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Technology-Based Innovative Solutions for Improving Perinatal Care Utilization: A Network Meta-Analysis

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About this design paper

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PROTOCOL

Technology-Based Innovative Solutions for Improving Perinatal Care Utilization: A Network Meta-Analysis

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Background

In 2015, an estimated 303,000 women died from complications related to pregnancy, childbirth, or the postnatal period (World Health Organization, 2019). Of maternal and neonatal deaths that occur globally, 99% occur in low- and middle-income countries (Langlois et al. 2015). The greatest barrier to reduce maternal and neonatal mortality and morbidity is attributed to the low coverage of essential pregnancy-related health services such as antenatal care (ANC) visits, post-natal care (PNC) visits, and delivery care in LMICs. For example, only about 50% of pregnant women in low-and middle-income countries (LMICs) receive the four mandatory antenatal consultations as recommended by the World Health Organization (WHO).

Providing essential health services to pregnant women is complex and not feasible in resource-limited settings as integrated and multiple interventions are required throughout the antenatal, delivery, and postnatal processes. Disruptions in coordinated services are exemplified through cases such as the Democratic Republic of the Congo, where ANC rates are above 90%, but PNC rates are 35% (Langlois et al. 2015). In addition, a wide disparity in healthcare utilization exists between urban-rural areas, particularly in hard-to-reach areas. Thus, increasing coverage to essential healthcare services for pregnant women, particularly in hard-to-reach areas, is a priority to reduce inequality of healthcare utilization and improve pregnancy outcomes.

Since the adoption of eHealth resolution by the WHO in 2005, a surge of technology-based interventions in public health has taken place. eHealth incorporates categories such as telehealth, electronic health records, eLearning, mHealth (mobile health), social media, and big data. Such interventions are widely being employed to increase utilization of preventative healthcare, such as ANC, PNC, and delivery care, at both individual- and community-levels. As a result, technology-based interventions are a potential promise to providing improvement in timeliness, accessibility, and affordability of healthcare services in resource-limited settings. Furthermore, women's access to digital- technology health interventions including mHealth have been shown to be gender-transformative, enabling of women's decision-making, social status and access to health resources, as well as enabling greater male participation in health areas typically targeting women (Jennings et al., 2013, WHO, 2019; LeFevre et al, 2020). The engagement of male partners in ways that support and do not undermine women's decision-making is increasingly identified as an important mechanism to accelerate progress in maternal and newborn health (MNH) (Ruane-McAteer et al, 2019). Technology-based health interventions have also the potential to make health services more responsive to user-needs by allowing the potential for women to give anonymous feedback on services provided (LeFevre et al, 2020).

Furthermore, in the recent context of Covid-19, health systems increasingly progressed towards technology-based interventions as an effective and agile solution to provide services. Although the evaluation of telehealth models used during Covid-19 is in the preliminary stages and require further monitoring over long-term, evidence shows benefit towards accelerating uptake of technology-based solutions for perinatal services. The uptake of telemedicine globally has been met with generally positive uptake by patients, physicians, governments, and insurers. For example, adoption of telehealth to deliver health education and monitoring of high-risk pregnancies in United States demonstrated its feasibility during Covid-19 pandemic (Aziz et al, 2020). Taking into account the telehealth programs required pregnant mothers to have ready access to equipment such as blood pressure or blood glucose monitor, we acknowledge the concerted efforts required to address such implementation challenges particularly in low-resource settings. Thinking forward to post-pandemic recovery stage, it is a critical time for health systems to address health systems' resilience to potential shocks – not only from pandemics, but also from climate change, war, or political conflicts. Given the potential of technology-based solutions demonstrated during Covid-19 in delivering low-cost and highly scalable services, future research is vital to understand and build models of technology integration into the health system.

