total	Weight	Odds Ratio IV, Random, 95% CI	Year	Odds Ratio IV, Random, 95% CI	Risk of Bias A B C D E F G H
Cluett	-0.758	0.433	49	50	17.8%	0.47 [0.20, 1.09]	2004		
Zanetti-Dallenbach,a	-0.144	0.282	89	146	21.3%	0.87 [0.50, 1.50]	2006		
da Silva	0.56	0.486	54	54	16.5%	1.75 [0.68, 4.54]	2009		
Henderson	0.086	0.277	114	459	21.4%	1.09 [0.63, 1.88]	2014		
Ulfsdottir	-1.232	0.205	306	306	22.9%	0.29 [0.20, 0.44]	2018		
Total (95% CI)			**612**	**1015**	**100.0%**	**0.71 [0.37, 1.39]**			

Heterogeneity: Tau² = 0.46; Chi² = 23.85, df = 4 (P < 0.0001); I² = 83%
Test for overall effect: Z = 0.99 (P = 0.32)

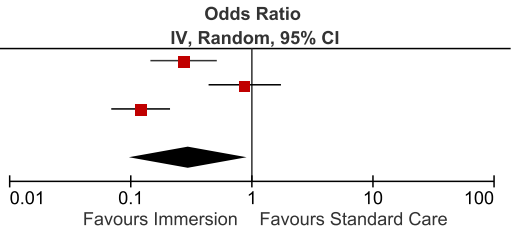


Risk of bias legend

(**A**) Domain 1: Bias due to sample selection
(**B**) Domain 2: Bias due to measurement of water immersion
(**C**) Domain 3: Bias due to comparability of the groups
(**D**) Domain 4: Bias due to departure from intended treatment
(**E**) Domain 5: Bias in measurement of the outcome: Maternal Medical Record
(**F**) Domain 6: Bias due to inadequate control for confounding
(**G**) Domain 7: Bias due to missing data
(**H**) Domain 8: Bias due to unreported outcomes

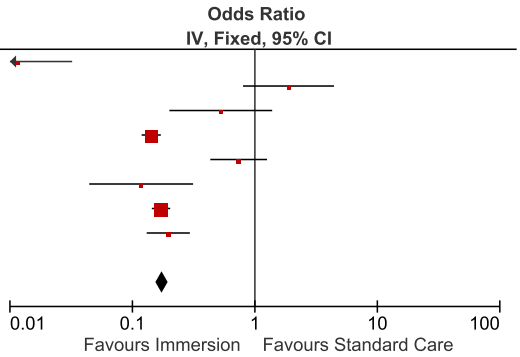
Study or Subgroup	log[Odds Ratio]	SE	Immersion Total	Standard Care Total	Weight	Odds Ratio IV, Random, 95% CI	Year
Zanetti-Dallenbach,a	-1.298	0.322	89	146	33.3%	0.27 [0.15, 0.51]	2006
Henderson	-0.135	0.351	114	459	32.6%	0.87 [0.44, 1.74]	2014
Ulfsdottir	-2.115	0.285	306	306	34.1%	0.12 [0.07, 0.21]	2018
Total (95% CI)			**509**	**911**	**100.0%**	**0.30 [0.10, 0.92]**	

Heterogeneity: Tau² = 0.87; Chi² = 19.18, df = 2 (P < 0.0001); I² = 90%
Test for overall effect: Z = 2.10 (P = 0.04)



Study or Subgroup	log[Odds Ratio]	SE	Immersion Total	Standard Care Total	Weight	Odds Ratio IV, Fixed, 95% CI	Year
Otigbah	-4.447	0.516	301	301	1.2%	0.01 [0.00, 0.03]	2000
Eckert	0.632	0.436	137	137	1.7%	1.88 [0.80, 4.42]	2001
Woodward	-0.641	0.493	50	30	1.4%	0.53 [0.20, 1.38]	2004
Geissbuehler, c	-1.949	0.092	3671	5901	39.2%	0.14 [0.12, 0.17]	2004
Zanetti-Dallenbach, b	-0.305	0.272	89	146	4.5%	0.74 [0.43, 1.26]	2007
Torkamani	-2.138	0.498	50	50	1.3%	0.12 [0.04, 0.31]	2010
Preston	-1.765	0.088	1244	14490	42.9%	0.17 [0.14, 0.20]	2019
Bailey	-1.628	0.207	397	397	7.7%	0.20 [0.13, 0.29]	2020
Total (95% CI)			**5939**	**21452**	**100.0%**	**0.18 [0.16, 0.20]**	

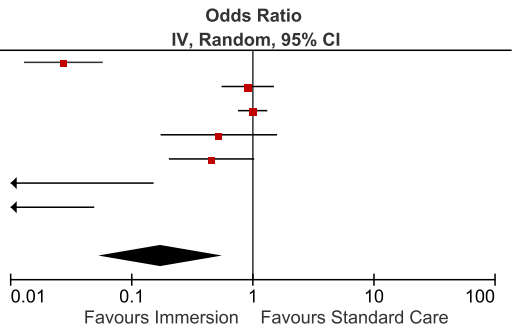
Heterogeneity: Chi² = 96.09, df = 7 (P < 0.00001); I² = 93%
Test for overall effect: Z = 30.24 (P < 0.00001)

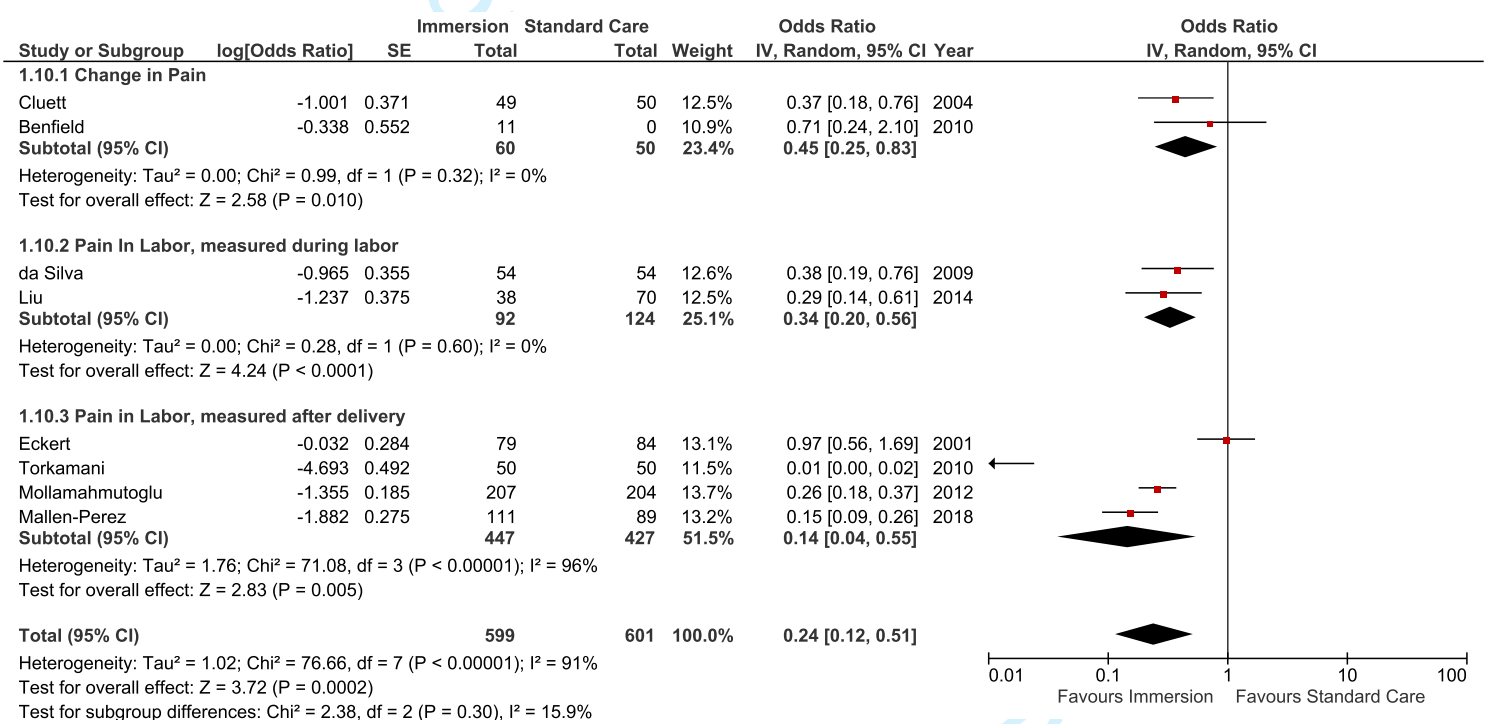


Study or Subgroup	log[Odds Ratio]	SE	Immersion Total	Standard Care Total	Weight	Odds Ratio IV, Random, 95% CI	Year
Geissbuhler, a	-3.603	0.382	3167	5901	16.4%	0.03 [0.01, 0.06]	2000
Eckert	-0.097	0.254	137	137	17.1%	0.91 [0.55, 1.49]	2001
Ohlsson	-0.004	0.142	612	625	17.4%	1.00 [0.75, 1.32]	2001
Woodward	-0.647	0.565	50	30	15.2%	0.52 [0.17, 1.58]	2004
Cluett	-0.786	0.414	49	50	16.2%	0.46 [0.20, 1.03]	2004
Zanetti-Dallenbach,a	-4.687	1.428	89	146	8.8%	0.01 [0.00, 0.15]	2006
Ulfsdottir	-5.8	1.42	306	306	8.9%	0.00 [0.00, 0.05]	2018
Total (95% CI)			**4410**	**7195**	**100.0%**	**0.17 [0.05, 0.56]**	

Heterogeneity: Tau² = 2.04; Chi² = 103.68, df = 6 (P < 0.00001); I² = 94%

Test for overall effect: Z = 2.94 (P = 0.003)

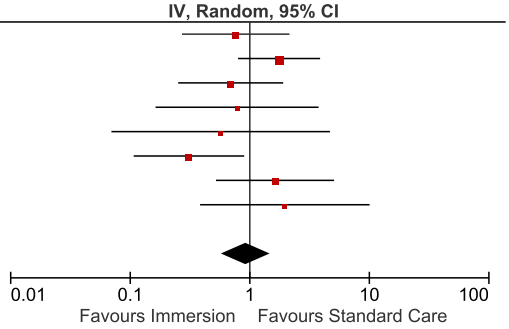



Immersion Standard Care Odds Ratio Odds Ratio
Study or Subgroup log[Odds Ratio] SE Total Total Weight IV, Random, 95% CI Year IV, Random, 95% CI
1.10.1 Change in Pain
Cluett -1.001 0.371 49 50 12.5% 0.37 [0.18, 0.76] 2004
Benfield -0.338 0.552 11 0 10.9% 0.71 [0.24, 2.10] 2010
Subtotal (95% CI) 60 50 23.4% 0.45 [0.25, 0.83]
Heterogeneity: Tau² = 0.00; Chi² = 0.99, df = 1 (P = 0.32); I² = 0%
Test for overall effect: Z = 2.58 (P = 0.010)
1.10.2 Pain In Labor, measured during labor
da Silva -0.965 0.355 54 54 12.6% 0.38 [0.19, 0.76] 2009
Liu -1.237 0.375 38 70 12.5% 0.29 [0.14, 0.61] 2014
Subtotal (95% CI) 92 124 25.1% 0.34 [0.20, 0.56]
Heterogeneity: Tau² = 0.00; Chi² = 0.28, df = 1 (P = 0.60); I² = 0%
Test for overall effect: Z = 4.24 (P < 0.0001)
1.10.3 Pain in Labor, measured after delivery
Eckert -0.032 0.284 79 84 13.1% 0.97 [0.56, 1.69] 2001
Torkamani -4.693 0.492 50 50 11.5% 0.01 [0.00, 0.02] 2010
Mollamahmutoglu -1.355 0.185 207 204 13.7% 0.26 [0.18, 0.37] 2012
Mallen-Perez -1.882 0.275 111 89 13.2% 0.15 [0.09, 0.26] 2018
Subtotal (95% CI) 447 427 51.5% 0.14 [0.04, 0.55]
Heterogeneity: Tau² = 1.76; Chi² = 71.08, df = 3 (P < 0.00001); I² = 96%
Test for overall effect: Z = 2.83 (P = 0.005)
Total (95% CI) 599 601 100.0% 0.24 [0.12, 0.51]
Heterogeneity: Tau² = 1.02; Chi² = 76.66, df = 7 (P < 0.00001); I² = 91%
Test for overall effect: Z = 3.72 (P = 0.0002)
Test for subgroup differences: Chi² = 2.38, df = 2 (P = 0.30), I² = 15.9%
0.01 0.1 1 10 100
Favours Immersion Favours Standard Care

Study or Subgroup	log[Odds Ratio]	SE	Immersion Total	Standard Care Total	Weight	Odds Ratio IV, Random, 95% CI	Year	Odds Ratio IV, Random, 95% CI
Eckert	-0.271	0.528	79	40	15.2%	0.76 [0.27, 2.15]	2001	
Ohlsson	0.564	0.403	612	625	21.8%	1.76 [0.80, 3.87]	2001	
Cluett	-0.368	0.516	49	50	15.7%	0.69 [0.25, 1.90]	2004	
Woodward	-0.245	0.801	50	30	7.8%	0.78 [0.16, 3.76]	2004	
Henderson	-0.56	1.074	114	459	4.6%	0.57 [0.07, 4.69]	2014	
Liu	-1.172	0.543	38	70	14.5%	0.31 [0.11, 0.90]	2014	
Barry	0.486	0.58	190	190	13.2%	1.63 [0.52, 5.07]	2020	
Neiman	0.675	0.833	58	111	7.3%	1.96 [0.38, 10.05]	2020	
Total (95% CI)			**1190**	**1575**	**100.0%**	**0.92 [0.58, 1.48]**		

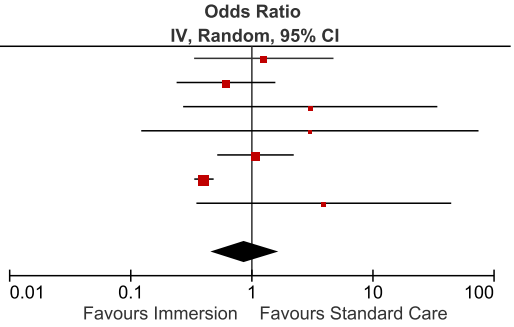
Heterogeneity: Tau² = 0.10; Chi² = 9.04, df = 7 (P = 0.25); I² = 23%

Test for overall effect: Z = 0.32 (P = 0.75)



Study or Subgroup	log[Odds Ratio]	SE	Immersion Total	Standard Care Total	Weight	Odds Ratio IV, Random, 95% CI	Year
Otigbah	0.227	0.676	301	301	13.6%	1.25 [0.33, 4.72]	2000
Geissbuehler, c	-0.492	0.479	3617	5901	18.8%	0.61 [0.24, 1.56]	2004
Zanetti-Dallenbach,a	1.11	1.233	89	133	5.9%	3.03 [0.27, 34.01]	2006
Menakaya	1.103	1.636	219	219	3.7%	3.01 [0.12, 74.40]	2013
Preston	0.069	0.371	1244	14490	22.2%	1.07 [0.52, 2.22]	2019
Snapp	-0.911	0.094	10252	16432	29.9%	0.40 [0.33, 0.48]	2019
Neiman	1.368	1.236	58	111	5.9%	3.93 [0.35, 44.28]	2020
Total (95% CI)			**15780**	**37587**	**100.0%**	**0.88 [0.46, 1.69]**	

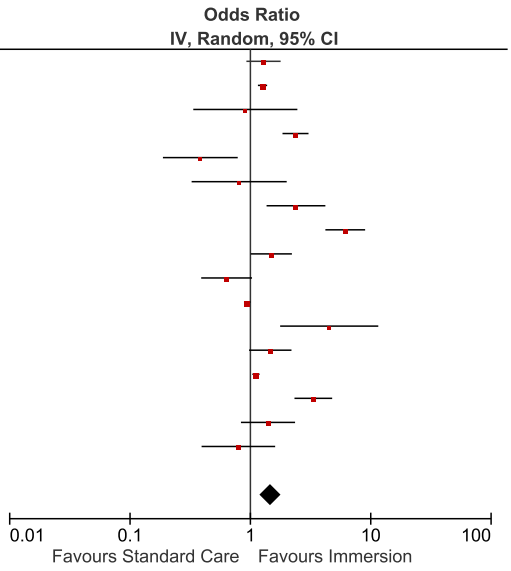
Heterogeneity: Tau² = 0.37; Chi² = 16.43, df = 6 (P = 0.01); I² = 63%
Test for overall effect: Z = 0.39 (P = 0.69)



Study or Subgroup	log[Odds Ratio]	SE	Immersion Total	Standard Care Total	Weight	Odds Ratio IV, Random, 95% CI	Year
Otigbah	0.251	0.167	301	301	7.1%	1.29 [0.93, 1.78]	2000
Geissbuehler, c	0.232	0.045	3617	5901	8.7%	1.26 [1.15, 1.38]	2004
Woodward	-0.097	0.508	50	30	2.7%	0.91 [0.34, 2.46]	2004
Thoeni	0.863	0.127	737	407	7.7%	2.37 [1.85, 3.04]	2005
Zanetti-Dallenbach, b	-0.958	0.365	89	146	4.0%	0.38 [0.19, 0.78]	2007
da Silva	-0.215	0.464	54	54	3.0%	0.81 [0.32, 2.00]	2009
Pagano	0.872	0.287	110	110	5.1%	2.39 [1.36, 4.20]	2010
Mollamahmutoglu	1.815	0.194	207	395	6.6%	6.14 [4.20, 8.98]	2012
Menakaya	0.4	0.201	219	219	6.5%	1.49 [1.01, 2.21]	2013
Henderson	-0.455	0.248	114	459	5.7%	0.63 [0.39, 1.03]	2014
Bovbjerg	-0.06	0.032	6521	10252	8.8%	0.94 [0.88, 1.00]	2016
Lim	1.508	0.479	118	118	2.9%	4.52 [1.77, 11.55]	2016
Ulfsdottir	0.38	0.207	306	306	6.4%	1.46 [0.97, 2.19]	2018
Snapp	0.106	0.035	10252	16432	8.7%	1.11 [1.04, 1.19]	2019
Bailey	1.204	0.184	397	397	6.8%	3.33 [2.32, 4.78]	2020
Barry	0.337	0.264	100	185	5.4%	1.40 [0.83, 2.35]	2020
Neiman	-0.23	0.359	58	108	4.1%	0.79 [0.39, 1.61]	2020
Total (95% CI)			**23250**	**35820**	**100.0%**	**1.47 [1.21, 1.78]**	

Heterogeneity: Tau² = 0.11; Chi² = 219.08, df = 16 (P < 0.00001); I² = 93%

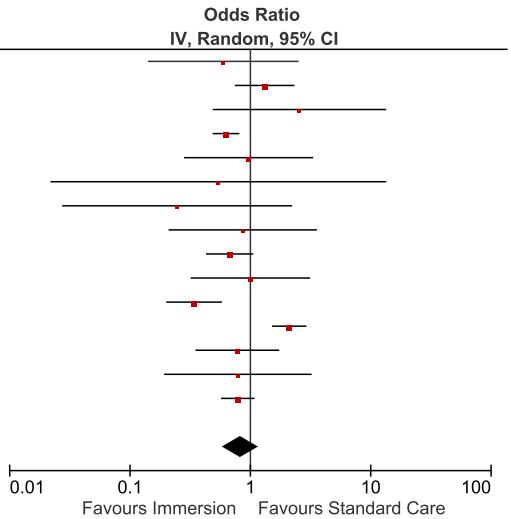
Test for overall effect: Z = 3.87 (P = 0.0001)



Study or Subgroup	log[Odds Ratio]	SE	Immersion Total	Standard Care Total	Weight	Odds Ratio IV, Random, 95% CI	Year
Otigbah	-0.518	0.735	301	301	3.9%	0.60 [0.14, 2.52]	2000
Ohlsson	0.273	0.291	612	625	9.4%	1.31 [0.74, 2.32]	2001
Eckert	0.939	0.846	137	137	3.2%	2.56 [0.49, 13.43]	2001
Geissbuehler, c	-0.467	0.131	3617	5901	11.9%	0.63 [0.48, 0.81]	2004
Thoeni	-0.034	0.63	737	407	4.8%	0.97 [0.28, 3.32]	2005
Zanetti-Dallenbach, b	-0.613	1.639	89	146	1.0%	0.54 [0.02, 13.46]	2007
Menakaya	-1.4	1.122	219	219	2.0%	0.25 [0.03, 2.22]	2013
Haslinger	-0.146	0.724	228	5031	4.0%	0.86 [0.21, 3.57]	2015
Bovbjerg	-0.397	0.231	6521	10252	10.4%	0.67 [0.43, 1.06]	2016
Ulfsdottir	0	0.583	306	306	5.3%	1.00 [0.32, 3.14]	2018
Jacoby	-1.078	0.272	1716	21320	9.7%	0.34 [0.20, 0.58]	2019
Preston	0.742	0.168	1244	6471	11.4%	2.10 [1.51, 2.92]	2019
Bailey	-0.249	0.409	397	397	7.5%	0.78 [0.35, 1.74]	2020
Barry	-0.24	0.72	100	185	4.0%	0.79 [0.19, 3.23]	2020
Hodgson	-0.242	0.164	2567	23201	11.4%	0.79 [0.57, 1.08]	2020
Total (95% CI)			**18791**	**74899**	**100.0%**	**0.84 [0.59, 1.18]**	

Heterogeneity: Tau² = 0.24; Chi² = 52.62, df = 14 (P < 0.00001); I² = 73%

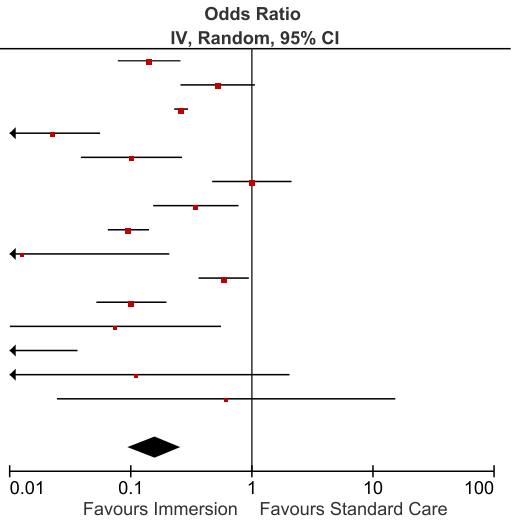
Test for overall effect: Z = 1.03 (P = 0.30)

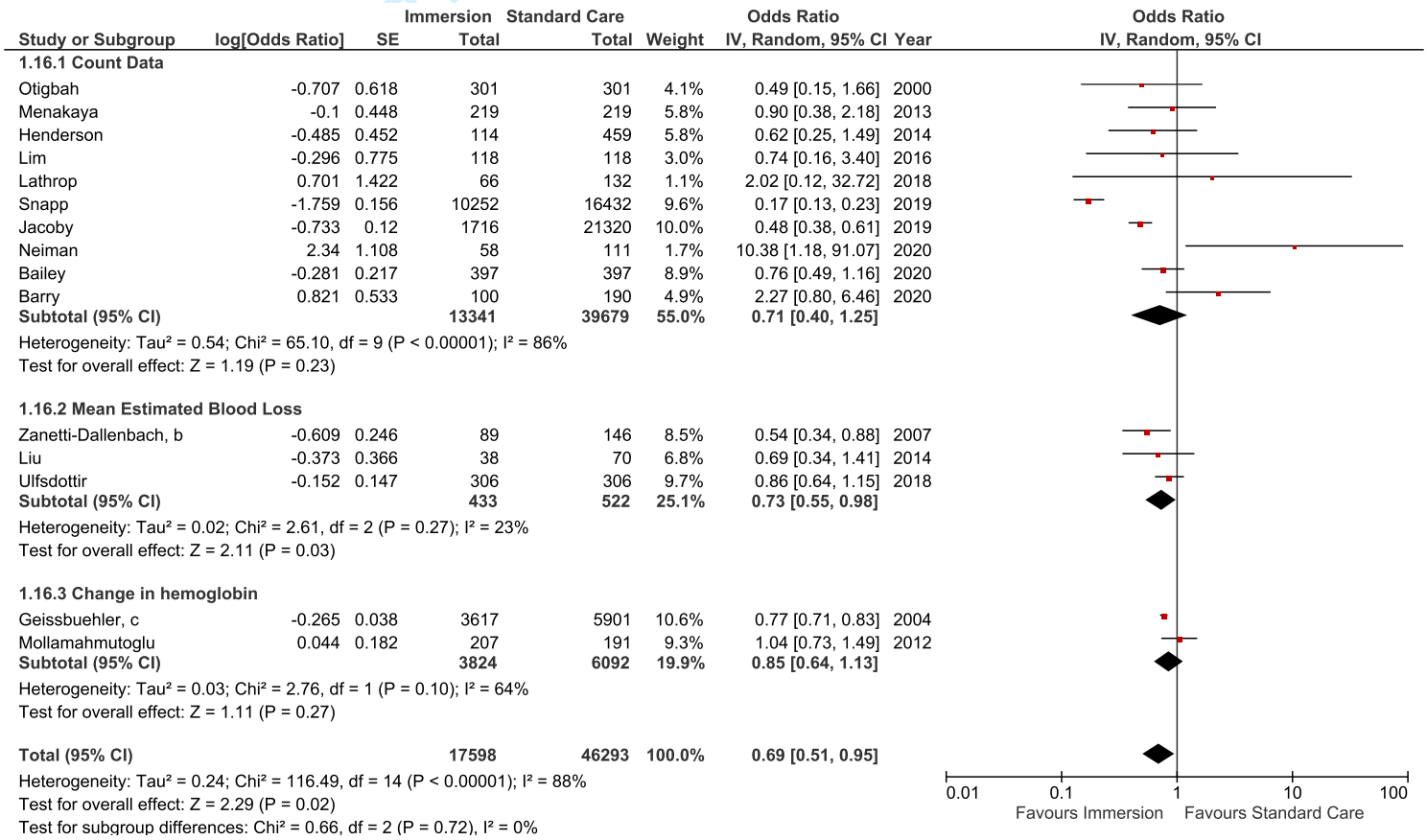


Study or Subgroup	log[Odds Ratio]	SE	Immersion Total	Standard Care Total	Weight	Odds Ratio IV, Random, 95% CI	Year
Otigbah	-1.953	0.304	301	301	8.8%	0.14 [0.08, 0.26]	2000
Eckert	-0.65	0.361	79	53	8.4%	0.52 [0.26, 1.06]	2001
Geissbuehler, b	-1.345	0.067	3617	5901	10.0%	0.26 [0.23, 0.30]	2002
Thoeni	-3.797	0.464	737	407	7.6%	0.02 [0.01, 0.06]	2005
Zanetti-Dallenbach,a	-2.289	0.491	89	146	7.3%	0.10 [0.04, 0.27]	2006
da Silva	0	0.385	54	54	8.2%	1.00 [0.47, 2.13]	2009
Torkamani	-1.065	0.414	50	50	8.0%	0.34 [0.15, 0.78]	2010
Mollamahmutoglu	-2.347	0.2	207	395	9.5%	0.10 [0.06, 0.14]	2012
Menakaya	-4.368	1.428	219	219	2.4%	0.01 [0.00, 0.21]	2013
Henderson	-0.536	0.244	114	459	9.2%	0.59 [0.36, 0.94]	2014
Haslinger	-2.291	0.34	288	5031	8.6%	0.10 [0.05, 0.20]	2015
Bovbjerg	-2.594	1.024	6521	10252	3.8%	0.07 [0.01, 0.56]	2016
Lim	-5.318	1.022	118	118	3.9%	0.00 [0.00, 0.04]	2016
Ulfsdottir	-2.21	1.493	306	306	2.3%	0.11 [0.01, 2.05]	2018
Neiman	-0.49	1.641	58	108	2.0%	0.61 [0.02, 15.28]	2020
Total (95% CI)			**12758**	**23800**	**100.0%**	**0.16 [0.10, 0.26]**	

Heterogeneity: Tau² = 0.65; Chi² = 114.27, df = 14 (P < 0.00001); I² = 88%

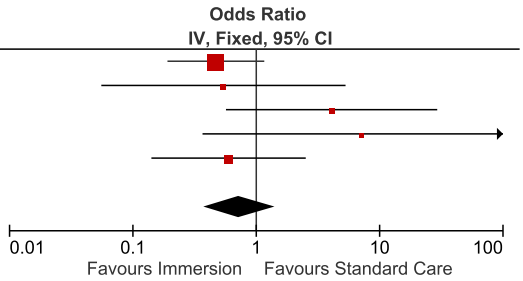
Test for overall effect: Z = 7.22 (P < 0.00001)




Immersion Standard Care Odds Ratio Odds Ratio
Study or Subgroup log[Odds Ratio] SE Total Total Weight IV, Random, 95% CI Year IV, Random, 95% CI
1.16.1 Count Data
Otigbah -0.707 0.618 301 301 4.1% 0.49 [0.15, 1.66] 2000
Menakaya -0.1 0.448 219 219 5.8% 0.90 [0.38, 2.18] 2013
Henderson -0.485 0.452 114 459 5.8% 0.62 [0.25, 1.49] 2014
Lim -0.296 0.775 118 118 3.0% 0.74 [0.16, 3.40] 2016
Lathrop 0.701 1.422 66 132 1.1% 2.02 [0.12, 32.72] 2018
Snapp -1.759 0.156 10252 16432 9.6% 0.17 [0.13, 0.23] 2019
Jacoby -0.733 0.12 1716 21320 10.0% 0.48 [0.38, 0.61] 2019
Neiman 2.34 1.108 58 111 1.7% 10.38 [1.18, 91.07] 2020
Bailey -0.281 0.217 397 397 8.9% 0.76 [0.49, 1.16] 2020
Barry 0.821 0.533 100 190 4.9% 2.27 [0.80, 6.46] 2020
Subtotal (95% CI) 13341 39679 55.0% 0.71 [0.40, 1.25]
Heterogeneity: Tau² = 0.54; Chi² = 65.10, df = 9 (P < 0.00001); I² = 86%
Test for overall effect: Z = 1.19 (P = 0.23)
1.16.2 Mean Estimated Blood Loss
Zanetti-Dallenbach, b -0.609 0.246 89 146 8.5% 0.54 [0.34, 0.88] 2007
Liu -0.373 0.366 38 70 6.8% 0.69 [0.34, 1.41] 2014
Ulfsdottir -0.152 0.147 306 306 9.7% 0.86 [0.64, 1.15] 2018
Subtotal (95% CI) 433 522 25.1% 0.73 [0.55, 0.98]
Heterogeneity: Tau² = 0.02; Chi² = 2.61, df = 2 (P = 0.27); I² = 23%
Test for overall effect: Z = 2.11 (P = 0.03)
1.16.3 Change in hemoglobin
Geissbuehler, c -0.265 0.038 3617 5901 10.6% 0.77 [0.71, 0.83] 2004
Mollamahmutoglu 0.044 0.182 207 191 9.3% 1.04 [0.73, 1.49] 2012
Subtotal (95% CI) 3824 6092 19.9% 0.85 [0.64, 1.13]
Heterogeneity: Tau² = 0.03; Chi² = 2.76, df = 1 (P = 0.10); I² = 64%
Test for overall effect: Z = 1.11 (P = 0.27)
Total (95% CI) 17598 46293 100.0% 0.69 [0.51, 0.95]
Heterogeneity: Tau² = 0.24; Chi² = 116.49, df = 14 (P < 0.00001); I² = 88%
Test for overall effect: Z = 2.29 (P = 0.02)
Test for subgroup differences: Chi² = 0.66, df = 2 (P = 0.72), I² = 0%
0.01 0.1 1 10 100
Favours Immersion Favours Standard Care

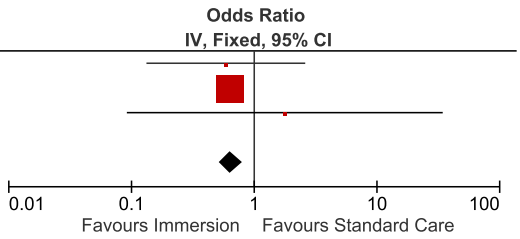
Study or Subgroup	log[Odds Ratio]	SE	Immersion Total	Standard Care Total	Weight	Odds Ratio IV, Fixed, 95% CI	Year
Ohlsson	-0.754	0.461	612	625	54.0%	0.47 [0.19, 1.16]	2001
Zanetti-Dallenbach, b	-0.613	1.163	89	146	8.5%	0.54 [0.06, 5.29]	2007
Henderson	1.406	1.006	114	459	11.3%	4.08 [0.57, 29.30]	2014
Lim	1.972	1.518	118	118	5.0%	7.19 [0.37, 140.78]	2016
Ulfsdottir	-0.517	0.735	306	306	21.2%	0.60 [0.14, 2.52]	2018
Total (95% CI)			**1239**	**1654**	**100.0%**	**0.73 [0.38, 1.42]**	

Heterogeneity: Chi² = 6.24, df = 4 (P = 0.18); I² = 36%
Test for overall effect: Z = 0.92 (P = 0.36)



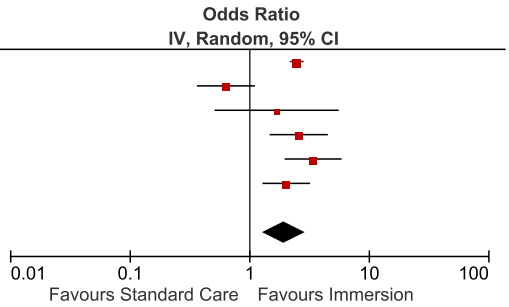
Study or Subgroup	log[Odds Ratio]	SE	Immersion Total	Standard Care Total	Weight	Odds Ratio IV, Fixed, 95% CI	Year
Cluett	-0.533	0.76	49	50	2.2%	0.59 [0.13, 2.60]	2004
Geissbuehler, c	-0.446	0.114	3617	5901	97.3%	0.64 [0.51, 0.80]	2004
Jacoby	0.573	1.512	1716	21320	0.6%	1.77 [0.09, 34.35]	2019
Total (95% CI)			**5382**	**27271**	**100.0%**	**0.64 [0.52, 0.80]**	

Heterogeneity: Chi² = 0.47, df = 2 (P = 0.79); I² = 0%
Test for overall effect: Z = 3.93 (P < 0.0001)



Study or Subgroup	log[Odds Ratio]	SE	Immersion Total	Standard Care Total	Weight	Odds Ratio IV, Random, 95% CI	Year
Geissbuhler, a	0.904	0.069	1587	1315	23.2%	2.47 [2.16, 2.83]	2000
Eckert	-0.46	0.285	79	84	16.7%	0.63 [0.36, 1.10]	2001
Cluett	0.517	0.61	49	50	8.1%	1.68 [0.51, 5.54]	2004
Zilkowksi	0.943	0.286	100	70	16.7%	2.57 [1.47, 4.50]	2009
Lathrop	1.219	0.28	66	132	16.9%	3.38 [1.95, 5.86]	2018
Ulfsdottir	0.702	0.234	306	306	18.5%	2.02 [1.28, 3.19]	2018
Total (95% CI)			**2187**	**1957**	**100.0%**	**1.95 [1.28, 2.96]**	

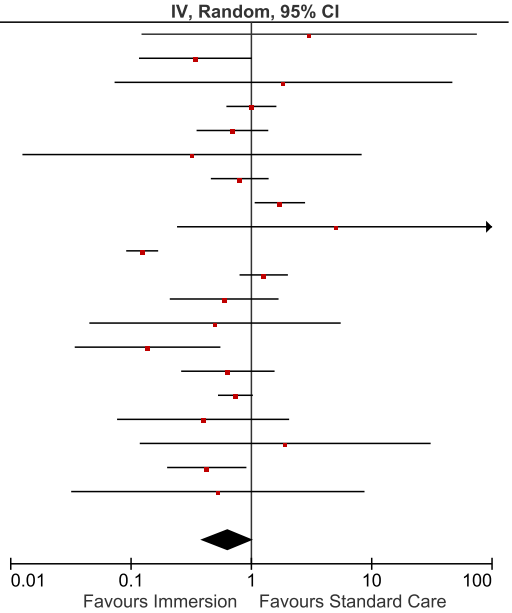
Heterogeneity: Tau² = 0.19; Chi² = 24.26, df = 5 (P = 0.0002); I² = 79%
Test for overall effect: Z = 3.13 (P = 0.002)



