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Maternal and neonatal outcomes following waterbirth: a cohort study of 17,530 waterbirths and 17,530 propensity score-matched land births

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Abstract

Objective: Investigate maternal and neonatal outcomes following waterbirth

Design: Retrospective cohort study, with propensity score matching to address confounding

Setting: Community births, United States

Sample: Medical records-based registry data from low-risk births were used to create waterbirth and land birth groups (n=17,530 each), propensity score-matched on >80 demographic and pregnancy risk covariables

Methods: Logistic regression models compared outcomes between the matched waterbirth and land birth groups

Main outcome measures: Maternal: immediate postpartum transfer to a hospital, any genital tract trauma, severe ($3^{rd}/4^{th}$ degree) trauma, haemorrhage >1000 cc, diagnosed haemorrhage regardless of estimated blood loss, uterine infection, uterine infection requiring hospitalisation, any hospitalisation in the first 6 weeks. Neonatal: umbilical cord avulsion; immediate neonatal transfer to a hospital; respiratory distress syndrome; any hospitalisation, neonatal intensive care unit (NICU) admission, or neonatal infection in the first 6 weeks; and neonatal death.

Results: Waterbirth was associated with improved or no difference in outcomes for most measures, including neonatal death (aOR 0.56 [95% CI, 0.31 – 1.0]), and maternal or neonatal hospitalisation in the first 6 weeks (0.87 [0.81 – 0.92] and 0.95 [0.90 – 0.99], respectively). Increased morbidity in the waterbirth group was observed for two outcomes only: uterine infection

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MLB designed and conducted analyses, wrote first draft of the manuscript, secured funding for the project; MC consulted on analysis plans, interpreted clinical findings, edited manuscript, secured funding for the project; ABC consulted on analysis plans and interpretation of clinical findings, edited manuscript.

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Ethical statement: This analysis of de-identified data was approved by the Institutional Review Board at Oregon State University on 6 March 2020.

(1.25 [1.05 – 1.48]) (but not hospitalisation for infection) and umbilical cord avulsion (1.57 [1.37 – 1.82]). Our results are concordant with other studies: waterbirth is neither as harmful as some current guidelines suggest, nor as benign as some proponents claim.

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Tweetable abstract:

New study demonstrates #waterbirth is neither as harmful as some current guidelines suggest, nor as benign as some proponents claim. @TheUpliftLab @BovbjergMarit @31415926abc @NICHD_NIH

Keywords

water birth; waterbirth; natural childbirth; propensity score

Introduction

Despite acceptance of the practice for low-risk labouring people in the United Kingdom,[1–3] waterbirth remains controversial in the United States.[4–7] The main objection from the American College of Obstetricians and Gynecologists (ACOG) is lack of randomised trial evidence;[4] however, large, definitive randomised trials are unlikely to be forthcoming.[8] First, women do not wish to participate,[9–12] leading to small, highly selected samples.[10,11] Second, blinding is impossible. Third, ethically, we cannot randomise people to the real exposure of interest (water*birth*--ACOG does not object to labouring in water, only to actual underwater birth[4]), because there needs to be sufficient leeway in the trial protocol to allow clinical judgement regarding continued immersion if complications arise. This is problematic from a scientific perspective, because the exposure of interest is whether *actually* being born underwater is dangerous, not whether *planning* to do so—but changing your mind if/when a complication arises—is dangerous.[4] Published estimates indicate up to 70% of women labouring in water either choose to or are asked by a provider to leave the water prior to birth.[11,13–24]

Finally, the intervention crossover discussed above would be unidirectional. Among participants randomised to waterbirth, one can imagine numerous scenarios in which the labouring person would be asked to get out of the tub to allow for closer monitoring, but it is highly unlikely that women randomised to land birth would begin immersion.[9,14,15,17,25] This one-way misclassification would lead to biased intention-to-treat analyses.[9,11,26–29]

One is thus left with observational data, presumably complicated by extensive confounding. Propensity score analysis addresses confounding by creating exposure and control groups that are matched on all available covariables and thus free of confounding by those covariables.[30–32] Propensity score matching therefore produces results with less confounding bias than one would normally encounter in a cohort analysis, and for waterbirth specifically, arguably less bias than an intention-to-treat analysis from an RCT would have.[26]

One small propensity score-based study comparing waterbirths to land births was recently published, but used only four variables for matching and included fewer than 400 waterbirths.[11] Our objective was to use propensity scores to create waterbirth and land birth groups matched on dozens of potential confounders, and investigate maternal and neonatal outcomes using a large (N > 60,000) retrospective cohort in which a substantial proportion of the sample experienced waterbirth.

Methods

Data come from medical records, via the Midwives Alliance of North America Statistics Project (MANA Stats), from 2012–2018. MANA Stats contains complete prenatal, birth, and postpartum care data for women attended by midwives, in community (home or birth centre) settings in the United States. Detailed data collection protocols and evidence of reliability and validity were presented elsewhere.[33]

We initially limited the (non-matched) dataset to women who: gave birth in the community setting, did not have missing data for waterbirth, whose foetus was born alive (and thus is at risk of adverse outcomes associated with underwater birth--water labour is not controversial, just waterbirth[4]), did not have a foetus with a congenital anomaly incompatible with life, and did not have a higher-risk pregnancy (pre-existing or gestational diabetes, pre-existing or pregnancy-induced hypertension, pre-eclampsia/eclampsia, twins, breech birth, or labour after caesarean without history of previous vaginal birth[34,35]; see Figure S1).