Comparison with existing literature

Despite an uptake of technology-based interventions, evidence remains inconclusive regarding its effectiveness due to a lack of comprehensive and concrete evaluations performed. This uncertainty raises a question of the role in targeting strategies in implementing technology-based interventions in healthcare utilization. Current literature is limited to evidence from pilot projects, systematic and/or pooled reviews assessing the impact of mHealth in improving continuum of care in LMICs (Feroz et al. 2017, Noordam et al. 2015, Wagnew et al. 2018, WHO 2011, Lee et al. 2016, Nair et al. 2010, Sondaal et al. 2016, Rosato et al. 2008), or identifying barriers to its uptake through stakeholder interviews (Tamrat & Kachnowsky 2012). These studies are limited to assessing an isolated range of interventions (such as mHealth only) or a limited range of outcomes (such as uptake of health services but not skilled birth attendance rates). Critically, none assess the complex interplay and impact of technology-based interventions over the dynamic antenatal-delivery-postnatal pathway. This systematic review and network meta-analysis aim to fill this gap in knowledge by synthesizing the impact of technology-based interventions on a comprehensive range of reported outcomes in ANC, PNC, and delivery care. Furthermore, our meta-analysis will evaluate the impact by sociodemographic, country and regional factors, which will further inform policymakers on the potential use of technology-based interventions in given contexts.

Policy relevance

This study directly addresses the Sustainable Development Goal of Maternal and Child Health (SDG3) by providing insights and evidence-informed recommendations for the utilization of technology-based interventions in addressing maternal health-care challenges in LMICs. The study will directly inform the planned update of WHO 2015 guidelines on health promotion interventions for Maternal and Newborn Health (MNH) (WHO, 2015), the update of the WHO guidelines on postnatal care 2013 (WHO, 2013), and the WHO guideline: recommendations on digital interventions for health system strengthening (WHO, 2019).

Although there is an increased utilization of technology-based interventions in public health, there is no consensus on the effectiveness of such interventions nor prior research done to investigate how complex interventions interplay in affecting outcomes throughout the pregnancy cycle. It will assess the impact of technology-based interventions by comparing the country-income level and population demographics. Therefore, our research offers a solution to this gap in the literature by providing a comprehensive review of all established outcomes and further examines the effectiveness of the interventions according to the sociodemographic, country, and regional contexts. This study strongly aligns with CEDIL's research priorities evaluating evidence on emerging use of technology, with a particular focus in LMICs. The study will be of special interest to WHO Department of Maternal, Newborn Child and Adolescent Health, but also to a much wider range of international policymakers and stakeholders involved in accelerating progress on MNH such as, the World Bank and OECD, UNWOMEN, UNFPA and UNESCO.

Objectives

To explore the impact of technology-based interventions in improving ANC visits, PNC visits, and delivery care services in LMICs using Bayesian network meta-analysis.

Review questions

1) What is the effectiveness of single and complex technology-based interventions in improving selected outcomes with regards to the target populations?
2) What is the impact of technology-based interventions on antenatal, postnatal, and delivery care services among women with a comprehensive range of outcomes?

3) How do technology-based interventions interact and produce causal outcomes through the antenatal-delivery-postnatal pathway?
4) Do these new technology-based solutions promote engagement of woman only or woman and partner woman and family?

Research Methods

Protocol registration

The review protocol will be registered in the Campbell Collaboration/PROSPERO database. This protocol adheres to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Protocols 2015 guidelines for preparing protocols of systematic reviews and network meta-analysis (Moher et al. 2015). We will report the study findings according to the PRISMA guideline.

Search strategy

We will search the following nine electronic databases: British Nursing Index, CINAHL PLUS, Cochrane Library, EMBASE, POPLINE, PsycINFO, PubMed, and Web of Science. Reference lists of included articles and relevant systematic review papers of other studies will also be reviewed for inclusion. Search terms will consist of Medical Subject Headings (MeSH), title/abstract (tiab), text words (tw) and other relevant field tag depending on the databases. We will also search WHO's international Clinical Trials Registry Platform, ClinicalTrials.gov, and the Cochrane Central Register of Controlled Trials, using the search terms "(pregnan* OR matern*) OR AND (eHealth OR mHealth OR telehealth) AND (intervention studies OR experimental studies OR randomized controlled trial OR Quasi-randomized controlled trial)". The search will not be limited by publication status, date or language of production. The brief search strategy is summarized in Table 1.

