Impact of m-health application used by community health volunteers on improving utilisation of maternal, new-born and child health care services in a rural area of Uttar Pradesh, India

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Abstract

Objective. To raise the quality of counselling by community health volunteers resulting in improved uptake of maternal, neonatal and child health services (MNCH), an m-health application was introduced under a project named ‘Reducing Maternal and Newborn Deaths (ReMiND)’ in district Kaushambi in India. We report the impact of this project on coverage of key MNCH services.

Methods. A pre- and post-quasi-experimental design was undertaken to assess the impact of intervention. This project was introduced in two community development blocks in Kaushambi district in 2012. Two other blocks from the same district were selected as controls after matching for coverage of two indicators at baseline – antenatal care and institutional deliveries. The Annual Health Survey conducted by the Ministry of Health and Family Welfare in 2011 served as pre-intervention data, whereas a household survey in four blocks of Kaushambi district in 2015 provided post-intervention coverage of key services. Propensity score matched samples from intervention and control areas in pre-intervention and post-intervention periods were analysed using difference-in-difference method to estimate the impact of ReMiND project.

Results. We found a statistically significant increase in coverage of iron–folic acid supplementation (12.58%), self-reporting of complication during pregnancy (13.11%) and after delivery (19.6%) in the intervention area. The coverage of three or more antenatal care visits, tetanus toxoid vaccination, full antenatal care and ambulance usage increased in intervention area by 10.3%, 4.28%, 1.1% and 2.06%, respectively; however, the changes were statistically insignificant.

Conclusion. Three of eight services which were targeted for improvement under ReMiND project registered a significant improvement as result of m-health intervention.

Keywords. m-health, impact assessment, maternal and child health, community health worker

Introduction

Mobile phones are now being increasingly used in developing countries [1]. With constraints in availability of skilled human resource and increased accessibility in remote areas, mobile phones are being viewed as a potent medium for effective and sustainable communication in the health sector [2]. As defined by the Global Observatory for e-Health, mobile health or m-health is defined as medical and public health practice supported by mobile devices, such as mobile phones, patient monitoring devices, personal digital assistants (PDAs) and other wireless devices [3]. This new mode of health communication is being employed for providing community education and trainings, facilitation of health education sessions and as a job aid for improving the counselling skills of community health workers [4]. Across the world, m-health has been used in field of maternal & child health [5], malaria [6, 7], diabetes [8, 9], HIV/AIDS [10], sexual and reproductive health [11], health behaviour change [12], etc.

India has one billion mobile phone users, 42.8% of whom are based in rural areas. On the one hand, the country witnesses magnificent growth in the telecom sector, on the other hand it still accounts for a quarter of new-born deaths globally and around 17% of maternal deaths [13, 14]. The state of Uttar Pradesh (UP) is one of the major contributors in total maternal and child deaths in India with low coverage of key maternal, neonatal and child health (MNCH) services [15]. The coverage rates of
institutional deliveries, full antenatal care (ANC) and full immunisation in UP were 45.6%, 29.6%, 45.3%, respectively, in year 2011–2012 [16]. The Government of India identified 19 high focus districts in Uttar Pradesh; Kaushambi is one with a maternal mortality ratio of 283. To improve health indicators across the country, accredited social health activists (ASHAs) were introduced as a new cadre of community health volunteers under National Rural Health Mission in 2005 to generate demand for health services by mobilising and motivating communities [17]. However, an ASHAs evaluation in 2011 identified a need to strengthen the quality of the 23-day training schedule developed by the Ministry of Health and Family Welfare (MoHFW) to bolster their counselling skills [18].

Keeping in view the success of m-health in other countries, a project named ‘Reducing Maternal and Newborn Deaths’ (ReMiND) was initiated in Kaushambi district of Uttar Pradesh. Its overall purpose was to improve the coverage of key MNCH services to lower the prevailing high maternal and infant mortality rates [16]. The intervention under the ReMiND project was development and implementation of an m-health application used as a job aid by ASHAs for registering pregnant women and for providing real-time guidance through key counselling points, decision support and simple referral algorithms for various maternal and child health issues [19]. This mobile application also provides timely alerts to ASHAs for individualised counselling of pregnant women, and serves as a tool for supervision of ASHAs’ performance. The m-health platform tracks and supports clients for ASHA workers and provides individualised service and counselling [20]. It replaces paper registers and flip charts with open-source software that runs on inexpensive phones.