We limited the sample to women who actually gave birth at home or in a birth centre, excluding those who planned community births, but experienced an intrapartum transfer —11–12% of the overall sample.[36] Intrapartum transfers were excluded because hospital waterbirth is still rare in the United States,[4,11] and a person transferring to a hospital-based provider because of a labour complication during a planned community birth would likely not be offered waterbirth at the hospital. Additionally, because intrapartum transfers are more likely to include complications, retaining these births in the sample would introduce bias in favour of waterbirth.[15,36] We previously published an analysis of intended, but not completed, waterbirths and refer readers specifically interested in that topic to our prior paper.[15] Applying these criteria yielded a sample size of 61,976 pregnancies, in which demographics and pregnancy risk characteristics were *not* equally distributed between the waterbirth and land birth groups (see Figure S1, and left-hand side of Table 1).

We then created the propensity scores, via an unconditional logistic regression model with waterbirth yes/no as the dependent variable. We included as predictors in that model: demographics, obstetric history, pre-gravid history of chronic diseases or psychosocial complications, prenatal care characteristics, pregnancy complications, psychosocial complications during pregnancy, and intrapartum characteristics/complications (see Table 2 for the complete list). The predicted probabilities of being exposed to waterbirth, calculated from this model with more than 80 predictor covariables, are the propensity scores.

To avoid list-wise deletion of records in a model containing so many predictors, and the bias that would result,[37] we allowed 'missing' to be a valid value for all categorical variables while creating the propensity scores, and set missing continuous variables to the sample-wide medians.[37,38] For instance, in the propensity score model, maternal education could be *yes* bachelor's degree (n=30,423; 49.1%), *no* bachelor's degree (n=30,979; 50.0%), or education is *missing* for that record (n=574; 0.9%). Only BMI was missing in more than 5% of the sample. This approach to missingness allows all records to be retained in the propensity score model, rather than losing some for each included variable. Thus, it not only increases statistical power for rare outcomes in the main analysis by maintaining a larger sample size, but also mitigates the bias that would result from records not being missing at random.[37] See Appendix S1 for details, including exact amount of missing data for each variable.

We then used the propensity scores to create a frequency-matched dataset, randomly sampling from within deciles of propensity scores to obtain equal-sized waterbirth and land birth groups. As one would expect, propensity scores, which are the predicted log odds of being exposed to waterbirth, based on the 80+ covariables listed in Table 2, were closer to 0 for pregnancies that ended with land birth, but closer to 1 for pregnancies that ended in waterbirth. Thus, the bottom five deciles contained more land births than waterbirths (from those deciles, all waterbirths were retained, along with a matching number of randomly-selected land births), but the top five deciles contained more waterbirths than land births, leading to inclusion of all land births but a randomly-selected subsample of waterbirths. See Table S1 for details.

To prevent us randomly drawing a matched sample that did not contain rare events, we repeated (bootstrapped) the propensity-score matching procedure 1000 times, and repeated the analyses described below on each of the 1000 samples. Final results were then averaged across these 1000 repetitions, with appropriate adjustments to the standard errors and confidence intervals.[37] The sample size (in each of the 1000 samples) after matching was 35,060 pregnancies: 17,530 waterbirths and 17,530 land births. As expected, after matching, all demographics, risk factors, and pregnancy characteristics were equally balanced between the exposed (waterbirth) and unexposed (land birth) groups (see right-hand side of Table 1).

Maternal and neonatal outcomes were then explored using unconditional logistic regression models, this time with waterbirth being the main *independent* variable of interest. We conducted the analysis using both the initial (unmatched) dataset, and the propensity score-matched dataset. All models for the latter controlled for the exact propensity scores, to alleviate potential residual confounding following frequency matching.

Maternal outcomes included haemorrhage > 1000 cc, diagnosis of postpartum haemorrhage (regardless of estimated blood loss, midwife indicated haemorrhage as a complication during 3rd stage, 4th stage, or after 4th stage; or reason for postpartum transport to a hospital was haemorrhage; or reason for maternal hospitalisation in the first 6 weeks was haemorrhage), any genital tract trauma, severe (3rd or 4th degree) trauma, postpartum transfer to a hospital (within 6 hours following birth) for a maternal indication, other maternal hospitalisation in the first 6 weeks postpartum, uterine infection in the first 6 weeks postpartum (midwife ticked "uterine infection" under the list of possible postpartum complications), and uterine infection that required hospitalisation. There were no maternal deaths in the sample.

Neonatal outcomes included umbilical cord avulsion, respiratory distress syndrome, neonatal transfer to a hospital (within 6 hours following birth), other neonatal hospitalisation in the first 6 weeks, neonatal intensive care unit (NICU) admission in the first 6 weeks, any neonatal infection in the first 6 weeks, and neonatal death (through 27 complete days). "Neonatal infection" was coded yes if the midwife indicated "signs/symptoms of infection" as either the reason for neonatal transfer or neonatal hospitalisation, or if "sepsis" was indicated as either a neonatal complication or cause of neonatal death.

These analyses were conducted using SPSS version 24.0.0.0 (IBM Corporation, Armonk, NY) and R version 3.3.2 (R Foundation for Statistical Computing, Vienna, Austria). We received ethical approval from the IRB at Oregon State University. All women and midwives provided informed consent. These analyses were funded by the US National Institutes of Health, grant number R03HD096094. Patients and members of the public were not involved with this research. A core outcomes dataset was not used for this research.

Results

Unmatched (unadjusted) results

Select sample demographics and pregnancy characteristics from before propensity score matching are shown in the left-hand columns of Table 1. In the pre-matching sample, 43% of pregnancies ended in waterbirth. Absolute risks, unadjusted odds ratios (OR), and 95% confidence intervals (CI), calculated using the unmatched sample, are shown in Table S2. In the unmatched data, waterbirth was associated with lower morbidity and mortality, across nearly all maternal and neonatal outcomes. One exception was umbilical cord avulsion, which was statistically significantly increased in the waterbirth group (OR 1.27 [95% CI, 1.01 – 1.58]). The absolute risk of umbilical cord avulsion in the unmatched sample was 0.6% (154/26,694) among waterbirths and 0.5% (160/35,282) among land births; absolute risk difference 12 per 10,000 additional avulsions among waterbirths, in unadjusted/unmatched analyses.

