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Neonatal outcomes of waterbirth: a systematic review and meta-analysis

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ABSTRACT

Introduction In 2015, 9% of babies born in the UK were delivered underwater. Waterbirth is increasing in popularity, despite uncertainty regarding its safety for neonates. This systematic review and meta-analysis appraises the existing evidence for neonatal outcomes following waterbirth.

Methods A structured electronic database search was performed with no language restrictions. All comparative studies which reported neonatal outcomes following waterbirth, and that were published since 1995, were included. Quality appraisal was performed using a modified Critical Appraisal Skills Programme scoring system. The primary outcome was neonatal mortality. Data for each neonatal outcome were tabulated and analysed. Meta-analysis was performed for comparable studies which reported sufficient data.

Results The majority of the 29 included studies were small, with limited follow-up and methodological flaws. They were mostly conducted in Europe and high-income countries. Reporting of data was heterogeneous. No significant difference in neonatal mortality, neonatal intensive care unit/special care baby unit admission rate, Apgar scores, umbilical cord gases or infection rates was found between babies delivered into water and on land.

Conclusions This systematic review and meta-analysis did not identify definitive evidence that waterbirth causes harm to neonates compared with land birth. However, there is currently insufficient evidence to conclude that there are no additional risks or benefits for neonates when comparing waterbirth and conventional delivery on land.

INTRODUCTION

In 2015, 9% of babies born in the UK were delivered underwater.[1] Waterbirth (WB) is an increasingly popular choice for women in labour, despite uncertainty regarding its safety for neonates.

Proponents argue that neonates are protected by the diving reflex of the newborn and benefit from an increased chance of uncomplicated vaginal delivery with delayed cord clamping. Concerns have been raised over possible increased risk of neonatal infection, aspiration, cord avulsion and mortality.[2] In addition, WB could influence early bacterial colonisation of the intestine, affecting the development of the gut microbiome. This mechanism is thought to be responsible for the altered infant microbiome, which develops following caesarean section, and has been linked to immunological disorders and obesity in childhood.[3–6]

In the USA, the American Academy of Pediatrics and the American College of Obstetricians and Gynecologists do not endorse WB as a routine delivery option,[7] citing rare and serious adverse events in the newborn. In the UK, the Royal Colleges of Midwives (RCM) and Obstetricians and Gynaecologists (RCOG) advocate giving all healthy women with uncomplicated pregnancies at term the option of WB.[8] However, they note that true informed choice on the benefits and risks of WB is clouded by the lack of good-quality safety data. This is partly because serious adverse events in low-risk pregnancy are rare. To be adequately powered to detect a difference in neonatal mortality rate, a study would need to have 3500 participants in each group.[9]

WB (delivering a baby underwater) should be differentiated from water immersion (WI) during the first stage of labour, which has known maternal benefits including reduced duration of the first stage and reduced need for epidural anaesthesia.[10]

The physiology of WB

Aquatic mammals, such as whales and dolphins, give birth underwater with the newborn not breathing until it reaches the surface.[11 12] This is facilitated by an enhanced antioxidant system and the diving reflex.[13] The diving reflex also exists in humans and provides some protection from drowning.[14 15] Some argue that this reflex of apnoea, bradycardia and peripheral vasoconstriction protects the human neonate from aspiration during WB. However, the presence of this reflex in newborns and the 'naturalness' of relying on an emergency reflex have been questioned.[16]

Postnatally, facial temperature (cold) receptors and laryngeal chemoreceptors trigger the trigeminal diving reflex and laryngeal chemoreflex, respectively, leading to apnoea when cold water comes into contact with either the face or the larynx.[17–19] Ninety-four per cent of newborns demonstrate this response between 24 and 72 h postnatally, and 100% do so at 2–6 months.[20] However, it is not known whether the reflex exists at birth or whether it is activated after the first breath.[16]

Even if the diving reflex does exist at birth, it may not be triggered by birth into water at body temperature. Fetal breathing movements persist in utero until the late third trimester, despite warm amniotic fluid surrounding the fetus.[21] The existenceof meconium aspiration syndrome is evidence that matter can be inhaled by the fetus or the immediate newborn. The presence of the diving reflex in newborns and its relevance to WB has been challenged, undermining the physiological arguments commonly used to support WB. Any potential risk posed to babies born into water depends on the presence or absence of other factors that regulate the first breath.

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The difficulty in elucidating whether, and why, newborns do not inhale when submerged arises from the uncertainty over the mechanism controlling the switch from fetal to extrauterine breathing. Hypothesised triggers to breathing in conventional birth on land include a combination of physical stimulation (such as light, temperature and handling), pain, hypercapnia, hypoxia, chronic endocrine changes, elastic recoil of thoracic tissue and diaphragmatic contraction.[22 23] Healthy babies delivered into warm water would not receive all of these stimuli. However, if a baby compromised by prior hypoxia and acidosis was born gasping, there would be a risk of aspiration of pool water.[24]

Inhibition of breathing in WB may therefore be determined by the balance of inhibitory and stimulatory triggers. Whether or not this mechanism is sufficient to prevent morbidity in the neonate is yet to be determined.

The aim of this study was to determine the safety of WB for the neonate compared with conventional vaginal delivery on land.