Study or Subgroup	log[Odds Ratio]	SE	Immersion Total	Standard Care Total	Weight	Odds Ratio IV, Random, 95% CI	Year
Eckert	1.106	1.637	137	137	1.9%	3.02 [0.12, 74.77]	2001
Geissbuehler, c	-1.071	0.551	3617	5901	5.8%	0.34 [0.12, 1.01]	2004
Woodward	0.614	1.649	50	30	1.9%	1.85 [0.07, 46.80]	2004
Zanetti-Dallenbach, b	0	0.244	89	146	7.3%	1.00 [0.62, 1.61]	2007
da Silva	-0.363	0.35	54	54	6.8%	0.70 [0.35, 1.38]	2009
Ros	-1.136	1.656	27	27	1.9%	0.32 [0.01, 8.25]	2009
Zilkowksi	-0.223	0.282	100	71	7.2%	0.80 [0.46, 1.39]	2009
Pagano	0.545	0.246	110	110	7.3%	1.72 [1.06, 2.79]	2010
Menakaya	1.619	1.552	219	219	2.0%	5.05 [0.24, 105.73]	2013
Bovbjerg	-2.09	0.156	6534	1574	7.6%	0.12 [0.09, 0.17]	2016
Lim	0.236	0.236	118	118	7.3%	1.27 [0.80, 2.01]	2016
Peacock	-0.521	0.531	592	2915	5.9%	0.59 [0.21, 1.68]	2018
Ulfsdottir	-0.696	1.227	306	306	2.8%	0.50 [0.05, 5.52]	2018
Jacoby	-1.987	0.711	1716	21320	4.9%	0.14 [0.03, 0.55]	2019
Sert	-0.45	0.456	34	30	6.3%	0.64 [0.26, 1.56]	2019
Snapp	-0.306	0.17	9290	15487	7.6%	0.74 [0.53, 1.03]	2019
Bailey	-0.924	0.84	397	397	4.3%	0.40 [0.08, 2.06]	2020
Barry	0.647	1.42	100	190	2.3%	1.91 [0.12, 30.88]	2020
Hodgson	-0.854	0.387	2567	23194	6.7%	0.43 [0.20, 0.91]	2020
Neiman	-0.642	1.432	58	31	2.3%	0.53 [0.03, 8.71]	2020
Total (95% CI)			**26115**	**72257**	**100.0%**	**0.63 [0.38, 1.05]**	

Heterogeneity: Tau² = 0.86; Chi² = 146.45, df = 19 (P < 0.00001); I² = 87%

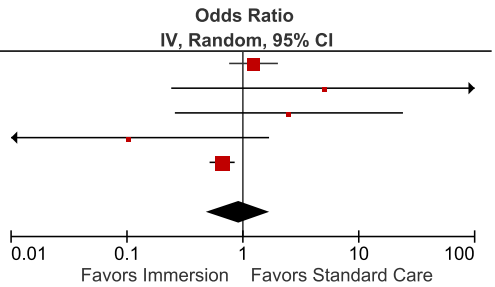
Test for overall effect: Z = 1.76 (P = 0.08)



Study or Subgroup	log[Odds Ratio]	SE	Immersion Total	Standard Care Total	Weight	Odds Ratio IV, Random, 95% CI	Year
Eckert	0.212	0.247	137	137	38.6%	1.24 [0.76, 2.01]	2001
Menakaya	1.619	1.552	219	219	3.8%	5.05 [0.24, 105.73]	2013
Henderson	0.915	1.156	830	689	6.4%	2.50 [0.26, 24.06]	2014
Jacoby	-2.263	1.42	1716	21320	4.4%	0.10 [0.01, 1.68]	2019
Hodgson	-0.412	0.127	2567	23194	46.8%	0.66 [0.52, 0.85]	2020
Total (95% CI)			**5469**	**45559**	**100.0%**	**0.91 [0.49, 1.69]**	

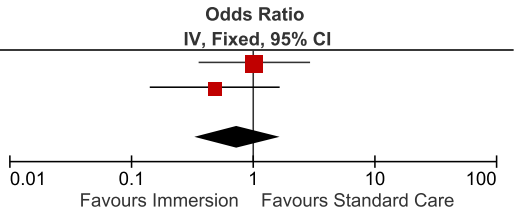
Heterogeneity: Tau² = 0.19; Chi² = 9.56, df = 4 (P = 0.05); I² = 58%

Test for overall effect: Z = 0.29 (P = 0.77)



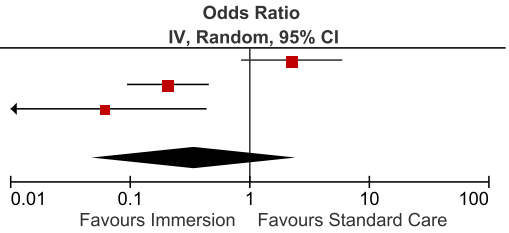
Study or Subgroup	log[Odds Ratio]	SE	Immersion Total	Standard Care Total	Weight	Odds Ratio IV, Fixed, 95% CI	Year
Ohlsson	0.021	0.538	612	625	57.6%	1.02 [0.36, 2.93]	2001
Lim	-0.729	0.627	118	118	42.4%	0.48 [0.14, 1.65]	2016
Total (95% CI)			**730**	**743**	**100.0%**	**0.74 [0.33, 1.65]**	

Heterogeneity: Chi² = 0.82, df = 1 (P = 0.36); I² = 0%
Test for overall effect: Z = 0.73 (P = 0.47)



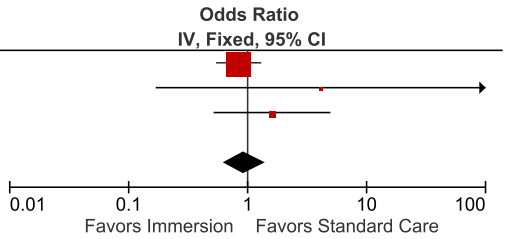
Study or Subgroup	log[Odds Ratio]	SE	Immersion Total	Standard Care Total	Weight	Odds Ratio IV, Random, 95% CI	Year
Ohlsson	0.806	0.497	612	625	35.5%	2.24 [0.85, 5.93]	2001
Geissbuehler, b	-1.577	0.402	3162	5272	36.6%	0.21 [0.09, 0.45]	2002
Jacoby	-2.798	1.003	1716	21320	27.9%	0.06 [0.01, 0.44]	2019
Total (95% CI)			**5490**	**27217**	**100.0%**	**0.34 [0.05, 2.43]**	

Heterogeneity: Tau² = 2.57; Chi² = 18.14, df = 2 (P = 0.0001); I² = 89%
Test for overall effect: Z = 1.07 (P = 0.28)



Study or Subgroup	log[Odds Ratio]	SE	Immersion Total	Standard Care Total	Weight	Odds Ratio IV, Fixed, 95% CI	Year
Bovbjerg	-0.173	0.223	6534	10290	85.6%	0.84 [0.54, 1.30]	2016
Jacoby	1.421	1.633	1716	21320	1.6%	4.14 [0.17, 101.66]	2019
Snapp	0.472	0.577	10252	16432	12.8%	1.60 [0.52, 4.97]	2019
Total (95% CI)			**18502**	**48042**	**100.0%**	**0.94 [0.63, 1.40]**	

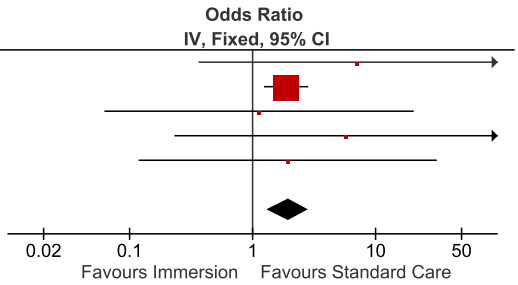
Heterogeneity: Chi² = 1.93, df = 2 (P = 0.38); I² = 0%
Test for overall effect: Z = 0.32 (P = 0.75)



Study or Subgroup	log[Odds Ratio]	SE	Immersion Total	Standard Care Total	Weight	Odds Ratio IV, Fixed, 95% CI	Year
Ulfsdottir	1.956	1.514	306	306	1.8%	7.07 [0.36, 137.47]	2018
Snapp	0.628	0.211	10252	16432	92.7%	1.87 [1.24, 2.83]	2019
Jacoby	0.121	1.477	1716	21320	1.9%	1.13 [0.06, 20.41]	2019
Barry	1.748	1.638	100	190	1.5%	5.74 [0.23, 142.37]	2020
Neiman	0.657	1.424	58	111	2.0%	1.93 [0.12, 31.44]	2020
Total (95% CI)			**12432**	**38359**	**100.0%**	**1.94 [1.30, 2.88]**	

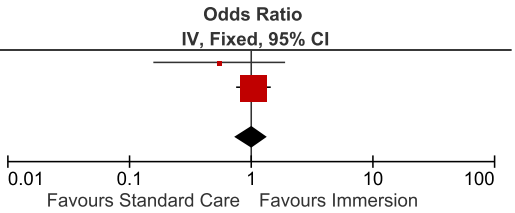
Heterogeneity: Chi² = 1.33, df = 4 (P = 0.86); I² = 0%

Test for overall effect: Z = 3.25 (P = 0.001)



Study or Subgroup	log[Odds Ratio]	SE	Immersion Total	Standard Care Total	Weight	Odds Ratio IV, Fixed, 95% CI	Year
Woodward	-0.606	0.636	50	30	6.5%	0.55 [0.16, 1.90]	2004
Ulfsdottir	0.042	0.167	306	306	93.5%	1.04 [0.75, 1.45]	2018
Total (95% CI)			**356**	**336**	**100.0%**	**1.00 [0.73, 1.37]**	

Heterogeneity: Chi² = 0.97, df = 1 (P = 0.32); I² = 0%
Test for overall effect: Z = 0.00 (P = 1.00)



Predesigned 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 stage

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

Embase (tested via HDAS, but this should work on Ovid. You may need an extra . after the .ti,ab. As I've seen this in online guides, but it doesn't work on HDAS. I'm hoping these are Emtree headings, but again, I've only been able to test of the HDAS version of Embase and not unadulterated Ovid)

S1 (Intrapartum OR intra-partum OR labor OR laboring OR labour OR labouring OR deliver* OR childbirth* OR birth* OR parturition).ti,ab 1,280,617

S2 exp CHILDBIRTH/ or exp LABOR/ 55,737

S3 S1 OR S2 1,290,620

S4 ((Water ADJ3 birth) OR waterbirth OR water-birth OR (birth* ADJ3 tub) OR (birth* ADJ3 pool*) OR (water ADJ3 immersion)).ti,ab 6,384

S5 "WATER BIRTH"/ 175

S6 S4 OR S5 6,421

S7 S3 AND S6 874

CENTRAL

(note for Claire – when running the searches, you need to be in Search Manager, and you have to actually search for the Mesh headings using the Mesh option next to the search box, you can't just copy and paste the line in)

S1 (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 98,911

S2 MeSH descriptor: [Labor, Obstetric] explode all trees 2,298

S3 MeSH descriptor: [Parturition] explode all trees 408

S4 S1 OR S2 OR S3 99,254

S5 ((water NEAR birth*) OR (water NEAR immersion) OR waterbirth* OR water-birth* OR (birth* NEAR tub) OR (birth* NEAR pool*)):ti OR ((water NEAR birth*) OR (water NEAR immersion) OR waterbirth* OR water-birth* OR (birth* NEAR tub) OR (birth* NEAR pool*)):ab 792

S6 S4 AND S5 117

CINAHL

Accessibility Information and TipsRevised Date: 07/2015				
Print Search History				
	Monday, March 09, 2020 9:20:23 AM	Monday, March 09, 2020 9:20:23 AM		
#	**Query**	**Query**	**Last Run Via**	**Results**
S8	((MH water birth) OR (S4 OR S5)) AND (S3 AND S6)	((MH water birth) OR (S4 OR S5)) AND (S3 AND S6)	Interface - EBSCOhost Research Databases	719
			Search Screen - Advanced Search	
			Database - CINAHL	
S7	((MH water birth) OR (S4 OR S5)) AND (S3 AND S6)	((MH water birth) OR (S4 OR S5)) AND (S3 AND S6)	Interface - EBSCOhost Research Databases	826
			Search Screen - Advanced Search	
			Database - CINAHL	
S6	(MH water birth) OR (S4 OR S5)	(MH water birth) OR (S4 OR S5)	Interface - EBSCOhost Research Databases	1,577
			Search Screen - Advanced Search	
			Database - CINAHL	
S5	MH water birth	MH water birth	Interface - EBSCOhost Research Databases	602
			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	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	Interface - EBSCOhost Research Databases	1,270
			Search Screen - Advanced Search	
			Database - CINAHL	

S3	(((MH childbirth+ OR MH labor+) OR (S1 OR S2)) AND (S1 OR S2)) AND (S1 OR S2)	(((MH childbirth+ OR MH labor+) OR (S1 OR S2)) AND (S1 OR S2)) AND (S1 OR S2)	Interface - EBSCOhost Research Databases	263,754
			Search Screen - Advanced Search	
			Database - CINAHL	
S2	MH childbirth+ OR MH labor+	MH childbirth+ OR MH labor+	Interface - EBSCOhost Research Databases	36,225
			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)	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)	Interface - EBSCOhost Research Databases	253,388

PSYCHINFO

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

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 History						
(7searches found)						
Search history sorted by search number descending						
	# ▼	**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
					More	

	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
					More

COCHRANE

Search Name:	water	
Date Run:	#######	
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

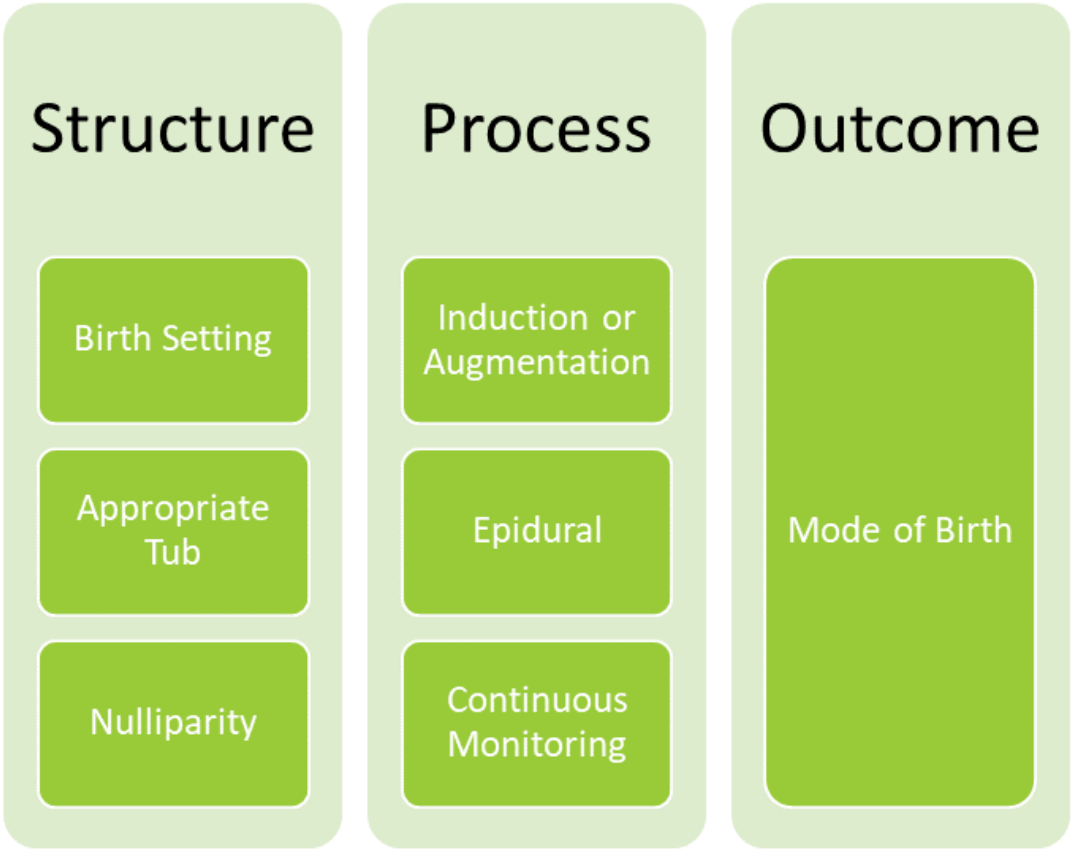
Database	**Number of hits**	
CINAHL	719	
pyshinfo	58	
MEDLINE	697	
EMBASE	552	
COCHRANE	87	
	2113	
Duplicates removed	446	
	1667	
Screened title/abstract	1667	
Excluded	1561	
Included for full text	**106**	
Full text EXCLUDED	49	
Full text INCLUDED	**57**	
BMC update	1	

	58	INCLUDED

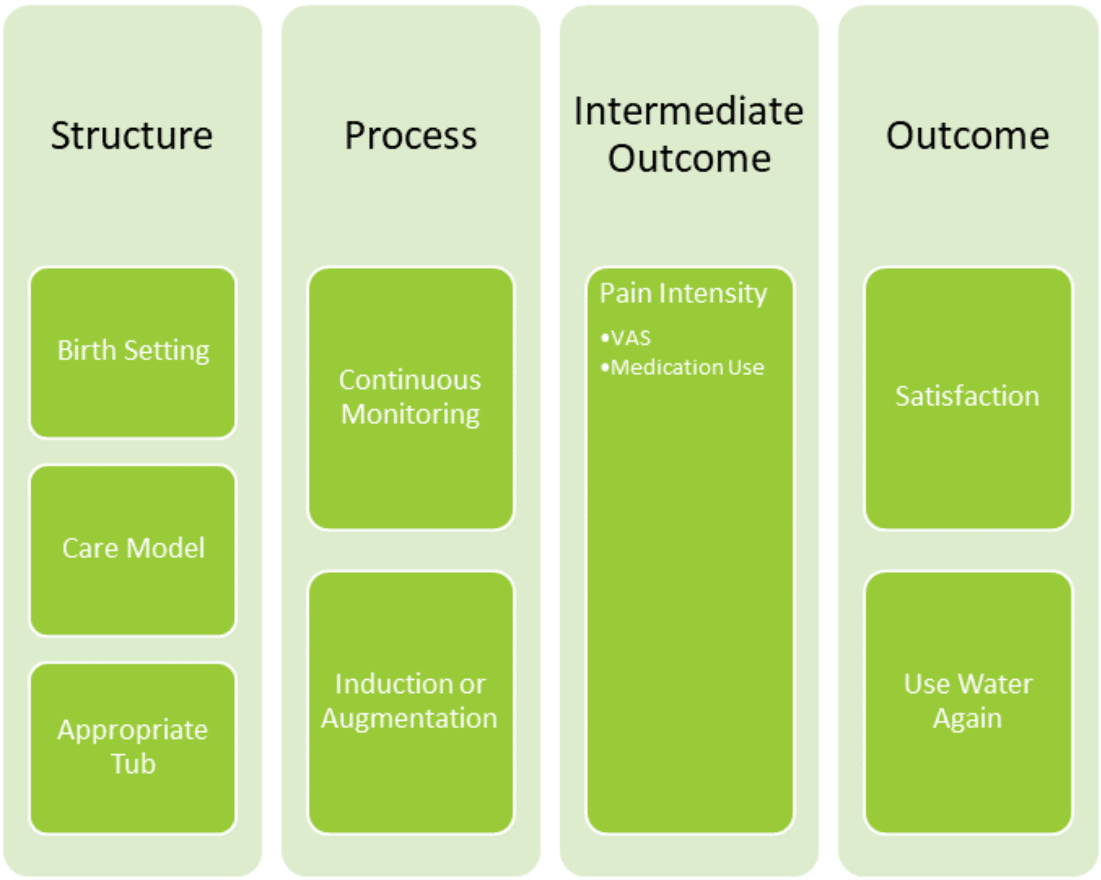
Reasons for exclusions	Number
Unable to obtain text	11
Wrong study outcomes	7
Wrong study design	6
Conference abstract	5
Discussion paper not research	2
Reprinted publication	1
Unable to translate text	9
Duplicate	4
Letter not research	2
Wrong publication type	1
Poster	1
	49

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

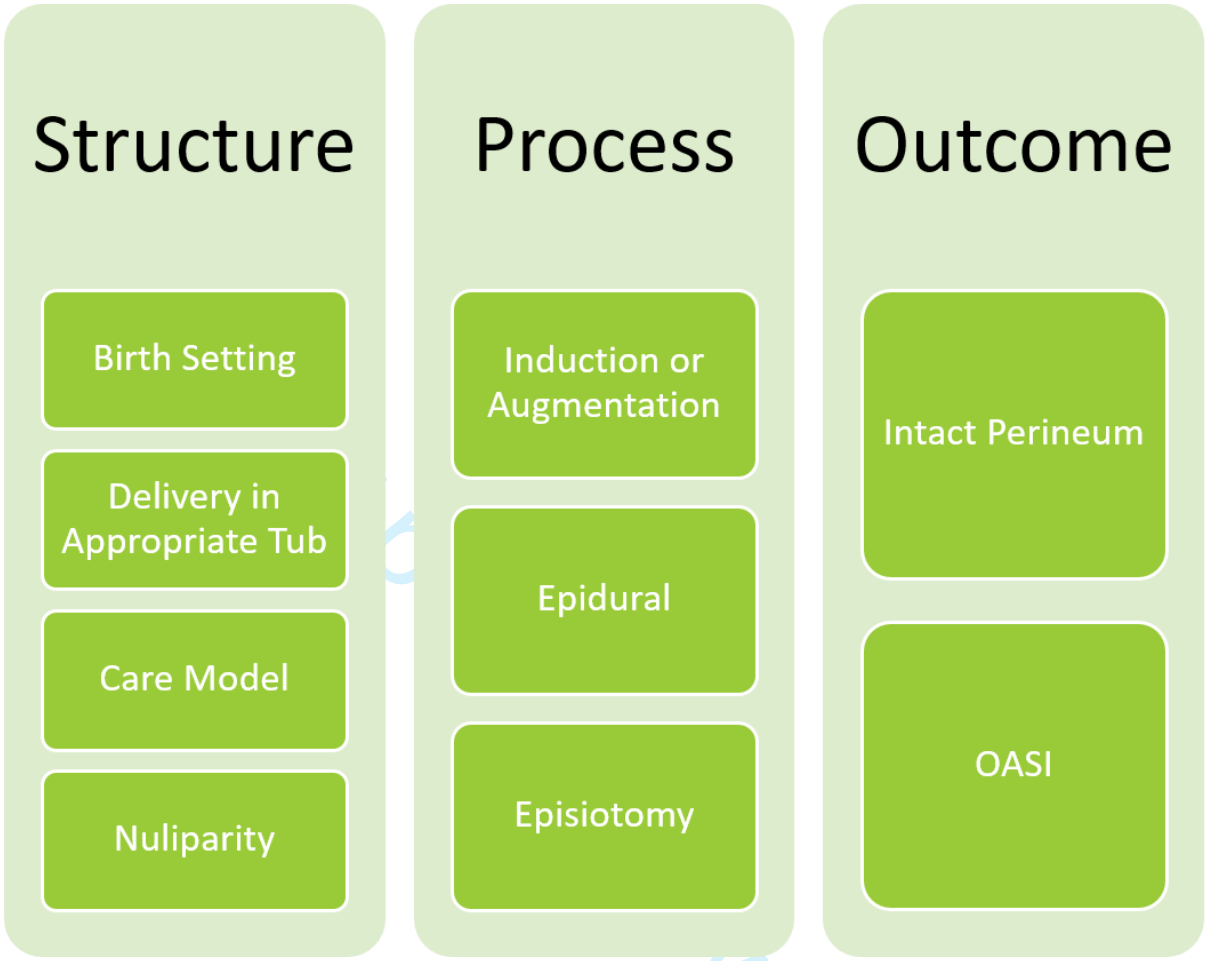
DAG 1: Assumptions about variables associated with variation in mode of birth.



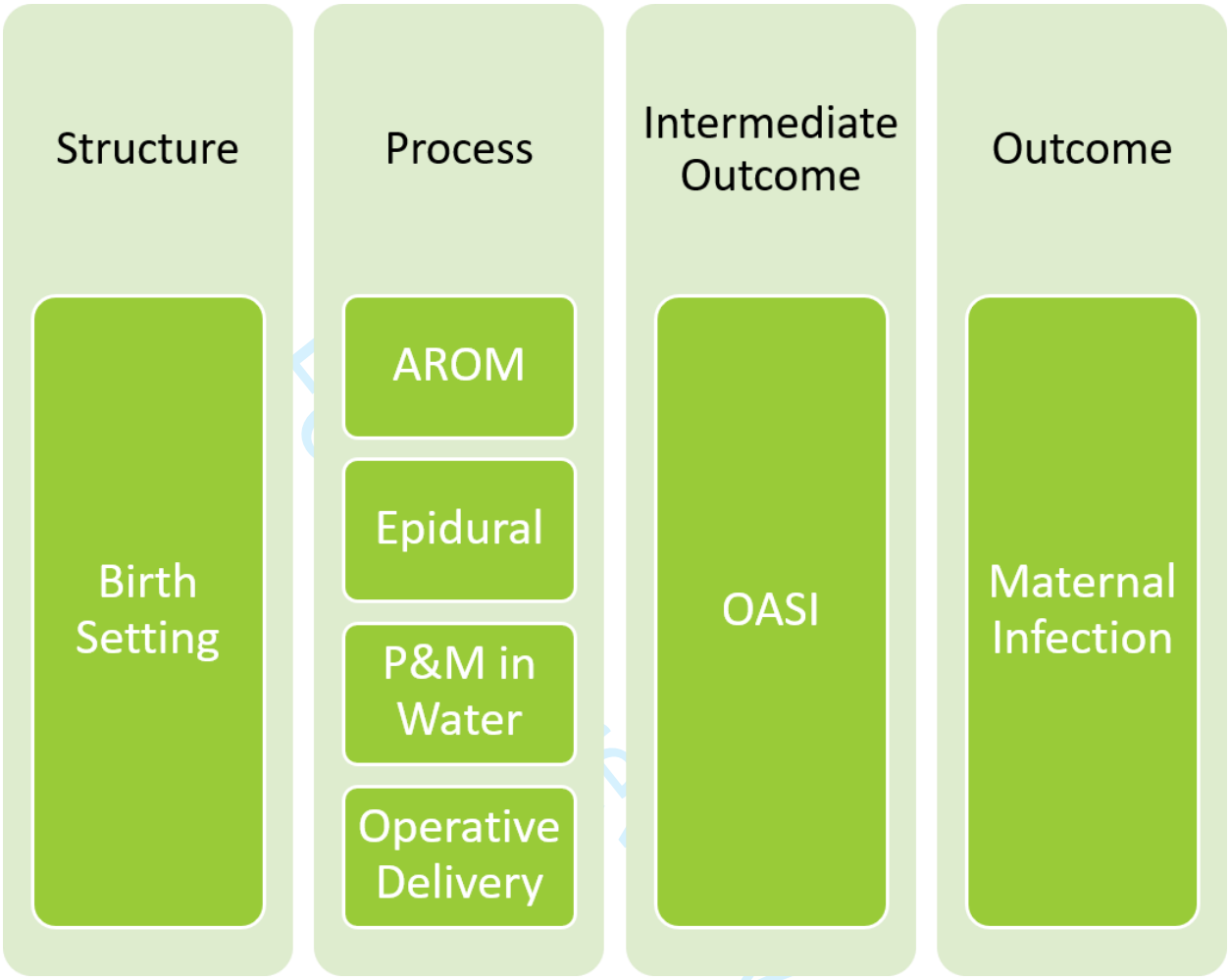
DAG 2: Assumptions about variables associated with variation in maternal satisfaction



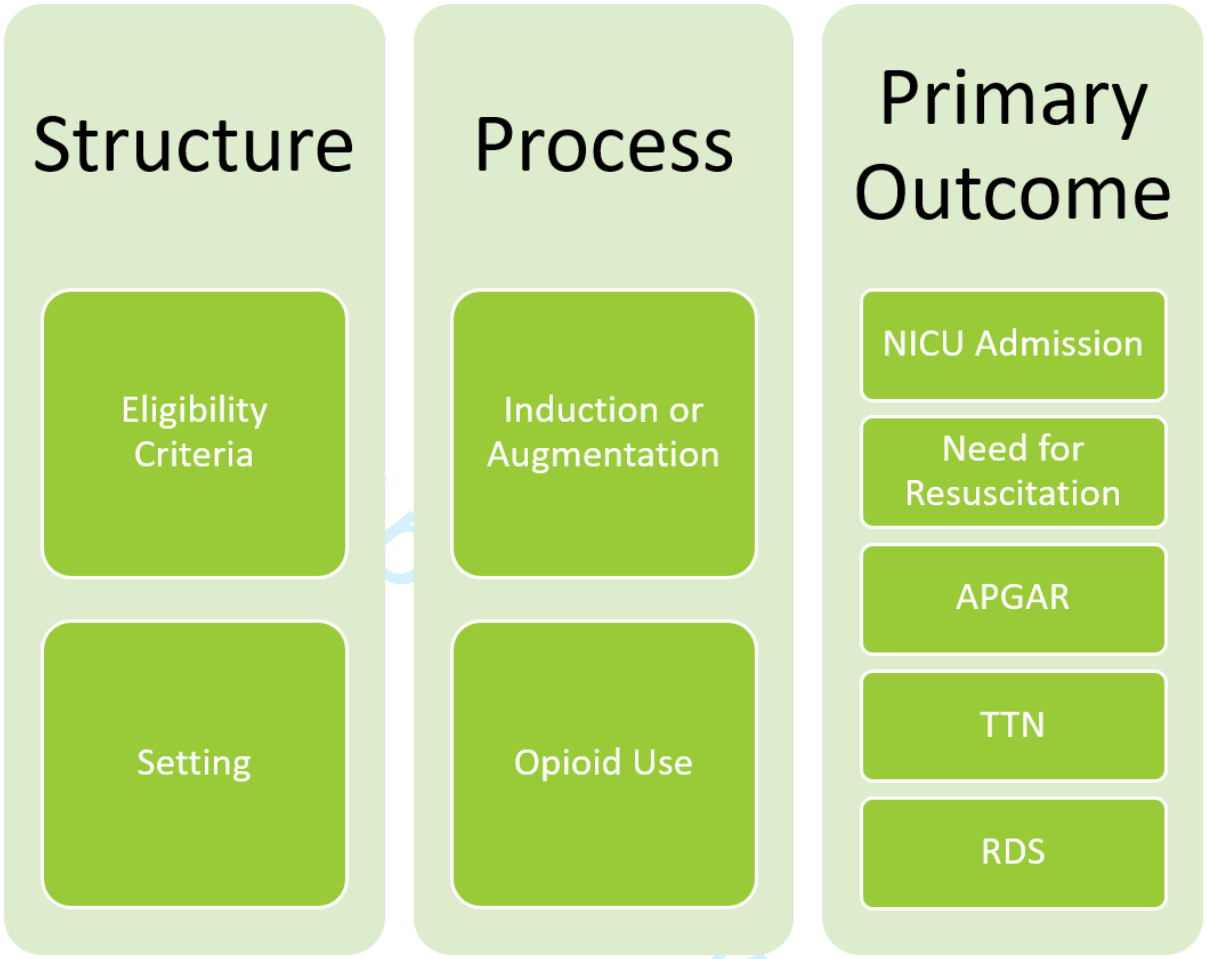
DAG 3: Assumptions about variables associated with variation in perineal outcomes.



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



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



Supplement 3: 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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Thoni, A., Zech, N., Moroder, L., & Ploner, F. (2007). Die Kontamination des Wassers und die Infektionsrate bei der Wassergeburt [Water contamination and infection rate after water births]. *Gynakologisch-geburtshilfliche Rundschau*, *47*(1), 33–38. https://doi.org/10.1159/000098123 [WRONG STUDY DESIGN]

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PRISMA 2020 Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	Title P.1
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	p.2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	p.4
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	p.4-5
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	p. 5 p.7
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	p.5 Supplement 1
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	p.5 Supplement 1
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	p.6-7
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	p.7
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	p.7
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	p.7
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	p.6-7
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	p.7-8
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	p.7-10 & Table 1
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	p.7-8
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	P7-8
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	p.7
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	7-8

PRISMA 2020 Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	7-8
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	7-8
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	7-8
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	PRISMA Fig 1
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	Supplement 3
Study characteristics	17	Cite each included study and present its characteristics.	Table 1,2,3 P.8-16
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	Table 4 p.17-20
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	Fig 3-24 P.17-27
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	p.17 Fig 2
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	Fig 3-24 P.17-27
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	Fig 3-24 P.17-27
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	Table 4 p.17-20
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	Fig 3-24 P.17-27
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	Table 5 p.27-28
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	p.28-30
	23b	Discuss any limitations of the evidence included in the review.	p.30-31
	23c	Discuss any limitations of the review processes used.	p.31
	23d	Discuss implications of the results for practice, policy, and future research.	p.31-32
OTHER INFORMATION			
Registration and	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	p.5

PRISMA 2020 Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
protocol	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	Link p.5
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	p.5
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	p.33
Competing interests	26	Declare any competing interests of review authors.	p.33
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	SR dedicated google drive

From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71
For more information, visit: http://www.prisma-statement.org/

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A 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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A 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. The objective of this study was to synthesise 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 (BMC) 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 or 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 7 domains based on the Robbins-I Risk of Bias Tool. All outcomes were summarised using an odds ratio (OR) and 95% confidence interval (CI). All calculations were conducted in Comprehensive Meta-Analysis Version 3, using the inverse variance method. Results of individual studies were converted to log odds ratio and standard error for synthesis. Fixed effects models were used when I^2 was less than 50%, otherwise random effects models were used. Cumulative meta-analysis and fail-safe N was calculated to determine stability and certainty of the estimates. Begg's Test and Egger's Regression Risk assessed risk of bias across studies. Trim & Fill analysis was used to estimate the magnitude of effect of the bias. Meta-regression was completed when at least ten 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 a waterbirth (n=151,742), seven involved water immersion for labour only (1,901), three studies reported on water immersion during labour and waterbirth (n=3,688) 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 – 0.56), injected opioids (k=8, n=27,391; OR 0.22 95% CI 0.13 – 0.38), episiotomy (k=15, n=36,558; OR 0.16; 95% CI 0.10 – 0.27), maternal pain (k=8, n=1,200; OR 0.24 95% CI 0.12 – 0.51), and postpartum hemorrhage (k=15, n=63891; OR 0.69 95% CI 0.51 – 0.95). There was an increase in Maternal satisfaction (k=6, n=4,144; OR 1.95 95% CI 1.28 – 2.96) and odds of an intact perineum (k=17, n=59070; OR 1.48; 95% CI 1.21 – 1.79) with water immersion. Waterbirth was associated with increased odds of cord avulsion (OR 1.94 95% CI 1.30 – 2.88), although the absolute risk remained low (4.3 per 1,000 vs 1.3 per 1,000). There were no differences in any other identified neonatal outcomes.

Limitations: 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.

Conclusions: This review endorses previous reviews showing clear benefits resulting from intrapartum water immersion for healthy women, particularly when conducted in the obstetric unit setting. There is no evidence of increased risk to the newborn.

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https://www.crd.york.ac.uk/prospero/display_record.php?RecordID=147001&VersionID=1368697

Strengths and Limitations of the 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
- This meta-analysis was limited to studies published in any language if it could be translated into English using Google Translate, and published in 2000 or later.
- Few studies were conducted in midwifery-led settings.

Author Contributions

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Research Ethics Approval

No patient involvement

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Competing Interests

There were no competing interests.

Data Sharing Statement

No data-sharing agreement was required for this research.