Propensity score-matched results

The propensity score matching worked as intended, with no differences observed between those women exposed to waterbirth and those unexposed, after matching (see right-hand columns of Table 1). For the matched sample, absolute risks, adjusted odds ratios, and 95% confidence intervals, and Numbers Needed to Treat/Harm for all outcomes are shown in Table 3.

For maternal outcomes, waterbirth in the matched data was associated with lower adjusted odds of haemorrhage >1000cc (aOR 0.79 [95% CI 0.75 – 0.83), diagnosis of haemorrhage (0.86 [0.82 – 0.90]), postpartum transfer to a hospital (0.82 [0.77 – 0.87]), and maternal hospitalisation in the first 6 weeks (0.87 [0.81 – 0.92]). Waterbirth was not associated with experiencing *any* genital tract trauma, but was associated with lower adjusted odds of severe trauma (0.90 [0.81 – 0.99]). On the other hand, waterbirth was associated with an increased adjusted odds of any uterine infection (1.25 [1.05 – 1.48]), but was not associated with infection requiring hospitalisation. The absolute risk of any uterine infection was 0.31% in the waterbirth group and 0.25% in the land birth group (risk difference 6 per 10,000 additional infections among waterbirths). We found no evidence of effect modification of infection risk by genital tract trauma (data not shown). See Table 3.

Neonates in the matched waterbirth group had lower odds of neonatal transfer (aOR 0.84 [95% CI 0.78 – 0.90]), respiratory distress syndrome (0.93 [0.86 – 0.99]), neonatal hospitalisation in the first 6 weeks (0.95 [0.90 – 0.99]), and neonatal death (0.56 [0.31 – 1.00]). Neither NICU admission in the first 6 weeks nor neonatal infection in the first 6 weeks was associated with waterbirth. Waterbirth in the matched analysis remained associated with a statistically significant increase in the relative odds of umbilical cord avulsion (1.57, [1.37 – 1.82]). The absolute risks of avulsion were low: 0.57% for waterbirths and 0.37% for land births (risk difference 20 per 10,000 additional avulsions among waterbirths). No neonatal death, in either group, included an umbilical cord avulsion. See Table 3.

Discussion

Main Findings

Our results suggest that for every 10,000 women who have a waterbirth, six will develop a postpartum uterine infection. On the other hand, these 10,000 waterbirths would simultaneously be associated with: 60 fewer haemorrhages >1000 cc, 74 fewer diagnoses of postpartum haemorrhage, 44 fewer instances of maternal postpartum transfer to a hospital from community settings, 28 fewer maternal hospitalisations in the first 6 weeks, eight fewer 3rd or 4th degree tears, and, importantly, no increase in hospitalisation for infection. For every 10,000 neonates born underwater, we would expect twenty cases of umbilical cord avulsion, but 12 fewer cases of respiratory distress syndrome, 26 fewer neonatal transfers to a hospital from community settings, 20 fewer neonatal hospitalisation in the first 6 weeks, and, importantly, no increase in neonatal deaths.

Interpretations

Compared to other studies that included at least 1000 waterbirths, our results are unique in suggesting an increased risk of maternal uterine infection, albeit with no increase in risk for infections that required hospitalisation. Snapp et al found fewer reproductive tract infections (RR 0.73 [0.52 – 1.04]),[40] and Geissbuehler et al reported less postpartum antibiotic use (3.1% waterbirth, 4.7% land birth),[16] but neither adjusted for confounders. Jacoby et al reported 80% fewer maternal fevers in the waterbirth group compared to the land birth group (aOR 0.21 [0.03 – 1.49], adjusted for primiparity).[39] Our own prior work suggested fewer postpartum reproductive tract infections in the waterbirth group (aOR 0.87 [0.69 – 1.09], adjusted for primiparity).[15] In our current paper, despite the 25% relative increase in “uterine infections” observed in women exposed to waterbirth, we observed no increase in the number hospitalised for infection (see table 3), suggesting that many so-called uterine infections subsequent to waterbirth were relatively minor and able to be managed in outpatient settings. Some of the lack of clarity around rates of uterine infection following waterbirth likely stems from ambiguities in the criteria for diagnosis, that then translates to inconsistent variable definitions in research (eg, defining infection as “fever” or “antibiotic use”).

Results are mixed for umbilical cord avulsion in large (>1000 waterbirths) studies. Jacoby et al reported no avulsions in the waterbirth group, and five (0.0002%) in the land birth group,[39] whereas Snapp et al reported 0.5% avulsions in the waterbirth group and 0.3% in the land birth group (RR 1.87 [1.24 – 2.82], unadjusted).[40] In a case series of 4030 waterbirths, Gilbert et al reported five infants (0.12%) who experienced umbilical cord avulsion.[41] A recent meta-analysis found no association between waterbirth and any adverse neonatal outcome, including umbilical cord avulsion.[29] Given the rigor of our analysis, we believe our current estimate of the increased risk of avulsion in waterbirth to be the most accurate yet published. However, despite our finding of increased risk of umbilical cord avulsion, we did not find a corresponding increase in neonatal morbidity or mortality, suggesting that midwives attending these births successfully managed cases of avulsion. None of the infants who experienced an avulsion in the larger sample (before matching), from either the waterbirth or the land birth group, died.