A systematic review highlighted that the use of mobile interventions by health care provider for diagnosis and management is generally consistent with modest benefits. Although a lot of research has been done on assessing effectiveness of m-health, still-high quality evidence is lacking [21]. So we undertook an impact assessment study of the ReMiND project to understand the impact of an m-health intervention delivered through ASHA workers for improving counselling to pregnant women that is likely to generate demand for MNCH services, thereby improving coverage of services.

Methods

Study setting

Kaushambi district has a high maternal mortality ratio of 283 deaths per 100 000 live births [22]. 92% of its 1.6 million population live in rural areas [23]. The utilisation of health services is poor in the district with only 5%, 11.3% and 10.7% of women receiving full antenatal care checkups, haemoglobin estimation and ultrasound tests, respectively [22]. With an institutional delivery rate of 60.2% and only 46.9% of infants receiving full immunisation, its poor health coverage makes the district a high priority of the country [22]. Low levels of knowledge and awareness among communities were identified as an important determinant for low coverage of MNCH services [24].

An m-health intervention under the ReMiND project was introduced in two purposively selected community development blocks of the district, namely Mooratganj and Manjhanpur in 2011. It was developed as a collaborative work of two NGOs (Catholic Relief Services (CRS) and Vatsalya); with Dimagi Inc. as the technology innovator. The m-health application served as a job aid for community health volunteers (ASHAs) to provide customised counselling messages for pregnant women [20]. Relatively, economic Java-based mobile phones were used in this intervention. A total of 259 ASHAs in two intervention blocks were trained in the use of the m-health application over a period of 1 year for antenatal care modules. The application had tailored content with locally relevant audio and visual prompts to equip ASHAs with multi-media job aids to support client assessment, counselling, early identification, treatment and/or rapid referral of pregnancy, postpartum and newborn complications [20]. Data entered about the services utilised by pregnant women were pooled on a common server and then used to provide timely reminders to ASHAs for the next due counselling, besides serving as tool for monitoring ASHA activities by supervisors [20]. The data were also shared with government officials during monthly meetings at primary health centres, thus ensuring participation by the government health system [20].

Theory of change

An important reason for the lack of utilisation of MNCH services is the reduced demand for services. The Coverage Evaluation Survey shows that 55% of pregnant women do not seek ANC and 28% women undergoing home deliveries do not consider it necessary [25]. This signifies a potential to increase utilisation through demand generation [16, 26].

One of the ways to generate demand is through quality counselling of pregnant women [21] and use of m-health with its associated audio visual support for improving the quality of counselling delivered through ASHAs.
Improved knowledge about the need for services was likely to drive demand and hence utilisation of MNCH services. Apart from this, continuous monitoring and supervision of ASHA performance through generation of real-time data on utilisation of MNCH services as a result of the m-health application is also likely to contribute towards increased coverage of preventive services. Increase in coverage of preventive services is likely to result in reduction of morbidities during pregnancy, childbirth and the neonatal period. Reduction in morbidity will in turn contribute to reduced mortality. The intervention is also likely to improve the care-seeking during an episode of illness. Improved care-seeking is likely to have an impact on mortality as a result of reduced case-fatality rates with treatment as compared with no treatment.

Study design
A pre- and post-quasi-experimental study with a control group was designed to undertake difference in difference (DID) analysis. We used AHS individual-level data for district Kaushambi to estimate coverage of services in the pre-intervention period. Individual-level AHS data are not available in the public domain and were accessed from the Ministry of Health and Family Welfare based on a special request for this study’s purpose. A cost-effectiveness analysis household survey conducted in 2015, henceforth referred to as CEAHH 2015, served as post-intervention data [16]. Both the CEAHH and AHS surveys used similar methods, tools and data collection techniques [16, 19]. More than three-fourths of the enumerators who undertook the CEAHH survey have conducted various coverage evaluation surveys in Uttar Pradesh including the AHS survey in 2011. The subsequent sections set out the methods of the CEAHH 2015 survey. However, a detailed description of the study design can be obtained from the study protocol published elsewhere [19].