METHODS

A systematic review and meta-analysis of comparative studies of WB versus conventional land birth, reporting neonatal outcomes, was carried out in accordance with current guidance,[25] using a prespecified and registered protocol (CRD42015030119 registered 10/12/15).[26]

Eligibility criteria

Inclusion criteria were peer-reviewed comparative studies reporting neonatal outcomes of WB versus vaginal delivery on land. This comprised randomised controlled trials (RCTs), prospective and retrospective cohort studies (PCS, RCS), case–control studies (CCS), cross-sectional studies (CSS) and surveillance studies. Exclusion criteria were non-comparative studies, case series, opinions, reviews and studies reporting neonatal outcomes following WI during labour without subsequent WB. No language restrictions were applied.

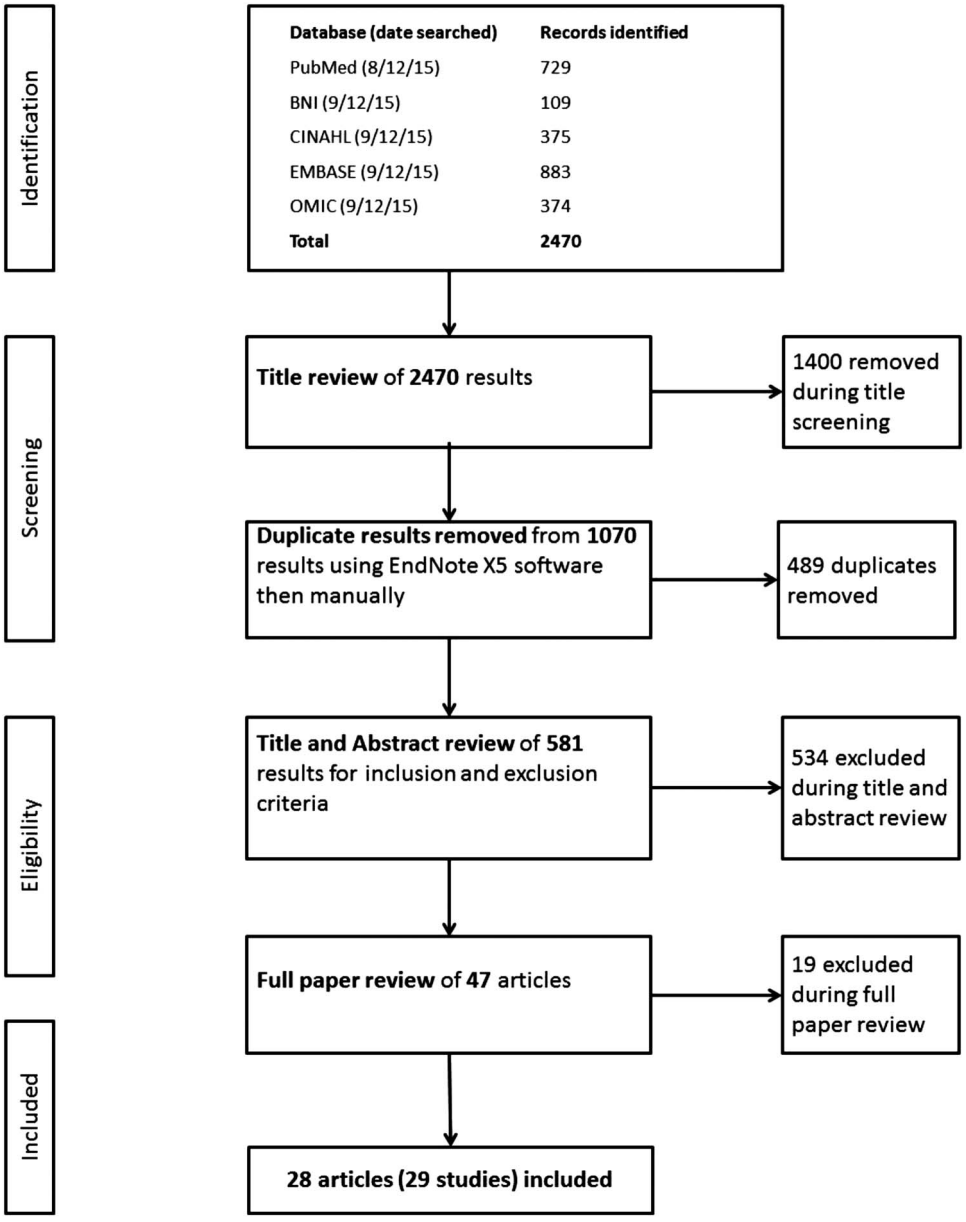

Figure 1 Preferred reporting items for systematic reviews and meta-analyses flow chart of search results and paper selection. A flow chart detailing search results and paper selection process. BMI, British Nursing Index; OMIC, Ovid Maternity and Infant Care.