Another outcome that has been closely examined in relation to waterbirth is genital tract trauma. In our previous work, we reported a significant relative increase in any genital tract trauma associated with waterbirth (aOR 1.11 [1.04 – 1.18], adjusted for primiparity), though the absolute risk difference was not clinically significant (50.7% versus 49.3%).[15] In our current, propensity score-matched work, we found no difference between the two groups (see Table 3). There are mixed results from the other literature in which authors reported on at least 1000 waterbirths (see left hand columns in Table S3), but ours is the only work to adjust for any confounders, and thus, we conclude that waterbirth is not associated with a clinically significant change in risk of any genital tract trauma.

Considering more severe (3rd or 4th degree) trauma, results across the literature are more consistent (see right hand columns in Table S3): all prior work, including our own, found that waterbirth is either not associated with severe trauma or is associated with lower risk of severe trauma. Although most of these studies controlled for no confounders, results are consistent enough across all studies[42] that we conclude waterbirth does not increase the risk of severe genital tract trauma.

Strengths and Limitations

This is the largest study published to-date on waterbirth, and we controlled for more than 80 demographic, health history, obstetric history, pregnancy, and intrapartum potential confounders. Given the feasibility and methodologic challenges, it is extremely unlikely that we will ever have conclusive RCT evidence on this topic; thus we must make the best of observational evidence.[8] This analysis used numerous methods to reduce biases and confounding, is adequately powered even for rare events like neonatal death, and is currently the best available evidence on the topic of waterbirth. The dataset includes births from all 50 United States, and, because there is not a national standard for either waterbirth protocols or community birth scope of practice, the dataset includes waterbirths (and land births) that occurred under all manner of different circumstances and protocols. This simplifies translation into practice; waterbirth can be incorporated into existing workflows, without worrying about protocol fidelity.

However, our study population is comprised of women who had community births. Thus, not only are their characteristics different than those who plan hospital births (though we did limit our sample to those likely to be deemed eligible for a waterbirth in a hospital setting),[35,43] but the care they receive during the prenatal, birth, and postpartum periods is quite different.[44] Midwives practicing in community settings are trained to support and facilitate physiologic birth, without interventions common in hospitals (eg, synthetic oxytocin, epidural, caesarean). They also, precisely because these interventions are not available in community settings, transfer care to hospital-based providers with some frequency.[36,45] The extent to which these practice variations might affect generalizability of our results is discussed below.

We adjusted for every available covariable (see Table 2), but as is true in any observational study, we could not control for unmeasured confounders. We also lacked data on additional variables of possible interest, such as shoulder dystocia or transfusion. Finally, participation by community birth midwives in MANA Stats is voluntary; it is possible midwives who participate have different outcomes than those who do not. Whether that would affect our overall results, and their ability to translate into hospital settings where there are specialist providers and more resources, is not clear.

Clinical Implications

Midwives and physicians attending women during waterbirth should be aware of the possibility for umbilical cord avulsions and postpartum uterine infections, which can occur even in women with an intact perineum. Our sample was comprised entirely of community births, and despite elevated frequencies of avulsion and uterine infection, we did not find corresponding increases in risk of maternal hospitalisation, or neonatal morbidity or mortality. Far fewer resources are immediately available to providers practicing in community settings. If, as our results suggest, waterbirth can be safely managed in the context of home or birth centre birth, surely it can also safely be managed in hospitals, where additional personnel and emergency treatments and facilities are readily available.

There are two caveats to the above statement. First, waterbirth requires intermittent foetal monitoring. Intermittent monitoring is standard of care in community settings, but many hospitals use continuous electronic foetal monitoring.[46–48] Identifying early signs of foetal distress and asking those women to discontinue water immersion for closer monitoring is important.[15,17,18,23] Hospitals that institute waterbirth programs should assure competency with intermittent monitoring is within the skill set of all providers who will attend waterbirths. Second, midwives practicing in community settings often provide more care during the postpartum period than is common in hospital-based practices.[44] With fewer postpartum visits, post-waterbirth infections may be missed. Hospitals that implement waterbirth must consider how individuals will be monitored for infection during the postpartum period.

Conclusion

This is the largest, most methodologically sound study to-date reporting outcomes following waterbirth. The propensity score matching methods allowed us to create waterbirth and land birth groups matched on more than 80 risk factor, pregnancy history, and demographic covariables, eliminating confounding by any of them. Our results confirm what all other large studies on this topic have found: waterbirth is neither as harmful as some current guidelines suggest, nor as benign as some proponents claim. Moderately-elevated relative risks of umbilical cord avulsion and mild postpartum uterine infection were balanced by low absolute risks, as well as reduced risks of numerous other indicators of maternal and neonatal morbidity and mortality. With caveats about intermittent foetal monitoring and postpartum surveillance for uterine infections, hospitals should be able to safely implement waterbirth programs for low-risk women if they wish.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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References