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.[1] Evidence from randomised controlled trials (RCTs) showed that labouring in water reduces the need for epidural analgesia whilst identifying no adverse maternal or neonatal effects.[2] In the UK, most birthing pool use occurs in midwifery-led birth settings: these include alongside midwifery units (co-located with a maternity hospital setting) and freestanding midwifery units (FMU) (in the community setting) and home birth.[3] The outcomes of birthing pool use may be different in midwifery-led settings compared to an obstetric setting because healthy women experience fewer interventions and operative birth when the birth occurs in a midwifery-led setting compared to 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.[4-10] It is likely that woman 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.[11-13] 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.[14, 15] However, a RCT proposal is likely to encounter ethical and recruitment challenges due to increasing acknowledgment 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.[16]

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

A protocol for the review was published in the International Prospective Register of Systematic Reviews PROSPERO2019 CRD42019147001 prior to completion of the searches. The PRISMA 2020 guideline was followed for conducting this work.[17] Institutional Review Board approval was not sought as meta-analyses are not human subjects research.

Patient and Public Involvement

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

Eligibility

Studies using any primary quantitative study design published in peer-reviewed journal or unpublished thesis.

1) Studies that examined maternal or neonatal interventions and/or outcomes when using the birthing pool for labour and/or birth.
2) Studies published in 2000 or later
3) Studies conducted in any language if it could be translated into English using Google Translate.

Search Strategy

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.[18]

- Population: women in labour and early postpartum
- 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/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.[19] The refined search terms and strategy with Boolean operators are provided in Supplement 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 de-duplicated in Zotero and collated into Rayyan systematic review software.[20] Initial screening (title/abstract) was carried out blind by HTC, CF1, 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 PH. 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 Process & Data Items

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 PH) 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, shoulder dystocia, maternal infection defined by symptoms and positive test, primary postpartum haemorrhage, manual removal of the placenta, 5-minute 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 7 domains based on the Robbins-I Risk of Bias Tool.[21] 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 PH). Disagreements were resolved by consensus meeting.

Summary Measures & Synthesis of Results

All outcomes were summarized using an odds ratio (OR) and 95% confidence interval (CI). All calculations were conducted in Comprehensive Meta-Analysis Version 3, using the inverse variance method.[22] Results of individual studies were converted to log odds ratio and standard error 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 BMI, prior caesarean, and pool type, however the data did not allow for these analyses. Forest plots were created in RevMan v5.4.1.[23]

Additional Analyses

Begg's Test and Egger's Regression Risk assessed risk of bias across studies.[24] Trim & Fill analysis was used to estimate the magnitude of effect of the bias.[25] Meta-regression was completed when at least ten studies provided data for an outcome when I^2 >50%.[26, 27] 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 (DAG) of the covariates and their role are available in Supplement 2.[28] For continuous covariates, the rate of a covariate (e.g. the induction rate in the sample) were used for regression. Categorical covariates were coded as dichotomous (e.g. described appropriate birth pool or did not describe the immersion receptacle).

Certainty Assessment

The fail-safe N estimates was calculated to determine the number of studies necessary to change the estimates.[29] 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.[30] Assessment of certainty with GRADE criteria was considered 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 recognize the importance of a standardized GRADE assessment for readers. The individual assessments made in this review were prepared in a table outlining scores per standard Grade criteria as a supplement.

Results

Study Selection

The searches generated 2,113 hits, reduced to 1,667 after duplicates were removed; n=1,561 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 Supplement 3 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 153,236 women were included into the review. Figure 1 PRISMA diagram illustrates the study selection process.[17]

[Insert Figure 1 Here]

Study Description

Most studies (k=31) were conducted in an obstetric setting or did not adequately report the setting, four studies were conducted in midwife-led settings, and one study mixed settings. Midwifery-led settings included planned home and birth centre births, a birth centre (not explicitly described as freestanding) and an alongside midwifery unit (co-located in an obstetric unit). Studies included randomised controlled trials (k=7; n=2,666), prospective studies (k=13; n=30,085), retrospective studies (k=15; n=120,474), and one pre-post study (n=11). Studies reported on waterbirth (k=25; n=146,499),

water immersion for labour (k=7; n=1,901), both (k=3; n=4,621) and one whose timing of immersion could not be determined (n=215). Full information is available in Table 1.

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, 2019	RCT	Obstetric	Waterbirth	2,422	1, 5, 10, 11, 13, 17
Barry, 2020	PO	Obstetric	Both	380	8, 10, 11, 13, 17, 23
Benfield, 2010	Pre-Post	Obstetric	Labor	11	4, 7
Bovbjerg, 2016	RO	Midwifery	Waterbirth	18,355	10, 11, 12, 17, 21
Cluett, 2004	RCT	Obstetric	Labor	99	2, 6, 7, 8, 15, 16
da Silva, 2009	RCT	Obstetric	Labor	108	2, 4, 7, 10, 12, 17
Eckert, 2001	RCT	Obstetric	Labor	274	1, 5, 6, 7, 8, 11, 12, 16, 17, 18
Geisbuehler, 2002	PO	Obstetric	Waterbirth	5,584	12, 20
Geissbuehler, 2004	PO	Obstetric	Waterbirth	9,518	5, 9, 10, 11, 13, 15, 17
Geissbuhler, 2000	PO	Obstetric	Waterbirth	7,508	6, 16
Haslinger, 2015	RO	Obstetric	Waterbirth	7,832	11, 12
Henderson, 2014	PO	Obstetric	Both	3,078	2, 3, 8, 10, 12, 13, 14, 18
Hodgson, 2020	RO	Mixed	Waterbirth	25,768	4, 11, 17, 18
Jacoby, 2019	RO	Obstetric	Waterbirth	23,036	11, 13, 15, 17, 18, 20, 21, 23
Lathrop, 2018	PO	Obstetric	Waterbirth	198	13, 16

Lim, 2016	RO	Obstetric	Waterbirth	236	4, 9, 10, 12, 13, 14, 17, 19
Liu, 2014	PO	Obstetric	Labor	108	4, 7, 8, 13
Mallen-Perez, 2018	PO	Obstetric	Unclear	215	7
Menakaya, 2013	RO	Obstetric	Waterbirth	438	9, 10, 11, 12, 13, 17, 18
Mollamahmutoglu, 2012	PO	Obstetric	Waterbirth	602	1, 7, 10, 12, 13
Neiman, 2020	RO	Obstetric	Both	230	4, 8, 9, 10, 12, 13, 17, 22, 23
Ohlsson, 2001	RCT	Obstetric	Labor	1,237	6, 8, 11, 14, 19, 20
Otigbah, 2000	RO	Obstetric	Waterbirth	602	1, 4, 5, 9, 10, 11, 12, 13
Pagano, 2010	RO	Obstetric	Waterbirth	220	10, 17
Peacock, 2018	RO	Obstetric	Waterbirth	3,507	17
Preston, 2019	RO	Midwifery	Waterbirth	15,734	5, 9, 11
Ros, 2009	PO	Obstetric	Waterbirth	54	17
Sert, 2019	RCT	Obstetric	Labor	64	17
Snapp, 2019	RO	Midwifery	Waterbirth	26,684	9, 10, 13, 17, 21, 23
Thoeni, 2005	RO	Obstetric	Waterbirth	1,600	10, 11, 12
Torkamani, 2010	PO	Obstetric	Waterbirth	100	5, 7, 12
Ulfsdottir, 2018	RO	Midwifery	Waterbirth	612	1, 2, 3, 4, 6, 10, 11, 12, 13, 14, 16, 17, 23, 24
Woodward, 2004	RCT	Obstetric	Waterbirth	80	4, 5, 6, 8, 10, 17, 24

Zanetti-Dallenbach, 2006	PO	Obstetric	Waterbirth	513	2, 3, 6, 9, 12
Zanetti-Dallenbach, 2007	PO	Obstetric	Waterbirth	368	4, 5, 10, 11, 13, 14, 17
Ziolkowski, 2009	RO	Obstetric	Waterbirth	171	16, 17

Study Type Key: RCT, Randomised Controlled Trial; PO, Prospective Observational; RO, Retrospective Observational

Interventions & Outcomes Key: 1) Labour Induction 2) Amniotomy 3) Augmentation 4) Fetal Monitoring 5) Opioids 6) Epidural 7) Pain 8) Cesarean Delivery 9) Shoulder Dystocia 10) Intact Perineum 11) OASI 12) Episiotomy 13) Postpartum Hemorrhage 14) Manual Removal of Placenta 15) Maternal Infection 16) Maternal Satisfaction 17) 5-Minute APGAR 18) Newborn Resuscitation 19) Transient Tachypnea 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.

Studies reported on 157,546 total participants, though for some studies subgroup analyses were appropriate for this review. 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=2,292) and reported as a sample characteristic for five studies (n=22,439).

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 Cesarean
Bailey, 2019	Yes	No	No	Yes	No
Barry, 2020	Yes	Yes	>30	Yes	n.d.
Benfield, 2010	Yes	n.d.	n.d.	n.d.	n.d.
Bovbjerg, 2016	Yes	n.d.	n.d.	Yes	No
Cluett, 2004	Yes	Yes	n.d.	n.d.	n.d.
da Silva, 2009	Yes	n.d.	n.d.	Yes	n.d.
Eckert, 2001	Yes	No	n.d.	Yes	n.d.
Geisbuehler, 2002	Yes	n.d.	n.d.	n.d.	n.d.
Geissbuehler, 2004	Yes	n.d.	>40	n.d.	n.d.
Geissbuhler, 2000	Yes	n.d.	n.d.	n.d.	n.d.
Haslinger, 2015	Yes	n.d.	n.d.	Yes	n.d.
Henderson, 2014	Yes	No	n.d.	n.d.	No
Hodgson, 2020	Yes	n.d.	n.d.	Yes	n.d.
Jacoby, 2019	Yes	Yes	n.d.	Yes	n.d.

Lathrop, 2018	Yes	n.d.	n.d.	Yes	n.d.
Lim, 2016	Yes	n.d.	n.d.	Yes	No
Liu, 2014	No	n.d.	No	Yes	Yes
Mallen-Perez, 2018	Yes	Yes	No	Yes	n.d.
Menakaya, 2013	Yes	Yes	n.d.	Yes	n.d.
Mollamahmutoglu, 2012	Yes	No	No	n.d.	Yes
Neiman, 2020	Yes	Yes	n.d.	Yes	Yes
Ohlsson, 2001	Yes	n.d.	n.d.	Yes	n.d.
Otigbah, 2000	Yes	No	n.d.	n.d.	n.d.
Pagano, 2010	Yes	n.d.	n.d.	n.d.	n.d.
Peacock, 2018	Yes	Yes	n.d.	n.d.	n.d.
Preston, 2019	Yes	Yes	No	n.d.	n.d.
Ros, 2009	Yes	n.d.	n.d.	Yes	Yes
Sert, 2019	Yes	Yes	n.d.	n.d.	Yes
Snapp, 2019	Yes	n.d.	n.d.	n.d.	n.d.
Thoeni, 2005	No	n.d.	n.d.	Yes	Yes
Torkamani, 2010	Yes	n.d.	n.d.	n.d.	n.d.
Ulfsdottir, 2018	Yes	Yes	No	n.d.	No

Woodward, 2004	Yes	Yes	n.d.	n.d.	Yes
Zanetti-Dallenbach, 2006	Yes	n.d.	n.d.	Yes	n.d.
Zanetti-Dallenbach, 2007	Yes	n.d.	n.d.	Yes	n.d.
Ziolkowski, 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.

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=3,273). Method of induction was not reported. Sixteen studies reported a fetal heart 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=5,595) or "hands-on" (k=2; n=6,463) the perineum. Third stage management was reported by six studies (n=5,595), 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=1,396).

Table 3: Description of care practices reported in included studies

Author	Appropriate Pool Described	Induction Method	Intermittent Auscultation	Perineum Method	3rd Stage Management	Placenta & Membranes
Bailey, 2019	No	n.d.	n.d.	n.d.	Active	Out of Pool
Barry, 2020	Yes	None	Mixed	Hands Off	Active	n.d.
Benfield, 2010	No	n.d.	No	n.d.	n.d.	n.d.
Bovbjerg, 2016	No	n.d.	n.d.	n.d.	n.d.	n.d.
Cluett, 2004	Yes	None	n.d.	n.d.	n.d.	n.d.
da Silva, 2009	No	n.d.	No	n.d.	n.d.	n.d.
Eckert, 2001	Yes	n.d.	n.d.	n.d.	n.d.	n.d.
Geisbuehler, 2002	No	n.d.	Yes	n.d.	n.d.	n.d.
Geissbuehler, 2004	No	n.d.	Yes	n.d.	n.d.	n.d.
Geissbuhler, 2000	No	n.d.	Yes	n.d.	n.d.	n.d.

Haslinger, 2015	No	n.d.	n.d.	Hands On	n.d.	n.d.
Henderson, 2014	No	n.d.	n.d.	Hands Off	Active	n.d.
Hodgson, 2020	No	n.d.	Yes	n.d.	n.d.	n.d.
Jacoby, 2019	No	None	n.d.	n.d.	n.d.	n.d.
Lathrop, 2018	No	n.d.	n.d.	n.d.	n.d.	n.d.
Lim, 2016	No	n.d.	No	n.d.	n.d.	n.d.
Liu, 2014	No	n.d.	Yes	n.d.	n.d.	n.d.
Mallen-Perez, 2018	Yes	None	n.d.	n.d.	n.d.	n.d.
Menakaya, 2013	Yes	None	n.d.	n.d.	n.d.	n.d.
Mollamahmutoglu, 2012	Yes	n.d.	Yes	Hands Off	Active	n.d.
Neiman, 2020	No	None	Yes	n.d.	n.d.	n.d.
Ohlsson, 2001	No	n.d.	n.d.	n.d.	n.d.	n.d.
Otigbah, 2000	Yes	n.d.	Yes	Hands Off	Active	Out of Pool
Pagano, 2010	No	n.d.	n.d.	n.d.	n.d.	n.d.

Peacock, 2018	No	None	n.d.	n.d.	n.d.	n.d.
Preston, 2019	No	None	n.d.	n.d.	n.d.	n.d.
Ros, 2009	No	n.d.	n.d.	n.d.	n.d.	n.d.
Sert, 2019	Yes	None	n.d.	n.d.	n.d.	n.d.
Snapp, 2019	No	n.d.	n.d.	n.d.	n.d.	n.d.
Thoeni, 2005	No	n.d.	n.d.	Hands On	n.d.	n.d.
Torkamani, 2010	No	n.d.	n.d.	n.d.	n.d.	n.d.
Ulfsdottir, 2018	Yes	None	No	n.d.	n.d.	n.d.
Woodward, 2004	No	None	Yes	n.d.	n.d.	n.d.
Zanetti-Dallenbach, 2006	No	n.d.	No	n.d.	Active	In Pool
Zanetti-Dallenbach, 2007	No	n.d.	No	n.d.	n.d.	n.d.
Ziolkowski, 2009	No	n.d.	Yes	n.d.	n.d.	n.d.

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

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 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.

[Insert Figure 2]

Labour Induction. Three studies provided data on labour induction (n=2,008), all conducted after 2010. Overall, this analysis found no difference between use of labour induction with water immersion and standard care (OR 0.43; 95% CI 0.16 – 1.16; random effects; Q=20.7 p<.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.

[Insert Figure 3]

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

Outcome	Studies	Sample	Effect OR (95% CI) Model	Heterogeneity Q (p) I^2%
Labor Induction[a]				

Obstetric Units	2	604 Immersion 792 Standard Care	0.32 (0.06 – 1.58) Random Effects	18 (<.01) 94%
Amniotomy[a]				
Obstetric Units	4	306 Immersion 709 Standard Care	0.95 (0.62 – 1.46) Random Effects	5 (.17) 40%
2010 and Earlier	3	192 Immersion 250 Standard care	0.87 (0.46 – 1.64) Random Effects	4 (.13) 51%
2011 and Later	2	420 Immersion 765 Standard care	0.56 (0.15 – 2.02) Random Effects	14 (<.01) 93%
Augmentation[a]				
Obstetric Units	2	203 Immersion 605 Standard Care	0.48 (0.16 – 1.51) Random Effects	6 (.02) 83%
2011 and Later	2	420 Immersion 765 Standard care	0.32 (0.05 – 2.24) Random Effects	19 (<.01) 95%
Opioid Use				
2010 and Earlier	6	4,298 Immersion 6,565 Standard care	0.23 (0.08 – 0.70) Random Effects	95 (<.01) 95%
2011 and Later	2	1,641 Immersion 14,887 Standard care	0.17 (0.15 – 0.20) Fixed Effects	0 (.54) 0%
Epidural[a]				
Obstetric Units	6	4,104 Immersion 6,889 Standard Care	0.26 (0.08 – 0.83) Random Effects	89 (<.01) 94%
2010 and Earlier	6	4,104 Immersion 6,889 Standard Care	0.26 (0.08 – 0.83) Random Effects	89 (<.01) 94%
Pain				

2010 and Earlier	3	182 Immersion	0.53 (0.27 – 1.03)	6 (.05)
		188 Standard Care	Random Effects	68%
2011 and Later	5	417 Immersion	0.15 (0.06 – 0.42)	48 (<.01)
		413 Standard Care	Random Effects	92%
Cesarean Delivery				
2010 and Earlier	4	790 Immersion	1.05 (0.63 – 1.74)	3 (.43)
		745 Standard Care	Fixed Effects	0%
2011 and Later	4	400 Immersion	0.84 (0.32 – 2.23)	6 (.12)
		830 Standard Care	Fixed Effects	48%
Shoulder Dystocia				
Obstetric Units	6	5,528 Immersion	1.06 (0.64 – 1.74)	4 (.60)
		21,155 Standard Care	Fixed Effects	0%
2010 and Earlier	3	4,007 Immersion	0.88 (0.42 – 1.83)	2 (.39)
		6,335 Standard Care	Fixed Effects	0%
2011 and Later	4	11,773 Immersion	0.87 (0.33 – 2.26)	11 (.01)
		31,252 Standard Care	Random Effects	73%
Intact Perineum				
Obstetric Units	14	6,170 Immersion	1.55 (1.12 – 2.16)	147 (<.01)
		8,866 Standard care	Random Effects	91%
Midwifery-led Units	3	17,079 Immersion	1.07 (0.91 – 1.26)	15 (<.01)
		23,249 Standard care	Random Effects	87%
Nulliparas	5	1,065 Immersion	1.59 (1.01 – 2.50)	12 (.01)
		894 Standard care	Random Effects	68%
Waterbirth vs No Water	8	954 Immersion	1.35 (0.67 – 2.72)	83 (<.01)
		1696 Standard care	Random Effects	92%

2010 and Earlier	7	4,958 Immersion	1.28 (0.90 – 1.82)	39 (<.01)
		6,949 Standard Care	Random Effects	85%
2011 and Later	10	18,292 Immersion	1.59 (1.22 – 2.07)	156 (<.01)
		28,871 Standard Care	Random Effects	94%
OASI				
Obstetric Units	13	10,720 Immersion	0.85 (0.57 – 1.30)	51 (<.001))
		57,870 Standard care	Random Effects	77%
Midwifery-led Units	2	6,827 Immersion	0.71 (0.47 – 1.08)	0 (.527)
		10,558 Standard care	Fixed Effects	0%
Nulliparas	2	870 Immersion	1.25 (0.42 – 3.71)	1 (.385)
		540 Standard care	Fixed Effects	0%
Waterbirth vs No Water	3	408 Immersion	0.57 (0.19 – 1.69)	1 (.681)
		550 Standard care	Fixed Effects	0%
2010 and Earlier	6	5,493 Immersion	0.73 (0.58 – 0.91)	8 (.16)
		7,517 Standard Care	Fixed Effects	37%
2011 and Later	9	13,298 Immersion	0.78 (0.48 – 1.28)	42 (<.01)
		67,382 Standard Care	Random Effects	81%
Episiotomy[a]				
Obstetric Units	14	6177 Immersion	0.17 (0.11 – 0.28)	109 (<.001)
		13,548 Standard care	Random Effects	88%
Nulliparas	3	886 Immersion	0.10 (0.02 – 0.60)	14 (<.001)
		582 Standard care	Random Effects	86%
Waterbirth vs No Water	5	691 Immersion	0.63 (0.02 – 0.20)	14 (.008)
		1022 Standard care	Random Effects	71%
2010 and Earlier	7	4,927 Immersion	0.21 (0.11 – 0.41)	52 (<.01)

		6,912 Standard Care	Random Effects	88%
2011 and Later	8	7,831 Immersion	0.09 (0.03 – 0.25)	53 (<.01)
		16,888 Standard Care	Random Effects	87%
Postpartum Hemorrhage				
Obstetric Units	13	7,040 Immersion	0.75 (0.60 – 0.94)	30 (.002)
		29,555 Standard care	Random Effects	60%
Midwifery-led Units	2	10,558 Immersion	0.39 (0.08 – 1.86)	56 (<.001)
		16,738 Standard care	Random Effects	98%
Waterbirth vs No Water	5	758 Immersion	1.02 (0.76 – 1.36)	4 (.439)
		1,177 Standard care	Fixed Effects	0%
2010 and Earlier	3	4,007 Immersion	0.72 (0.59 – 0.88)	2 (.30)
		6,348 Standard Care	Random Effects	17%
2011 and Later	12	13,591 Immersion	0.76 (0.48 – 1.20)	97 (<.01)
		39,945 Standard Care	Random Effects	89%
Manual Removal of Placenta				
Obstetric Units	4	1,239 Immersion	0.78 (0.37 – 1.64)	6 (.105)
		1,654 Standard care	Fixed Effects	51%
2010 and Earlier	2	701 Immersion	0.48 (0.21 – 1.11)	0 (.91)
		771 Standard Care	Fixed Effects	0%
2011 and Later	3	538 Immersion	1.48 (0.50 – 4.38)	4 (.16)
		883 Standard Care	Fixed Effects	45%
Maternal Satisfaction				
Obstetric Units	5	1,802 Immersion	2.02 (1.28 – 3.19)	24 (<.01)
		1,568 Standard care	Random Effects	83%
2010 and Earlier	4	1,815 Immersion	1.64 (0.83 – 3.24)	22 (<.01)

		1,519 Standard Care	Random Effects	86%
2011 and Later	2	372 Immersion	2.55 (1.54 – 4.23)	2 (.16)
		438 Standard Care	Random Effects	50%
APGAR				
Obstetric Units	18	10,286 Immersion	0.85 (0.66 – 1.08)	29 (.047)
		54,361 Standard care	Random Effects	38%
Midwifery-led Units	3	17,092 Immersion	0.33 (0.07 – 1.54)	57 (<.001)
		18,31 Standard care	Random Effects	96%
Waterbirth vs No Water	6	614 Immersion	1.07 (0.76 – 1.51)	3 (.643)
		655 Standard care	Fixed Effects	0%
2010 and Earlier	8	4,184 Immersion	1.00 (0.77 – 1.29)	7 (.120)
		6,476 Standard care	Fixed Effects	39%
2011 and Later	12	21,931 Immersion	0.52 (0.25 – 1.05)	101 (<.001)
		65,781 Standard care	Random Effects	89%
Neonatal Death				
Midwifery-led units	2	16,786 Immersion	0.91 (0.61 – 1.34)	1 (.297)
		26,722 Standard care	Fixed Effects	8%
Cord Avulsion				
Obstetric Units	3	1,874 Immersion	2.18 (0.34 – 11.97)	1 (.757)
		21,621 Standard care	Fixed Effects	0%
Midwifery-led Units	2	10,649 Immersion	1.92 (1.28 – 2.89)	1 (.386)
		16,829 Standard care	Fixed Effects	0%

a. Random Effects models were used for intervention (labor 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.

Amniotomy. Five studies provided data on amniotomy (n=1,627). Overall, this analysis found no difference (OR 0.71 ; 95% CI 0.37 – 1.39; random effects; Q=23.9 p<.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.

[Insert Figure 4]

Augmentation. Three studies provided data to compare augmentation of labour (n=1,420). This analysis favoured water immersion (OR 0.30; 95% CI 0.10 – 0.92; random effects; Q=19.2 p<.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.

[Insert Figure 5]

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 – 0.38; random effects; Q=96.1 p<.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 972 additional studies would be needed to change the estimate to no difference.

[Insert Figure 6]

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 – 0.83; random effects; Q=89.5 p<.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.

[Insert Figure 7]

Pain. Eight studies provided data for analysis of pain (n=1,200), 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 – 0.51; random effects; Q=76.7 p<.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 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.

[Insert Figure 8]

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. The meta-analysis indicated no difference between water immersion and standard care for caesarean birth (OR 0.92 95% CI 0.58 – 1.48; fixed effects; Q=9.0 p=.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.

[Insert Figure 9]

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. There was no difference between water immersion and standard care (OR 0.88 95% CI 0.46 – 1.69; random effects; Q=16 p=.012; I^2=63%). The subgroup analysis of studies in an obstetric setting and

the most recent studies remained no difference. Cumulative meta-analysis indicated there has consistently been no difference.

[Insert Figure 10]

Intact Perineum. Seventeen studies provided data on intact perineum (n=59,070). This analysis favoured water immersion (OR 1.47; 95% CI 1.21 – 1.78; random effects; Q=219.1 p<.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<.001) and the proportion of nulliparas in the sample (p=.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 – 6.04; random effects; Q=2 p=.504 I^2=0%).

[Insert Figure 11]

OASI. Fifteen studies provided data on obstetric anal sphincter injuries (n=93,690)**.** This analysis found no difference (OR 0.84 95% CI 0.59 – 1.18; random effects; Q=52.6 p<.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 favoured water immersion in obstetric settings (OR 0.71 95% CI 0.50 – 0.99; random effects; Q=16 p=.011; I^2=37%).

Meta-regression of the studies with the a priori selected control variables was not able to reduce the heterogeneity.

[Insert Figure 12]

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 – 0.26; random effects; Q=114.3 p<.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 primiparas in the sample accounted for some of the variance (R^2=.76; p=.001; 7 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 in proportion of primiparas, the result remained in favour of water immersion (OR 0.04 95% CI 0.01 – 0.13; random effects; Q=12 p=.038; I^2=57%).

[Insert Figure 13]

Third Stage Management. No studies provided comparison data for third stage management.

Postpartum Hemorrhage. Fifteen studies provided data about postpartum hemorrhage (n=63,891) using three different measures: count of postpartum hemorrhage defined as >500 ml blood loss, mean estimated blood loss, and change in hemoglobin. Overall, this analysis favoured water nimmersion (OR 0.69 95% CI 0.51 – 0.95; random effects; Q=116.5 p<.001; I^2=88%). Subgroup analysis revealed no difference in odds of postpartum hemorrhage 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; 9 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.

[Insert Figure 14]

Manual removal of the placenta. Five studies provided data to assess risk for manual removal of the placenta (n=2,893). This analysis indicated no difference (OR 0.73 95% CI 0.38-1.42; fixed effects; Q=6.2 p=.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.

[Insert Figure 15]

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 – 0.80; fixed effects; Q=0.5 p=.792; I^2=0%), however one study carried 97% of the weight for this synthesis. Fail-safe analysis estimated 2 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.

[Insert Figure 16]

Maternal Satisfaction. Six studies provided data on a measure of maternal satisfaction (n=4,144). Due to heterogeneity in measurement tool, this analysis used random effects modeling 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 – 2.96; random effects; Q=24.3 p<.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 would be necessary to change the estimate from favouring water to no difference.

[Insert Figure 17]

5-Minute APGAR. Twenty-one studies provided data for 5-minute APGAR (n=98,372). This analysis found no difference (OR 0.63 95% CI 0.38 – 1.05; random effects; Q=146.5 p<.001; I^2=87%). Three additional studies reported on 5-minute APGAR but did not provide data in a usable format; two found no difference and one reported in favor of water immersion. 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=.85; p=.001; 9 studies). After accounting for setting the analysis favoured water immersion (OR 0.14 95% CI 0.06 – 0.36; random effects; Q=20 p=.034; I^2=50%).

[Insert Figure 18]

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 – 1.69; random effects; Q=9.6 p=.048; I^2=58%. Cumulative meta-analysis indicated this outcome has been stable at no difference since first reported.

[Insert Figure 19]

Transient tachypnea of the newborn. Two studies provided data on transient tachypnea of the newborn (n=1,473), both were conducted in an obstetric setting. This analysis found no difference (OR 0.74; 95% CI 0.33-1.65; fixed effects; Q=0.8 p=.364; I^2=0%). Too few studies were available to conduct cumulative meta-analysis and subgroup analysis.

[Insert Figure 20]

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 – 2.43; random effects; Q=18.1 p<.001; I^2=89%). Three studies were too few for cumulative meta-analysis.

[Insert Figure 21]

Neonatal intensive care unit 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 – 1.40; fixed effects; Q=1.9 p=.381; I^2=0%). Subgroup analysis by setting revealed no difference in midwifery-led settings. Three studies were too few for cumulative meta-analysis.

[Insert Figure 22]

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 – 2.88; fixed effects; Q=1.3 p=.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 – 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 5 additional studies would be needed to change the estimate to no difference.

[Insert Figure 23]

Breastfeeding Initiation. Two studies provided data on breastfeeding initiation (n=692). This analysis found no difference (OR 1.00 95% CI 0.73 – 1.37; fixed effects; Q=1.0 p=.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.

[Insert Figure 24]

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 & fill estimates of the magnitude of bias indicate the magnitude was too small to affect the results.

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

		Begg's Test		
		Rank Correlation	Egger's Regression	Trim & Fill Direction of Bias[a]
Outcome	k	S-statistic (*p*)	Intercept (*p*)	OR (95% CI)
Amniotomy	5	4 (.164)	5.04 (.129)	Standard Care 0.43 (0.34 – 0.53)
Induction	3	-3 (0.059)	-10 (.238)	--
Augmentation	3	3 (0.59)	28.96 (.057)	Standard Care 0.12 (0.09 – 0.16)
Opioid	8	-2 (.402)	2.13 (.197)	Standard Care 0.17 (0.15 – 0.19)
Epidural	7	-9 (.088)	-4.51 (.039)	Immersion 0.67 (0.54 – 0.83)
Cesarean	8	-2 (.402)	-0.74 (.327)	--
Pain	8	0 (.500)	-1.67 (.339)	Standard Care 0.16 (0.07 – 0.37)
Satisfaction	6	-5 (.174)	-1.26 (.216)	Immersion 1.73 (1.13 – 2.64)
Intact Perineum	14	-10 (.340)	2.13 (.045)	Standard Care 1.71 (1.40 – 2.10)
Episiotomy	13	-11 (.274)	-1.27 (.121)	Immersion 0.20 (0.13 – 0.32)
OASI	14	3 (.435)	0.40 (.234)	Standard Care

				0.64 (0.50 – 0.82)
Shoulder Dystocia	7	5 (.226)	1.85 (.001)	Standard Care
				0.68 (0.38 – 1.21)
Maternal Infection	3	--	0.34 (.290)	--
Postpartum Hemorrhage	13	9 (.328)	-0.23 (.412)	Standard Care
				0.52 (0.39 – 0.71)
Retained Placenta	5	6 (.071)	2.11 (.068)	Standard Care
				0.76 (0.29 – 2.03)
APGAR	16	-34 (.179)	0.86 (.209)	Standard Care
				0.59 (0.36 – 0.96)
Neonatal Resuscitation	5	2 (.312)	0.69 (.282)	--
Transient Tachypnea	2	--	--	--
Respiratory Distress	3	1 (.301)	-1.77 (.426)	--
Neonatal Death	3	1 (.301)	1.34 (.078)	Standard Care
				0.84 (0.53 – 1.33)
Cord Avulsion	5	6 (.071)	0.36 (.182)	Standard Care
				1.86 (1.26 – 2.75)
Breastfeeding Initiation	2	--	--	--

a. Trim & Fill analysis conducted with random effects model and indicates OR and 95% Confidence Interval estimate if bias were corrected.

Certainty of Estimates

Fail-safe N was calculated for the 8 outcomes that favored either water immersion or standard care. For the outcomes that favored water immersion, the minimum number of studies needed to change the estimate was 100. For the outcome that favored standard care, cord avulsion, five additional studies would be needed. The assessment of certainty of estimates using the GRADE criteria and the fail-safe N are available in Supplement 4.

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 to midwifery-led settings and this has been reported for women who labour and/or give birth in water.[9, 31-33] 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.[34, 35] Furthermore, labouring and/or giving birth in water does not increase the likelihood of obstetric anal sphincter injury (OASI), particularly in obstetric settings, which corroborates previous waterbirth research.[36, 37] A significant postpartum haemorrhage (PPH) reduction was another important finding, which is also supported in the literature.[38]

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.[39] One study with a caesarean rate of 26% is generalisable to settings with a higher low risk caesarean birth rate.[40]

Our results for newborns mirror those reported in three substantial newborn specific systematic reviews.[11-13] 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.[9, 41] The incidence of cord avulsion was 4.3 per 1,000 births in water compared to 1.3 per 1,000 births with standard care. Interestingly, the incidence of cord avulsion varied from 0.2 per 1,000 to 11.8 per 1,000 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.[42]

Our results show that water immersion has the potential to make a meaningful contribution to the global agenda toward promoting physiologic birth.[43-47] 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.[48, 49, 50] Differences between birth settings in intact perineum and postpartum haemorrhage 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 labour induction and episiotomy are reduced with water immersion, while maternal satisfaction is increased. Given these results, water immersion for labour and waterbirth is an intervention that can be used to achieve physiologic 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.[3, 9] 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 to fragmented care models.[51] Birth pool use is most prevalent in midwifery-

led settings, but most research on water immersion has been conducted in obstetric 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 (EFM) 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. The inclusion of women with raised BMI in the study populations suggest 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 to enable examination for any associations between active or physiological management and postpartum haemorrhage. 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 & 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 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. This review did not include grey literature.

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 pharmacologic 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 -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. It has clear benefits for healthy women and their newborns when conducted in an obstetric setting and may have benefits for populations previously excluded from water immersion. Future research should focus on facilitating equity of access to water immersion in all birth settings and identification of best practice.