Study eligibility criteria

The study eligibility criteria are defined in the following PICOS framework (P-Participants/study population, I-interventions, C-Comparator, O-Outcomes, and S-Study design/settings). We will include studies if the study meets the following criteria:

1) **Population:** We will include studies if the study population is pregnant women aged 10-49 years. If the study population included high-risk population such as pregnant women with HIV/AIDS, cancer, preeclampsia, or other severe diseases at the baseline, we will exclude those studies.
2) **Intervention:** All types of technology-based healthcare interventions (e.g., eHealth intervention, mHealth intervention, and telehealth intervention) will be considered for this review.
3) **Comparison:** We will include studies if the study compares the effectiveness of any form of technology-based healthcare interventions with usual care.
4) **Outcome:** We intend to include studies that reported perinatal healthcare utilization such as ANC visits, institutional delivery, skilled birth attendance at the time of delivery, proportion of birth preparedness, proportion of post-natal care utilization both for mother and newborn. We will also include studies if they reported any adverse maternal and birth outcomes that occurred during the perinatal period.
5) **Types of study:** We will consider all randomized controlled trials (RCTs), cluster RCTs, quasi RCTs, and quasi experimental studies (controlled before and after studies) in this review. We will exclude qualitative studies, case studies, cross-sectional studies, review studies, discussion papers, case reports, commentaries, editorials, expert opinions, and ongoing research with insufficient PICOS information.
6) **Settings:** We will include studies conducted in low-and middle-income countries based on World Bank categories (World Bank, 2019).

Outcome variables

- **Primary outcome variables:** number of ANC visits, institutional delivery, and skilled birth attendance at the time of delivery, birth preparedness, PNC visits both for mother and newborn.
- **Secondary outcome variables:** number of maternal and early neonatal deaths, proportion of women with gestational diabetes and hypertension, low birth weight, and preterm births, reported increases in women' access to digital and mobile technologies, engagement of men and/or significant others in care pathway; impact on gender equality and any adverse outcomes.

Selection of the study

Following the search strategy, all articles extracted from the nine electronic databases will be stored in EndNote and duplicates will be identified and deleted. After removing the duplicates, the combined articles will be screened through Rayyan QRCI tool. In the first stage, two reviewers will independently screen titles and abstracts based on inclusion and exclusion criteria. In the second stage of screening, both reviewers will then independently review full texts of selected studies to assess eligibility. Any discrepancies between the reviewers at the two stages will be resolved through discussion.

Data extraction

A coding framework will be developed and piloted prior to undertaking data extraction for all included studies using EPPI Reviewer 4 software. For eligible studies, two reviewers will independently extract data on author information, year of publication, survey year, country, region, settings, study design, types of interventions, sample size, frequency/rate of ANC visits, institutional delivery, skill birth attendance, and post-natal care visits by different household, individuals or health provider characteristics. Inter-coder reliability will be tested to ensure moderate agreement, until Cohen's kappa reaches 0.41 or above (McHugh, 2012), and the review team are satisfied that screeners are making consistent decisions. Disagreements will be solved through discussion. When the information is unclear or full-text articles not available, we will contact the corresponding or co-authors to collect our required information. For articles written in languages other than English (Spanish, Chinese, German, Italian and others), data will be extracted with the assistance of colleagues who are native speakers in these languages.

Study quality assessment

We will use the Cochrane Collaboration's Tool to assess the study quality. The tool consists of the following domains: random sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data, selective outcome reporting, and other bias. Non-randomised studies will be coded using ROBINS-I (Sterne et al., 2016). We will classify the studies having high, low and unclear risk of bias based on their guideline (Higgins et al., 2011). Two reviewers will independently assess the study quality, which will be cross-checked by two other authors. Any discrepancy will be solved through discussion.

Data analysis

Pairwise meta-analysis

To summarize the effect size of individual interventions for each outcome separately, we will use Bayesian fixed or random effects meta-analysis depending on the extent of heterogeneity. For dichotomous outcome variables, the effect size odds ratio (OR), relative risk (RR), or hazard ratios (HR) with 95% confidence interval (CI) will be utilized in the meta-analysis. For continuous outcome variables, standardized mean difference (SMD) with standard deviation/95% CI will be considered in the meta-analysis. The relative risk (RR) is used as the common measure in trials, observational, or even in cross-sectional studies. Consistent with previous study (Zhang and Yu, 1998), we will treat ORs equal to RRs when the incidence of outcome is not common (<10%) in the study population. Otherwise, we will convert ORs into RRs according to Zhang proposed methodology (Zhang and Yu, 1998). We will directly consider RRs when the study reported hazard ratios and incidence density ratios. If the RR or OR is unavailable, we will estimate unadjusted RR from raw data.