1. Blotkamp A National Maternity and Perinatal Audit: Organisational Report 2019. NMPA; 2019. Accessed August 30, 2021. https://maternityaudit.org.uk/pages/reports
2. The Royal College of Midwives. Evidence based guidelines for midwifery-led care in labour; immersion in water for labour and birth. Published 2018. Accessed August 30, 2021. https://www.rcm.org.uk/media/2539/professionals-blue-top-guidance.pdf
3. National Institute for Health and Care Excellence. Intrapartum care for healthy women and babies. Accessed August 30, 2021. https://www.nice.org.uk/guidance/cg190
4. American College of Obstetricians and Gynecologists' Committee on Obstetric Practice. Committee Opinion No. 679: Immersion in Water During Labor and Delivery. Obstet Gynecol. 2016;128(5):e231–e236. doi:10.1097/AOG.0000000000001771 [PubMed: 27776074]
5. American College of Nurse Midwives. Hydrotherapy during Labor and Birth.; 2014. Accessed March 3, 2020. http://www.midwife.org/acnm/files/ccLibraryFiles/Filename/000000004048/Hydrotherapy-During-Labor-and-Birth-April-2014.pdf
6. A Model Practice Template for Hydrotherapy in Labor and Birth. J Midwifery Womens Health. 2017;62(1):120–126. doi:10.1111/jmwh.12587 [PubMed: 27883366]
7. American Academy of Pediatrics Committee on Fetus and Newborn, American College of Obstetricians and Gynecologists Committee on Obstetric Practice. Immersion in water during labor and delivery. Pediatrics. 2014;133(4):758–761. doi:10.1542/peds.2013-3794 [PubMed: 24652300]
8. Bovbjerg ML. Opposition to Waterbirth Is Not Evidence Based. J Womens Health 2002. Published online October 2, 2020. doi:10.1089/jwh.2020.8790
9. Woodward J, Kelly SM. A pilot study for a randomised controlled trial of waterbirth versus land birth. BJOG Int J Obstet Gynaecol. 2004;111(6):537–545. doi:10.1111/j.1471-0528.2004.00132.x

10. Cluett ER, Burns E, Cuthbert A. Immersion in water during labour and birth. Cochrane Database Syst Rev. 2018;5:CD000111. doi:10.1002/14651858.CD000111.pub4 [PubMed: 29768662]
11. Bailey JM, Zielinski RE, Emeis CL, Kane Low L. A retrospective comparison of waterbirth outcomes in two United States hospital settings. Birth. 2020;47(1):98–104. doi:10.1111/birt.12473 [PubMed: 31820494]
12. Aird IA, Luckas MJ, Buckett WM, Bousfield P. Effects of intrapartum hydrotherapy on labour related parameters. Aust N Z J Obstet Gynaecol. 1997;37(2):137–142. [PubMed: 9222454]
13. Alderdice F, Renfrew M, Marchant S, et al. Labour and birth in water in England and Wales. BMJ. 1995;310(6983):837. [PubMed: 7711622]
14. Lewis L, Hauck YL, Butt J, Hornbuckle J. Obstetric and neonatal outcomes for women intending to use immersion in water for labour and birth in Western Australia (2015–2016): A retrospective audit of clinical outcomes. Aust N Z J Obstet Gynaecol. 2018;58(5):539–547. doi:10.1111/ajo.12758 [PubMed: 29344940]
15. Bovbjerg Marit, Cheyney MJ, Everson C. Maternal and newborn outcomes following waterbirth: the MANA Statistics Project 2004–2009 cohort (n=18,343). J Midwifery Womens Health. 2016;61(1):11–20.
16. Geissbuehler V, Stein S, Eberhard J. Waterbirths compared with landbirths: an observational study of nine years. J Perinat Med. 2004;32(4):308–314. doi:10.1515/JPM.2004.057 [PubMed: 15346814]
17. Sidebottom AC, Vacquier M, Simon K, et al. Who Gives Birth in the Water? A Retrospective Cohort Study of Intended versus Completed Waterbirths. J Midwifery Womens Health. 2019;64(4):403–409. doi:10.1111/jmwh.12961 [PubMed: 30968545]
18. Camargo JCS, Varela V, Ferreira FM, et al. The Waterbirth Project: São Bernardo Hospital experience. Women Birth J Aust Coll Midwives. 2018;31(5):e325–e333. doi:10.1016/j.wombi.2017.12.008
19. Henderson J, Burns EE, Regalia AL, Casarico G, Boulton MG, Smith LA. Labouring women who used a birthing pool in obstetric units in Italy: prospective observational study. BMC Pregnancy Childbirth. 2014;14:17. doi:10.1186/1471-2393-14-17 [PubMed: 24423216]
20. Burns E, Greenish K. Water birth. Pooling information. Nurs Times. 1993;89(8):47–49.
21. Fair CD, Crawford A, Houpt B, Latham V. “After having a waterbirth, I feel like it’s the only way people should deliver babies”: The decision making process of women who plan a waterbirth. Midwifery. 2020;82:102622. doi:10.1016/j.midw.2019.102622 [PubMed: 31951904]
22. Burns EE, Boulton MG, Cluett E, Cornelius VR, Smith LA. Characteristics, interventions, and outcomes of women who used a birthing pool: a prospective observational study. Birth Berkeley Calif. 2012;39(3):192–202. doi:10.1111/j.1523-536X.2012.00548.x
23. Sidebottom AC, Vacquier M, Simon K, et al. Maternal and Neonatal Outcomes in Hospital-Based Deliveries With Water Immersion. Obstet Gynecol. 2020;136(4):707–715. doi:10.1097/AOG.0000000000003956 [PubMed: 32925614]
24. Lewis L, Hauck YL, Crichton C, et al. The perceptions and experiences of women who achieved and did not achieve a waterbirth. BMC Pregnancy Childbirth. 2018;18(1):23. doi:10.1186/s12884-017-1637-5 [PubMed: 29320998]
25. Neiman E, Austin E, Tan A, Anderson CM, Chipps E. Outcomes of Waterbirth in a US Hospital-Based Midwifery Practice: A Retrospective Cohort Study of Water Immersion During Labor and Birth. J Midwifery Womens Health. Published online September 6, 2019. doi:10.1111/jmwh.13033
26. Hernán MA, Alonso A, Logan R, et al. Observational studies analyzed like randomized experiments: an application to postmenopausal hormone therapy and coronary heart disease. Epidemiol Camb Mass. 2008;19(6):766–779. doi:10.1097/EDE.0b013e3181875e61
27. Lathrop A, Bonsack CF, Haas DM. Women’s experiences with water birth: A matched groups prospective study. Birth Berkeley Calif. 2018;45(4):416–423. doi:10.1111/birt.12362
28. Nutter E, Meyer S, Shaw-Battista J, Marowitz A. Waterbirth: an integrative analysis of peer-reviewed literature. J Midwifery Womens Health. 2014;59(3):286–319. doi:10.1111/jmwh.12194 [PubMed: 24850284]