Figures

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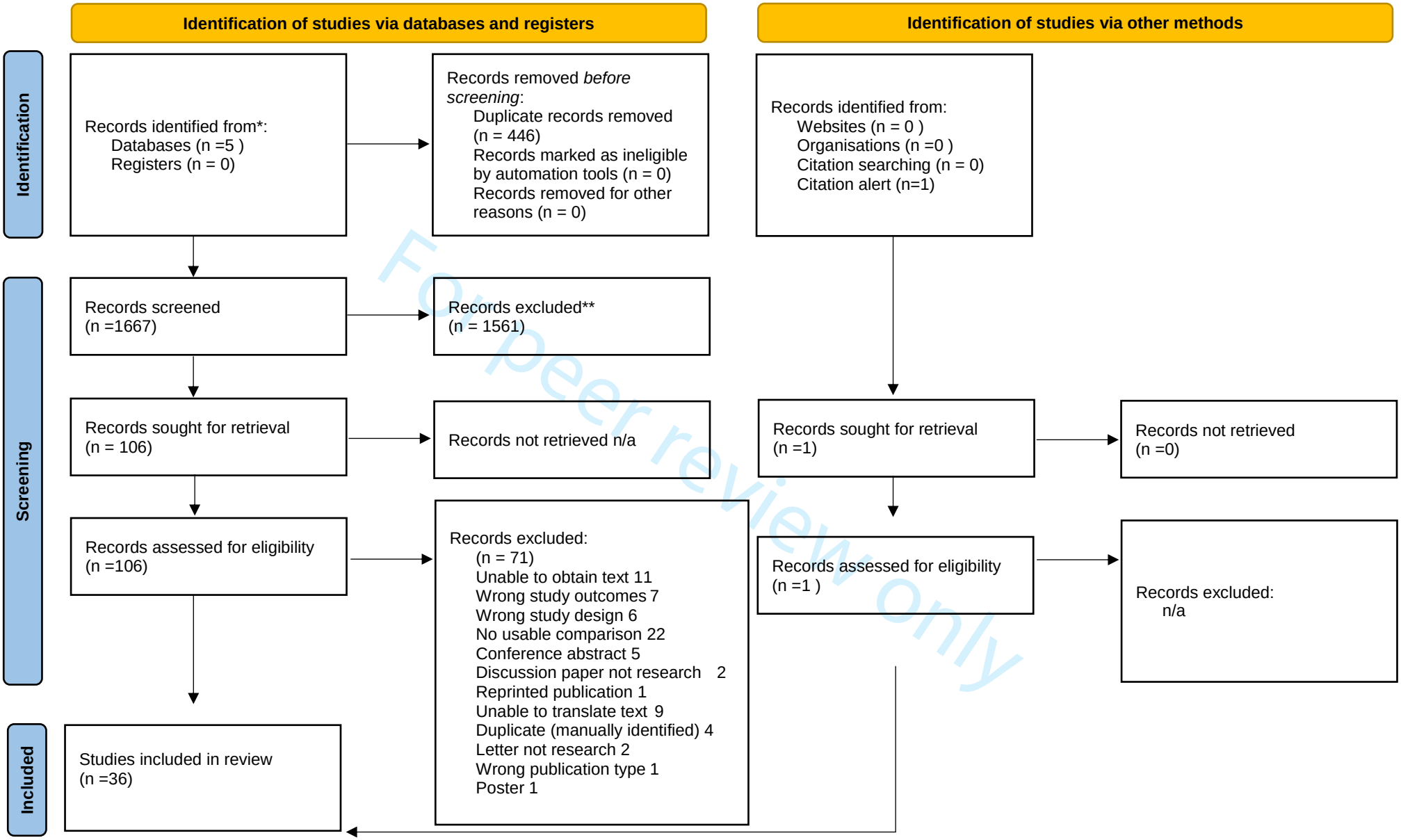


Figure 1 PRISMA 2020 flow diagram for new systematic reviews which included searches of databases, registers and other sources

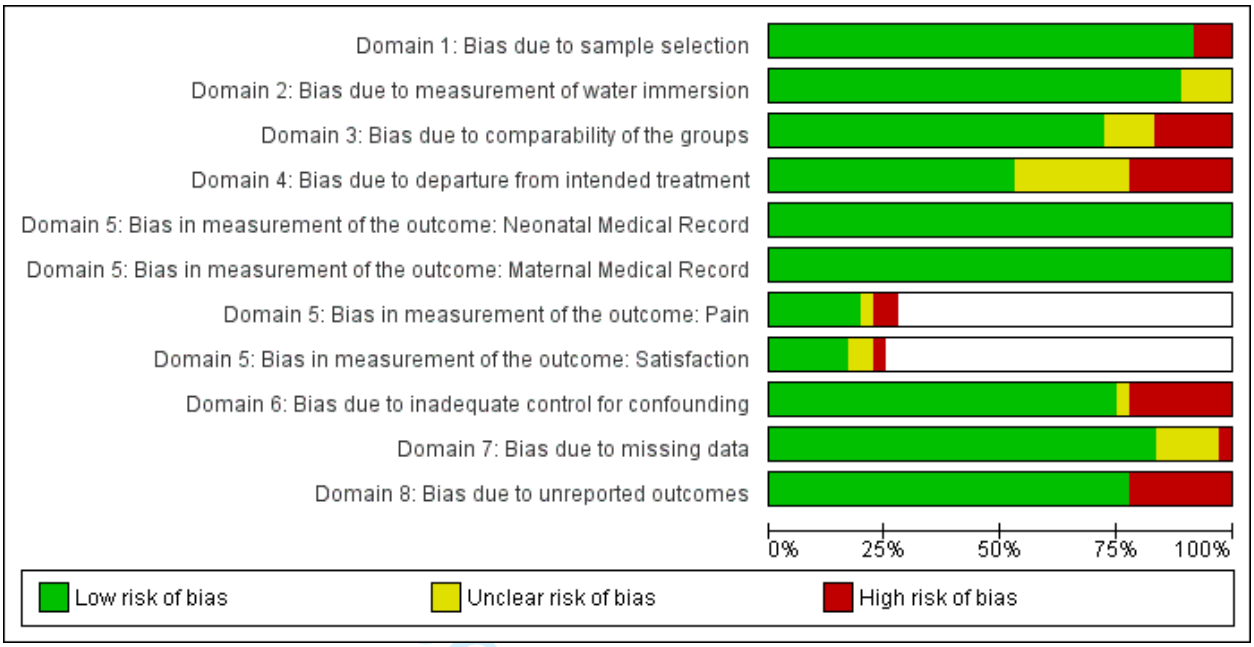
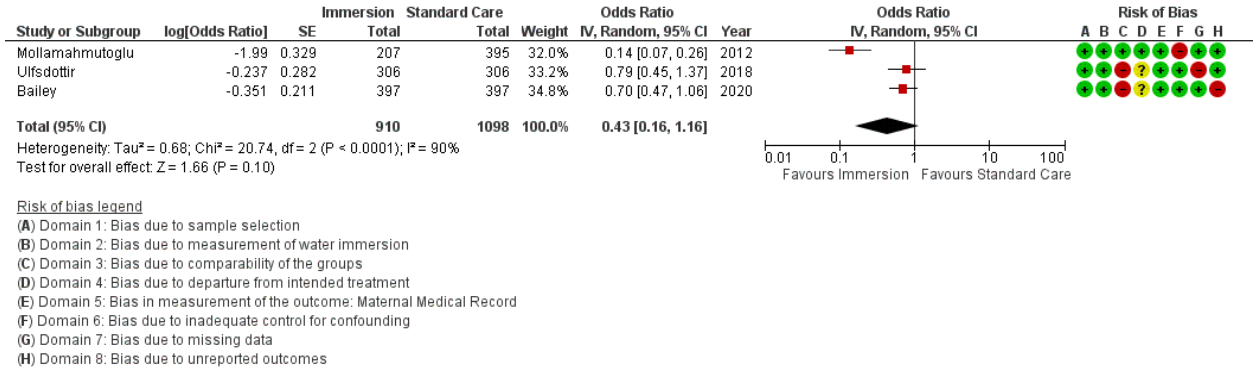
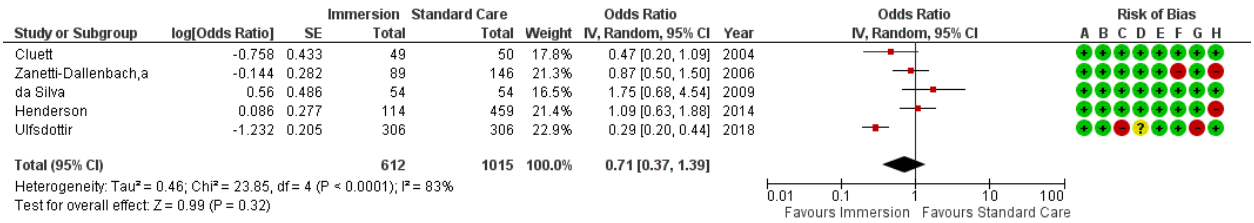


Figure 2 Risk of bias assessment

Figure 3 Forest Plot of Synthesis of Labour Induction



Risk of bias legend
(**A**) Domain 1: Bias due to sample selection
(**B**) Domain 2: Bias due to measurement of water immersion
(**C**) Domain 3: Bias due to comparability of the groups
(**D**) Domain 4: Bias due to departure from intended treatment
(**E**) Domain 5: Bias in measurement of the outcome: Maternal Medical Record
(**F**) Domain 6: Bias due to inadequate control for confounding
(**G**) Domain 7: Bias due to missing data
(**H**) Domain 8: Bias due to unreported outcomes



Risk of bias legend
(**A**) Domain 1: Bias due to sample selection
(**B**) Domain 2: Bias due to measurement of water immersion
(**C**) Domain 3: Bias due to comparability of the groups
(**D**) Domain 4: Bias due to departure from intended treatment
(**E**) Domain 5: Bias in measurement of the outcome: Maternal Medical Record
(**F**) Domain 6: Bias due to inadequate control for confounding
(**G**) Domain 7: Bias due to missing data
(**H**) Domain 8: Bias due to unreported outcomes

Figure 4 Forest Plot of Synthesis of Amniotomy

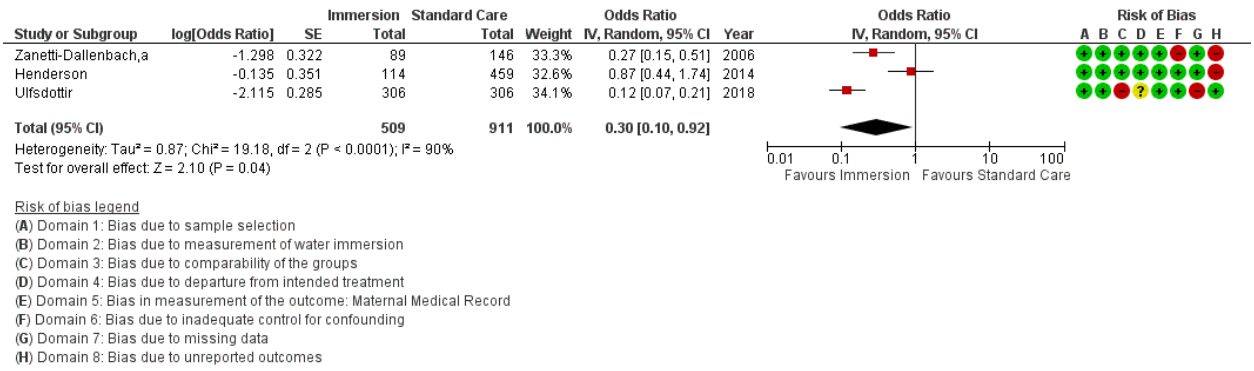
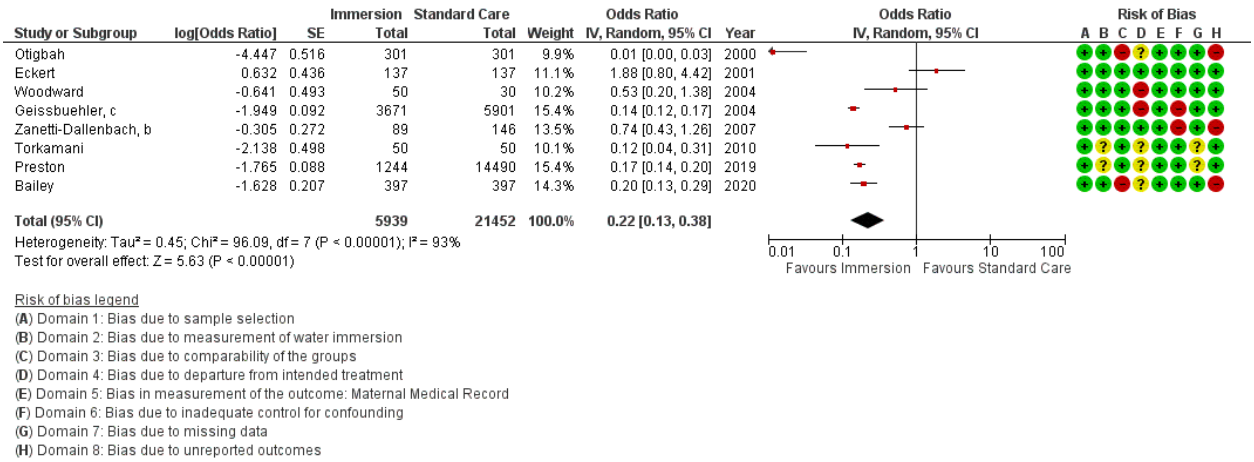
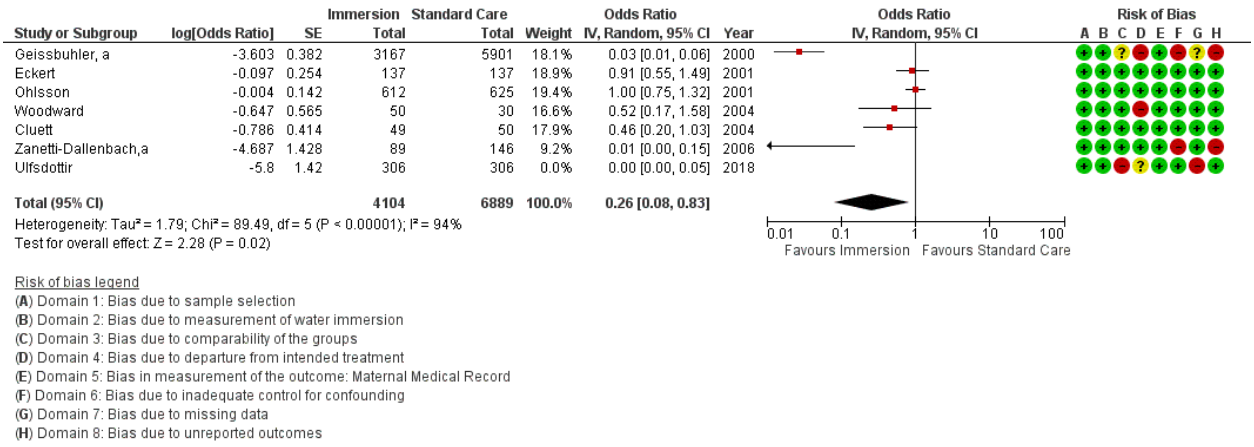


Figure 5 Forest Plot of Synthesis of Augmentation of Labour



Risk of bias legend
(**A**) Domain 1: Bias due to sample selection
(**B**) Domain 2: Bias due to measurement of water immersion
(**C**) Domain 3: Bias due to comparability of the groups
(**D**) Domain 4: Bias due to departure from intended treatment
(**E**) Domain 5: Bias in measurement of the outcome: Maternal Medical Record
(**F**) Domain 6: Bias due to inadequate control for confounding
(**G**) Domain 7: Bias due to missing data
(**H**) Domain 8: Bias due to unreported outcomes

Figure 6 Forest Plot of Synthesis of Opioid Use



Risk of bias legend
(**A**) Domain 1: Bias due to sample selection
(**B**) Domain 2: Bias due to measurement of water immersion
(**C**) Domain 3: Bias due to comparability of the groups
(**D**) Domain 4: Bias due to departure from intended treatment
(**E**) Domain 5: Bias in measurement of the outcome: Maternal Medical Record
(**F**) Domain 6: Bias due to inadequate control for confounding
(**G**) Domain 7: Bias due to missing data
(**H**) Domain 8: Bias due to unreported outcomes

Figure 7 Forest Plot of Synthesis of Epidural Use

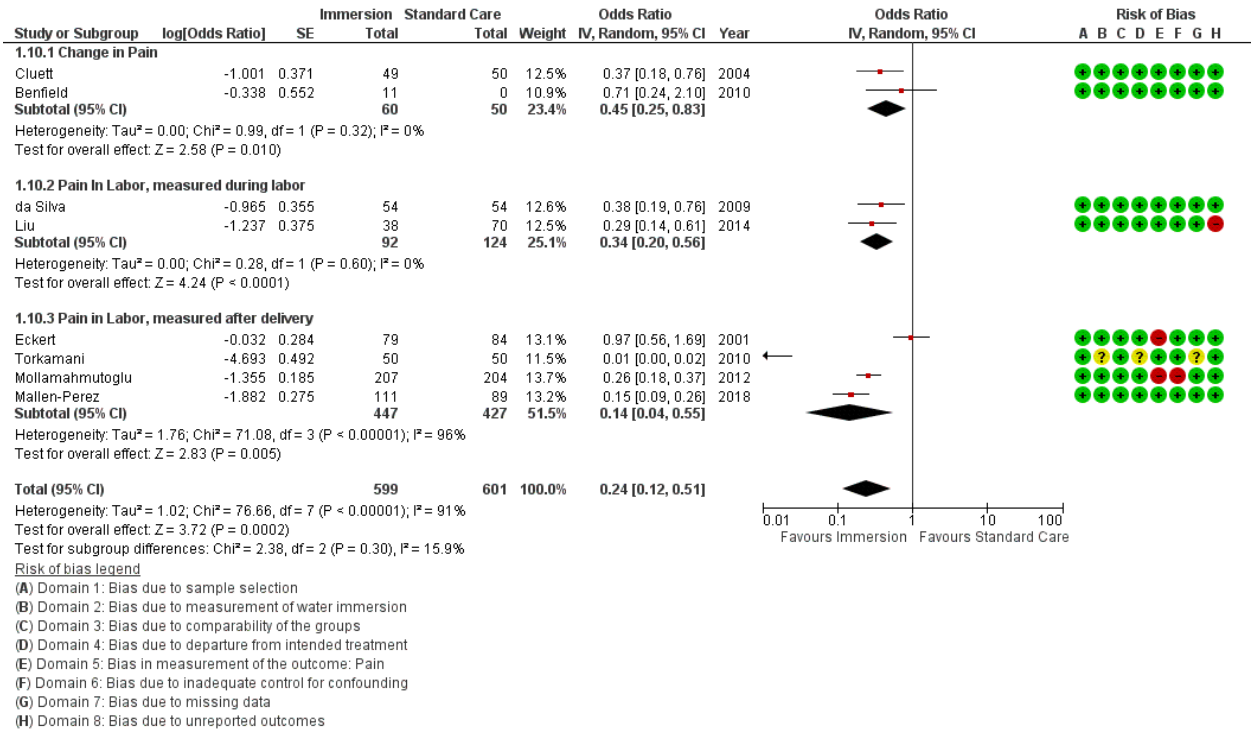
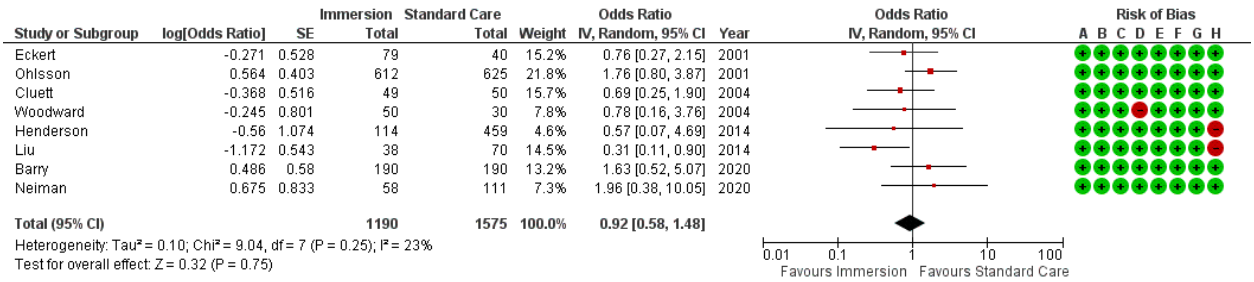
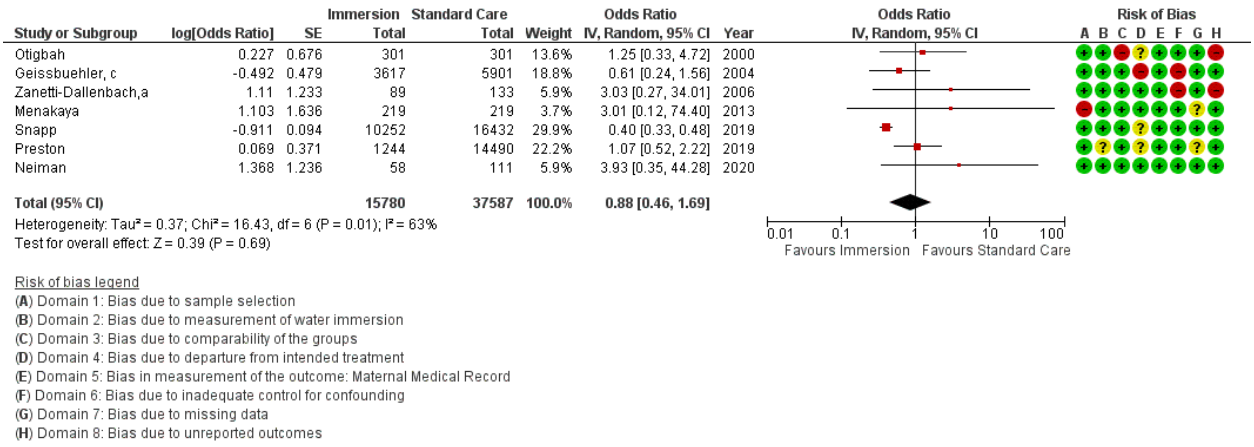


Figure 8 Forest Plot of Synthesis of Pain



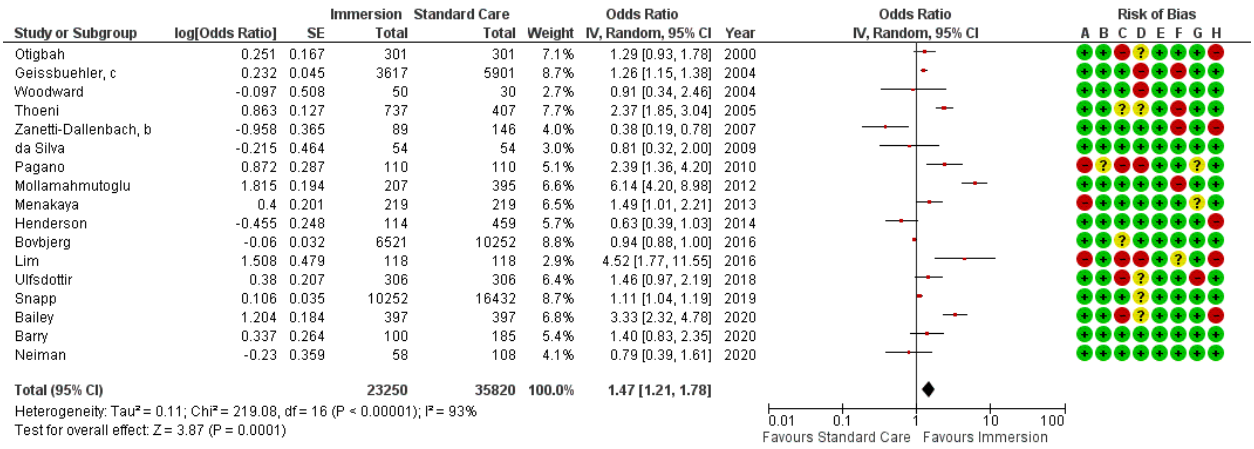
Risk of bias legend
(**A**) Domain 1: Bias due to sample selection
(**B**) Domain 2: Bias due to measurement of water immersion
(**C**) Domain 3: Bias due to comparability of the groups
(**D**) Domain 4: Bias due to departure from intended treatment
(**E**) Domain 5: Bias in measurement of the outcome: Maternal Medical Record
(**F**) Domain 6: Bias due to inadequate control for confounding
(**G**) Domain 7: Bias due to missing data
(**H**) Domain 8: Bias due to unreported outcomes

Figure 9 Forest Plot of Synthesis of Cesarean Delivery



Risk of bias legend
(**A**) Domain 1: Bias due to sample selection
(**B**) Domain 2: Bias due to measurement of water immersion
(**C**) Domain 3: Bias due to comparability of the groups
(**D**) Domain 4: Bias due to departure from intended treatment
(**E**) Domain 5: Bias in measurement of the outcome: Maternal Medical Record
(**F**) Domain 6: Bias due to inadequate control for confounding
(**G**) Domain 7: Bias due to missing data
(**H**) Domain 8: Bias due to unreported outcomes

Figure 10 Forest Plot of Synthesis of Shoulder Dystocia



Risk of bias legend

(**A**) Domain 1: Bias due to sample selection

(**B**) Domain 2: Bias due to measurement of water immersion

(**C**) Domain 3: Bias due to comparability of the groups

(**D**) Domain 4: Bias due to departure from intended treatment

(**E**) Domain 5: Bias in measurement of the outcome: Maternal Medical Record

(**F**) Domain 6: Bias due to inadequate control for confounding

(**G**) Domain 7: Bias due to missing data

(**H**) Domain 8: Bias due to unreported outcomes

Figure 11 Forest Plot of Synthesis of Intact Perineum

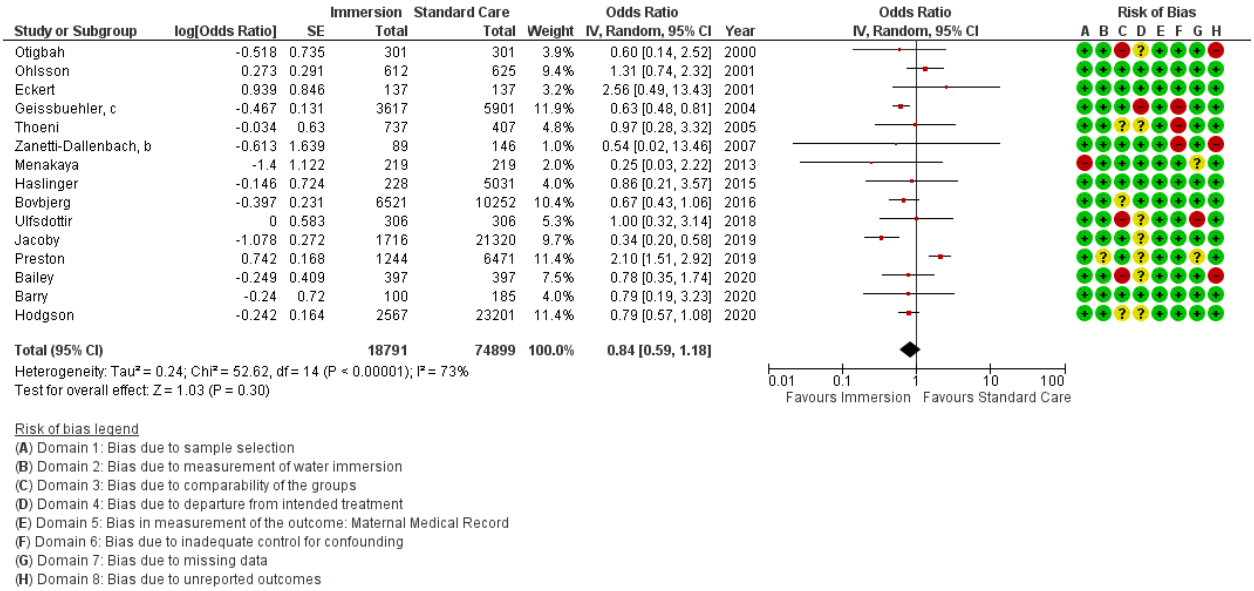
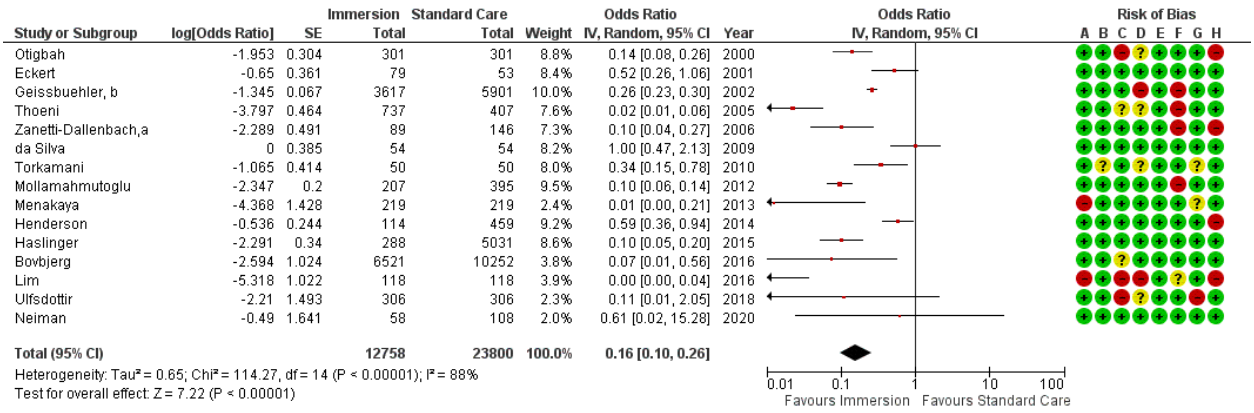


Figure 12 Forest Plot of Synthesis of Obstetric Anal Sphincter Injuries (OASI)



Risk of bias legend

(**A**) Domain 1: Bias due to sample selection

(**B**) Domain 2: Bias due to measurement of water immersion

(**C**) Domain 3: Bias due to comparability of the groups

(**D**) Domain 4: Bias due to departure from intended treatment

(**E**) Domain 5: Bias in measurement of the outcome: Maternal Medical Record

(**F**) Domain 6: Bias due to inadequate control for confounding

(**G**) Domain 7: Bias due to missing data

(**H**) Domain 8: Bias due to unreported outcomes

Figure 13 Forest Plot of Synthesis of Episiotomy

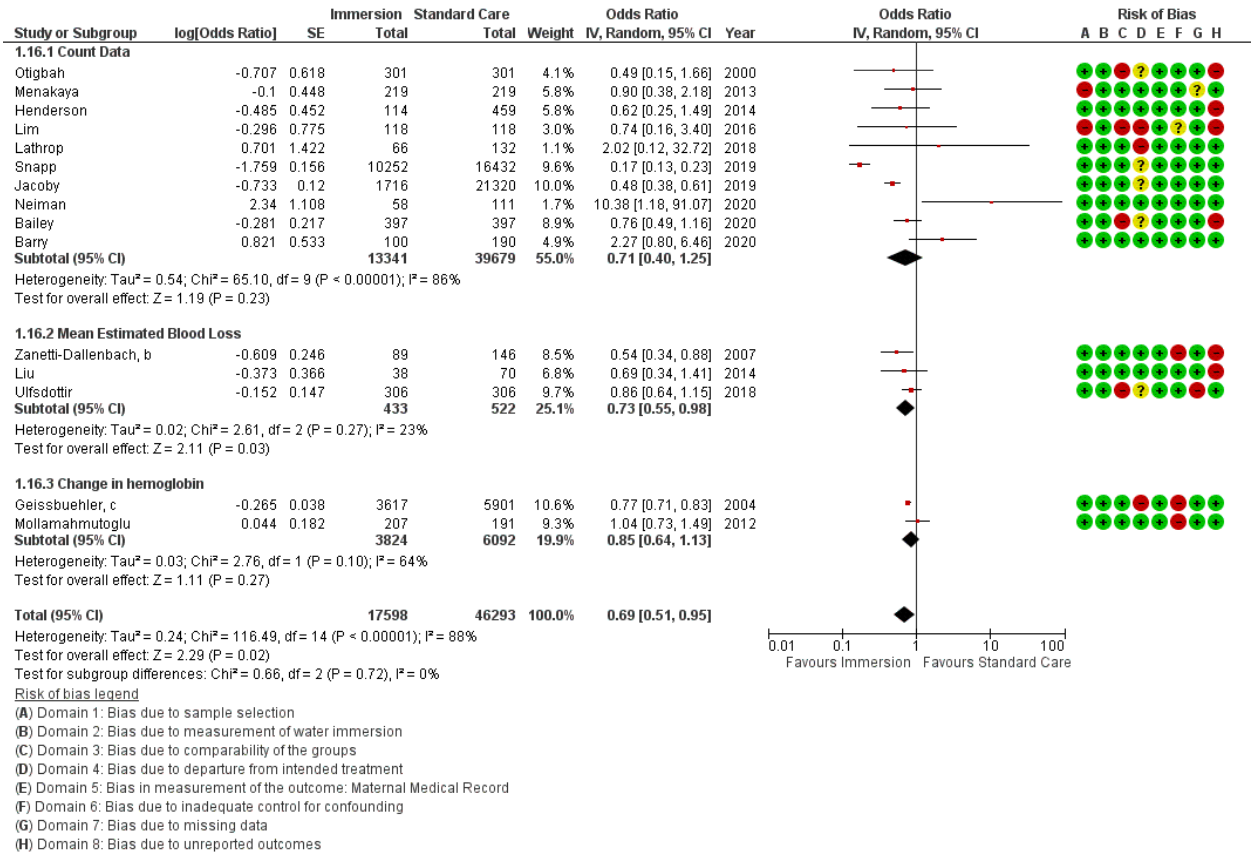
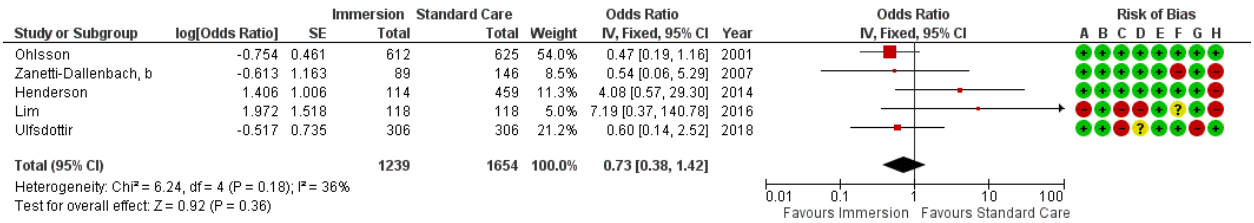


Figure 14 Forest Plot of Synthesis of Postpartum Hemorrhage



Risk of bias legend
(**A**) Domain 1: Bias due to sample selection
(**B**) Domain 2: Bias due to measurement of water immersion
(**C**) Domain 3: Bias due to comparability of the groups
(**D**) Domain 4: Bias due to departure from intended treatment
(**E**) Domain 5: Bias in measurement of the outcome: Maternal Medical Record
(**F**) Domain 6: Bias due to inadequate control for confounding
(**G**) Domain 7: Bias due to missing data
(**H**) Domain 8: Bias due to unreported outcomes

Figure 15 Forest Plot of Synthesis of Manual Removal of the Placenta

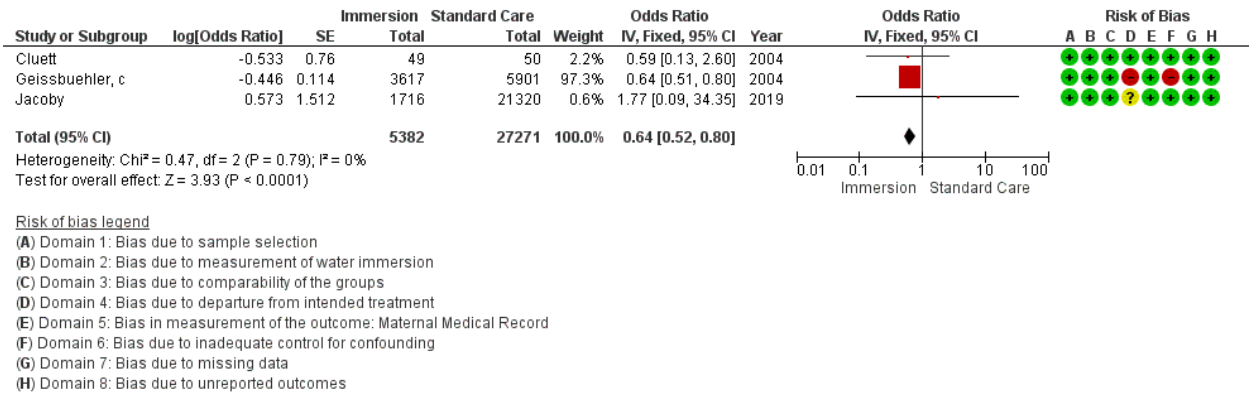
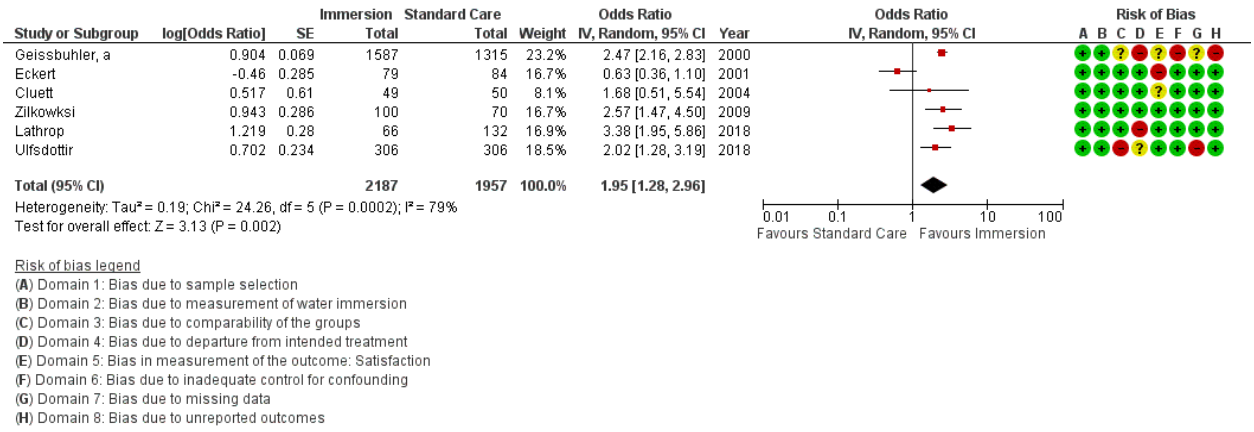
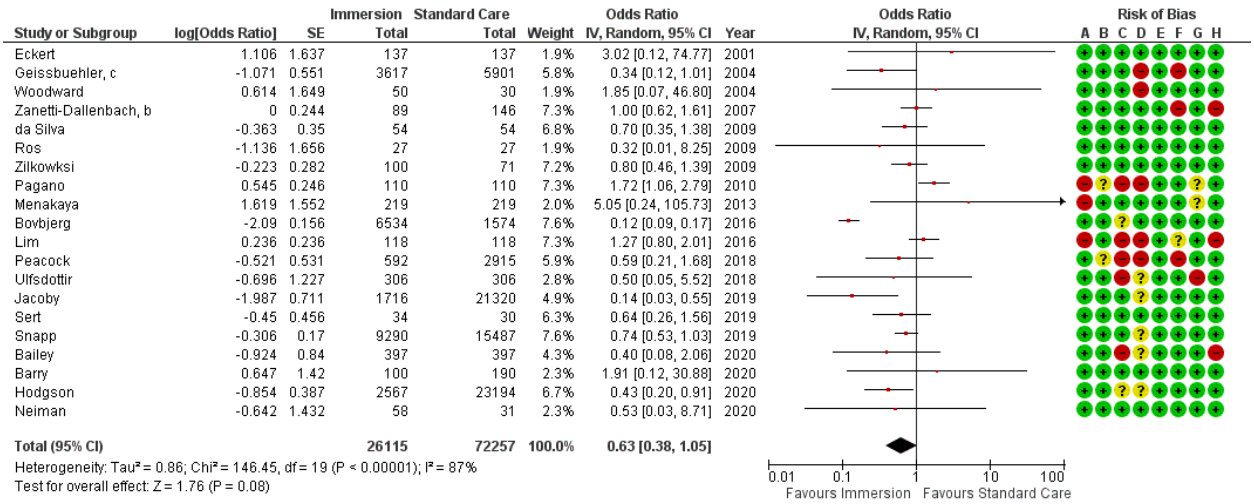