Table 1 Details of included studies and quality scores

Author, year, country	Study design	WB n	Control n	WB group	Control group	Follow-up	Quality score	Other comment
Nikodem, 1999,[48] South Africa	RCT	60	60	Low-risk SVD; all had WB in one of two state hospitals. 59 SVD, 1 ventouse	Low-risk SVD in one of two state hospitals. 58 SVD, 1 CS, 1 ventouse	24 h	16	Women in this trial were consented and randomised after onset of labour.
Woodward *et al* 2004,[40] UK	RCT	40	20	Low-risk women on labour ward; 10 WB, 13 WI, 16 did not use pool, 1 withdrawn. 33 SVD, 4 instrumental, 2 CS	Low-risk women on labour ward; 1 WI, 1 WB. 14 SVD, 3 instrumental, 3 CS	6 weeks	14	Of 40 allocated WB, only 10 delivered in water. One woman allocated to control group delivered in water.
Ghasemi *et al* 2013,[52] Iran	RCT	83	88	Low-risk women in hospital. 78 WB, 4 CS, 1 ventouse	Low-risk women in hospital. 74 SVD, 14 CS	1 week	14	
Gayiti *et al* 2015,[53] China	RCT	60	60	Low-risk women; all had WB in hospital.	Low-risk women; all had 'traditional delivery method' in hospital. Included AROM and continuous fetal monitoring	Not defined	10	WB group did not have AROM or continuous monitoring.
Chaichian *et al* 2009,[54] Iran	RCT	53	53	Low-risk women; all had WB in hospital.	Low-risk women; 'conventional delivery method of the hospital'	Not defined	8	Unclear from the description whether any women withdrew from the study.
Woodward *et al* 2004,[40] UK	PCS	10	10	Low-risk women on labour ward. 5 WB, 1 WI, 4 did not use pool. 7 SVD, 2 caesarean section, 1 ventouse.	Low-risk women in labour ward; 10 did not use pool. 9 SVD, 1 ventouse	6 weeks	14	Of 10 in WB arm only 5 delivered in water.
Mollamahmutoglu *et al* 2012,[55] Turkey	PCS	207	204	Low-risk women; all had WB in hospital.	Low-risk women having 'conventional delivery' in hospital.	Not defined	12	Study also provides epidural group for comparison, not included in this review.
Zanetti-Dällenbach *et al* 2007,[46] Switzerland	PCS	89	146	Low-risk women; all had WB in hospital.	Low-risk women; all had 'normal vaginal delivery' in hospital.	Until discharge	12	Study also provides WI group for comparison, not included in this review. Women having operative delivery excluded from study. Significant difference in ethnicity compared with WB group (more Swiss, less Mediterranean)
Ros 2009,[49] South Africa	PCS	27	27	Low-risk women; all had WB in one of two private birthing centres.	Low-risk women having conventional delivery in government hospital labour ward.	14 days	11	
Hawkins 1995,[56] UK	PCS	16	16	Low-risk women, all had WB in midwifery unit in hospital.	Low-risk women; group comprised of women having next 'routine' delivery following a WB in hospital.	7 days	11	
Geissbühler *et al* 2003,[41] Switzerland	PCS	3617	5901	Mixed risk cohort of women having WB in hospital.	All women having single cephalic SVD	Not defined	10	All women had free choice to have WB at this centre. WB cohort therefore included high-risk and premature deliveries. However, control group had significantly greater proportion of women with high-risk antenatal histories, pre-eclampsia, pathological cardiotocography and meconium-stained liquor.
Torkamani *et al* 2010,[44] Iran	PCS	50	50	Multiparous women with term pregnancies, uncertain risk profile. All had WB in hospital.	Multiparous women with term pregnancies having 'normal delivery' in hospital.	Not defined	9	Unclear if additional inclusion or exclusion criteria were applied to the WB group.
Sipinksi *et al* 2000,[57] Poland	PCS	135	135	Women having WB in hospital. Indeterminate risk profile	Consecutive 'normal vaginal deliveries' on labour ward	Not defined	4	The authors do not report inclusion or exclusion criteria for either group. Baseline characteristics are not reported.
Menakaya *et al* 2012,[43] Australia	RCS	219	219	Mixed risk women; all had WB in hospital.	Women having SVD on land in hospital within 24 h of WB. Matched for gestational age, parity and risk.	Not defined	14	Low-risk women and those with GBS and PROM were allowed into pool if no signs of chorioamnionitis (hence, mixed risk).
Bodner *et al* 2002,[58] Austria	RCS	140	140	Low-risk women; all had WB in hospital.	Women having 'normal SVD' in hospital, matched for parity.	Not defined	14	