29. Vanderlaan J, Hall PJ, Lewitt M. Neonatal outcomes with water birth: A systematic review and meta-analysis. Midwifery. 2018;59:27–38. doi:10.1016/j.midw.2017.12.023 [PubMed: 29353689]
30. Cheng YW, Hubbard A, Caughey AB, Tager IB. The association between persistent fetal occiput posterior position and perinatal outcomes: an example of propensity score and covariate distance matching. Am J Epidemiol. 2010;171(6):656–663. doi:10.1093/aje/kwp437 [PubMed: 20139128]
31. Austin PC. Balance diagnostics for comparing the distribution of baseline covariates between treatment groups in propensity-score matched samples. Stat Med. 2009;28(25):3083–3107. doi:10.1002/sim.3697 [PubMed: 19757444]
32. Westreich D, Cole SR. Invited commentary: positivity in practice. Am J Epidemiol. 2010;171(6):674–677; discussion 678–681. doi:10.1093/aje/kwp436 [PubMed: 20139125]
33. Cheyney M, Bovbjerg M, Everson C, Gordon W, Hannibal D, Vedam S. Development and validation of a national data registry for midwife-led births: the Midwives Alliance of North America Statistics Project 2.0 dataset. J Midwifery Womens Health. 2014;59(1):8–16. [PubMed: 24479670]
34. Cox KJ, Bovbjerg ML, Cheyney M, Leeman LM. Planned Home VBAC in the United States, 2004–2009: Outcomes, Maternity Care Practices, and Implications for Shared Decision Making. Birth. 2015;42(4):299–308. doi:10.1111/birt.12188 [PubMed: 26307086]
35. Bovbjerg ML, Cheyney M, Brown J, Cox KJ, Leeman L. Perspectives on risk: Assessment of risk profiles and outcomes among women planning community birth in the United States. Birth. 2017;44(3):209–221. doi:10.1111/birt.12288 [PubMed: 28332220]
36. Cheyney M, Bovbjerg M, Everson C, Gordon W, Hannibal D, Vedam S. Outcomes of care for 16,924 planned home births in the United States: the midwives alliance of north america statistics project, 2004 to 2009. J Midwifery Womens Health. 2014;59(1):17–27. [PubMed: 24479690]
37. Harrell FE Jr. Regression Modeling Strategies, with Applications to Linear Models, Logistic Regression, and Survival Analysis. Springer; 2001.
38. Kim S, Egerter S, Cubbin C, Takahashi ER, Braveman P. Potential implications of missing income data in population-based surveys: an example from a postpartum survey in California. Public Health Rep Wash DC 1974. 2007;122(6):753–763.
39. Snapp C, Stapleton SR, Wright J, Niemczyk NA, Jolles D. The Experience of Land and Water Birth Within the American Association of Birth Centers Perinatal Data Registry, 2012–2017. J Perinat Neonatal Nurs. 2020;34(1):16–26. doi:10.1097/JPN.0000000000000450 [PubMed: 31834005]
40. Jacoby S, Becker G, Crawford S, Wilson RD. Water Birth Maternal and Neonatal Outcomes Among Midwifery Clients in Alberta, Canada, from 2014 to 2017: A Retrospective Study. J Obstet Gynaecol Can JOGC J Obstet Gynecol Can JOGC. 2019;41(6):805–812. doi:10.1016/j.jogc.2018.12.014
41. Gilbert RE, Tookey PA. Perinatal mortality and morbidity among babies delivered in water: surveillance study and postal survey. BMJ. 1999;319(7208):483–487. [PubMed: 10454400]
42. Hill AB. The Environment and Disease: Association or Causation? Proc R Soc Med. 1965;58(5):295–300. [PubMed: 14283879]
43. Martin Joyce A, Hamilton Brady E, Osterman MJK, Driscoll Anne K. Births: Final Data for 2019. Natl Vital Stat Rep. 2021;70(2).
44. Cheyney M, Olsen C, Bovbjerg M, Everson C, Darragh I, Potter B. Practitioner and Practice Characteristics of Certified Professional Midwives in the United States: Results of the 2011 North American Registry of Midwives Survey. J Midwifery Womens Health. 2015;60(5):534–545. doi:10.1111/jmwh.12367 [PubMed: 26382198]
45. Stapleton SR, Osborne C, Illuzzi J. Outcomes of care in birth centers: demonstration of a durable model. J Midwifery Womens Health. 2013;58(1):3–14. doi:10.1111/jmwh.12003 [PubMed: 23363029]
46. Declercq ER, Sakala C, Corry MP, Applebaun S, Herrlich A. Listening to Mothers III: Pregnancy and BIrth. Childbirth Connection; 2013. Accessed July 5, 2018. http://transform.childbirthconnection.org/reports/listeningtomothers/
47. Heelan L Fetal Monitoring: Creating a Culture of Safety With Informed Choice. J Perinat Educ. 2013;22(3):156–165. doi:10.1891/1058-1243.22.3.156 [PubMed: 24868127]

48. Cypher RL. Electronic Fetal Monitoring Documentation. J Perinat Neonatal Nurs. 2018;32(1):24–33. [PubMed: 29240649]

Table 1.