Figure 16 Forest Plot of Synthesis for Maternal Infection



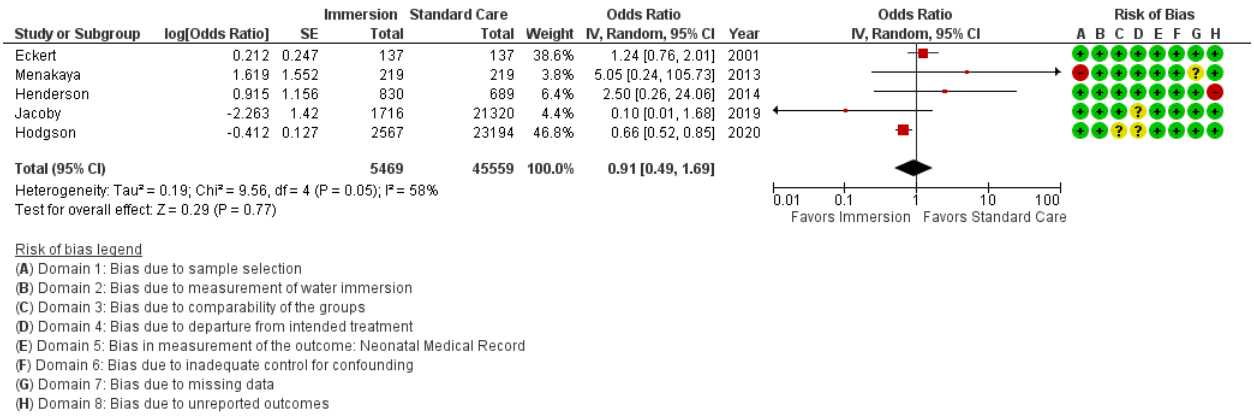
Risk of bias legend
(**A**) Domain 1: Bias due to sample selection
(**B**) Domain 2: Bias due to measurement of water immersion
(**C**) Domain 3: Bias due to comparability of the groups
(**D**) Domain 4: Bias due to departure from intended treatment
(**E**) Domain 5: Bias in measurement of the outcome: Satisfaction
(**F**) Domain 6: Bias due to inadequate control for confounding
(**G**) Domain 7: Bias due to missing data
(**H**) Domain 8: Bias due to unreported outcomes

Figure 17 Forest Plot of Synthesis of Maternal Satisfaction Measures



Risk of bias legend
(**A**) Domain 1: Bias due to sample selection
(**B**) Domain 2: Bias due to measurement of water immersion
(**C**) Domain 3: Bias due to comparability of the groups
(**D**) Domain 4: Bias due to departure from intended treatment
(**E**) Domain 5: Bias in measurement of the outcome: Neonatal Medical Record
(**F**) Domain 6: Bias due to inadequate control for confounding
(**G**) Domain 7: Bias due to missing data
(**H**) Domain 8: Bias due to unreported outcomes

Figure 18 Forest Plot of Synthesis of 5-Minute APGAR



Risk of bias legend
(**A**) Domain 1: Bias due to sample selection
(**B**) Domain 2: Bias due to measurement of water immersion
(**C**) Domain 3: Bias due to comparability of the groups
(**D**) Domain 4: Bias due to departure from intended treatment
(**E**) Domain 5: Bias in measurement of the outcome: Neonatal Medical Record
(**F**) Domain 6: Bias due to inadequate control for confounding
(**G**) Domain 7: Bias due to missing data
(**H**) Domain 8: Bias due to unreported outcomes

Figure 19 Forest Plot of Synthesis of Neonatal Resuscitation

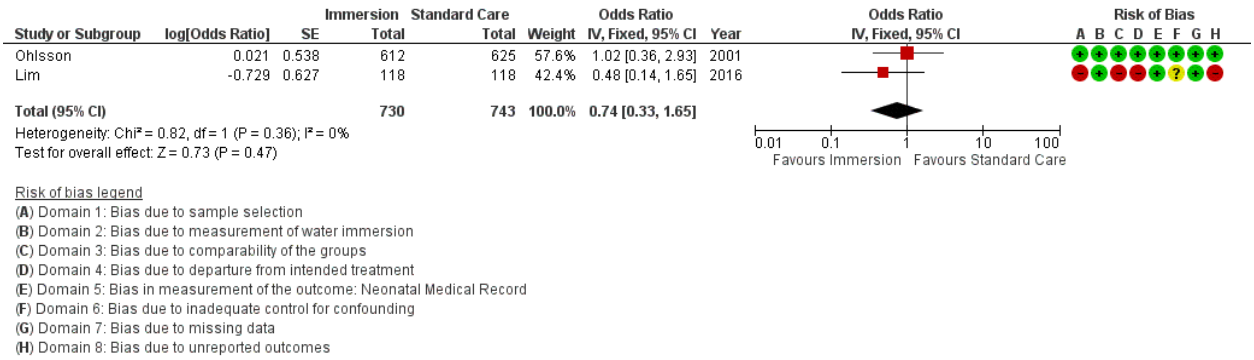


Figure 20 Forest Plot of Synthesis of Transient Tachypnea of the Newborn

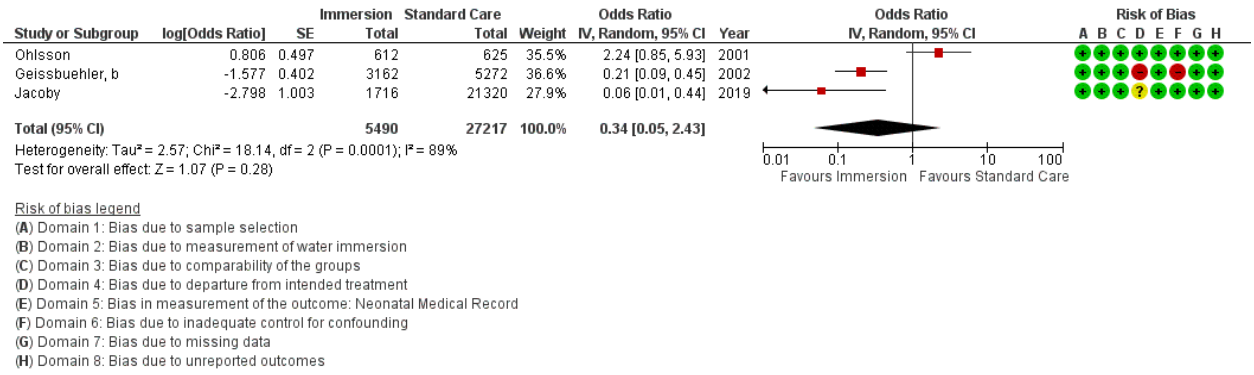
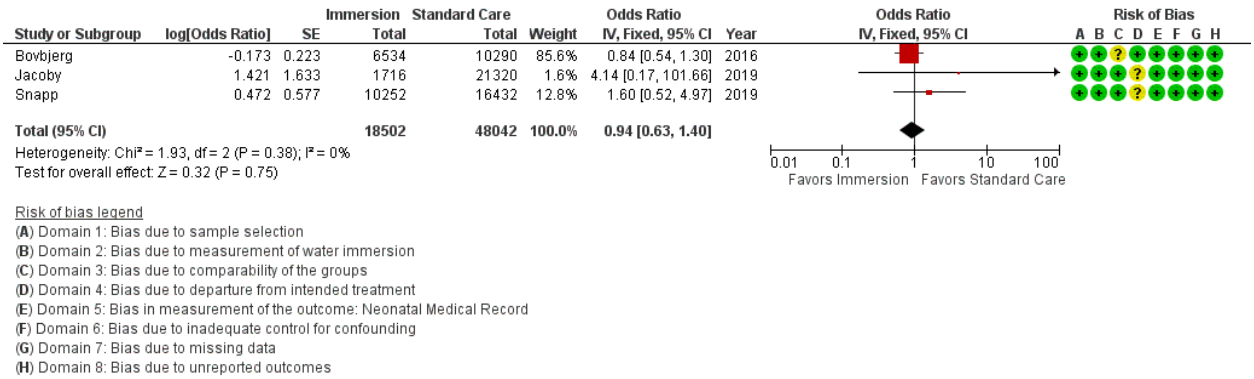
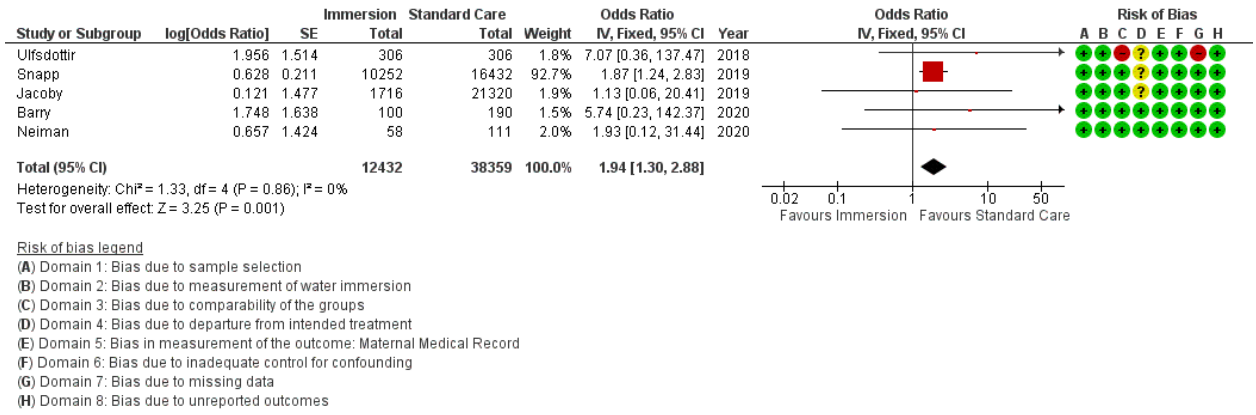


Figure 21 Forest plot of Synthesis of Respiratory Distress



Risk of bias legend
(**A**) Domain 1: Bias due to sample selection
(**B**) Domain 2: Bias due to measurement of water immersion
(**C**) Domain 3: Bias due to comparability of the groups
(**D**) Domain 4: Bias due to departure from intended treatment
(**E**) Domain 5: Bias in measurement of the outcome: Neonatal Medical Record
(**F**) Domain 6: Bias due to inadequate control for confounding
(**G**) Domain 7: Bias due to missing data
(**H**) Domain 8: Bias due to unreported outcomes

Figure 22 Forest Plot of Synthesis of Neonatal Death



Risk of bias legend
(**A**) Domain 1: Bias due to sample selection
(**B**) Domain 2: Bias due to measurement of water immersion
(**C**) Domain 3: Bias due to comparability of the groups
(**D**) Domain 4: Bias due to departure from intended treatment
(**E**) Domain 5: Bias in measurement of the outcome: Maternal Medical Record
(**F**) Domain 6: Bias due to inadequate control for confounding
(**G**) Domain 7: Bias due to missing data
(**H**) Domain 8: Bias due to unreported outcomes

Figure 23 Forest Plot of Synthesis of Cord Avulsion

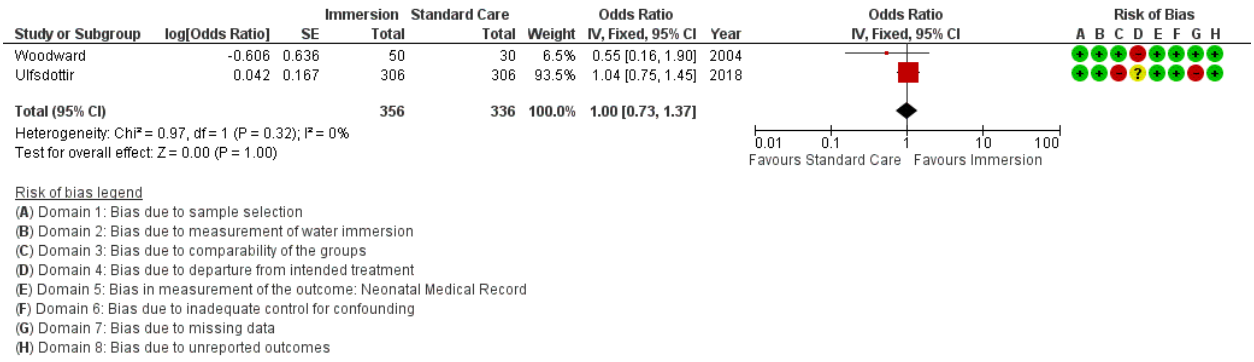


Figure 24 Forest Plot of Synthesis of Breastfeeding Initiation

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
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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
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Psychinfo Search

Accessibility Information and TipsRevised Date: 07/2015

Print Search History

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

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		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 Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE with Full Text	697
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 Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE with Full Text	5,881
S3	(MH Parturition+ OR MH Labor, Obstetric+) OR (S1 OR S2)	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE with Full Text	988,860

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

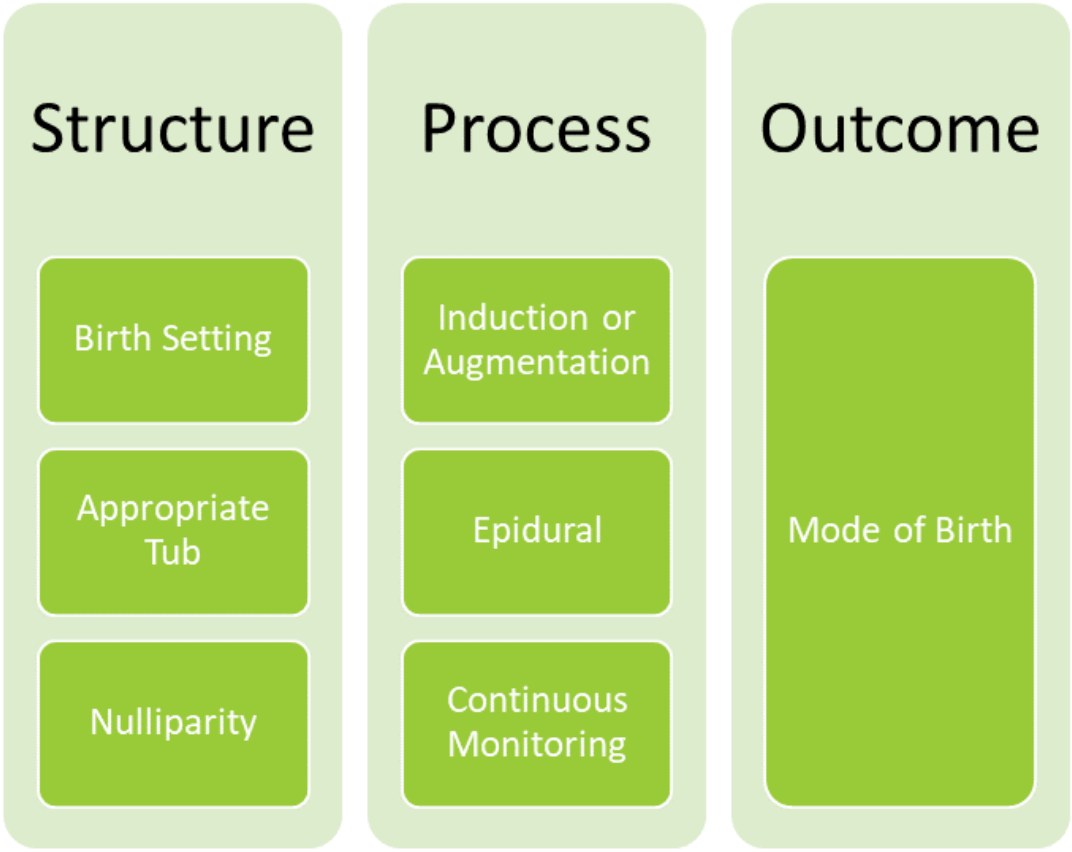
COCHRANE	87	
	2113	
Duplicates removed	446	
	1667	
Screened title/abstract	1667	
Excluded	1561	
Included for full text	**106**	
Full text EXCLUDED	49	
Full text INCLUDED	**57**	
BMC update	1	
	58	INCLUDED

Excluded Reasons

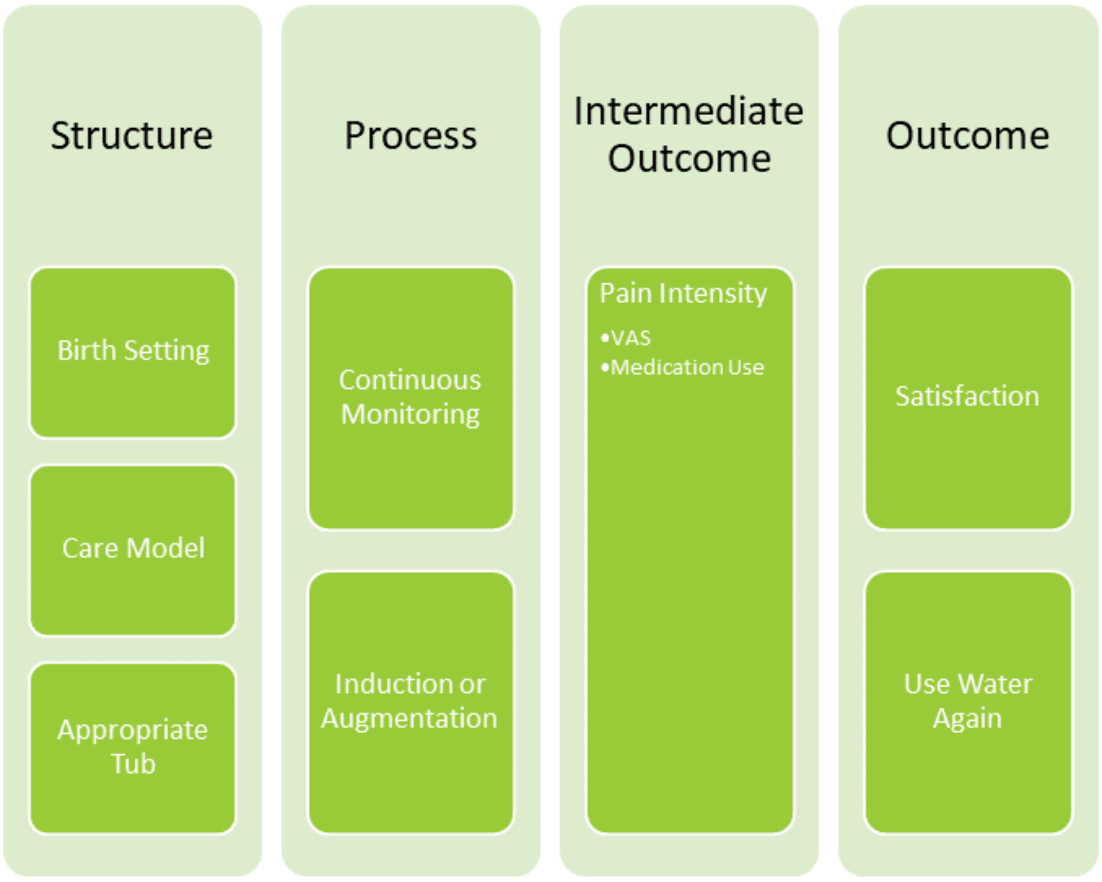
Reasons for exclusions	**Number**
Unable to obtain text	11
Wrong study outcomes	7
Wrong study design	6
Conference abstract	5
Discussion paper not research	2
Reprinted publication	1
Unable to translate text	9
Duplicate	4
Letter not research	2
Wrong publication type	1
Poster	1
	49

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

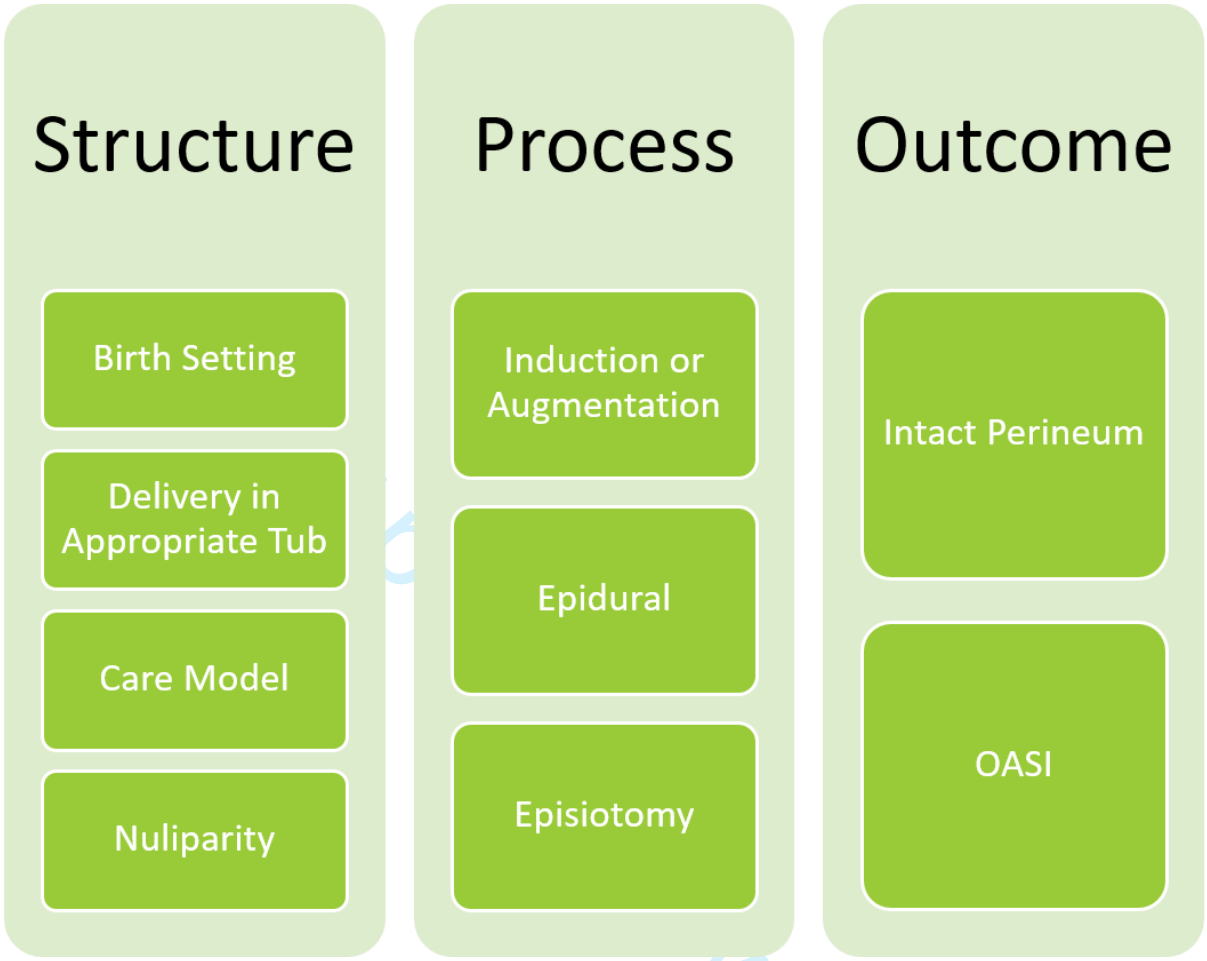
DAG 1: Assumptions about variables associated with variation in mode of birth.



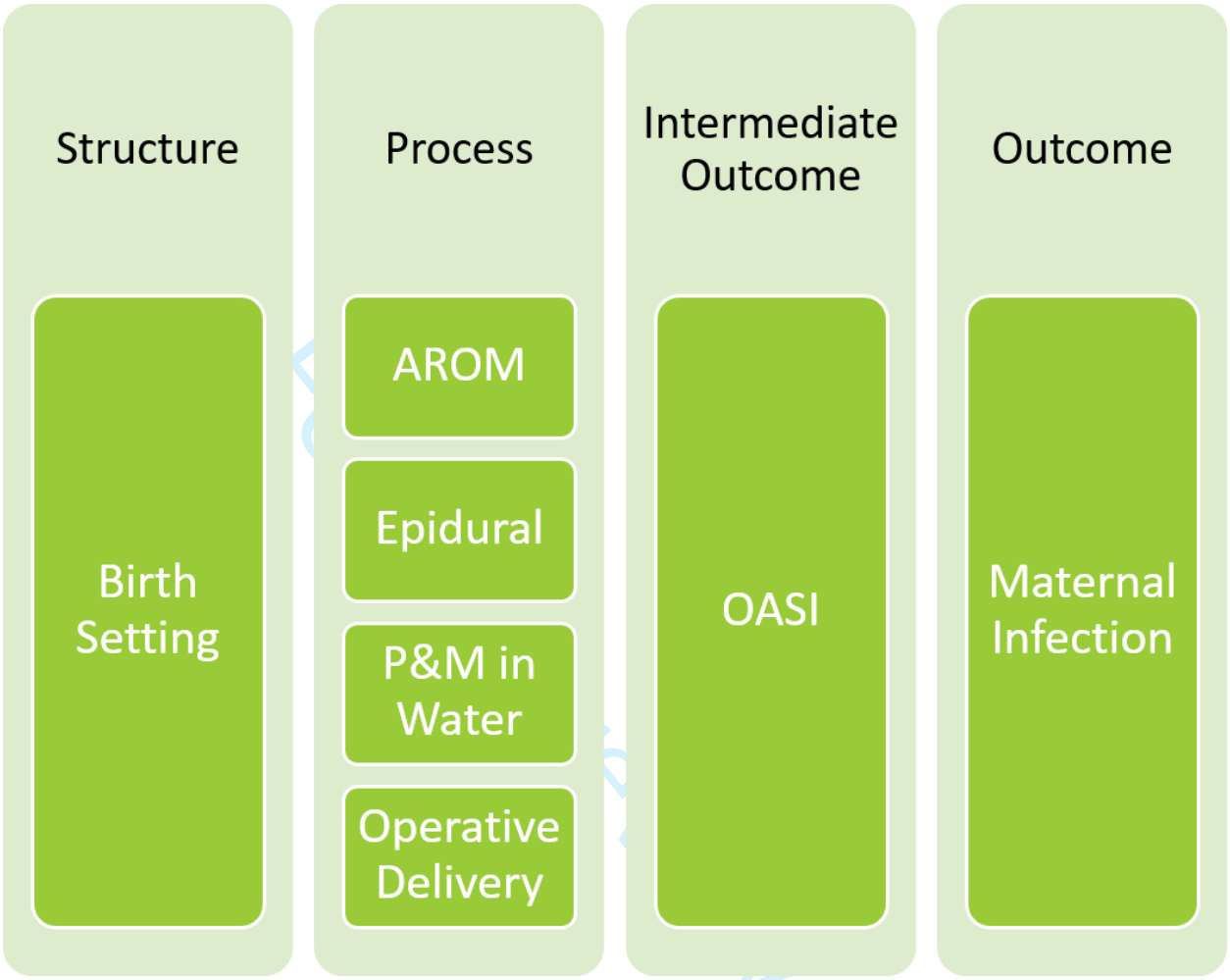
DAG 2: Assumptions about variables associated with variation in maternal satisfaction



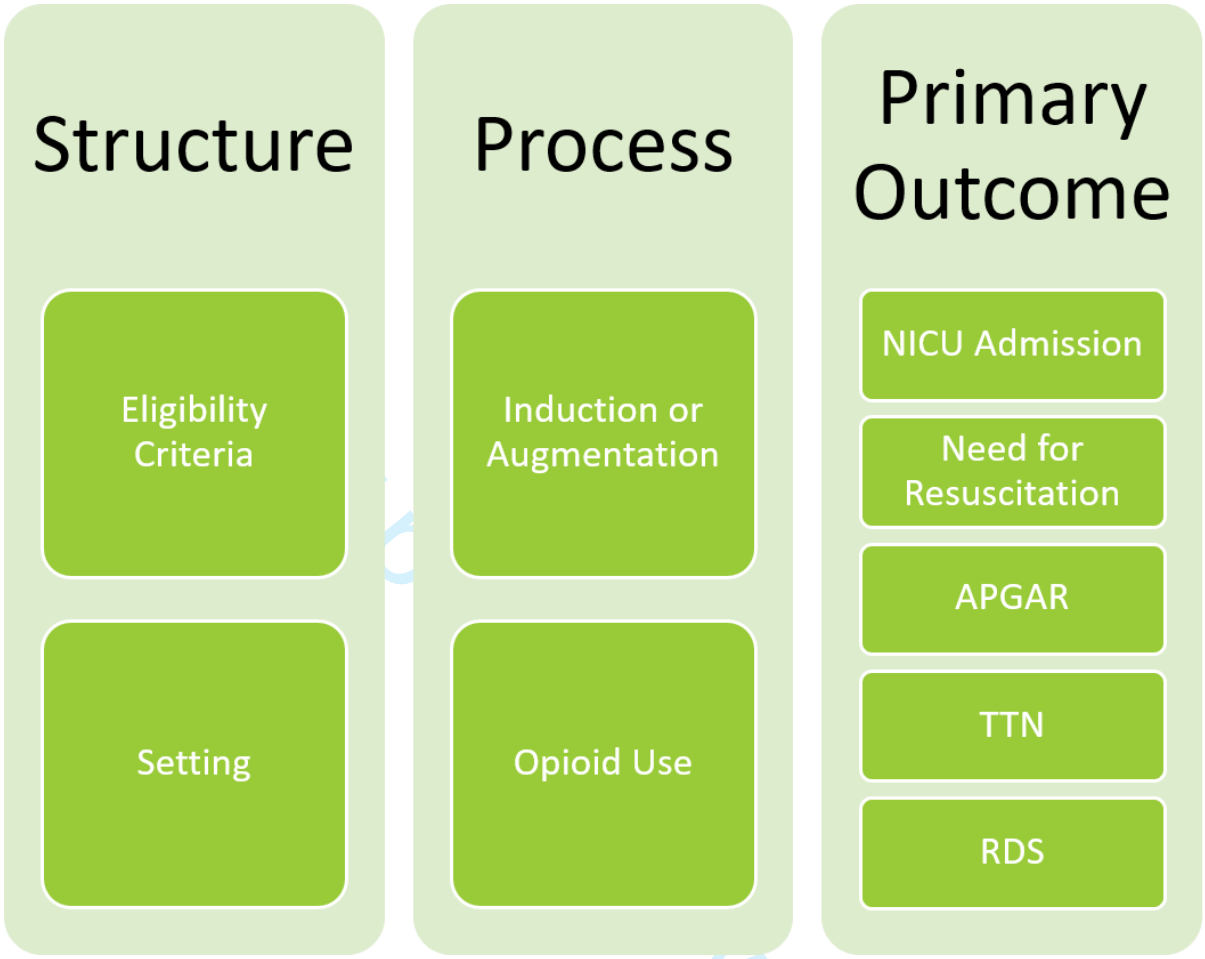
DAG 3: Assumptions about variables associated with variation in perineal outcomes.



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



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



Supplement 3: Studies excluded during full text review; systematic review and meta-analysis of interventions and outcomes with water birth.

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Supplement 4: 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.

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			
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	-

PRISMA 2020 Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	Title P.1
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	p1
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	p6
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	p7
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	p7-8
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	p8
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	p8, Sup 1
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	p9
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	p9
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	P9
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	P9
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	p9, 10
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	P10
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	p10
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	P10 Tables 2-3
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	P10
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	P10
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	P10
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	P10-11
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	P10
Certainty	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	p11

PRISMA 2020 Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
assessment			
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	P11; figure 1
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	Supplement 3
Study characteristics	17	Cite each included study and present its characteristics.	Table 1,2,3
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	Figures 3-24
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	Figures 3-24
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	P24-36; Figures 3-24
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	P24-36; Figures 3-24
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	P24-36; Figures 3-24
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	P24-36; Table 4
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	P24-36; Table 5
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	P 38; Supplement 4
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	P39
	23b	Discuss any limitations of the evidence included in the review.	P41-42
	23c	Discuss any limitations of the review processes used.	P41-42
	23d	Discuss implications of the results for practice, policy, and future research.	P42
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	P7
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	P4
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	P4

PRISMA 2020 Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	P4
Competing interests	26	Declare any competing interests of review authors.	P5
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	NA

From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71

For more information, visit: http://www.prisma-statement.org/

PRISMA 2020 for Abstracts Checklist

Section and Topic	Item #	Checklist item	Reported (Yes/No)
TITLE			
Title	1	Identify the report as a systematic review.	YES
BACKGROUND			
Objectives	2	Provide an explicit statement of the main objective(s) or question(s) the review addresses.	YES
METHODS			
Eligibility criteria	3	Specify the inclusion and exclusion criteria for the review.	YES
Information sources	4	Specify the information sources (e.g. databases, registers) used to identify studies and the date when each was last searched.	YES
Risk of bias	5	Specify the methods used to assess risk of bias in the included studies.	YES
Synthesis of results	6	Specify the methods used to present and synthesise results.	YES
RESULTS			
Included studies	7	Give the total number of included studies and participants and summarise relevant characteristics of studies.	YES
Synthesis of results	8	Present results for main outcomes, preferably indicating the number of included studies and participants for each. If meta-analysis was done, report the summary estimate and confidence/credible interval. If comparing groups, indicate the direction of the effect (i.e. which group is favoured).	YES
DISCUSSION			
Limitations of evidence	9	Provide a brief summary of the limitations of the evidence included in the review (e.g. study risk of bias, inconsistency and imprecision).	YES
Interpretation	10	Provide a general interpretation of the results and important implications.	YES
OTHER			
Funding	11	Specify the primary source of funding for the review.	YES
Registration	12	Provide the register name and registration number.	YES

From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71

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BMJ Open

A 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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Keywords:	Pain management < ANAESTHETICS, Maternal medicine < OBSTETRICS, PRIMARY CARE

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A 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 (BMC) 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 usng the birthing pool ofr 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 7 domains based on the Robbins-I Risk of Bias Tool. All outcomes were summarised using an odds ratio (OR) and 95% confidence interval (CI). All calculations were conducted in Comprehensive Meta-Analysis Version 3, using the inverse variance method. Results of individual studies were converted to log odds ratio and standard error 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 & Fill analysis was used to estimate the magnitude of effect of the bias.Meta-regression was completed when at least ten 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 a waterbirth (n=151,742), seven involved water immersion for labour only (1,901), three studies reported on water immersion during labour and waterbirth (n=3,688) 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 – 0.56), injected opioids (k=8, n=27,391; OR 0.22 95% CI 0.13 – 0.38), episiotomy (k=15, n=36,558; OR 0.16; 95% CI 0.10 – 0.27), maternal pain (k=8, n=1,200; OR 0.24 95% CI 0.12 – 0.51), and postpartum hemorrhage (k=15, n=63891; OR 0.69 95% CI 0.51 – 0.95). There was an increase in maternal satisfaction (k=6, n=4,144; OR 1.95 95% CI 1.28 – 2.96) and odds of an intact perineum (k=17, n=59070; OR 1.48; 95% CI 1.21 – 1.79) with water immersion. Waterbirth was associated with increased odds of cord avulsion (OR 1.94 95% CI 1.30 – 2.88), although the absolute risk remained low (4.3 per 1,000 vs 1.3 per 1,000). 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.