Study area and sampling
The CEAHH 2015 survey was carried out in two intervention and two control community development blocks of Kaushambi district. The control blocks (Kara and Chail) were selected after matching them with intervention blocks (Mooratganj and Manjhanpur) for two health service utilisation indicators viz., per cent of women receiving three or more ANC checkups and coverage of institutional deliveries. For estimating the sample size for ‘mothers with child aged 29 days to 6 months’; neonatal & child morbidity rates and institutional delivery coverage were used to estimate sample size. The difference in rates of full immunisation coverage was used to calculate sample size for ‘mothers with child aged 12–23 months’ in both intervention and control areas. Within the survey blocks, villages were taken as the primary sampling unit (PSU) for the survey. 10% of all villages, that is 69 villages, were randomly selected from each of the intervention and control areas using probability proportional to size (PPS) method. Then, a household enumeration was undertaken to identify and enlist all mothers in two categories. One category was of mothers with children aged 29 days to 6 months and other of mothers with children aged 12–23 months on the date of survey. The number of women to be interviewed per PSU was calculated by PPS method based on the relative size of the PSU. Within each PSU, women in both categories were selected using systematic random sampling. If more than one child in a single age category was present in a given household, one of them was selected randomly. If both the category of clients were present in same household, then each child formed part of the respective sampling frame and had equal probability of getting selected.

Sample size
We calculated sample size based on a 5% change in the coverage of MNCH services and neonatal and child morbidity rate, considering a power of 80% and an alpha error of 5%. Baseline coverage of 15.1%, 30.8% and 18.9% were assumed for institutional delivery and full immunisation coverage and neonatal morbidity rate, respectively [16, 27]. Considering these parameters, sample sizes of 1053 women with a child in the age of 29 days to 6 months, and 1391 women with child in the age of 12–23 months from intervention and control area, respectively, were considered appropriate.

Overall, the AHS 2011 data for district Kaushambi consisted of 450 mothers with a child in the age 29 days to 6 months, and 310 women with a child in the age group of 12–23 months. Within this, 225 mothers with a child in the age group of 29 days to 6 months belonged to both the intervention and control arm, respectively, and hence were included for analysis. Similarly, for the mothers with child in the age group of 12–23 months, the sample comprised 124 and 186 in intervention and control area, respectively.

Data collection and quality control
Data for CEAHH 2015 were collected from April to August 2015 by a team of 35 graduate level field investigators. Mothers with child in age of 29 days to
6 months were interviewed for collecting information on socio-demographic characteristics, utilisation of antenatal care services, institutional delivery and post-natal care; and data on occurrence of any morbidity during neonatal period, its care-seeking and out of pocket expenditure. Women with the children in the age group of 12–23 months were interviewed for socio-demographic characteristics and immunisation status of their infants.

To ensure the quality of data collected during survey, process was monitored for adherence to the sampling plan along with correctness, completeness and accuracy of data. A team of supervisors kept track of sampling techniques being followed by the investigators during the procedure of data collection. The supervisors also cross checked the forms filled by the field investigators by re-interviewing 5% randomly selected women.

Data analysis

The impact assessment results of the CEAHH survey were computed with the help of SPSS 21 and R 3.2.2 package. Since the choice of the two intervention blocks was not random, it could have resulted in selection bias. To minimise this, the propensity score method (PSM) was used to control for the demand-side characteristics among women in intervention and control group which could influence utilisation of various MNCH services [19]. Thus, each woman in the intervention arm was matched on the basis of characteristics such as religion, caste, occupation of father and education of mother with women in the control arm. Nearest neighbour method with 1:1 algorithm and calliper width of 0.025 were used for matching. This calliper width provides only 5% variation in the original coverage and maintains the power of the study. The overall balance test indicated that there were no differences among the women in the intervention and control area. Also, relative multivariate imbalance L1 shows reduction in L1 approaching to zero from 0.377 and 0.25 in intervention and control areas, respectively, suggesting successful matching of the cases in AHS 2011 and CEAHH 2015, respectively (Refer 'Figure S1A & B' and 'Table S1 & S3').

Then, we compared changes in coverage of services in intervention area from 2011 to 2015, relative to the control area using difference-in-difference analysis (DID). Given a two-period setting where \( t = 0 \) before the programme and \( t = 1 \) after programme implementation, letting \( Y^T_t \) and \( Y^C_t \) be the respective outcomes for a programme beneficiary and non-treated units in time \( t \), the DD method estimates the average impact of the intervention is as follows:

\[
DD = E(Y^T_1 - Y^T_0 | T_1 = 1) - E(Y^C_1 - Y^C_0 | T_1 = 0) \tag{1}
\]

In equation (1), \( T_1 = 1 \) denotes treatment or the presence of the programme at \( t = 1 \) which is evaluated from CEAHH data, whereas \( T_1 = 0 \) denotes untreated areas which is evaluated using AHS data (Ref. Appendix S2).