Demographic and pregnancy risk factors for women who had a waterbirth and women who did not have a waterbirth, before and after propensity score matching. The "before" data are presented as percents and frequencies from the dataset as a whole, whereas the "after" data are the percents with 95% confidence intervals, from the propensity score matched datasets that were resampled 1000 times (see methods). Data come from the Midwives Alliance of North America Statistics Project (MANA Stats), birth years 2012–2018. The sample was limited to lower-risk pregnancies not missing information on waterbirth (see Figure S1).

	Before Matching			*After Matching*		
Comparison Variable	**Waterbirths % (n)**	**Land births % (n)**	**p-value (Chi-square test)**	**Waterbirths % (95% CI)**	**Land births % (95% CI)**	**p-value (Chi-square test)**
Total	**43.1% (26,694)**	**56.9% (35,282)**		**50.0% (n=17,530)**	**50.0% (n=17,530)**	
Midwife-identified race of mother = White	86.6% (23,044)	86.3% (30,379)	0.42	86.5% (86.2 – 86.7)	86.5% (86.3 – 86.7)	0.78
Mother is married or partnered	95.0% (25,350)	95.2% (33,569)	0.29	95.2% (95.0 – 95.4)	95.3% (95.1 – 95.4)	0.66
Maternal education BA/BS or more	48.7% (12,860)	50.2% (17,563)	**<0.001**	49.3% (48.9 – 49.7)	49.5% (49.2 – 49.7)	0.71
Mother eligible for Medicaid	23.4% (6239)	22.6% (7951)	0.015	23.4% (23.0 – 23.7)	23.8% (23.5 – 24.0)	0.39
Place of birth						
home	68.2% (18,199)	72.5% (25,584)	**<0.001**	73.7% (73.3 – 74.0)	73.3% (73.0 – 73.5)	0.68
birth center	31.8% (8495)	27.5% (9698)		26.2% (25.9 – 26.6)	26.6% (26.4 – 26.8)	
Primary midwife credential						
Certified Professional Midwife[a]	74.7% (19,930)	70.3% (24,800)	**<0.001**	72.5% (72.2 – 72.8)	72.3% (72.0 – 72.6)	0.97
Certified Nurse Midwife	10.2% (2716)	13.2% (4652)		11.6% (11.4 – 11.8)	11.8% (11.5 – 12.0)	
Both CPM and CNM	3.2% (857)	3.6% (1259)		3.4% (3.3 – 3.5)	3.5% (3.4 – 3.6)	
Other[b]	12.0% (3191)	13.0% (4571)		12.5% (12.3 – 12.7)	12.5% (12.3 – 12.6)	
Pre-gravid BMI						
<25	63.0% (16,807)	65.5% (23,126)	**<0.001**	64.6% (64.2 – 64.9)	64.7% (64.4 – 64.9)	0.98
25 - <30	19.7% (5249)	18.6% (6574)		19.0% (18.7 – 19.3)	19.0% (18.8 – 19.2)	
30 - <35	7.3% (1949)	6.5% (2281)		6.9% (6.6 – 7.0)	6.8% (6.7 – 7.0)	
35+	4.0% (1065)	3.2% (1135)		3.4% (3.3 – 3.6)	3.4% (3.3 – 3.5)	
Missing	6.1% (1624)	6.1% (2166)		6.2% (6.0 – 6.3)	6.1% (6.0 – 6.3)	
Mother is primiparous	23.4% (6235)	32.3% (11,399)	**<0.001**	26.5% (26.2 – 26.7)	26.4% (26.1 – 26.6)	0.98
If multipara, labor after cesarean[c]	4.3% (870)[d]	4.2% (1003)[d]	0.80	4.3% (4.1 – 4.4)[d]	4.2% (4.0 – 4.3)[d]	0.43

Comparison Variable	*Before Matching*			*After Matching*		
	Waterbirths % (n)	**Land births % (n)**	**p-value (Chi-square test)**	**Waterbirths % (95% CI)**	**Land births % (95% CI)**	**p-value (Chi-square test)**
	mean (SD)	**mean (SD)**		**mean (95% CI)**	**mean (95% CI)**	
Maternal age	30.5 (4.8)	30.6 (5.0)	**0.004** [e]	30.7 (30.6 – 30.7)	30.7 (30.6 – 30.7)	1.0[e]
Gestational age, days[f]	281.1 (7.9)	281.1 (8.1)	0.92[e]	281.1 (281.0 – 281.1)	281.0 (280.9 – 281.0)	0.56

[a] In the United States, Certified Nurse Midwives (CNMs) and Certified Professional Midwives (CPMs) both practice in community birth settings. CNMs obtain a nursing degree first, then obtain midwifery training via a Master's degree in Nurse-Midwifery. The CPM is a direct-entry credential that does not requiring nursing training. CPMs must meet all standards set out by the International Confederation of Midwives (https://internationalmidwives.org/our-work/policy-and-practice/global-standards.html)

[b] "other" includes midwifery students attending as primary but under supervision, clinicians with other credentials (eg Naturopathic Doctor, Doctor of Osteopathy), and records missing midwife credential information.

[c] all women in this group also have a history of vaginal birth; women with a history of cesarean only are not in the sample

[d] denominator is multiparas only

[e] for maternal age and gestational age, the p-values are from a t-test assuming equal variances

[f] preterm birth is contraindicated in the community setting; this is thus the median gestational age

Table 2.