Registration: PROSPERO 2019 CRD42019147001 Revised July 2020 https://www.crd.york.ac.uk/prospero/display_record.php?RecordID=147001&VersionID=1368697

Strengths and Limitations of the 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.

Funding Statement

This work was supported by Oxford Brookes University.

Author Contributions

EB: conceptualisation, protocol writing, investigation, methodology, writing-original draft, writing-review and editing, project administration, funding acquisition for Open Access publication.
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JV: conceptualisation, methodology, investigation, data curation, formal analysis, writing – original draft, writing – review and editing, visualisation.
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HC: Validation, Review
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CR: Methodology, Review
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Academic Consultant Neonatologist, Newborn Services, Southmead Hospital, North Bristol Trust, Bristol.

Research Ethics Approval

No patient involvement

Funding

This research received no specific grant for funding from any agency in the public, commercial or not-for-profit sectors

Competing Interests

There were no competing interests

Data Sharing Statement

No data-sharing agreement was required for this research.

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 whilst 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 (co-located with a maternity hospital setting) and freestanding midwifery units (FMU) (in the community setting) and home birth.[2] The outcomes of birthing pool use may be different in midwifery-led settings compared to an obstetric setting because healthy women experience fewer interventions and operative birth when the birth occurs in a midwifery-led setting compared to 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 woman 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, a RCT proposal is likely to encounter ethical and recruitment challenges due to increasing acknowledgment 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

A protocol for the review was published in the International Prospective Register of Systematic Reviews PROSPERO2019 CRD42019147001 prior to completion of the searches. The PRISMA 2020 guideline was followed for conducting this work.[16] Institutional Review Board approval was not sought as Institutional Review Board approval was not sought as meta-analyses are not human subjects research.

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 postpartum
- 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/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 Supplement 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 de-duplicated 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 PH. 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 Process & Data Items

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 PH) 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, shoulder dystocia, maternal infection defined by symptoms and positive test, primary postpartum haemorrhage, manual removal of the placenta, 5-minute 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 7 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 PH). Disagreements were resolved by consensus meeting.

Summary Measures & Synthesis of Results

All outcomes were summarized using an odds ratio (OR) and 95% confidence interval (CI). All calculations were conducted in Comprehensive Meta-Analysis Version 3, using the inverse variance method.[21] Results of individual studies were converted to log odds ratio and standard error 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 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 was calculated to determine the number of studies necessary to change the estimates.[23] Forest plots were created in RevMan v5.4.1.[24]

Additional Analyses

Begg's Test and Egger's Regression Risk assessed risk of bias across studies.[25] Trim & Fill analysis was used to estimate the magnitude of effect of the bias.[26] Meta-regression was completed when at least ten 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 (DAG) of the covariates and their role are available in Supplement 2.[29] For continuous covariates, the rate of a covariate (e.g. the induction

rate in the sample) were used for regression. Categorical covariates were coded as dichotomous (e.g. described appropriate birth pool or did not describe the immersion receptacle).

Certainty Assessment

The fail-safe N estimates was 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 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 supplement 3.

Results

Study Selection

The searches generated 2,113 hits, reduced to 1,667 after duplicates were removed; n=1,561 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 Supplement 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 153,236 women were included into the review.[30-66] Figure 1 PRISMA diagram illustrates the study selection process.[16]

[Insert Figure 1 Here]

Study Description

Most studies (k=32) 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 4, 29, 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 randomised controlled trials

(k=7; n=2,666), prospective studies (k=13; n=30,085), retrospective studies (k=15; n=120,474), and one pre-post study (n=11). Studies reported on waterbirth (k=25; n=146,499), water immersion for labour (k=7; n=1,901), both (k=3; n=4,621) and one whose timing of immersion could not be determined (n=215). Full information is available in Table 1.

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, 2019	RCT	Obstetric	Waterbirth	2,422	1, 5, 10, 11, 13, 17
Barry, 2020	PO	Obstetric	Both	380	8, 10, 11, 13, 17, 23
Benfield, 2010	Pre-Post	Obstetric	Labor	11	4, 7
Bovbjerg, 2016	RO	Midwifery	Waterbirth	18,355	10, 11, 12, 17, 21
Cluett, 2004	RCT	Obstetric	Labor	99	2, 6, 7, 8, 15, 16
da Silva, 2009	RCT	Obstetric	Labor	108	2, 4, 7, 10, 12, 17
Eckert, 2001	RCT	Obstetric	Labor	274	1, 5, 6, 7, 8, 11, 12, 16, 17, 18
Geisbuehler, 2002	PO	Obstetric	Waterbirth	5,584	12, 20
Geissbuehler, 2004	PO	Obstetric	Waterbirth	9,518	5, 9, 10, 11, 13, 15, 17
Geissbuhler, 2000	PO	Obstetric	Waterbirth	7,508	6, 16
Haslinger, 2015	RO	Obstetric	Waterbirth	7,832	11, 12
Henderson, 2014	PO	Obstetric	Both	3,078	2, 3, 8, 10, 12, 13, 14, 18
Hodgson, 2020	RO	Mixed	Waterbirth	25,768	4, 11, 17, 18
Jacoby, 2019	RO	Obstetric	Waterbirth	23,036	11, 13, 15, 17, 18, 20, 21, 23
Lathrop, 2018	PO	Obstetric	Waterbirth	198	13, 16
Lim, 2016	RO	Obstetric	Waterbirth	236	4, 9, 10, 12, 13, 14, 17, 19
Liu, 2014	PO	Obstetric	Labor	108	4, 7, 8, 13
Mallen-Perez, 2018	PO	Obstetric	Unclear	215	7

Menakaya, 2013	RO	Obstetric	Waterbirth	438	9, 10, 11, 12, 13, 17, 18
Mollamahmutoglu, 2012	PO	Obstetric	Waterbirth	602	1, 7, 10, 12, 13
Neiman, 2020	RO	Obstetric	Both	230	4, 8, 9, 10, 12, 13, 17, 22, 23
Ohlsson, 2001	RCT	Obstetric	Labor	1,237	6, 8, 11, 14, 19, 20
Otigbah, 2000	RO	Obstetric	Waterbirth	602	1, 4, 5, 9, 10, 11, 12, 13
Pagano, 2010	RO	Obstetric	Waterbirth	220	10, 17
Peacock, 2018	RO	Obstetric	Waterbirth	3,507	17
Preston, 2019	RO	Midwifery	Waterbirth	15,734	5, 9, 11
Ros, 2009	PO	Obstetric	Waterbirth	54	17
Sert, 2019	RCT	Obstetric	Labor	64	17
Snapp, 2019	RO	Midwifery	Waterbirth	26,684	9, 10, 13, 17, 21, 23
Thoeni, 2005	RO	Obstetric	Waterbirth	1,600	10, 11, 12
Torkamani, 2010	PO	Obstetric	Waterbirth	100	5, 7, 12
Ulfsdottir, 2018	RO	Midwifery	Waterbirth	612	1, 2, 3, 4, 6, 10, 11, 12, 13, 14, 16, 17, 23, 24
Woodward, 2004	RCT	Obstetric	Waterbirth	80	4, 5, 6, 8, 10, 17, 24
Zanetti-Dallenbach, 2006	PO	Obstetric	Waterbirth	513	2, 3, 6, 9, 12
Zanetti-Dallenbach, 2007	PO	Obstetric	Waterbirth	368	4, 5, 10, 11, 13, 14, 17
Ziolkowski, 2009	RO	Obstetric	Waterbirth	171	16, 17

Study Type Key: RCT, Randomised Controlled Trial; PO, Prospective Observational; RO, Retrospective Observational

Interventions & Outcomes Key: 1) Labour Induction 2) Amniotomy 3) Augmentation 4) Fetal Monitoring 5) Opioids 6) Epidural 7) Pain 8) Cesarean Delivery 9) Shoulder Dystocia 10) Intact Perineum 11) OASI 12) Episiotomy 13) Postpartum Hemorrhage 14)

Manual Removal of Placenta 15) Maternal Infection 16) Maternal Satisfaction 17) 5-Minute APGAR 18) Newborn Resuscitation 19) Transient Tachypnea 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.

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=2,292) and reported as a sample characteristic for five studies (n=22,439).

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 Cesarean
Bailey, 2019	Yes	No	No	Yes	No
Barry, 2020	Yes	Yes	>30	Yes	n.d.
Benfield, 2010	Yes	n.d.	n.d.	n.d.	n.d.
Bovbjerg, 2016	Yes	n.d.	n.d.	Yes	No
Cluett, 2004	Yes	Yes	n.d.	n.d.	n.d.
da Silva, 2009	Yes	n.d.	n.d.	Yes	n.d.
Eckert, 2001	Yes	No	n.d.	Yes	n.d.
Geisbuehler, 2002	Yes	n.d.	n.d.	n.d.	n.d.
Geissbuehler, 2004	Yes	n.d.	>40	n.d.	n.d.
Geissbuhler, 2000	Yes	n.d.	n.d.	n.d.	n.d.
Haslinger, 2015	Yes	n.d.	n.d.	Yes	n.d.
Henderson, 2014	Yes	No	n.d.	n.d.	No
Hodgson, 2020	Yes	n.d.	n.d.	Yes	n.d.
Jacoby, 2019	Yes	Yes	n.d.	Yes	n.d.
Lathrop, 2018	Yes	n.d.	n.d.	Yes	n.d.
Lim, 2016	Yes	n.d.	n.d.	Yes	No
Liu, 2014	No	n.d.	No	Yes	Yes
Mallen-Perez, 2018	Yes	Yes	No	Yes	n.d.

Menakaya, 2013	Yes	Yes	n.d.	Yes	n.d.
Mollamahmutoglu, 2012	Yes	No	No	n.d.	Yes
Neiman, 2020	Yes	Yes	n.d.	Yes	Yes
Ohlsson, 2001	Yes	n.d.	n.d.	Yes	n.d.
Otigbah, 2000	Yes	No	n.d.	n.d.	n.d.
Pagano, 2010	Yes	n.d.	n.d.	n.d.	n.d.
Peacock, 2018	Yes	Yes	n.d.	n.d.	n.d.
Preston, 2019	Yes	Yes	No	n.d.	n.d.
Ros, 2009	Yes	n.d.	n.d.	Yes	Yes
Sert, 2019	Yes	Yes	n.d.	n.d.	Yes
Snapp, 2019	Yes	n.d.	n.d.	n.d.	n.d.
Thoeni, 2005	No	n.d.	n.d.	Yes	Yes
Torkamani, 2010	Yes	n.d.	n.d.	n.d.	n.d.
Ulfsdottir, 2018	Yes	Yes	No	n.d.	No
Woodward, 2004	Yes	Yes	n.d.	n.d.	Yes
Zanetti-Dallenbach, 2006	Yes	n.d.	n.d.	Yes	n.d.
Zanetti-Dallenbach, 2007	Yes	n.d.	n.d.	Yes	n.d.
Ziolkowski, 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.

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=3,273). Method of induction was not reported. Sixteen studies reported a fetal heart 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=5,595) or "hands-on" (k=2; n=6,463) the perineum. Third stage management was reported by six studies (n=5,595), 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=1,396).

Table 3: Description of care practices reported in included studies

Author	Appropriate Pool Described	Induction Method	Intermittent Auscultation	Perineum Method	3rd Stage Management	Placenta & Membranes
Bailey, 2019	No	n.d.	n.d.	n.d.	Active	Out of Pool
Barry, 2020	Yes	None	Mixed	Hands Off	Active	n.d.
Benfield, 2010	No	n.d.	No	n.d.	n.d.	n.d.
Bovbjerg, 2016	No	n.d.	n.d.	n.d.	n.d.	n.d.
Cluett, 2004	Yes	None	n.d.	n.d.	n.d.	n.d.
da Silva, 2009	No	n.d.	No	n.d.	n.d.	n.d.
Eckert, 2001	Yes	n.d.	n.d.	n.d.	n.d.	n.d.
Geisbuehler, 2002	No	n.d.	Yes	n.d.	n.d.	n.d.
Geissbuehler, 2004	No	n.d.	Yes	n.d.	n.d.	n.d.
Geissbuhler, 2000	No	n.d.	Yes	n.d.	n.d.	n.d.
Haslinger, 2015	No	n.d.	n.d.	Hands On	n.d.	n.d.
Henderson, 2014	No	n.d.	n.d.	Hands Off	Active	n.d.
Hodgson, 2020	No	n.d.	Yes	n.d.	n.d.	n.d.
Jacoby, 2019	No	None	n.d.	n.d.	n.d.	n.d.
Lathrop, 2018	No	n.d.	n.d.	n.d.	n.d.	n.d.
Lim, 2016	No	n.d.	No	n.d.	n.d.	n.d.
Liu, 2014	No	n.d.	Yes	n.d.	n.d.	n.d.
Mallen-Perez, 2018	Yes	None	n.d.	n.d.	n.d.	n.d.

Menakaya, 2013	Yes	None	n.d.	n.d.	n.d.	n.d.
Mollamahmutoglu, 2012	Yes	n.d.	Yes	Hands Off	Active	n.d.
Neiman, 2020	No	None	Yes	n.d.	n.d.	n.d.
Ohlsson, 2001	No	n.d.	n.d.	n.d.	n.d.	n.d.
Otigbah, 2000	Yes	n.d.	Yes	Hands Off	Active	Out of Pool
Pagano, 2010	No	n.d.	n.d.	n.d.	n.d.	n.d.
Peacock, 2018	No	None	n.d.	n.d.	n.d.	n.d.
Preston, 2019	No	None	n.d.	n.d.	n.d.	n.d.
Ros, 2009	No	n.d.	n.d.	n.d.	n.d.	n.d.
Sert, 2019	Yes	None	n.d.	n.d.	n.d.	n.d.
Snapp, 2019	No	n.d.	n.d.	n.d.	n.d.	n.d.
Thoeni, 2005	No	n.d.	n.d.	Hands On	n.d.	n.d.
Torkamani, 2010	No	n.d.	n.d.	n.d.	n.d.	n.d.
Ulfsdottir, 2018	Yes	None	No	n.d.	n.d.	n.d.
Woodward, 2004	No	None	Yes	n.d.	n.d.	n.d.
Zanetti-Dallenbach, 2006	No	n.d.	No	n.d.	Active	In Pool
Zanetti-Dallenbach, 2007	No	n.d.	No	n.d.	n.d.	n.d.
Ziolkowski, 2009	No	n.d.	Yes	n.d.	n.d.	n.d.

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

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 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.

[Insert Figure 2]

Labour Induction. Three studies provided data on labour induction (n=2,008), all conducted after 2010. Overall, this analysis found no difference between use of labour induction with water immersion and standard care (OR 0.43; 95% CI 0.16 – 1.16; random effects; Q=20.7 p<.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]

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

Outcome	Studies	Sample	Effect OR (95% CI) Model	Heterogeneity Q (p) I^2%
Labor Induction[a]				
Obstetric Units	2	604 Immersion 792 Standard Care	0.32 (0.06 – 1.58) Random Effects	18 (<.01) 94%
Amniotomy[a]				
Obstetric Units	4	306 Immersion 709 Standard Care	0.95 (0.62 – 1.46) Random Effects	5 (.17) 40%
2010 and Earlier	3	192 Immersion 250 Standard care	0.87 (0.46 – 1.64) Random Effects	4 (.13) 51%
2011 and Later	2	420 Immersion 765 Standard care	0.56 (0.15 – 2.02) Random Effects	14 (<.01) 93%
Augmentation[a]				
Obstetric Units	2	203 Immersion 605 Standard Care	0.48 (0.16 – 1.51) Random Effects	6 (.02) 83%
2011 and Later	2	420 Immersion 765 Standard care	0.32 (0.05 – 2.24) Random Effects	19 (<.01) 95%
Opioid Use				
2010 and Earlier	6	4,298 Immersion 6,565 Standard care	0.23 (0.08 – 0.70) Random Effects	95 (<.01) 95%
2011 and Later	2	1,641 Immersion 14,887 Standard care	0.17 (0.15 – 0.20) Fixed Effects	0 (.54) 0%
Epidural[a]				
Obstetric Units	6	4,104 Immersion 6,889 Standard Care	0.26 (0.08 – 0.83) Random Effects	89 (<.01) 94%
2010 and Earlier	6	4,104 Immersion 6,889 Standard Care	0.26 (0.08 – 0.83) Random Effects	89 (<.01) 94%
Pain				
2010 and Earlier	3	182 Immersion	0.53 (0.27 – 1.03)	6 (.05)

		188 Standard Care	Random Effects	68%
2011 and Later	5	417 Immersion	0.15 (0.06 – 0.42)	48 (<.01)
		413 Standard Care	Random Effects	92%
Cesarean Delivery				
2010 and Earlier	4	790 Immersion	1.05 (0.63 – 1.74)	3 (.43)
		745 Standard Care	Fixed Effects	0%
2011 and Later	4	400 Immersion	0.84 (0.32 – 2.23)	6 (.12)
		830 Standard Care	Fixed Effects	48%
Shoulder Dystocia				
Obstetric Units	6	5,528 Immersion	1.06 (0.64 – 1.74)	4 (.60)
		21,155 Standard Care	Fixed Effects	0%
2010 and Earlier	3	4,007 Immersion	0.88 (0.42 – 1.83)	2 (.39)
		6,335 Standard Care	Fixed Effects	0%
2011 and Later	4	11,773 Immersion	0.87 (0.33 – 2.26)	11 (.01)
		31,252 Standard Care	Random Effects	73%
Intact Perineum				
Obstetric Units	14	6,170 Immersion	1.55 (1.12 – 2.16)	147 (<.01)
		8,866 Standard care	Random Effects	91%
Midwifery-led Units	3	17,079 Immersion	1.07 (0.91 – 1.26)	15 (<.01)
		23,249 Standard care	Random Effects	87%
Nulliparas	5	1,065 Immersion	1.59 (1.01 – 2.50)	12 (.01)
		894 Standard care	Random Effects	68%
Waterbirth vs No Water	8	954 Immersion	1.35 (0.67 – 2.72)	83 (<.01)
		1696 Standard care	Random Effects	92%
2010 and Earlier	7	4,958 Immersion	1.28 (0.90 – 1.82)	39 (<.01)
		6,949 Standard Care	Random Effects	85%
2011 and Later	10	18,292 Immersion	1.59 (1.22 – 2.07)	156 (<.01)
		28,871 Standard Care	Random Effects	94%
OASI				
Obstetric Units	13	10,720 Immersion	0.85 (0.57 – 1.30)	51 (<.001))
		57,870 Standard care	Random Effects	77%
Midwifery-led Units	2	6,827 Immersion	0.71 (0.47 – 1.08)	0 (.527)
		10,558 Standard care	Fixed Effects	0%
Nulliparas	2	870 Immersion	1.25 (0.42 – 3.71)	1 (.385)

		540 Standard care	Fixed Effects	0%
Waterbirth vs No Water	3	408 Immersion	0.57 (0.19 – 1.69)	1 (.681)
		550 Standard care	Fixed Effects	0%
2010 and Earlier	6	5,493 Immersion	0.73 (0.58 – 0.91)	8 (.16)
		7,517 Standard Care	Fixed Effects	37%
2011 and Later	9	13,298 Immersion	0.78 (0.48 – 1.28)	42 (<.01)
		67,382 Standard Care	Random Effects	81%
Episiotomy[a]				
Obstetric Units	14	6177 Immersion	0.17 (0.11 – 0.28)	109 (<.001)
		13,548 Standard care	Random Effects	88%
Nulliparas	3	886 Immersion	0.10 (0.02 – 0.60)	14 (<.001)
		582 Standard care	Random Effects	86%
Waterbirth vs No Water	5	691 Immersion	0.63 (0.02 – 0.20)	14 (.008)
		1022 Standard care	Random Effects	71%
2010 and Earlier	7	4,927 Immersion	0.21 (0.11 – 0.41)	52 (<.01)
		6,912 Standard Care	Random Effects	88%
2011 and Later	8	7,831 Immersion	0.09 (0.03 – 0.25)	53 (<.01)
		16,888 Standard Care	Random Effects	87%
Postpartum Hemorrhage				
Obstetric Units	13	7,040 Immersion	0.75 (0.60 – 0.94)	30 (.002)
		29,555 Standard care	Random Effects	60%
Midwifery-led Units	2	10,558 Immersion	0.39 (0.08 – 1.86)	56 (<.001)
		16,738 Standard care	Random Effects	98%
Waterbirth vs No Water	5	758 Immersion	1.02 (0.76 – 1.36)	4 (.439)
		1,177 Standard care	Fixed Effects	0%
2010 and Earlier	3	4,007 Immersion	0.72 (0.59 – 0.88)	2 (.30)
		6,348 Standard Care	Random Effects	17%
2011 and Later	12	13,591 Immersion	0.76 (0.48 – 1.20)	97 (<.01)
		39,945 Standard Care	Random Effects	89%
Manual Removal of Placenta				
Obstetric Units	4	1,239 Immersion	0.78 (0.37 – 1.64)	6 (.105)
		1,654 Standard care	Fixed Effects	51%
2010 and Earlier	2	701 Immersion	0.48 (0.21 – 1.11)	0 (.91)
		771 Standard Care	Fixed Effects	0%

2011 and Later	3	538 Immersion 883 Standard Care	1.48 (0.50 – 4.38) Fixed Effects	4 (.16) 45%
Maternal Satisfaction				
Obstetric Units	5	1,802 Immersion 1,568 Standard care	2.02 (1.28 – 3.19) Random Effects	24 (<.01) 83%
2010 and Earlier	4	1,815 Immersion 1,519 Standard Care	1.64 (0.83 – 3.24) Random Effects	22 (<.01) 86%
2011 and Later	2	372 Immersion 438 Standard Care	2.55 (1.54 – 4.23) Random Effects	2 (.16) 50%
APGAR				
Obstetric Units	18	10,286 Immersion 54,361 Standard care	0.85 (0.66 – 1.08) Random Effects	29 (.047) 38%
Midwifery-led Units	3	17,092 Immersion 18,31 Standard care	0.33 (0.07 – 1.54) Random Effects	57 (<.001) 96%
Waterbirth vs No Water	6	614 Immersion 655 Standard care	1.07 (0.76 – 1.51) Fixed Effects	3 (.643) 0%
2010 and Earlier	8	4,184 Immersion 6,476 Standard care	1.00 (0.77 – 1.29) Fixed Effects	7 (.120) 39%
2011 and Later	12	21,931 Immersion 65,781 Standard care	0.52 (0.25 – 1.05) Random Effects	101 (<.001) 89%
Neonatal Death				
Midwifery-led units	2	16,786 Immersion 26,722 Standard care	0.91 (0.61 – 1.34) Fixed Effects	1 (.297) 8%
Cord Avulsion				
Obstetric Units	3	1,874 Immersion 21,621 Standard care	2.18 (0.34 – 11.97) Fixed Effects	1 (.757) 0%
Midwifery-led Units	2	10,649 Immersion 16,829 Standard care	1.92 (1.28 – 2.89) Fixed Effects	1 (.386) 0%

a. Random Effects models were used for intervention (labor 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.

[Insert Figure 3]

Amniotomy. Five studies provided data on amniotomy (n=1,627). Overall, this analysis found no difference (OR 0.71 ; 95% CI 0.37 – 1.39; random effects; Q=23.9 p<.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.

[Insert Figure 4]

Augmentation. Three studies provided data to compare augmentation of labour (n=1,420). This analysis favoured water immersion (OR 0.30; 95% CI 0.10 – 0.92; random effects; Q=19.2 p<.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.

[Insert Figure 5]

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 – 0.38; random effects; Q=96.1 p<.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 972 additional studies would be needed to change the estimate to no difference.

[Insert Figure 6]

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 – 0.83; random effects; Q=89.5 p<.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.

[Insert Figure 7]

Pain. Eight studies provided data for analysis of pain (n=1,200), 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 – 0.51; random effects; Q=76.7 p<.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 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.

[Insert Figure 8]

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 a randomised controlled trial 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 – 1.48; fixed effects; Q=9.0 p=.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.

[Insert Figure 9]

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 – 1.69; random effects; Q=16 p=.012; I^2=63%). The subgroup analysis of studies in an obstetric setting and the most recent studies remained no difference. Cumulative meta-analysis indicated there has consistently been no difference.

[Insert Figure 10]

Intact Perineum. Seventeen studies provided data on intact perineum (n=59,070). This analysis favoured water immersion (OR 1.47; 95% CI 1.21 – 1.78; random effects; Q=219.1 p<.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<.001) and the proportion of nulliparas in the sample (p=.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 – 6.04; random effects; Q=2 p=.504 I^2=0%).

[Insert Figure 11]

OASI. Fifteen studies provided data on obstetric anal sphincter injuries (n=93,690)**.** This analysis found no difference (OR 0.84 95% CI 0.59 – 1.18; random effects; Q=52.6 p<.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.

[Insert Figure 12]

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 – 0.26; random effects; Q=114.3 p<.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=.76; p=.001; 7 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 in proportion of nulliparas, the result remained in favour of water immersion (OR 0.04 95% CI 0.01 – 0.13; random effects; Q=12 p=.038; I^2=57%).

[Insert Figure 13]

Third Stage Management. No studies provided comparison data for third stage management.

Postpartum Hemorrhage. Fifteen studies provided data about postpartum hemorrhage (n=63,891) using three different measures: count of postpartum hemorrhage defined as >500 ml blood loss, mean estimated blood loss, and change in hemoglobin. Overall, this analysis favoured water immersion (OR 0.69 95% CI 0.51 – 0.95; random effects; Q=116.5 p<.001; I^2=88%). Subgroup analysis revealed no difference in odds of postpartum hemorrhage 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; 9 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.

[Insert Figure 14]

Manual removal of the placenta. Five studies provided data to assess risk for manual removal of the placenta (n=2,893). This analysis indicated no difference (OR 0.73 95% CI 0.38-1.42; fixed effects; Q=6.2 p=.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.

[Insert Figure 15]

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 – 0.80; fixed effects; Q=0.5 p=.792; I^2=0%), however one study carried 97% of the weight for this synthesis. Fail-safe analysis estimated 2 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.

[Insert Figure 16]

Maternal Satisfaction. Six studies provided data on a measure of maternal satisfaction (n=4,144). Due to heterogeneity in measurement tool, this analysis used random effects modeling 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 – 2.96; random effects; Q=24.3 p<.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 would be necessary to change the estimate from favouring water to no difference.

[Insert Figure 17]

5-Minute APGAR. Twenty-one studies provided data for 5-minute APGAR (n=98,372). This analysis found no difference (OR 0.63 95% CI 0.38 – 1.05; random effects; Q=146.5 p<.001; I^2=87%). Three additional studies reported on 5-minute APGAR but did not provide data in a usable format; two found no difference [47,52] and one reported in favor of water immersion.[61] 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=.85; p=.001; 9 studies). After accounting for setting the analysis favoured water immersion (OR 0.14 95% CI 0.06 – 0.36; random effects; Q=20 p=.034; I^2=50%).

[Insert Figure 18]

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 – 1.69; random effects; Q=9.6 p=.048; I^2=58%. Cumulative meta-analysis indicated this outcome has been stable at no difference since first reported.

[Insert Figure 19]

Transient tachypnea of the newborn. Two studies provided data on transient tachypnea of the newborn (n=1,473), both were conducted in an obstetric setting. This analysis found no difference (OR 0.74; 95% CI 0.33-1.65; fixed effects; Q=0.8 p=.364; I^2=0%). Too few studies were available to conduct cumulative meta-analysis and subgroup analysis.

[Insert Figure 20]

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 – 2.43; random effects; Q=18.1 p<.001; I^2=89%). Three studies were too few for cumulative meta-analysis.

[Insert Figure 21]

Neonatal intensive care unit 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 – 1.40; fixed effects; Q=1.9 p=.381; I^2=0%). Subgroup analysis by setting revealed no difference in midwifery-led settings. Three studies were too few for cumulative meta-analysis.

[Insert Figure 22]

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 – 2.88; fixed effects; Q=1.3 p=.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 – 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 5 additional studies would be needed to change the estimate to no difference.

[Insert Figure 23]

Breastfeeding Initiation. Two studies provided data on breastfeeding initiation (n=692). This analysis found no difference (OR 1.00 95% CI 0.73 – 1.37; fixed effects; Q=1.0 p=.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.

[Insert Figure 24]

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 & fill estimates of the magnitude of bias indicate the magnitude was too small to affect the results.

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 & Fill Direction of Bias[a] OR (95% CI)
Amniotomy	5	4 (.164)	5.04 (.129)	Standard Care 0.43 (0.34 – 0.53)
Induction	3	-3 (0.059)	-10 (.238)	--
Augmentation	3	3 (0.59)	28.96 (.057)	Standard Care 0.12 (0.09 – 0.16)
Opioid	8	-2 (.402)	2.13 (.197)	Standard Care 0.17 (0.15 – 0.19)
Epidural	7	-9 (.088)	-4.51 (.039)	Immersion 0.67 (0.54 – 0.83)
Cesarean	8	-2 (.402)	-0.74 (.327)	--
Pain	8	0 (.500)	-1.67 (.339)	Standard Care 0.16 (0.07 – 0.37)
Satisfaction	6	-5 (.174)	-1.26 (.216)	Immersion 1.73 (1.13 – 2.64)
Intact Perineum	14	-10 (.340)	2.13 (.045)	Standard Care 1.71 (1.40 – 2.10)
Episiotomy	13	-11 (.274)	-1.27 (.121)	Immersion 0.20 (0.13 – 0.32)
OASI	14	3 (.435)	0.40 (.234)	Standard Care 0.64 (0.50 – 0.82)
Shoulder Dystocia	7	5 (.226)	1.85 (.001)	Standard Care 0.68 (0.38 – 1.21)
Maternal Infection	3	--	0.34 (.290)	--
Postpartum Hemorrhage	13	9 (.328)	-0.23 (.412)	Standard Care 0.52 (0.39 – 0.71)
Retained Placenta	5	6 (.071)	2.11 (.068)	Standard Care 0.76 (0.29 – 2.03)
APGAR	16	-34 (.179)	0.86 (.209)	Standard Care 0.59 (0.36 – 0.96)
Neonatal Resuscitation	5	2 (.312)	0.69 (.282)	--
Transient Tachypnea	2	--	--	--
Respiratory Distress	3	1 (.301)	-1.77 (.426)	--
Neonatal Death	3	1 (.301)	1.34 (.078)	Standard Care 0.84 (0.53 – 1.33)
Cord Avulsion	5	6 (.071)	0.36 (.182)	Standard Care 1.86 (1.26 – 2.75)
Breastfeeding Initiation	2	--	--	--

a. Trim & Fill analysis conducted with random effects model and indicates OR and 95% Confidence Interval estimate if bias were corrected.

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 to midwifery-led settings and this has been reported for women who labour and/or give birth in water.[3,67-69] 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.[70,71] Furthermore, labouring and/or giving birth in water does not increase the likelihood of obstetric anal sphincter injury (OASI), which corroborates previous waterbirth research.[7,72,73]A significant postpartum haemorrhage (PPH) reduction was another important finding, which is also supported in the literature.[74]

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.[3,75] The incidence of cord avulsion was 4.3 per 1,000 births in water compared to 1.3 per 1,000 births with standard care. Interestingly, the incidence of cord avulsion varied from 0.2 per 1,000 to 11.8 per 1,000 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.[76]

Our results show that water immersion has the potential to make a meaningful contribution to the global agenda toward promoting physiologic birth.[77,78,79,80,81] 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.[82,83,84,85] Differences between birth settings in intact perineum and postpartum haemorrhage 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 labour induction and episiotomy are reduced with water immersion, while maternal satisfaction is increased. Given these results, water immersion for labour and waterbirth is an intervention that can be used to achieve physiologic 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 to fragmented care models.[85] 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 (EFM) 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 postpartum haemorrhage. 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 & 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 postpartum haemorrhage.