Finally, the DID equation uses the baseline end-line data from intervention and control areas and calculates the average difference in the participants and non-participants over the years using the following equation:

\[
Y_{it} = \alpha + \beta T_{i1} t + \rho T_{i1} + \gamma t + \delta_1 C_1 + \delta_2 C_2 + \delta_3 C_3 + \delta_4 C_4 + \epsilon_{it} \tag{2}
\]

where \( T_{i1} \) is the treatment variable, \( t(1, \ldots, T) \) is the time and \( Y_{it} \) is the outcome of the programme. We used outcome in the form of coverage of key MNCH services such as ANC visits, consumption of iron–folic acid (IFA) supplementation, tetanus toxoid vaccine and full antenatal care were measured. Quality of antenatal care using indicators such as measurement of height, weight, blood pressure; a blood and urine test was also assessed. The control variables \( C_1, C_2, C_3 \) and \( C_4 \) represent socio-demographic variables: religion, caste, education of mother and occupation of father. Thirdly, we also assessed the impact on the identification and reporting of complications by pregnant women during pregnancy and after childbirth. Finally, coverage of institutional deliveries, ambulance usage for delivery and full immunisation were also assessed. Note that the ReMiND project was aimed at targeting only the quality of counselling services which were meant to generate demand for antenatal care services such as number of ANC visits, IFA supplementation, TT vaccination, full ANC care and seeking institutional care for delivery. Besides, women were counselled about recognition of danger signs or complications during pregnancy and after delivery. The intervention aimed at improving their knowledge, and as a result reporting of such complications and appropriate care-seeking.

During the period of evaluation, ReMiND project did not specifically target quality of ANC care at the health facilities, utilisation of postnatal care services or immunisation.

Ethical approval

The Ethics Committee of the Post Graduate Institute of Medical Sciences, PGIMER, Chandigarh approved the study.
Results

The data from respondents of AHS survey in 2011 and CEAHH survey in 2015 yielded pre-intervention and post-intervention coverage for various MNCH services, respectively.

Pre-Intervention data: The AHS 2011 data comprised of 1508 women with a child under 1 year of age. Of these, 225 women with children between 29 days and 6 months of age were included each from intervention and control areas after matched analysis. For the second category, AHS 2011 data comprised of 124 and 186 women in intervention and control areas, respectively, who had children aged 12–23 months. After matching, a sample of 99 women each from intervention and control area, respectively, was selected.

Post-Intervention data: The matched CEAHH 2015 data comprised of 534 women with a child between 29 days to 6 months for intervention and control areas, respectively, and 1019 women with a child between 12 and 23 months age from intervention and control area, respectively.

Socio-demographic characteristics: before and after matching

The overall unmatched sample of women in both AHS and CEAHH data were similar in terms of average age and religion. However, statistically significant differences were observed in terms of caste (P < 0.001), mother’s education (P = 0.005) and father’s occupation (P < 0.001) in the overall sample (Ref. Table S2). After matching, the women from intervention and control areas in both the datasets were similar in terms of all socio-demographic characteristics, the only exception being distribution of religion. However, the difference was very small – 90.9% and 87.5% were Hindus in both intervention and control area, respectively (Ref. Table 1).

Coverage of MNCH services: 2011–2015: unmatched analysis

The coverage of various maternal, neonatal and child health services show an improvement in service utilisation in both the areas (Table 2). In the intervention area, there was an increase in 69.5% in coverage of ambulance usage from 2011 to 2015. Similarly, the coverage of weight measurement, blood test, urine test, self-reporting of illnesses during pregnancy, institutional delivery and full immunisation increased in the range of 30–40% from 2011 to 2015. Coverage of IFA consumption and ≥3 ANC visits did not register much change in intervention area between the intervening years.

Similarly, the women in the control area reported an increase in 70.5% for ambulance usage. An increase in 30%–50% was observed in control area in the coverage of weight measurement, blood test, institutional delivery and full immunisation indicators. No significant change occurred in the coverage of self-reporting of illnesses after delivery. Utilisation for public sector for treatment of complications during pregnancy almost doubled (20.0–49.6%) over the study period in intervention area, with minimal change in the control area (27.40–32.7%).