Continued

Table 1 Continued

Author, year, country	Study design	WB n	Control n	WB group	Control group	Follow-up	Quality score	Other comment
Otigbah *et al* 2000,[47] UK	RCS	301	301	Low-risk women; all had WB in hospital.	Women having next low-risk SVD on labour ward register, matched for parity and age	Not defined	14	
Kolivand *et al* 2014,[59] Iran	RCS	43	62	Low-risk women having WB in hospital.	Women having normal vaginal delivery, meeting inclusion criteria for WB, matched for parity and age.	1 month	10	
Schröcksnadel *et al* 2003,[45] Austria	RCS	218	218	Indeterminate risk women; all had WB in hospital.	Women matched for age, parity, gestational age.	Not defined	8	Significant difference in ethnicity and level of maternal education between WB and control group. This study also included unmatched data from a rural centre which were excluded from this systematic review as it was non-comparative.
Pagano *et al* 2010,[60] Italy	RCS	110	110	Low-risk nulliparous women all had WB in hospital.	Women having next low-risk land delivery on birth register of hospital	Not defined	8	No description of matching process; unclear if all control group women were also nulliparous.
Kowalewska *et al* 2004,[61] Poland	RCS	42	71	All women having WB in hospital in study period. Indeterminate risk profile	Women who had the first live vaginal delivery on labour ward for each month during the study period.	Until discharge	7	No matching of control group, significant differences in baseline characteristics. Mortality and cord gas data not included in this review as no comparative data reported. Apgar not included as no time (1 vs 5 min) specified.
Pellantova *et al* 2003,[62] Czech Republic	RCS	70	70	Low-risk women having WB in hospital.	Women having 'conventional deliveries' without contraindications for WB.	Not defined	7	Controls were not matched. Different baseline parity between groups.
Aird *et al* 1997,[63] UK	RCS	67	100	Low-risk women; all had WB in hospital.	Group comprised of women having next SVD on birth register in hospital, matched for parity and age	Not defined	6	The authors do not report all neonatal outcomes separated for WI and WB groups. Only WB outcomes included in this systematic review.
Burke *et al* 1995,[64] UK	RCS	50	50	Low-risk women 'randomly selected from pool register' of hospital.	Women having next low-risk SVD selected from birth register of hospital, matched for age and parity	Until discharge	6	Women in WB group were not allowed analgesia, except Entonox, from 4 h prior to pool use. Control group did not have this restriction.
Thoni *et al* 2010,[65] Italy	RCS	2625	899	Low-risk women; all had WB in hospital.	Controls unmatched, had vaginal delivery on bed or using birthing stool in hospital.	Not defined	6	Number of controls differs for different analyses, uncertain of sampling methodology, characteristics of controls, or comparability of groups.
Garland *et al* 2002,[66] UK	RCS	680	680	Mixed risk women having WB in 10 different birthing centres operating alongside hospitals	Women on birth register delivering at similar time in same birthing centre, matched for parity, VBAC, age, ethnicity	Not defined	5	The 10 centres had distinct inclusion and exclusion criteria, and data collection methods. VBAC was allowed, hence cohort is 'mixed risk'.
Moneta *et al* 2001,[67] Poland	RCS	109	110	All women having WB in hospital in study period. Indeterminate risk profile.	Randomly selected women 'giving birth in traditional way' on labour ward at same time as WB.	Not defined	2	Random selection of controls not described; no matching described. The WB group had a higher proportion of primiparous women.
Carpenter *et al* 2012,[68] New Zealand	CCS	14	26	Neonates born at term in birth centres and hospitals within catchment area of tertiary NICU. All admitted to NICU with respiratory distress requiring pressure support following WB.	Neonates born at term in one of two local birth centres. All admitted to NICU with respiratory distress requiring pressure support following vaginal delivery on land	Until discharge	14	Neonates with encephalopathy or congenital heart disease excluded from both groups.
Dahlen *et al* 2013,[69] Australia	Retrospective cross-sectional	819	5220	All women having WB in birth centre alongside a hospital. Indeterminate risk profile.	All women having vaginal delivery in birth centre over same time period	Not defined	9	Outcomes recorded from midwives' own handwritten notes. No data from women transferred out of birthing centre during labour.
Gilbert *et al* 1999,[42] UK	Surveillance	4032	10 307	All perinatal deaths and NICU/SCBU admissions within 48 h in UK following WB. Indeterminate risk profile.	Low-risk deliveries from NorthWest Thames region 1992–3	7 days for mortality, 48 h for NICU admission	8	This surveillance study gives multiple control groups. The largest low-risk group was used here for comparison.

AROM, artificial rupture of membranes; CCS, case–control study; CS, caesarean section; GBS, group B streptococcus; NICU, neonatal intensive care unit; PCS, prospective cohort study; PROM, premature rupture of membranes; RCS, retrospective cohort study; RCT, randomised controlled trial; SCBU, special care baby unit; SVD, spontaneous vaginal delivery; VBAC, vaginal birth after caesarean section; WB, waterbirth; WI, water immersion during first stage of labour.

The primary outcome was neonatal mortality. Secondary outcomes were combined neonatal intensive care unit (NICU) or special care baby unit (SCBU) admission, resuscitation at birth, Apgar scores at 1 and 5 min, arterial and venous umbilical cord blood pH, postnatal infection and knot in umbilical cord.

Search strategy and information sources

Five databases were searched from 1 January 1995 to 8 December 2015: PubMed, EMBASE, Cumulative Index to Nursing and Allied Health Literature, British Nursing Index and Ovid Maternity and Infant Care. The search protocol is detailed in the online supplementary file A. Following removal of duplicates, titles and abstracts were screened by a single reviewer. Papers were hand-searched for references. Foreign language papers were translated by a medically qualified native speaker. All papers excluded following full text review were independently read by two authors, with reference to a third senior author in case of disagreement.

Data extraction and quality appraisal

Included studies were grouped by study design; data extraction was then performed using a predesigned form. Data on study design, methodology, primary outcome and secondary outcomes were captured when reported.