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 pharmacologic 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 -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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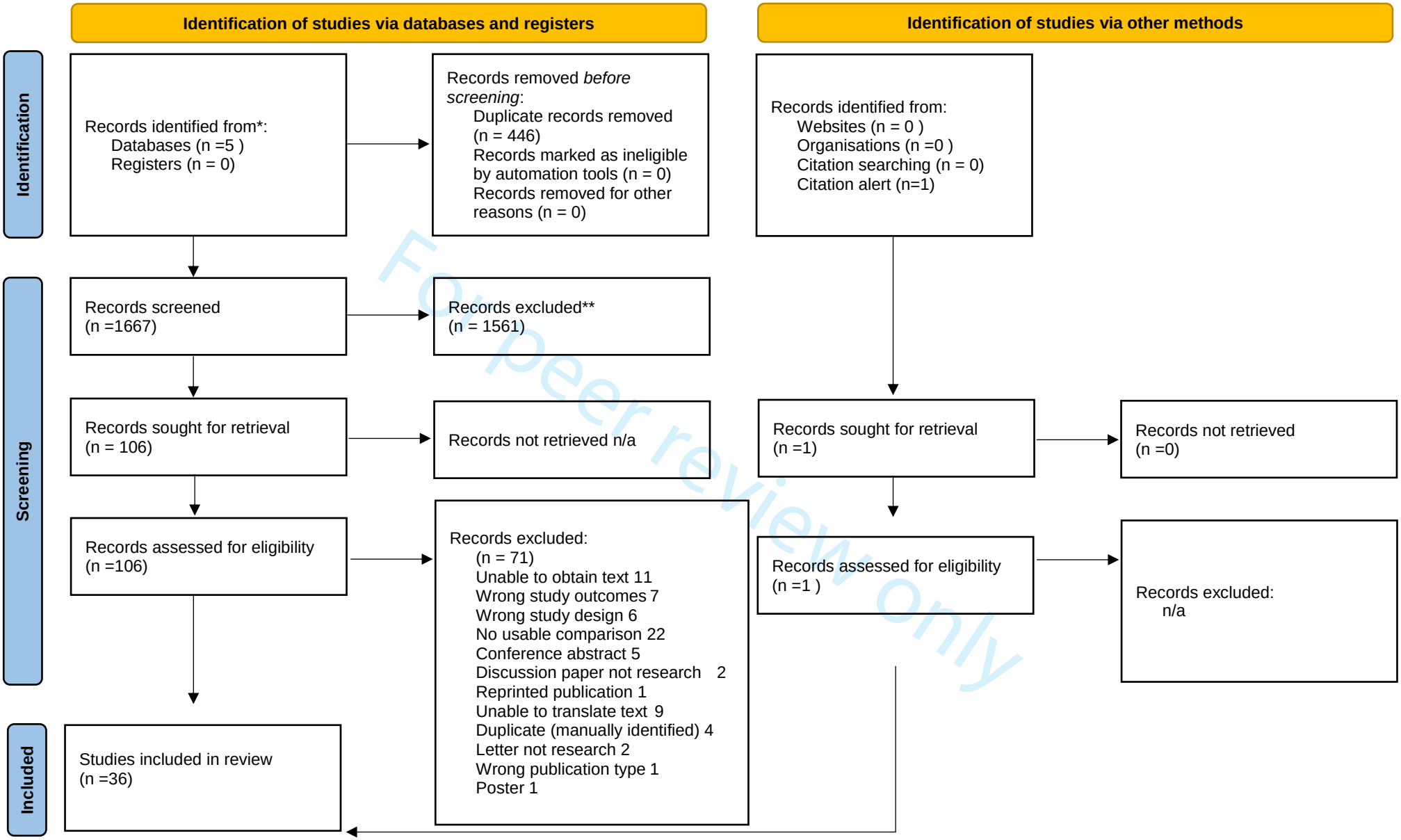


Figure 1 PRISMA 2020 flow diagram for new systematic reviews which included searches of databases, registers and other sources

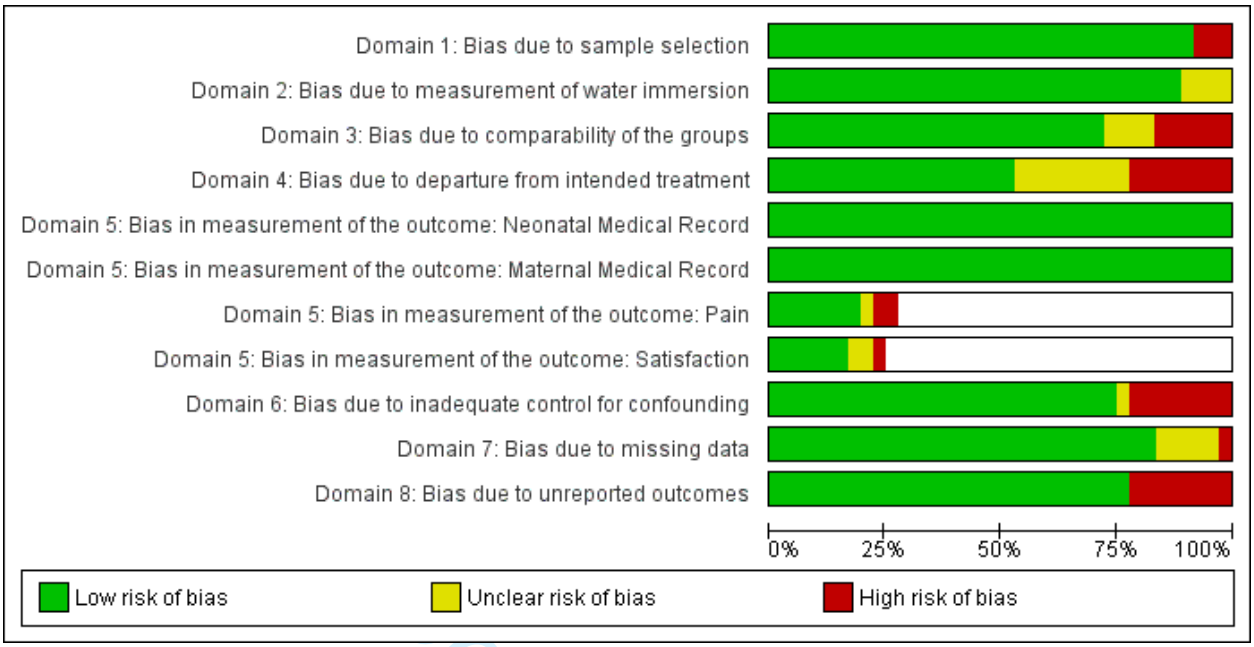
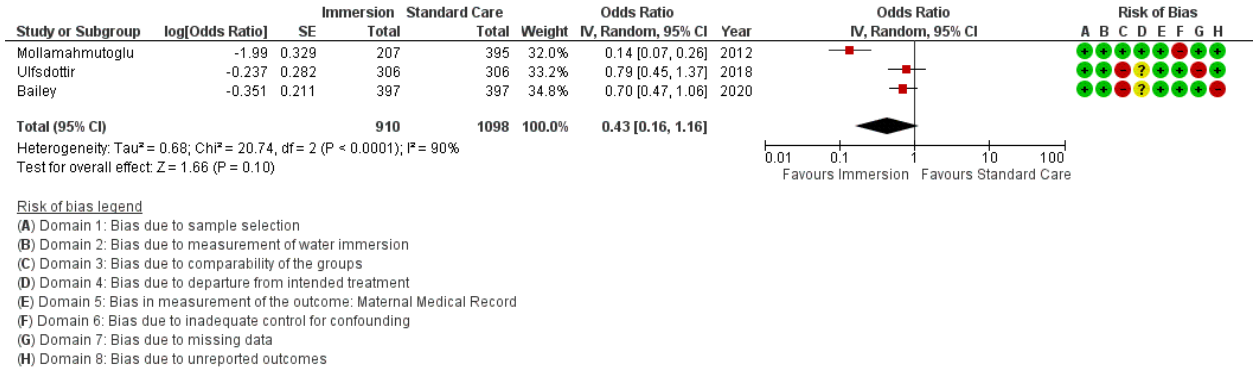
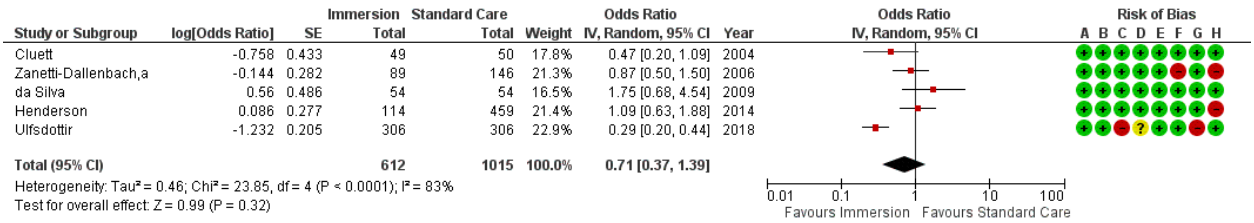


Figure 2 Risk of bias assessment

Figure 3 Forest Plot of Synthesis of Labour Induction



Risk of bias legend
(**A**) Domain 1: Bias due to sample selection
(**B**) Domain 2: Bias due to measurement of water immersion
(**C**) Domain 3: Bias due to comparability of the groups
(**D**) Domain 4: Bias due to departure from intended treatment
(**E**) Domain 5: Bias in measurement of the outcome: Maternal Medical Record
(**F**) Domain 6: Bias due to inadequate control for confounding
(**G**) Domain 7: Bias due to missing data
(**H**) Domain 8: Bias due to unreported outcomes



Risk of bias legend
(**A**) Domain 1: Bias due to sample selection
(**B**) Domain 2: Bias due to measurement of water immersion
(**C**) Domain 3: Bias due to comparability of the groups
(**D**) Domain 4: Bias due to departure from intended treatment
(**E**) Domain 5: Bias in measurement of the outcome: Maternal Medical Record
(**F**) Domain 6: Bias due to inadequate control for confounding
(**G**) Domain 7: Bias due to missing data
(**H**) Domain 8: Bias due to unreported outcomes

Figure 4 Forest Plot of Synthesis of Amniotomy

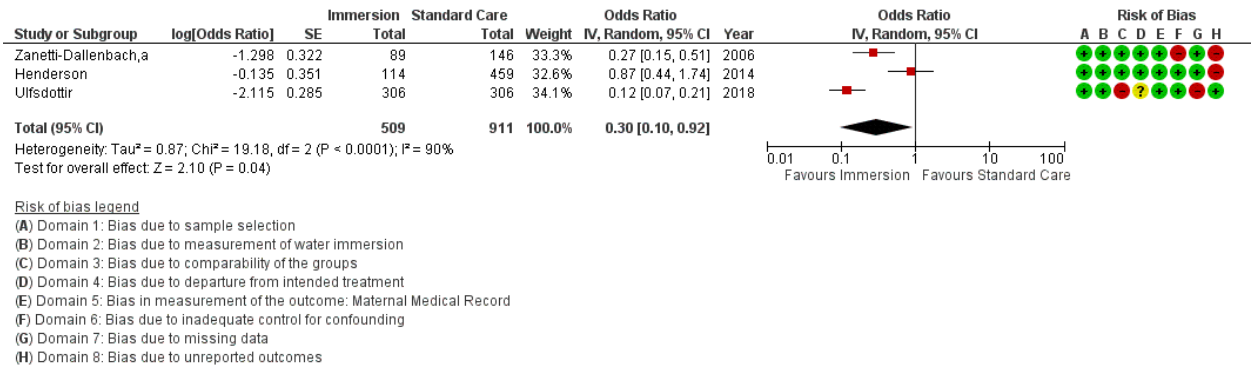
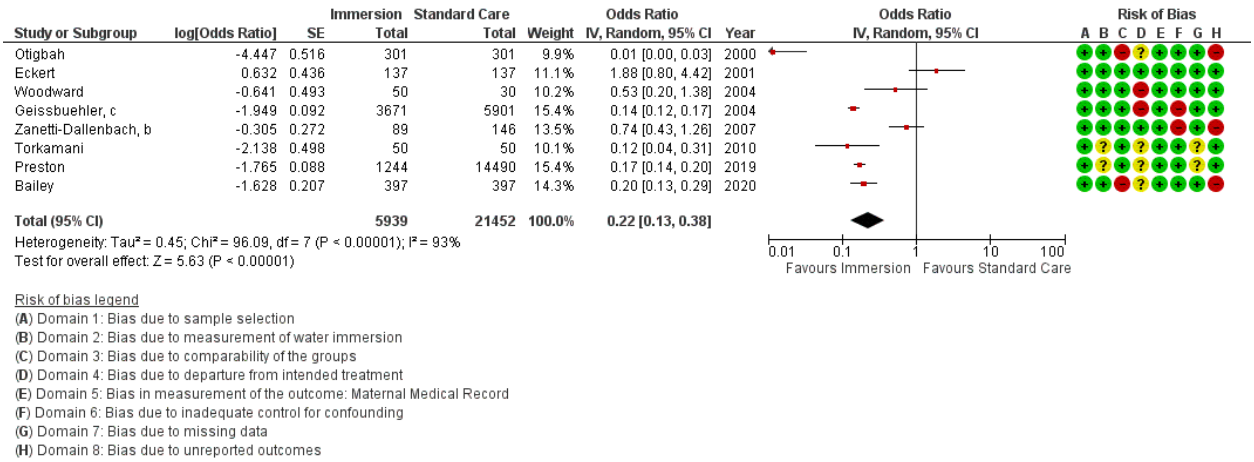


Figure 5 Forest Plot of Synthesis of Augmentation of Labour



Risk of bias legend
(**A**) Domain 1: Bias due to sample selection
(**B**) Domain 2: Bias due to measurement of water immersion
(**C**) Domain 3: Bias due to comparability of the groups
(**D**) Domain 4: Bias due to departure from intended treatment
(**E**) Domain 5: Bias in measurement of the outcome: Maternal Medical Record
(**F**) Domain 6: Bias due to inadequate control for confounding
(**G**) Domain 7: Bias due to missing data
(**H**) Domain 8: Bias due to unreported outcomes

Figure 6 Forest Plot of Synthesis of Opioid Use

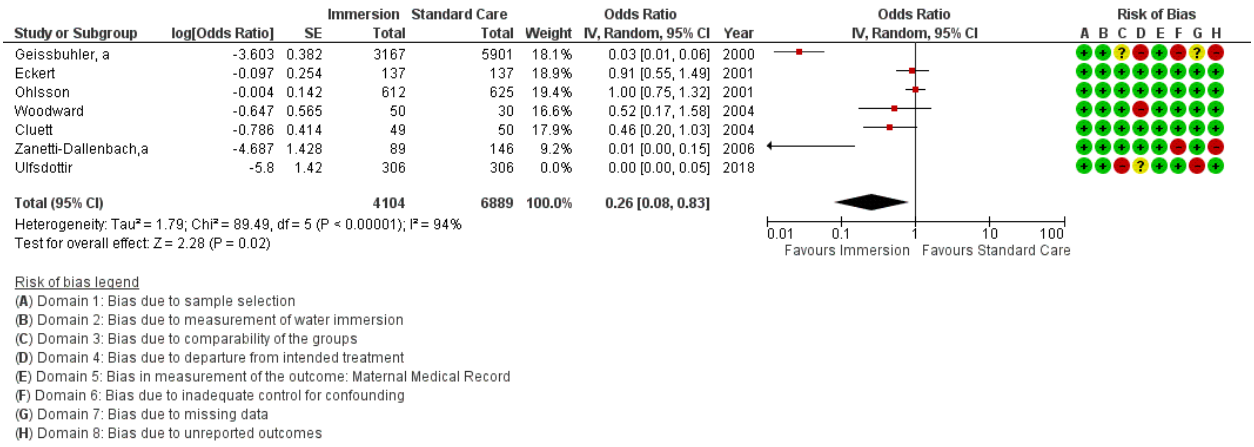


Figure 7 Forest Plot of Synthesis of Epidural Use

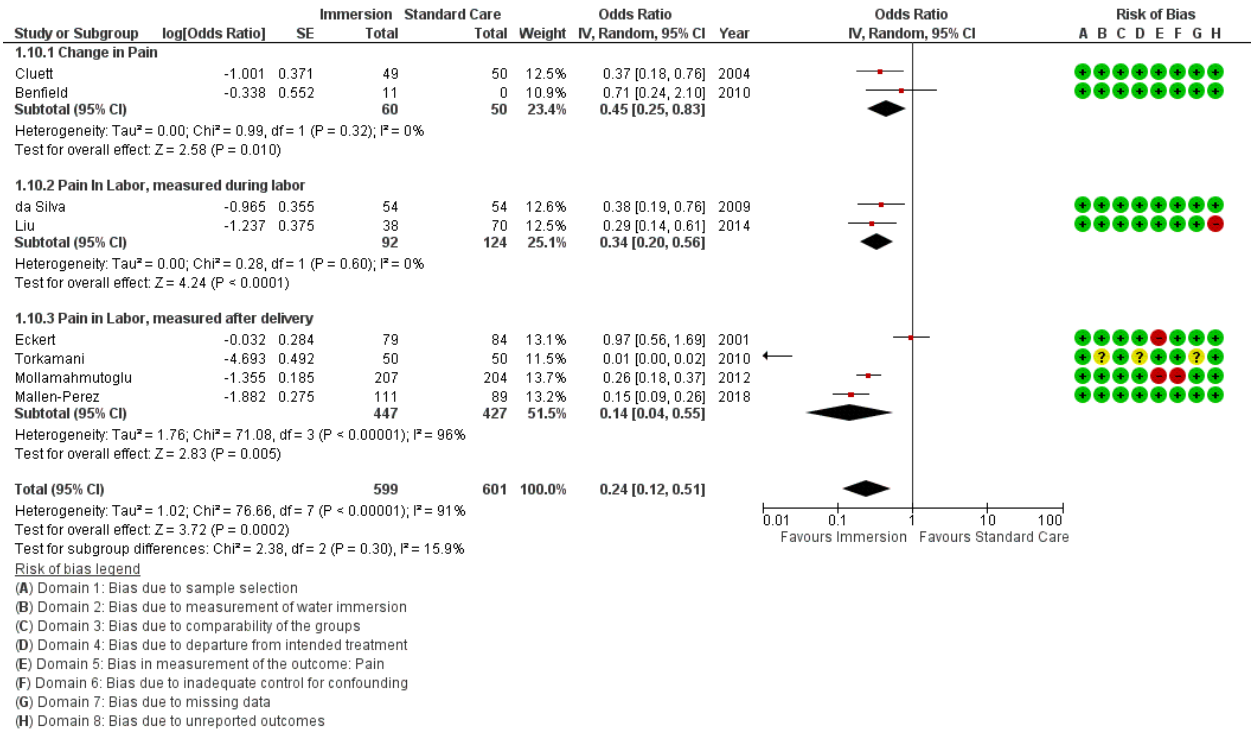
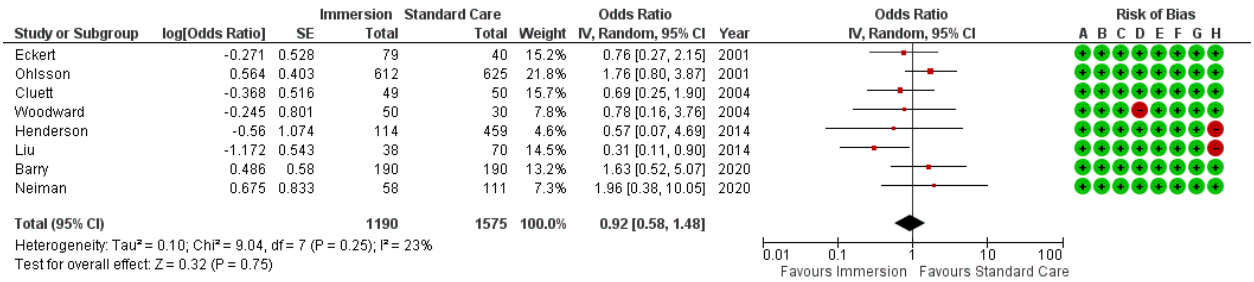
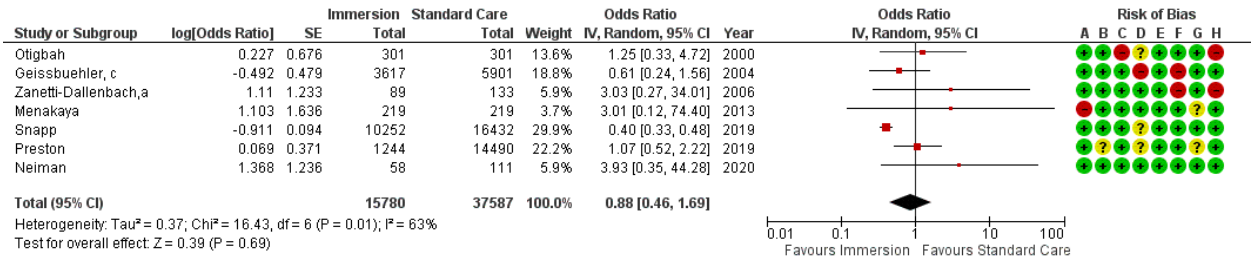


Figure 8 Forest Plot of Synthesis of Pain



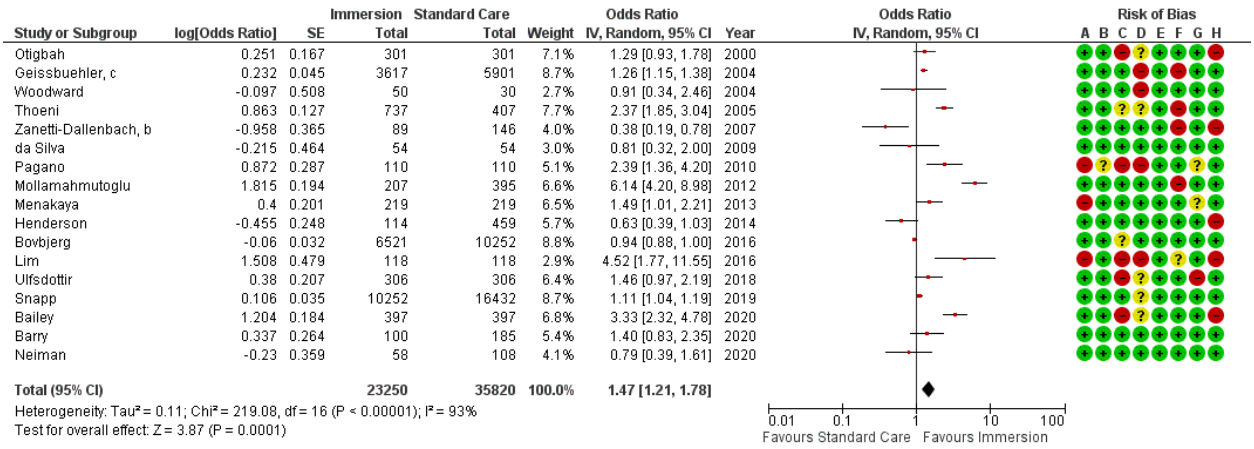
Risk of bias legend
(**A**) Domain 1: Bias due to sample selection
(**B**) Domain 2: Bias due to measurement of water immersion
(**C**) Domain 3: Bias due to comparability of the groups
(**D**) Domain 4: Bias due to departure from intended treatment
(**E**) Domain 5: Bias in measurement of the outcome: Maternal Medical Record
(**F**) Domain 6: Bias due to inadequate control for confounding
(**G**) Domain 7: Bias due to missing data
(**H**) Domain 8: Bias due to unreported outcomes

Figure 9 Forest Plot of Synthesis of Cesarean Delivery



Risk of bias legend
(A) Domain 1: Bias due to sample selection
(B) Domain 2: Bias due to measurement of water immersion
(C) Domain 3: Bias due to comparability of the groups
(D) Domain 4: Bias due to departure from intended treatment
(E) Domain 5: Bias in measurement of the outcome: Maternal Medical Record
(F) Domain 6: Bias due to inadequate control for confounding
(G) Domain 7: Bias due to missing data
(H) Domain 8: Bias due to unreported outcomes

Figure 10 Forest Plot of Synthesis of Shoulder Dystocia



Risk of bias legend

(**A**) Domain 1: Bias due to sample selection

(**B**) Domain 2: Bias due to measurement of water immersion

(**C**) Domain 3: Bias due to comparability of the groups

(**D**) Domain 4: Bias due to departure from intended treatment

(**E**) Domain 5: Bias in measurement of the outcome: Maternal Medical Record

(**F**) Domain 6: Bias due to inadequate control for confounding

(**G**) Domain 7: Bias due to missing data

(**H**) Domain 8: Bias due to unreported outcomes

Figure 11 Forest Plot of Synthesis of Intact Perineum

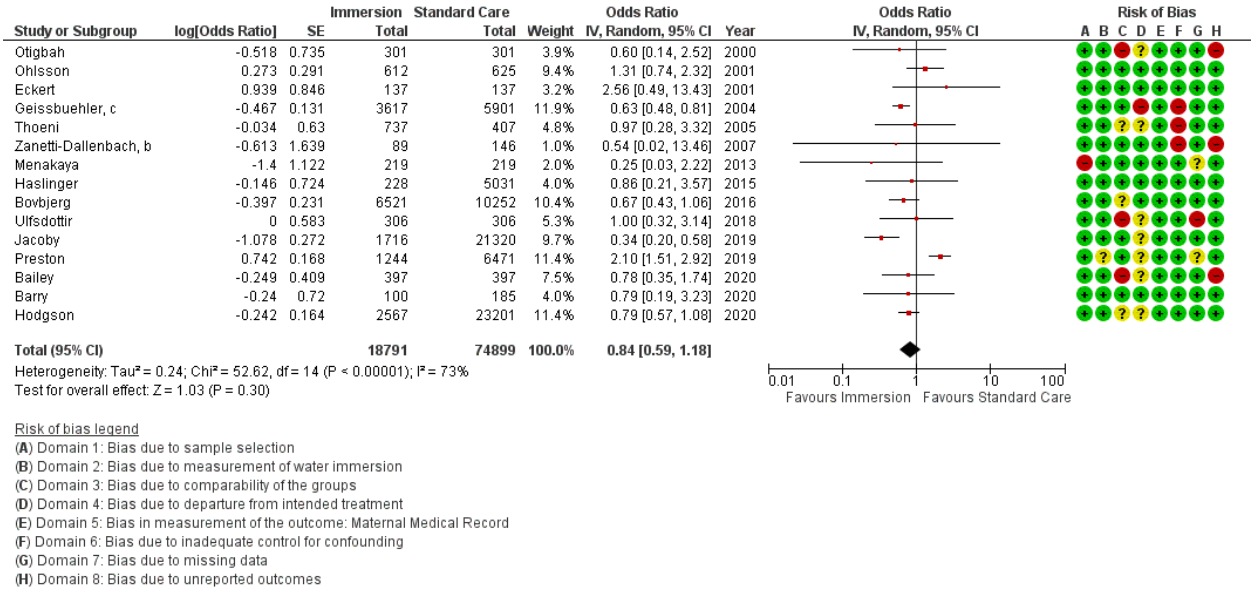
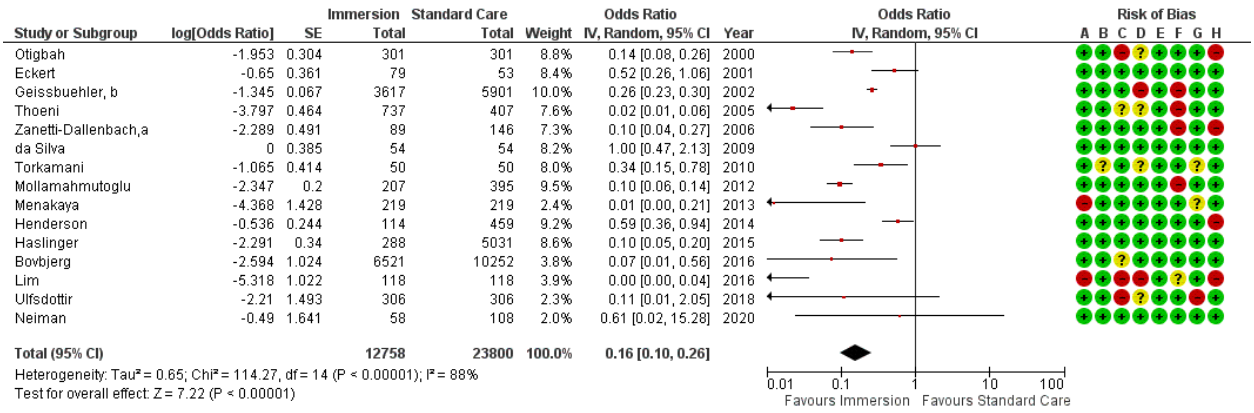


Figure 12 Forest Plot of Synthesis of Obstetric Anal Sphincter Injuries (OASI)



Risk of bias legend
(**A**) Domain 1: Bias due to sample selection
(**B**) Domain 2: Bias due to measurement of water immersion
(**C**) Domain 3: Bias due to comparability of the groups
(**D**) Domain 4: Bias due to departure from intended treatment
(**E**) Domain 5: Bias in measurement of the outcome: Maternal Medical Record
(**F**) Domain 6: Bias due to inadequate control for confounding
(**G**) Domain 7: Bias due to missing data
(**H**) Domain 8: Bias due to unreported outcomes

Figure 13 Forest Plot of Synthesis of Episiotomy

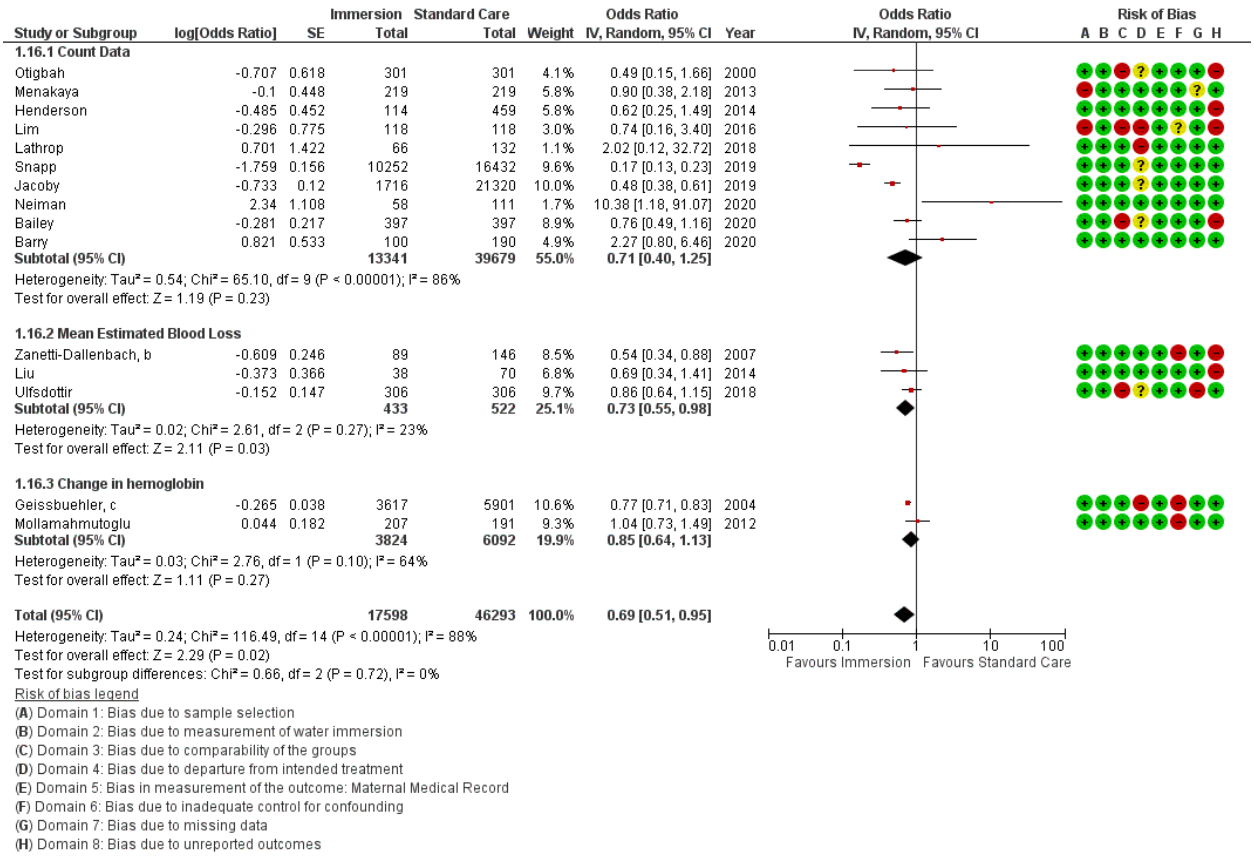
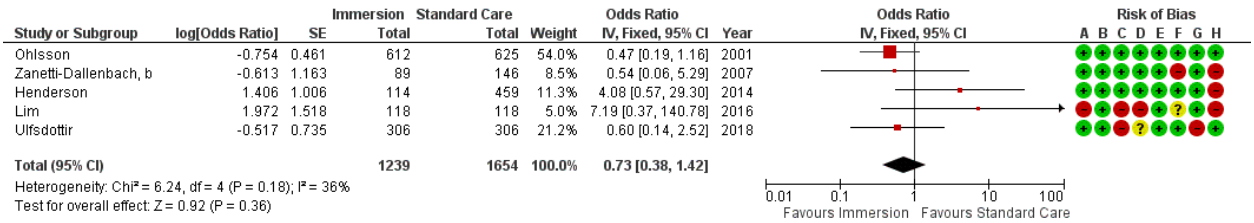


Figure 14 Forest Plot of Synthesis of Postpartum Hemorrhage



Risk of bias legend
(**A**) Domain 1: Bias due to sample selection
(**B**) Domain 2: Bias due to measurement of water immersion
(**C**) Domain 3: Bias due to comparability of the groups
(**D**) Domain 4: Bias due to departure from intended treatment
(**E**) Domain 5: Bias in measurement of the outcome: Maternal Medical Record
(**F**) Domain 6: Bias due to inadequate control for confounding
(**G**) Domain 7: Bias due to missing data
(**H**) Domain 8: Bias due to unreported outcomes

Figure 15 Forest Plot of Synthesis of Manual Removal of the Placenta

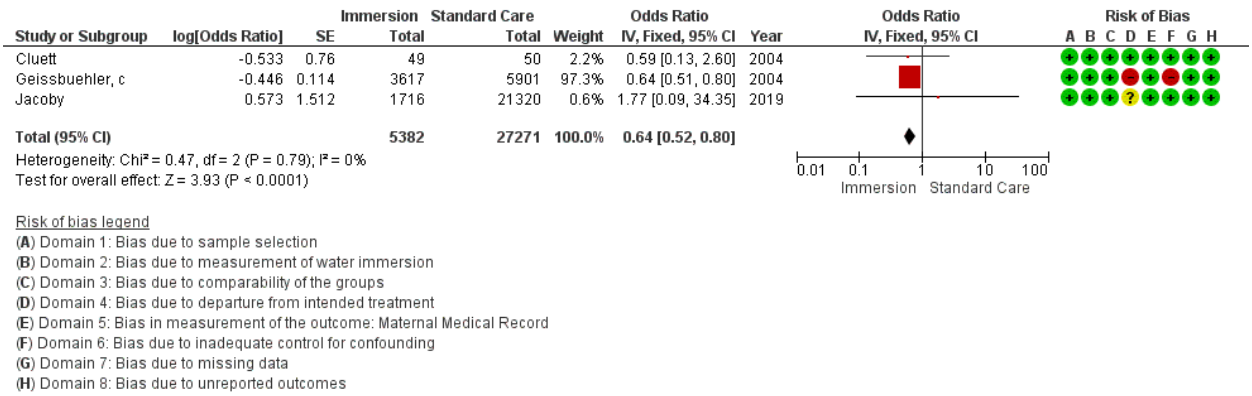
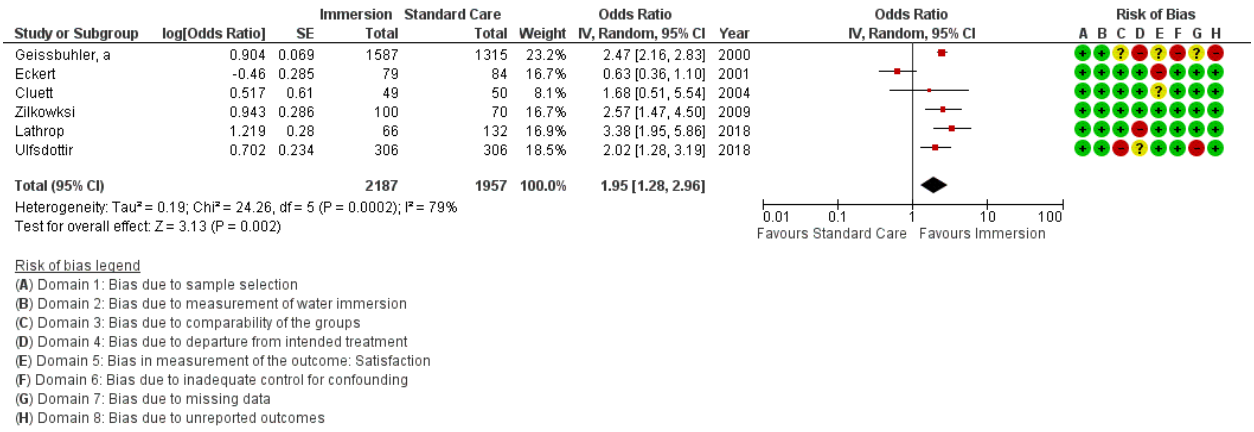
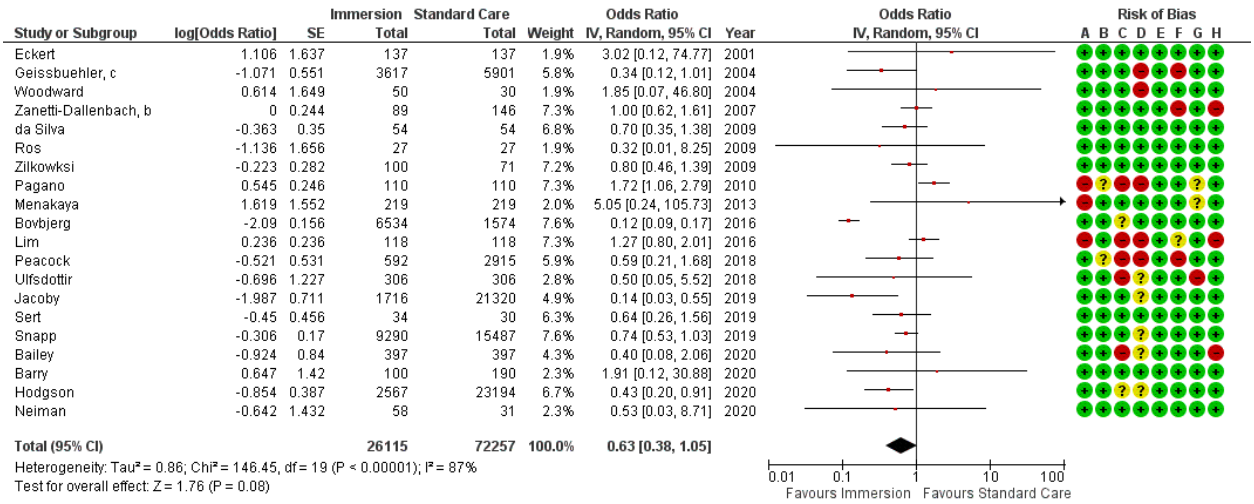