Assessing heterogeneity

Regarding the assessment for heterogeneity in the included studies, we will calculate the chi square statistic and I^2 statistic. We will follow the Cochrane guideline for classifying heterogeneity (Higgins et al., 2019). If there is no heterogeneity (P>0.05, I^2 < 25%), a fixed effect model will be performed (Higgins et al., 2003). Otherwise, a random effects model will be used to obtain pool effect size for each intervention. Where heterogeneity is identified in the meta-analysis, we will perform subgroup analysis to estimate pool effect for each intervention by country, region, age group, year of publication, survey year, etc. Subgroup analysis will be performed using Bayesian meta-regression. We will use funnel plots and Egger's test (Sterne & Egger, 2006) to assess publication bias.

Dealing with missing data

If the study does not contain sufficient data such as means and standard deviations to calculate effect size estimates, the authors will be contacted for further information. If sufficient data cannot be obtained, the study will be excluded from the meta-analysis but presented in a narrative synthesis. In cases where data is missing due to attrition rates of more than 20%, the studies will be included with sensitivity analysis conducted to measure its impact on analysis. In studies with results of both 'intention to treat' and 'as treated' analysis presented, the 'intention to treat' will always be preferred.

Network meta-analysis

In the first stage of analysis, network plots will be developed to show the direct comparison between treatment arms and offer a summary description of their characteristics. After that, the contribution plots will develop to show the influence and contribution of each direct comparison to the whole network. For Bayesian network meta-analysis, we will develop algorithm in Bayesian framework based on log scale of effect size and estimate the posterior distribution of the treatment effect size. Bayesian network meta-analysis will be utilized to identify most the effective interventions for each outcome. To pool the direct and indirect or different indirect outcomes simultaneously, we will use Bayesian network meta-analysis.

Bayesian network meta-analysis will be based on sampling from the posterior distribution over the parameters using Gibbs Monte Carlo, a Markov chain Monte Carlo (MCMC) method, as implemented in the algorithm in JAGS open source software (version 4.2). In MCMC algorithm, we used 40,000 iterations with three chains, 500 sample burn-in, and 10 thinning due to reduce autocorrelation. Vague priors, such as $N(0, 10^6)$ for the study-specific baseline and treatment effect coefficients will be used to insure estimates of effect sizes and precision. Surface under the cumulative ranking curve (SUCRA) will be used for presenting the results. The SUCRA value will be presented as the percentage of the area under the curve, denoting the higher the SUCRA value reflected the better the treatment method. Gelman-Rubin diagnostic statistics and potential scale reduction factor (PSRF) will be used to check the convergence of the model (Gelman A. et al, 2013). Furthermore, we will perform the inconsistency analysis to assess disagreement between direct and indirect evidence which can suggest that the transitivity assumption might not hold. The inconsistency factors in the closed loop will be assessed by the common method described by Chaimani et al. 2013. Inconsistency analysis will be presented as a funnel plot. Data management will be performed in Stata version 16.1 /MP and analysis will be performed in R (version 3.6.4), and JAGS (version 4.2.0).

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Table 1. Keywords used in electronic search strategy

SL	Query
1.	expectant mother OR pregnant women OR pregnant mother OR pregnancy
2.	computer OR tablet OR phone OR mobile OR mobile phone OR mobile device OR smartphone OR smart-phone OR cell phone OR cellphone OR cellular phone OR web OR website OR Internet OR online OR on-line OR technology OR digital technology OR mobile technology OR health technology OR wireless technology OR wireless device OR iPhone OR i-Phone OR iPad OR i-Pad OR iPod OR i-Pod
3.	SMS OR short message service OR short messaging OR mobile phone messaging OR MMS OR multimedia message service OR multi-media message OR SMS advice OR SMS reminder OR text message OR text messaging OR texting
4.	mobile call OR mobile calling OR mobile communication OR voice call OR voice calling OR voice message OR video conference
5.	mobile applications OR mobile apps OR mobile app OR smartphone app OR app OR apps OR email OR e-mail OR personal digital assistant OR PDA
6.	#2 OR #3 OR #4 OR #5
7.	eHealth OR e-Health OR electronic health OR digital health OR telehealth OR telemedicine OR telecommunication OR mHealth OR m-Health OR mobile health OR mobile medicine OR mcare OR m-care OR mobile care OR mHealth messaging OR mobile telehealth OR mobile telehealth care OR m-Edu OR medu OR m-education OR mobile education OR mLearning OR eLearning
8.	#6 AND #7
9.	(Intervention studies OR experimental studies OR randomized controlled trial OR controlled clinical trial OR randomized OR placebo OR clinical trials as topic OR randomly OR trial) NOT (animals NOT humans)
10.	#1 AND #8 AND #9

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