Variables included in the propensity score generation model.

category	included variables
maternal demographics	race/ethnicity, partner status, education, expected payment source, WIC eligibility, maternal age, pre-gravid BMI, region of residence [New England, mid-Atlantic, Southeast, Midwest, Southwest, West], whether the mother was Amish
obstetric history	gravidity, parity, history of cesarean, history of vaginal birth, history of other cervical surgery, history of other uterine surgery
pre-gravid history of chronic diseases	asthma, genetic disorders, hypothyroidism, frequent urinary tract infections, sexually-transmitted infections
pre-gravid history of psychosocial complications	anxiety, depression, eating disorders, domestic violence, sexual abuse, substance abuse
prenatal care characteristics	credentials held by the attending midwife, actual place of birth (home or birth center), number of prenatal visits
pregnancy complications	anemia, asthma, cholestasis, congenital anomalies diagnosed antenatally, spontaneous abortion of a twin with continuing pregnancy, group B strep infection, heart disease, hepatitis B or C infection, hyperemesis, hyperthyroid, hypothyroid, intrauterine growth restriction, urinary tract infection, oligohydramnois, polyhydramnios, preterm labor or premature rupture of membranes, post-term pregnancy, unexpected preterm birth diagnosed by clinical exam of the newborn, placenta previa, placental abruption, puritic urticarcical papules and plaques of pregnancy, Rh sensitivity, sexually-transmitted infections, genital herpes, single umbilical artery
psychosocial complications during pregnancy	anxiety, depression, eating disorder, sexual abuse, substance abuse, domestic violence
intrapartum characteristics and complications	whether an induction was attempted, either pharmacologic or non-pharmacologic, cord prolapse, maternal dehydration, malposition/malpresentation, maternal exhaustion, maternal request for pharmacologic pain relief, maternal shock, light meconium, thick or particulate meconium, non-reassuring fetal heart tones, hypertension, pre-eclampsia, prolonged rupture of membranes with or without labor, urine retention, maternal pushing position, failure to progress in the first stage[a], failure to progress in the second stage[a], length of active labor, length of pushing, length of time membranes were ruptured

[a]As indicated by the attending midwife; no standard definitions were given

Table 3.

Comparison of outcomes between women who had waterbirth and land birth, after propensity score matching. Adjusted odds ratios are from unconditional logistic regression models, using bootstrapped propensity-score matched data from MANA Stats, birth years 2012–2018. The model controls for exact propensity score (dataset was frequency-matched on propensity score deciles, with the matching being repeated 1000 times). ORs are presented as waterbirth compared to land birth. Thus, an OR < 1 means the outcome is less likely among waterbirths, and an OR > 1 means the outcome is more likely among waterbirths. Absolute risks (proportions) and the corresponding 95% confidence intervals were calculated from the bootstrapped samples. Number Needed to Treat (NNT) and Number Needed to Harm (NNH) are both presented in terms of waterbirth—NNT for associations wherein waterbirth was protective, and NNH for associations wherein waterbirth was harmful.

Outcome	Waterbirths % (95% CI)	Land births % (95% CI)	aOR (95% CI)	NNT	NNH
Total sample	**n=17,530 (50.0%)**	**n=17,530 (50.0%)**			
Maternal outcomes					
Postpartum (within 6 hours) transfer to a hospital	2.05% (1.96 – 2.16)	2.50% (2.41 – 2.60)	**0.82 (0.77 – 0.87)**	222	
Hemorrhage > 1000cc	2.38% (2.28 – 2.47)	2.99% (2.90 – 3.11)	**0.79 (0.75 – 0.83)**	164	
Diagnosed with hemorrhage in 3rd or 4th stage of labor	4.69% (4.55 – 4.84)	5.43% (5.30 – 5.56)	**0.86 (0.82 – 0.90)**	135	
Any genital tract trauma	49.3% (48.9 – 49.6)	49.2% (48.9 – 49.5)	1.00 (0.99 – 1.02)	---	---
3rd or 4th degree trauma	0.75% (0.69 – 0.81)	0.84% (0.79 – 0.90)	**0.90 (0.81 – 0.99)**	1111	
Maternal hospitalisation in the first 6 weeks	1.91% (1.82 – 2.00)	2.20% (2.12 – 2.29)	**0.87 (0.81 – 0.92)**	345	
Maternal uterine infection in the first 6 weeks	0.31% (0.27 – 0.35)	0.25% (0.22 – 0.28)	**1.25 (1.05 – 1.48)**		1667
Hospitalised uterine infection in the first 6 weeks	0.12% (0.10 – 0.14)	0.11% (0.09 – 0.12)	1.11 (0.85 – 1.44)	---	---
Neonatal outcomes					
Umbilical cord avulsion	0.57% (0.52 – 0.63)	0.37% (0.33 – 0.41)	**1.57 (1.37 – 1.82)**		500
Neonatal (within 6 hours) transfer to a hospital	1.39% (1.31 – 1.45)	1.65% (1.58 – 1.73)	**0.84 (0.78 – 0.90)**	385	
Respiratory distress syndrome	1.49% (1.41 – 1.56)	1.61% (1.53 – 1.69)	**0.93 (0.86 – 0.99)**	833	
NICU admission in the first 6 weeks	1.84% (1.75 – 1.95)	1.94% (1.86 – 2.03)	0.95 (0.89 – 1.02)	---	---
Neonatal hospitalisation in the first 6 weeks	3.39% (3.27 – 3.52)	3.58% (3.47 – 3.69)	**0.95 (0.90 – 0.99)**	526	
Neonatal infection in the first 6 weeks	0.90% (0.83 – 0.96)	0.91% (0.86 – 0.96)	0.99 (0.90 – 1.09)	---	---
Neonatal death	0.28/1000 (0.17 – 0.40)	0.51/1000 (0.34 – 0.68)	**0.56 (0.31 – 1.00)**	4348	

aOR: adjusted odds ratio; CI: confidence interval; NICU: neonatal intensive care unit; NNH: number needed to harm; NNT: number needed to treat