Figure 16 Forest Plot of Synthesis for Maternal Infection



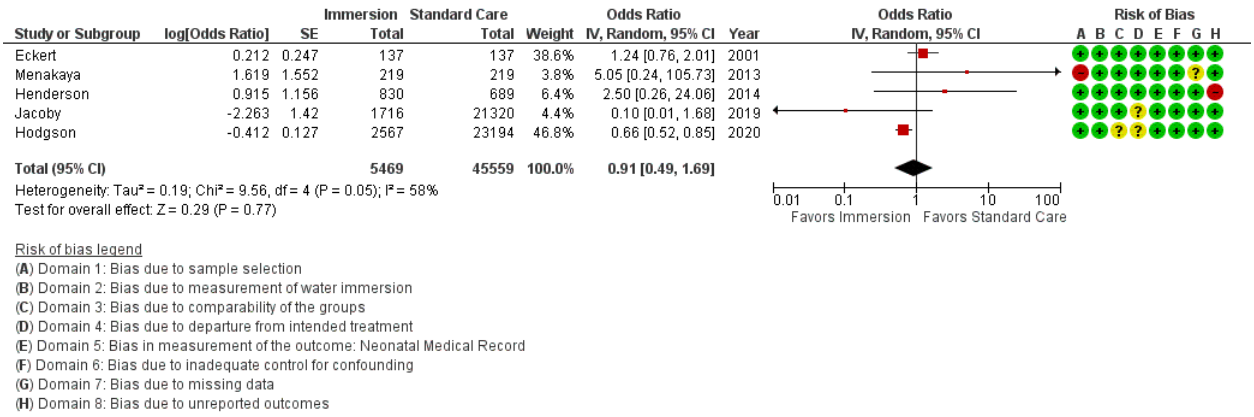
Risk of bias legend
(**A**) Domain 1: Bias due to sample selection
(**B**) Domain 2: Bias due to measurement of water immersion
(**C**) Domain 3: Bias due to comparability of the groups
(**D**) Domain 4: Bias due to departure from intended treatment
(**E**) Domain 5: Bias in measurement of the outcome: Satisfaction
(**F**) Domain 6: Bias due to inadequate control for confounding
(**G**) Domain 7: Bias due to missing data
(**H**) Domain 8: Bias due to unreported outcomes

Figure 17 Forest Plot of Synthesis of Maternal Satisfaction Measures



Risk of bias legend
(**A**) Domain 1: Bias due to sample selection
(**B**) Domain 2: Bias due to measurement of water immersion
(**C**) Domain 3: Bias due to comparability of the groups
(**D**) Domain 4: Bias due to departure from intended treatment
(**E**) Domain 5: Bias in measurement of the outcome: Neonatal Medical Record
(**F**) Domain 6: Bias due to inadequate control for confounding
(**G**) Domain 7: Bias due to missing data
(**H**) Domain 8: Bias due to unreported outcomes

Figure 18 Forest Plot of Synthesis of 5-Minute APGAR



Risk of bias legend
(**A**) Domain 1: Bias due to sample selection
(**B**) Domain 2: Bias due to measurement of water immersion
(**C**) Domain 3: Bias due to comparability of the groups
(**D**) Domain 4: Bias due to departure from intended treatment
(**E**) Domain 5: Bias in measurement of the outcome: Neonatal Medical Record
(**F**) Domain 6: Bias due to inadequate control for confounding
(**G**) Domain 7: Bias due to missing data
(**H**) Domain 8: Bias due to unreported outcomes

Figure 19 Forest Plot of Synthesis of Neonatal Resuscitation

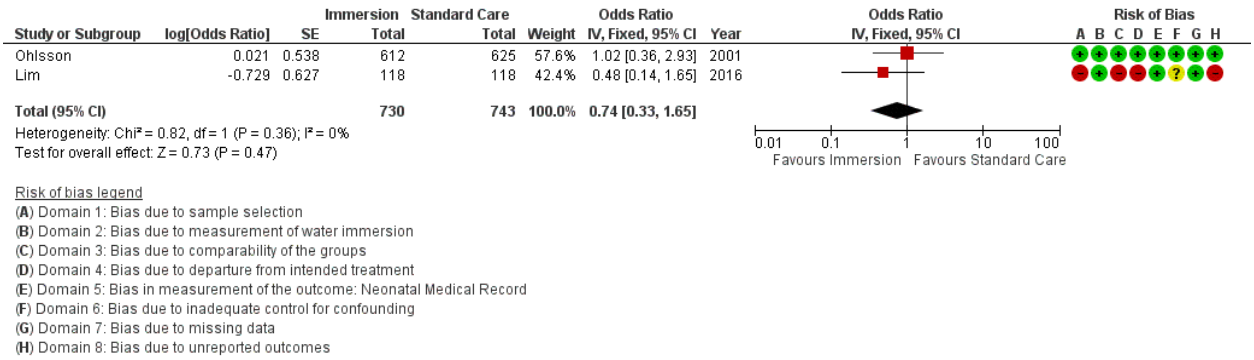


Figure 20 Forest Plot of Synthesis of Transient Tachypnea of the Newborn

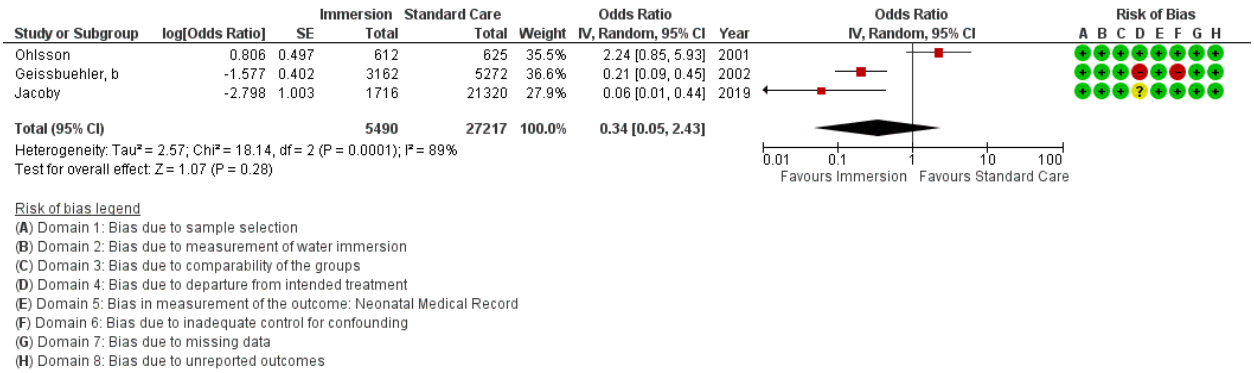
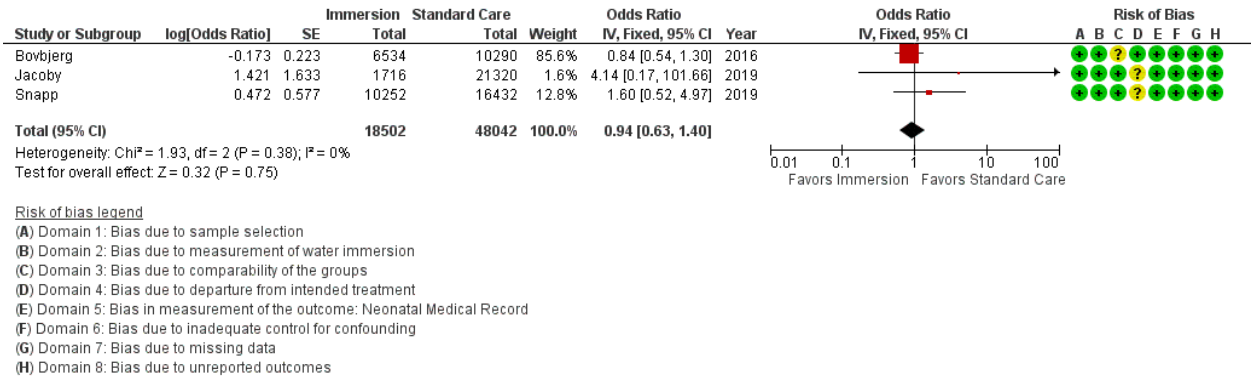
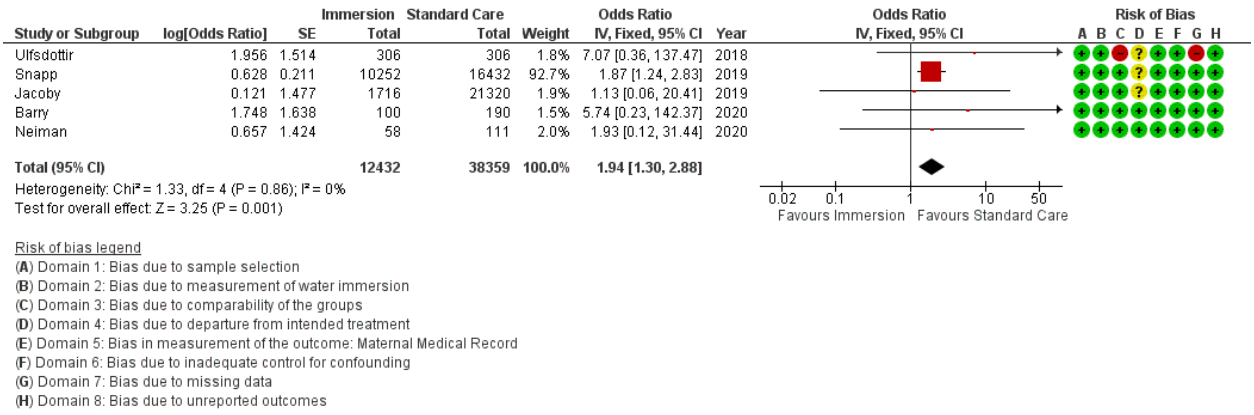


Figure 21 Forest plot of Synthesis of Respiratory Distress



Risk of bias legend
(**A**) Domain 1: Bias due to sample selection
(**B**) Domain 2: Bias due to measurement of water immersion
(**C**) Domain 3: Bias due to comparability of the groups
(**D**) Domain 4: Bias due to departure from intended treatment
(**E**) Domain 5: Bias in measurement of the outcome: Neonatal Medical Record
(**F**) Domain 6: Bias due to inadequate control for confounding
(**G**) Domain 7: Bias due to missing data
(**H**) Domain 8: Bias due to unreported outcomes

Figure 22 Forest Plot of Synthesis of Neonatal Death



Risk of bias legend
(**A**) Domain 1: Bias due to sample selection
(**B**) Domain 2: Bias due to measurement of water immersion
(**C**) Domain 3: Bias due to comparability of the groups
(**D**) Domain 4: Bias due to departure from intended treatment
(**E**) Domain 5: Bias in measurement of the outcome: Maternal Medical Record
(**F**) Domain 6: Bias due to inadequate control for confounding
(**G**) Domain 7: Bias due to missing data
(**H**) Domain 8: Bias due to unreported outcomes

Figure 23 Forest Plot of Synthesis of Cord Avulsion

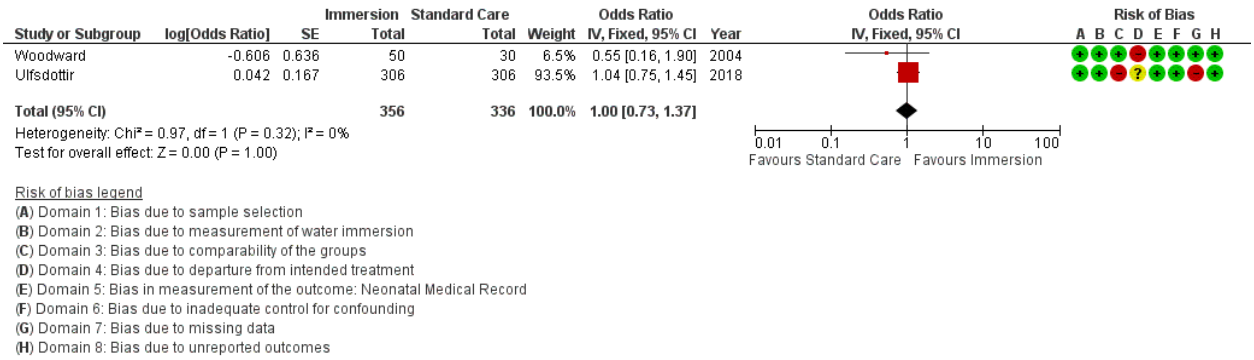


Figure 24 Forest Plot of Synthesis of Breastfeeding Initiation

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 Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE with Full Text	697
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 Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE with Full Text	5,881
S3	(MH Parturition+ OR MH Labor, Obstetric+) OR (S1 OR S2)	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE with Full Text	988,860

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

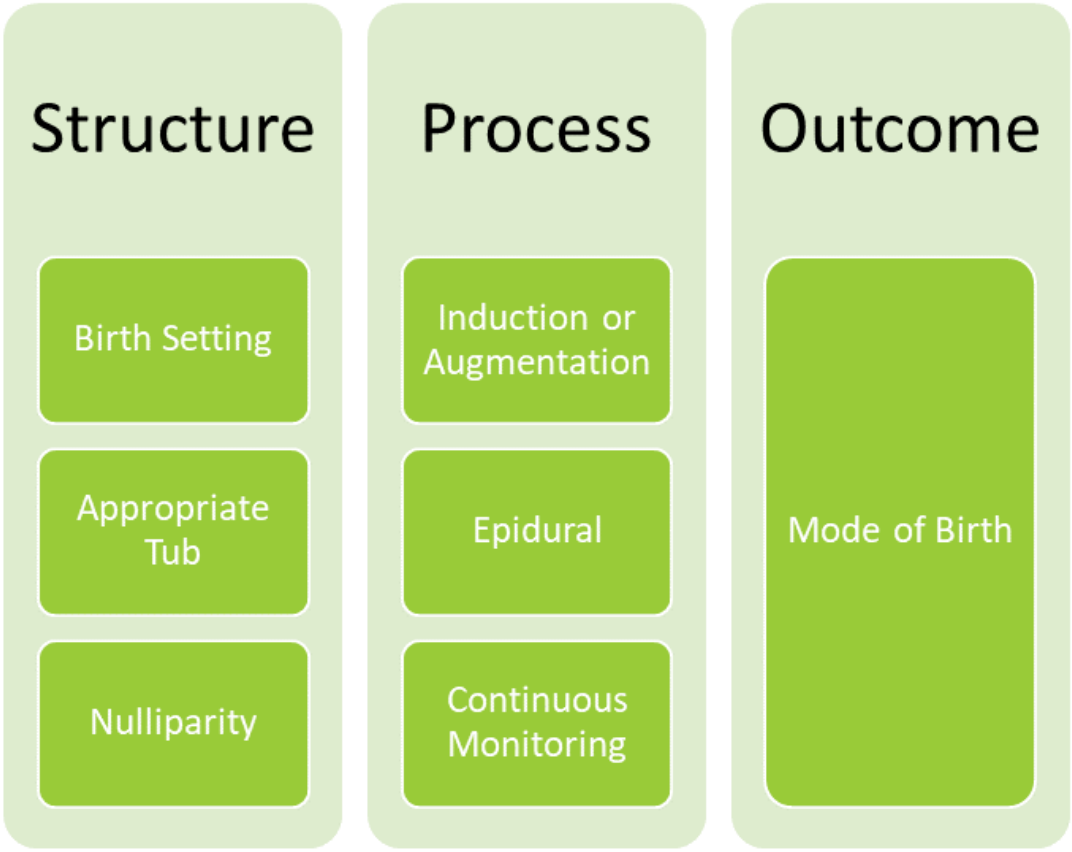
COCHRANE	87	
	2113	
Duplicates removed	446	
	1667	
Screened title/abstract	1667	
Excluded	1561	
Included for full text	**106**	
Full text EXCLUDED	49	
Full text INCLUDED	**57**	
BMC update	1	
	58	INCLUDED

Excluded Reasons

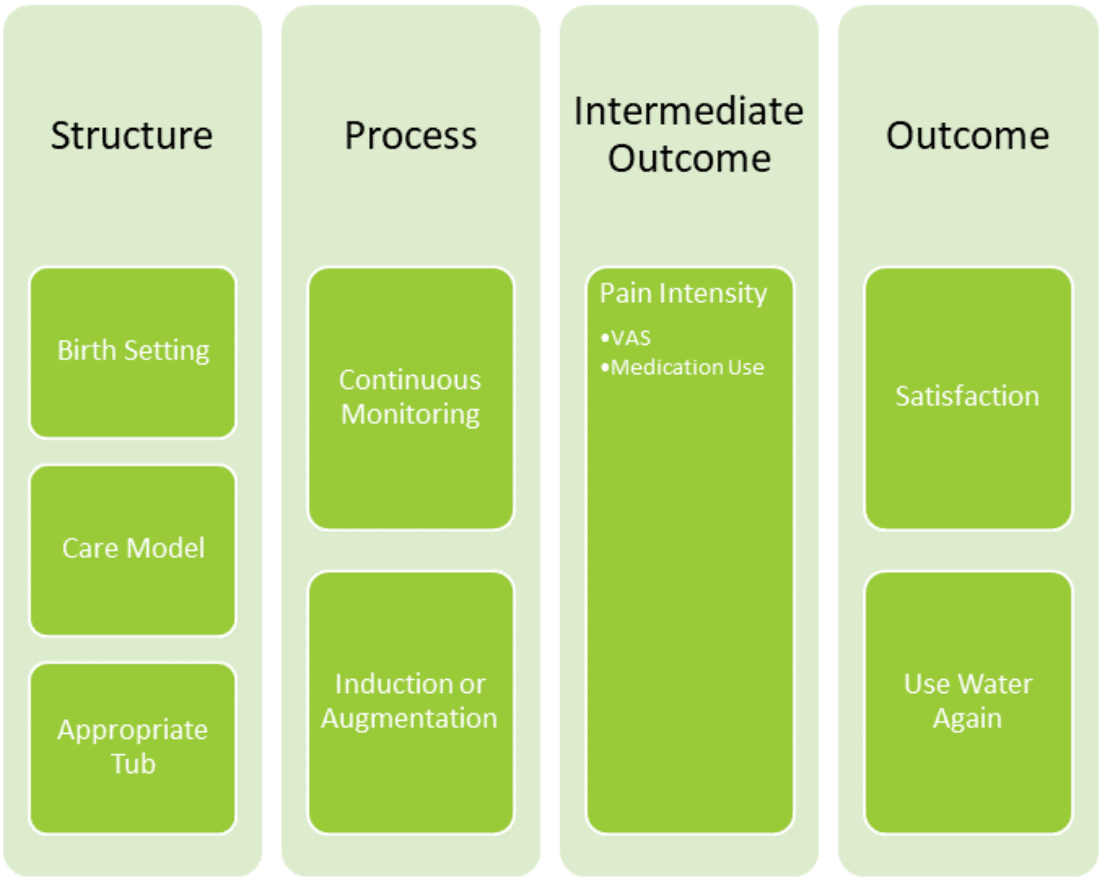
Reasons for exclusions	**Number**
Unable to obtain text	11
Wrong study outcomes	7
Wrong study design	6
Conference abstract	5
Discussion paper not research	2
Reprinted publication	1
Unable to translate text	9
Duplicate	4
Letter not research	2
Wrong publication type	1
Poster	1
	49

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

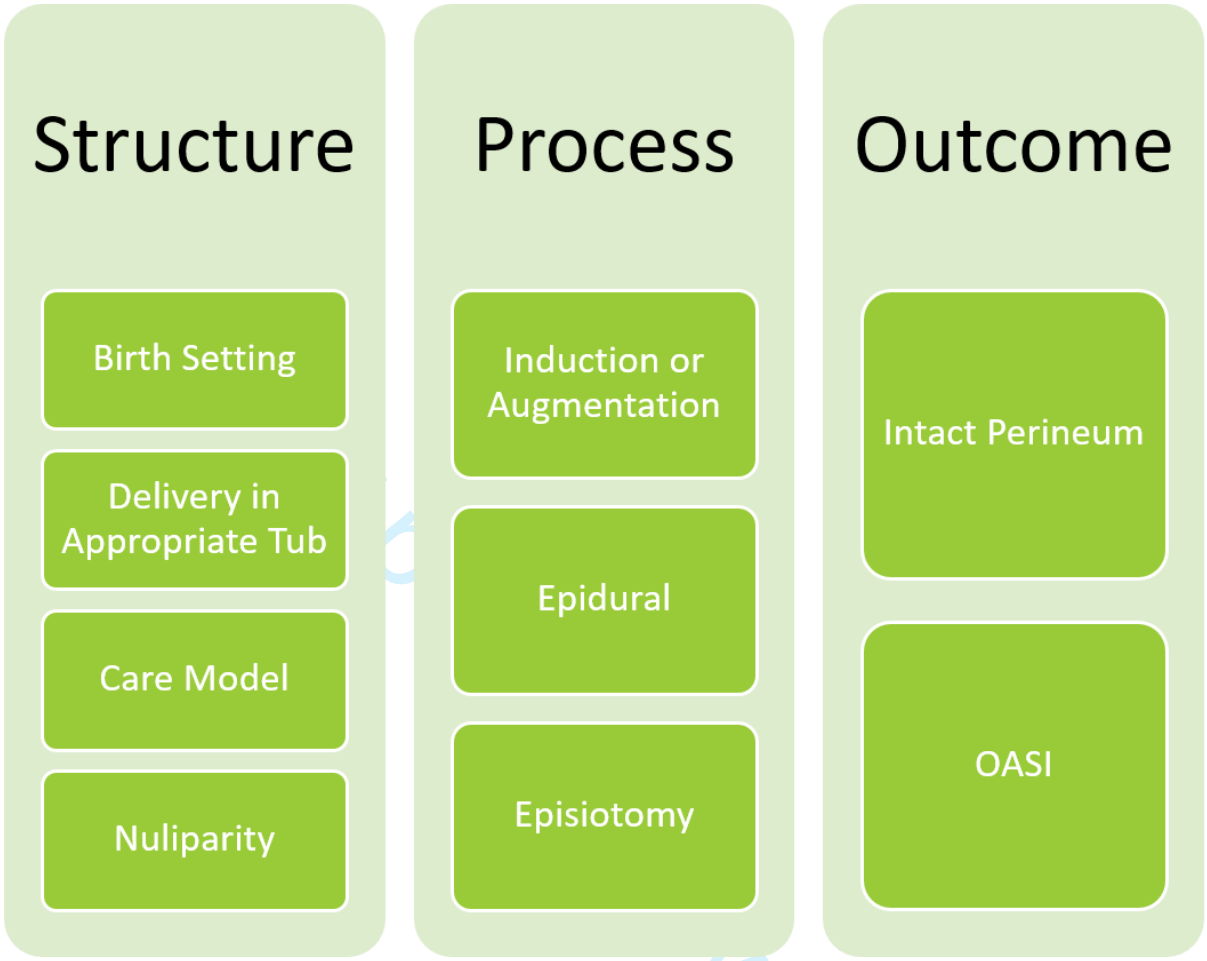
DAG 1: Assumptions about variables associated with variation in mode of birth.



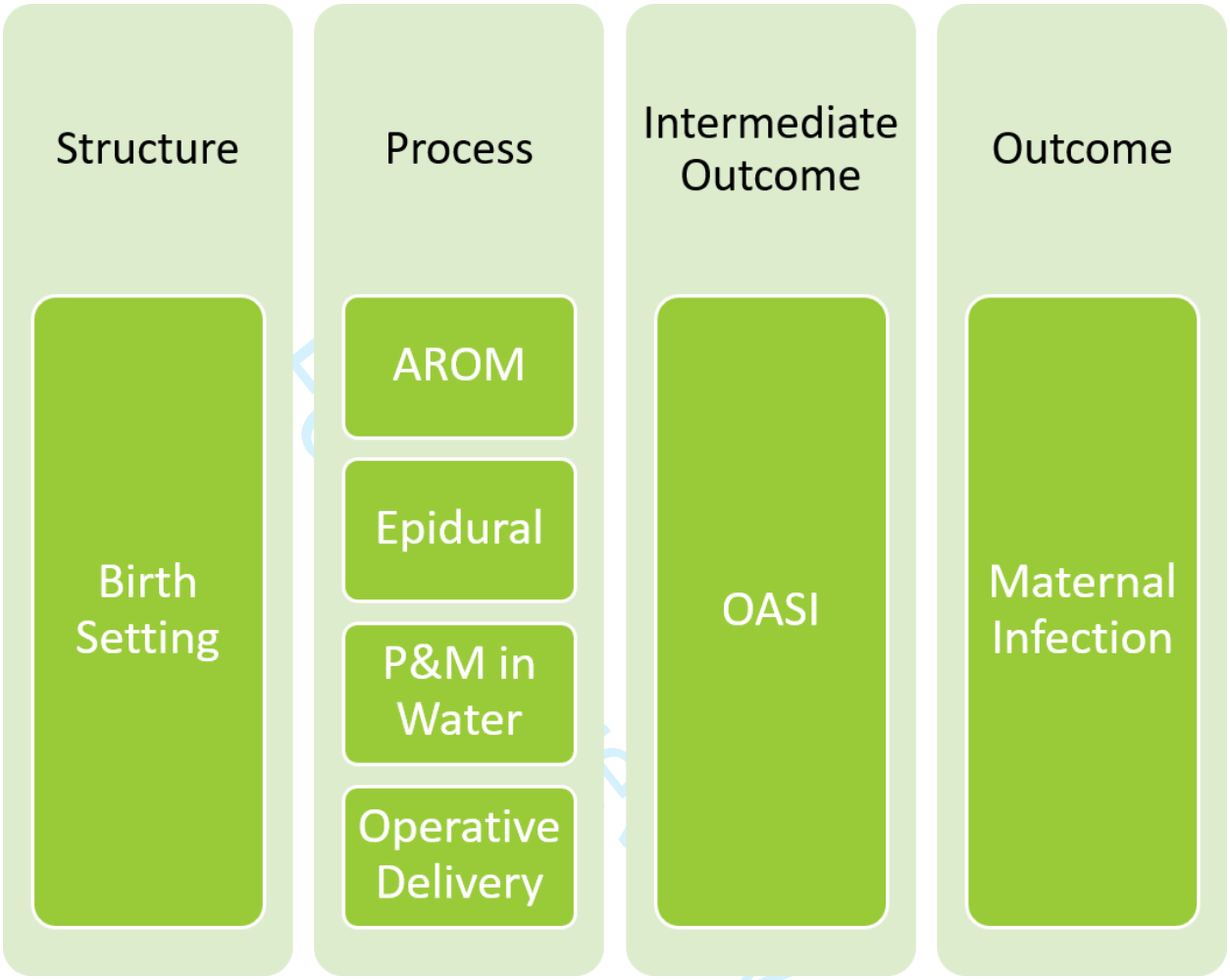
DAG 2: Assumptions about variables associated with variation in maternal satisfaction



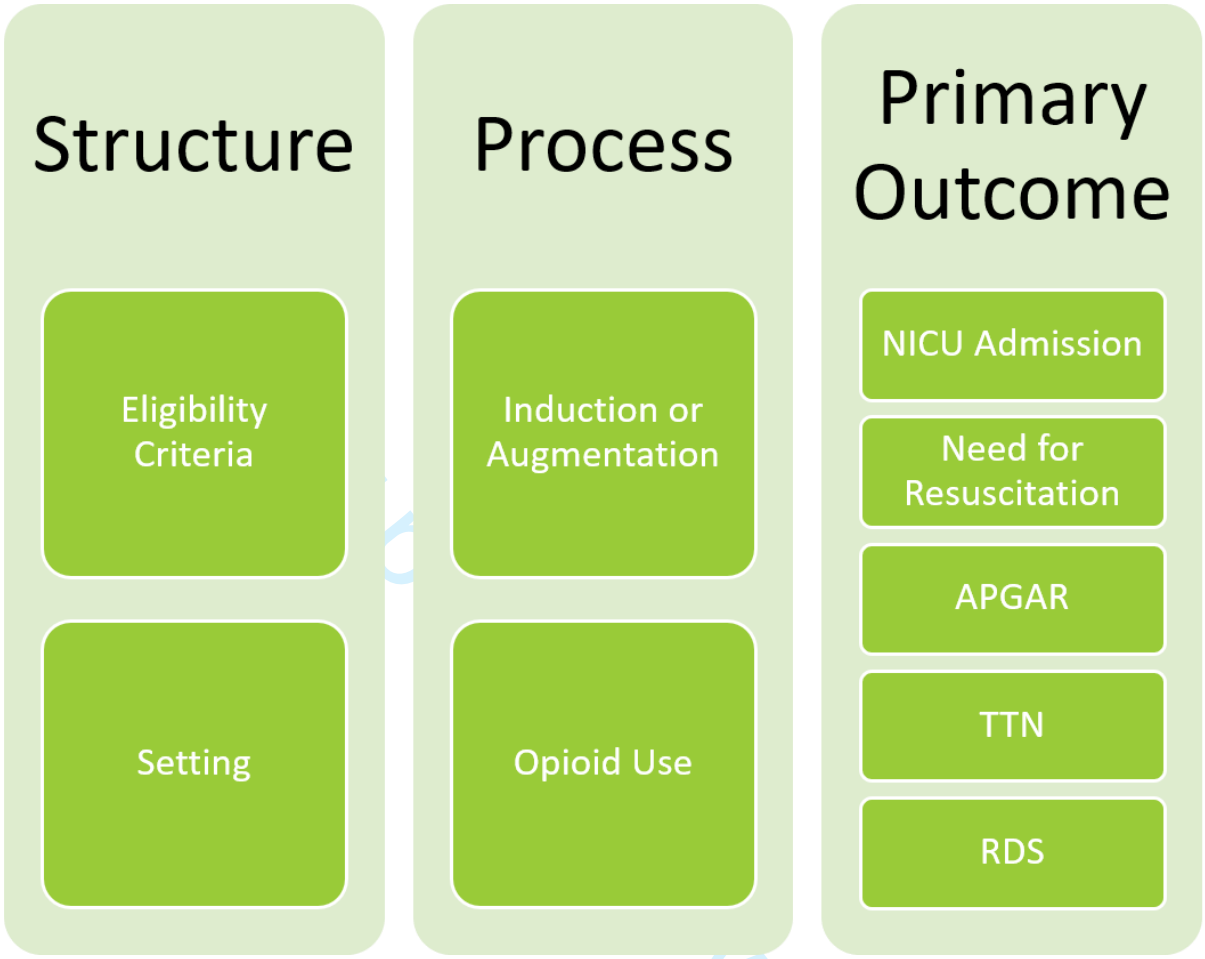
DAG 3: Assumptions about variables associated with variation in perineal outcomes.



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.

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			
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.

Bodner, K., Bodner-Adler, B., Wierrani, F., Mayerhofer, K., Fousek, C., Niedermayr, A., & Grünberger, W. (2002). Effects of water birth on maternal and neonatal outcomes. *Wiener Klinische Wochenschrift*, *114*(10), 391–395. [UNABLE TO OBTAIN TEXT]

Burns EE, Boulton MG, Cluett E, Cornelius V, Smith LA (2012) Characteristics, Interventions, and Outcomes of Women Who Used a Birthing Pool: A Prospective Observational Study *Birth,* 39, (3), 192-202 https://doi.org/10.1111/j.1523-536X.2012.00548.x [WRONG STUDY DESIGN]

Burns, E., Price, L., Carpenter, J., & Smith, L. (2020). Predictors of obstetric anal sphincter injury during waterbirth: a secondary analysis of a prospective observational study. *International urogynecology journal*, *31*(3), 651–656. https://doi.org/10.1007/s00192-019-04167-6 [WRONG STUDY DESIGN]

Camargo, J., Varela, V., Ferreira, F. M., Pougy, L., Ochiai, A. M., Santos, M. E., & Grande, M. (2018). The Waterbirth Project: São Bernardo Hospital experience. *Women and birth : journal of the Australian College of Midwives*, *31*(5), e325–e333. https://doi.org/10.1016/j.wombi.2017.12.008 [WRONG STUDY DESIGN]

Carlson N.S., Corwin E.J., & Lowe N.K. (2017). Labor Intervention and Outcomes in Women Who Are Nulliparous and Obese: Comparison of Nurse-Midwife to Obstetrician Intrapartum Care. *J. Midwifery Women's Health*, *62*(1), 29–39. [WRONG STUDY OUTCOMES]

Carpenter, L., & Weston, P. (2012). Neonatal respiratory consequences from water birth. *Journal of paediatrics and child health*, *48*(5), 419–423. https://doi.org/10.1111/j.1440-1754.2011.02241.x [WRONG STUDY DESIGN]

Cluett ER, Pickering RM, & Brooking JI. (2001). An investigation into the feasibility of comparing three management options (augmentation, conservative and water) for nulliparae with dystocia in the first stage of labour. *Midwifery*, *17*(1), 35–43. [WRONG STUDY DESIGN]

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PRISMA 2020 Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	Title P.1
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	p1
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	p6
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	p7
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	p7-8
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	p8
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	p8, Sup 1
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	p9
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	p9
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	P9
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	P9
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	p9, 10
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	P10
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	p10
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	P10 Tables 2-3
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	P10
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	P10
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	P10
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	P10-11
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	P10
Certainty	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	p11

PRISMA 2020 Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
assessment			
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	P11; figure 1
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	Supplement 3
Study characteristics	17	Cite each included study and present its characteristics.	Table 1,2,3
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	Figures 3-24
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	Figures 3-24
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	P24-36; Figures 3-24
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	P24-36; Figures 3-24
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	P24-36; Figures 3-24
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	P24-36; Table 4
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	P24-36; Table 5
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	P 38; Supplement 4
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	P39
	23b	Discuss any limitations of the evidence included in the review.	P41-42
	23c	Discuss any limitations of the review processes used.	P41-42
	23d	Discuss implications of the results for practice, policy, and future research.	P42
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	P7
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	P4
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	P4

PRISMA 2020 Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	P4
Competing interests	26	Declare any competing interests of review authors.	P5
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	NA

From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71

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PRISMA 2020 for Abstracts Checklist

Section and Topic	Item #	Checklist item	Reported (Yes/No)
TITLE			
Title	1	Identify the report as a systematic review.	YES
BACKGROUND			
Objectives	2	Provide an explicit statement of the main objective(s) or question(s) the review addresses.	YES
METHODS			
Eligibility criteria	3	Specify the inclusion and exclusion criteria for the review.	YES
Information sources	4	Specify the information sources (e.g. databases, registers) used to identify studies and the date when each was last searched.	YES
Risk of bias	5	Specify the methods used to assess risk of bias in the included studies.	YES
Synthesis of results	6	Specify the methods used to present and synthesise results.	YES
RESULTS			
Included studies	7	Give the total number of included studies and participants and summarise relevant characteristics of studies.	YES
Synthesis of results	8	Present results for main outcomes, preferably indicating the number of included studies and participants for each. If meta-analysis was done, report the summary estimate and confidence/credible interval. If comparing groups, indicate the direction of the effect (i.e. which group is favoured).	YES
DISCUSSION			
Limitations of evidence	9	Provide a brief summary of the limitations of the evidence included in the review (e.g. study risk of bias, inconsistency and imprecision).	YES
Interpretation	10	Provide a general interpretation of the results and important implications.	YES
OTHER			
Funding	11	Specify the primary source of funding for the review.	YES
Registration	12	Provide the register name and registration number.	YES

From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71

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