Risk of bias was considered during a quality assessment process. This used one of four appraisal tools (according to study design) modified from the Critical Appraisal Skills Programme (CASP) system (see online supplementary file B).[27] Studies with score ≥11 were assigned as 'higher' quality.

Data extraction and quality appraisal were performed independently by two reviewers (HT, EL) for a random sample of 25% of included papers to check for interobserver error. Data were tabulated for analysis (see online supplementary file C).

Statistical analysis

Aggregate data were extracted from original studies. Where percentages were reported without numbers, the numbers were calculated. For binary outcomes (neonatal mortality, NICU/SCBU admission, Apgar <7 or <8, infection), the risk difference (RD) and 95% CI were calculated.[28] Mean and median Apgar scores were compared between groups and reported as difference in average score (with 95% CI when SD was available). The median and range, or mean and calculated 95% range, of umbilical cord gas results were compared between groups. Results of non-parametric significance tests performed by authors of the original studies are included.

Meta-analysis was performed for comparable studies which reported sufficient data, specifically those with a low-risk maternal cohort and a matched control group (for retrospective studies) which reported binary outcomes or means with SD. RDs (for binary outcomes) or mean differences (for numerical outcomes) were combined using inverse-variance weighing and a random effects model. Heterogeneity was measured using I^2. Results for studies with mixed or indeterminate risk cohorts were presented in tables and figures, and subject to narrative analysis.

Two sensitivity analyses were performed using only RCTs or higher quality studies (quality score ≥11).

RESULTS

The initial search found 2470 articles, of which 47 underwent full text appraisal (figure 1) and 28 were included. Excluded studies are listed in online supplementary file E.[29–39] One article included a description of two studies (an RCT and PCS) which were considered separately.[40] There was complete agreement between the two independent reviewers about the choice of exclusion. There were only minor differences in quality appraisal (two points or less in four of seven studies), which were resolved by discussion.

Table 1 lists the design, quality score and specific limitations and risks of bias of included studies.

The 29 included studies comprised 5 RCTs, 9 PCS, 12 RCS, 1 CCS, 1 CSS and 1 nationwide surveillance study. They were performed in 12 countries, but the majority in Europe and high-income countries (eight in UK, four in Iran, three in Poland, two each in Australia, Austria, Switzerland, South Africa and Italy and one each in New Zealand, China, Turkey and the Czech Republic).

Study sizes ranged from 20 to 14 309 births (total number of included births=39 302). All studies were set in a hospital or birth centre; most were small, single-centred and reported on a limited number of neonatal outcomes with short follow-up (see table 1). Eighteen studies were limited to low-risk women, three specified a mixed risk population and eight had an indeterminate risk cohort.

All studies had some risk of bias, as assessed by the modified CASP criteria (see online supplementary file B). None of the RCTs were blinded (due to the nature of the intervention). Funnel plots were reviewed for all meta-analysable outcomes; no clear evidence of publication bias was noted.

Primary outcome

Neonatal mortality was reported in 10 studies (figure 2) with a total of 27 deaths. Four studies were suitable for meta-analysis, and one neonatal death was reported in these studies. Combined RD per 1000 live births (RD_{1000}) was 0 (95% CI −10 to 10).

None of the remaining studies reported a significant difference in neonatal mortality. Two had sufficient power to detect a difference, one of which reported no deaths.[41] The other was a large nationwide surveillance study comparing 4032 WB to 10 307 low-risk deliveries; RD_{1000} was 0 (95% CI −10 to 20).[42]

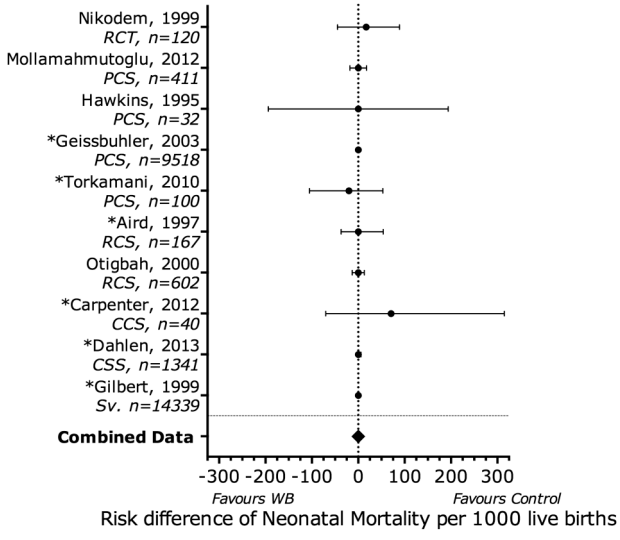

Figure 2 Difference in risk of neonatal mortality. A forest plot showing the RD of neonatal mortality per 1000 live births between the WB and control groups. RD and 95% CI are plotted for each study. Studies with an asterisk (*) were not included in the meta-analysis (combined data). CSS, cross-sectional studies; PCS, prospective cohort studies; RCT, randomised controlled trial; RD, risk difference; WB, waterbirth.

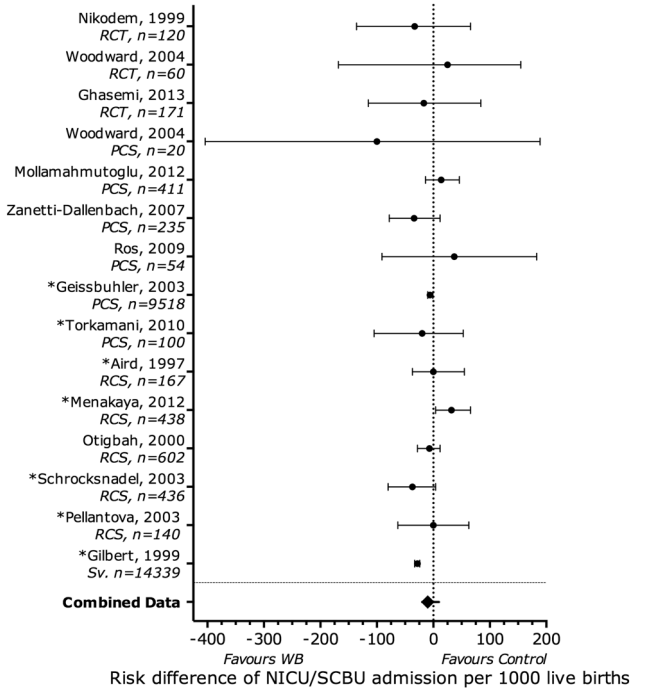

Figure 3 Difference in risk of NICU/SCBU admission. A forest plot showing the RD of NICU/SCBU admission per 1000 live births between the WB and control groups. RD and 95% CI are plotted for each study. Studies with an asterisk (*) were not included in the meta-analysis (combined data). NICU, neonatal intensive care unit; PCS, prospective cohort studies; RCT, randomised controlled trial; RD, risk difference; SCBU, special care baby unit; WB, waterbirth.

Secondary outcomes

Data on NICU/SCBU admission were reported in 15 studies (figure 3). Meta-analysis of eight studies found no significant difference between groups; RD_{1000} −10 (95% CI −20 to 10). Narrative review of remaining studies identified that the majority concurred with the meta-analysis. The nationwide surveillance study reported WB infants had lower rates of NICU/SCBU admission; RD_{1000} −28 (95% CI −33 to −24).[42] One large PCS reproduced this finding; however, the control group in this study comprised women of all levels of risk.[41] One RCS reported higher rates of NICU/SCBU admission following WB.[43]

Apgar scores were the most widely reported neonatal outcome (26 studies, figure 4), but variable reporting complicates any synthesis. Seven studies reported the proportion of neonates scoring <7; there was no significant RD in any study at 1 or 5 min. Combined percentage RD ($RD_{\%}$) from meta-analysable studies was 0% (95% CI −1 to 1) at 5 min; at 1 min, data were heterogeneous (I^2=86%). Similarly, four studies reported the proportion of neonates with an Apgar score <8. Combined $RD_{\%}$ from three studies was 1% (95% CI −5.0% to 8.0%). The remaining PCS reported a $RD_{\%}$ of −14% (95% CI −24% to −4%); however, risk profiles in this study were undefined.[44]

Combined data from studies reporting numerical Apgar scores identified marginally higher scores among WB neonates at 1 min; mean difference 0.09 (95% CI 0.0 to 0.18). At 5 min, data were heterogeneous (I^2=69%). Average scores were high (see online supplementary file C).

Nine studies reported cord gas analysis. However, five only performed cord gases on a subset of neonates; six only reported arterial results and only three reported both arterial and venous results (see figure 5 and online supplementary file C). WB was associated with significantly higher arterial pH in two studies[41 45] and higher venous pH in one study.[46]

Of the 11 studies reporting on infection, 10 did not report any significant differences; one PCS found significantly more infections in controls (table 2).[41]

Serious adverse events, not otherwise covered above, were also described. In one RCS, three knotted umbilical cords were noted in the WB group versus none in controls.[47] In a national surveillance study, five incidents of snapped umbilical cord were recorded following WB; however, no reliable comparator data are available for this outcome.[42] Resuscitation was another adverse event, which was variably reported. Only two studies specifically reported on neonatal resuscitation as an outcome.[48 49] Both reported resuscitation events in the WB group, and none in the control group; however, the differences were not significant.

Sensitivity analyses

Two sensitivity analyses were conducted separately; the first included 12 studies with higher quality scores (≥11), and the second 5 RCTs (see online supplementary file D). Neither sensitivity analysis identified any significant findings compared with the primary analysis. In the primary analysis, WB neonates had greater Apgar scores at 1 min; this finding was conserved among high-quality studies, but not in RCTs.

DISCUSSION

Key findings

Most of the 29 studies addressing the comparison of neonatal outcomes following WB were small, observational and based on low-risk mothers. This perhaps reflects the ethical difficulty associated with randomisation. There was no difference in neonatal mortality following WB compared with land birth. Analysis of the five measures of neonatal morbidity did not identify any consistent findings.

No meta-analysis was possible for umbilical cord gases (non-normal data) or infection rate (inconsistent definition of outcome between primary studies).

There is some evidence of higher mean Apgar scores and higher cord gas pH, following WB; however, this describes variation within the normal range and is of uncertain clinical significance.

Comparison with previous work

Previous systematic reviews of WB have largely concentrated on maternal outcomes.[10 50] Only one recent systematic review specifically addressed neonatal outcomes.[51] The present study covers a longer time interval and contains a larger number of studies. We corroborate their findings that, for the majority of neonatal outcomes, there are no significant differences between WB and land birth.

Strengths and limitations

This is the largest systematic review and meta-analysis considering neonatal outcomes following WB performed to date. Strengths include a comprehensive search strategy, 20-year time span, inclusion of eight foreign language papers, wide inclusion criteria and use of sensitivity analyses. Limitations include use of a single reviewer to perform the literature search, quality appraisal and data capture; though, a random sample of included papers were checked for consistency.

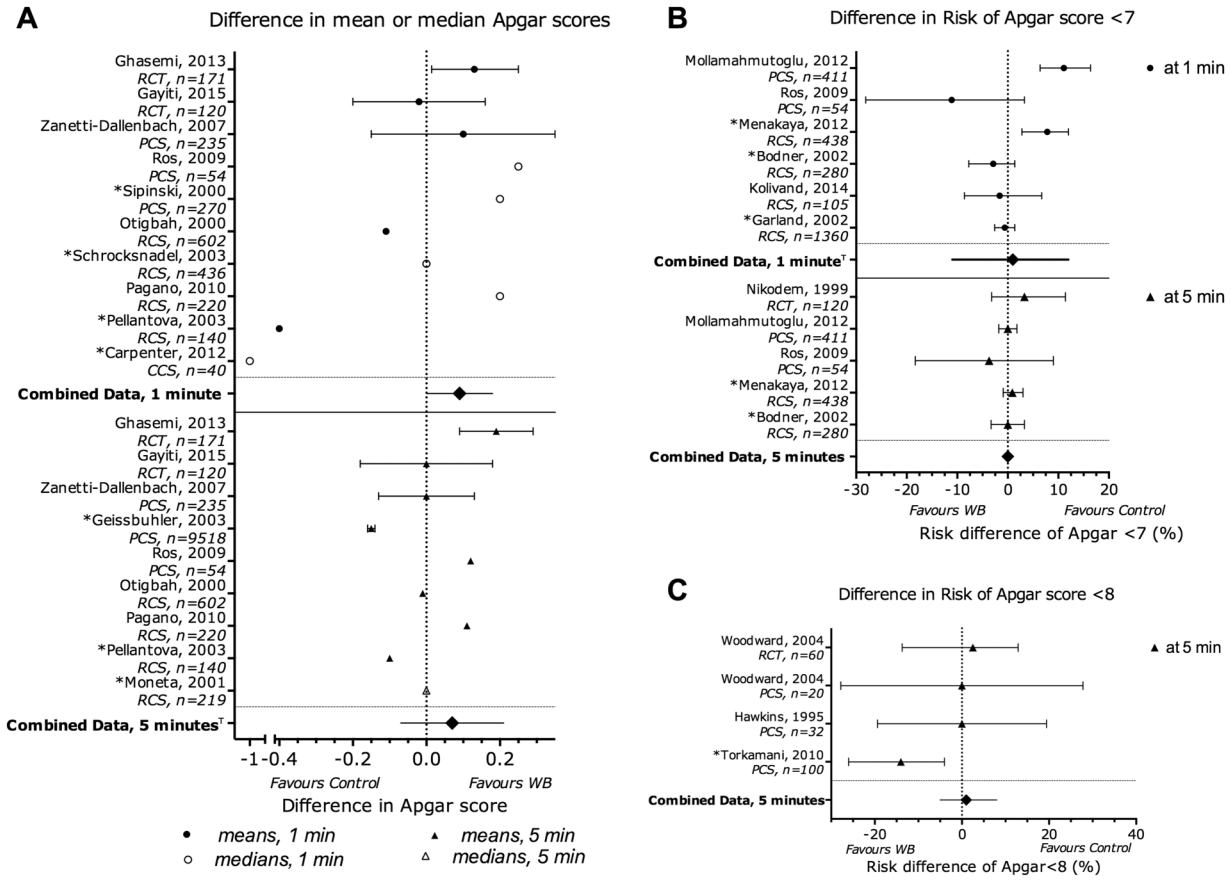

Figure 4 Comparison of Apgar scores. Three forest plots comparing WB and control groups. (A) Mean difference (with 95% CI) of Apgar score at 1 and 5 min. (B) RD and 95% CI of having an Apgar score <7 at 1 and 5 min. (C) RD and 95% CI of having an Apgar score <8 at 5 min. For each plot, studies with an asterisk (*) were not included in the meta-analysis (combined data). A (^{T}) symbol indicates significant heterogeneity (I^2>60%) in the combined data. CCS, case–control studies; PCS, prospective cohort studies; RCS, retrospective cohort studies; RCT, randomised controlled trial; RD, risk difference; WB, waterbirth.

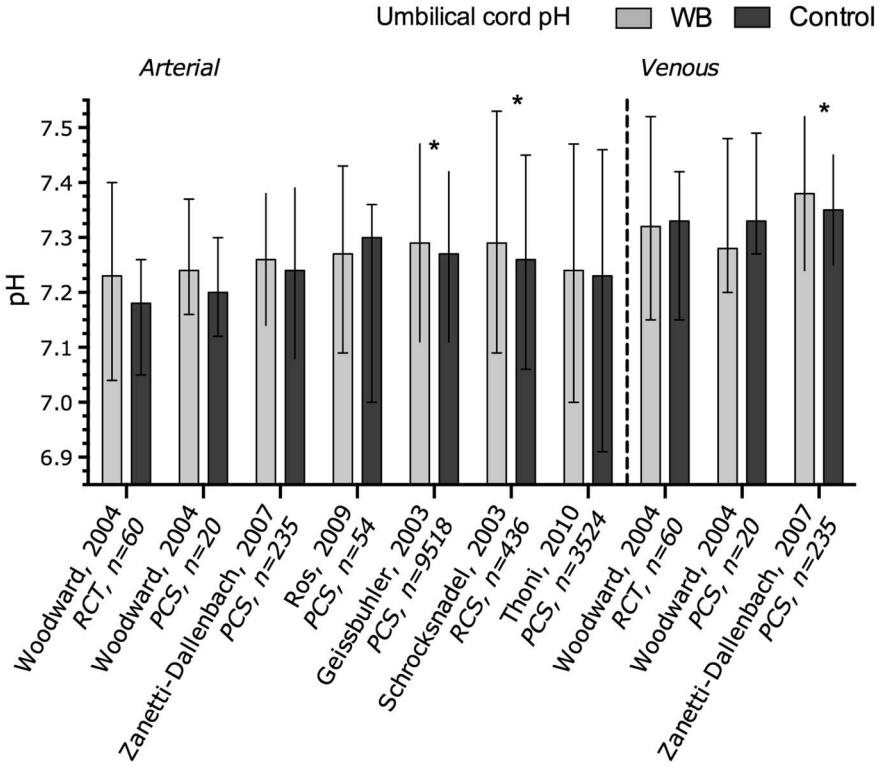

Figure 5 Comparison of umbilical cord blood pH. A side-by-side bar chart comparing arterial or venous cord blood pH in waterbirth (light grey bars) and control (dark grey bars) groups. Median and range (bars with capped lines) or mean and calculated 95% range (bars with uncapped lines) are plotted for each study. An asterisk (*) indicates a statistically significant difference. PCS, prospective cohort studies; RCT, randomised controlled trial; WB, waterbirth.

Table 2 Comparison of neonatal infection rate

Author, year	Study design	N		Infection, n (%)		Risk difference % (95% CI)
		WB	Control	WB	Control	
Woodward *et al* 2004[40]	RCT	40	20	0	0	0% (−16% to 8.8%)
Woodward *et al* 2004[40]	PCS	10	10	0	0	0% (−28% to 28%)
Mollamahmutoglu *et al* 2012[55]	PCS	207	395	0	0	0% (−1% to 1.8%)
Zanetti-Dällenbach *et al* 2007[46]	PCS	89	146	5* (5.6%)	2 (1.4%)	4.2% (−0.5% to 11.2%)
Hawkins 1995[56]	PCS	16	16	3† (18.8%)	0	18.8% (−4.1% to 43%)
Geissbühler *et al* 2003[41]	PCS	3617	5901	20 (0.55%)	60 (1.0%)	−0.5% (−0.8% to −0.1%)
Bodner *et al* 2002[58]	RCS	140	140	0	2 (1.4%)	−1.4% (−5.1% to 1.4%)
Otigbah *et al* 2000[47]	RCS	301	301	0	0	0% (−1.3% to 1.3%)
Kowalewska *et al* 2004[61]	RCS	42	71	2‡ (4.8%)	5§ (7.0%)	−2.3% (−11.4% to 9.4%)
Pellantova *et al* 2003[62]	RCS	70	70	0	0	0% (−5.2% to 5.2%)
Thoni *et al* 2010[65]	RCS	2625	899	26 (0.98%)	15 (1.64%)	−0.7% (−1.8% to 0.1%)

Notable findings regarding specific infections, which were highlighted by study authors in discussion, included.
*Five WB neonates developed conjunctivitis, while no babies in the control group did.
†One severe septicaemia following WB with pseudomonas.
‡One episode of aspiration pneumonia and one pseudomonas skin infection following WB.
§Five intrauterine infections in the control group.
PCS, prospective cohort study; RCS, retrospective cohort study; RCT, randomised controlled trial; WB, waterbirth.

Implications for clinicians and research

Clinicians should inform women about the present, largely reassuring, data about the safety of WB for their baby. There is no evidence of a difference in neonatal mortality or morbidity. However, uncertainties remain, as existing evidence is not strong enough to examine the relative risk of rare and potentially devastating adverse events. Nor is there any evidence evaluating potential long-term implications of WB versus land birth.

In order to assist informed decision-making by pregnant women, their companions and health professionals, a large multi-centre RCT or PCS is a priority. There are undoubted maternal benefits of WI as well as practical and emotional difficulties in exiting the pool immediately prior to delivery.[10] Further research must consider the full safety profile of WB by evaluating whether underwater delivery aids physiological fetal-to-neonatal transition (possibly by avoiding interventions), affects the risk of rare adverse events or causes any long-term benefits or harms, for example, by influencing the developing microbiome.

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Neonatal outcomes of waterbirth: a systematic review and meta-analysis

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Notes