Matched analysis

The coverage of MNCH services in the matched dataset is shown in Table 3. The coverage of ≥2 tetanus toxoid and ambulance usage increased by more than 80% in the intervention area. Similarly an increase in coverage varying from 40% to 60% was observed for weight measurement, blood test, urine test, self-reporting of illnesses during pregnancy and institutional delivery in the intervention area. Similar to the intervention area, coverage of ≥2 tetanus toxoid and ambulance usage also increased by more than 75% in the control area, whereas coverage for weight measurement, blood pressure, blood test, urine test, self-reporting of illnesses during pregnancy and institutional delivery increased by 30–65%.

Effectiveness of m-health: difference-in-difference findings

The effectiveness of the m-health intervention is assessed with the help of equation 1 along with inclusion of socio-demographic variables (religion, caste, education of mother and occupation of father). As a result, a statistically significant increase in coverage IFA supplementation (12.58%), identification and self-reporting of illnesses/ complication during pregnancy (13.11%) and after delivery (19.6%) was observed in the intervention area vs. the control area (Tables 2 and 3). The coverage of ≥3 ANC visits, ≥2 tetanus toxoid, full ANC and ambulance usage also increased in the intervention area by 10.3%, 4.28%, 1.1% and 2.06%, respectively; however, the change was statistically insignificant. We found a statistically insignificant change in quality of ANC care such as blood pressure, urine test, weight measurement and blood test during ANC care between the intervention and control areas. Similarly, there was statistically insignificant change in the coverage of institutional delivery and full immunisation (Table 4).
### Table 1  Socio-demographic profile of the study populations under Annual Health Survey, 2011 and CEAHH Survey, 2015 in the intervention and control blocks of district Kaushambi after propensity score matching

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Category</th>
<th>Pre-AHS 2011</th>
<th>Post-CEAHH 2015</th>
<th>Occupation of father</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Intervention (n = 99)</td>
<td>Control (n = 99)</td>
<td>Total (n = 198)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(%)</td>
<td>(%)</td>
<td>(%)</td>
</tr>
<tr>
<td>Religion</td>
<td>Hindu</td>
<td>79.80</td>
<td>81.80</td>
<td>80.80</td>
</tr>
<tr>
<td></td>
<td>Muslim</td>
<td>20.20</td>
<td>18.20</td>
<td>19.20</td>
</tr>
<tr>
<td></td>
<td>Others</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Caste</td>
<td>SC</td>
<td>41.40</td>
<td>42.40</td>
<td>41.90</td>
</tr>
<tr>
<td></td>
<td>ST</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>Others</td>
<td>58.60</td>
<td>57.60</td>
<td>58.10</td>
</tr>
<tr>
<td>Education of Mother</td>
<td>Up to 5</td>
<td>7.10</td>
<td>7.10</td>
<td>7.10</td>
</tr>
<tr>
<td></td>
<td>Up to 8</td>
<td>9.10</td>
<td>8.10</td>
<td>8.60</td>
</tr>
<tr>
<td></td>
<td>Up to 10</td>
<td>8.10</td>
<td>7.10</td>
<td>7.60</td>
</tr>
<tr>
<td></td>
<td>Up to 12</td>
<td>3.00</td>
<td>3.00</td>
<td>3.00</td>
</tr>
<tr>
<td></td>
<td>Graduate and above</td>
<td>2.00</td>
<td>2.00</td>
<td>2.00</td>
</tr>
<tr>
<td></td>
<td>Literate but not formally educated</td>
<td>3.00</td>
<td>4.00</td>
<td>3.50</td>
</tr>
<tr>
<td></td>
<td>Illiterate</td>
<td>67.70</td>
<td>68.70</td>
<td>68.20</td>
</tr>
<tr>
<td></td>
<td>Self-Employed</td>
<td>35.40</td>
<td>35.40</td>
<td>35.40</td>
</tr>
<tr>
<td></td>
<td>Wagers</td>
<td>19.20</td>
<td>19.20</td>
<td>19.20</td>
</tr>
<tr>
<td></td>
<td>S (Regular salaried)</td>
<td>44.40</td>
<td>44.40</td>
<td>44.40</td>
</tr>
<tr>
<td></td>
<td>Unemployed</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>Others</td>
<td>Na</td>
<td>Na</td>
<td>Na</td>
</tr>
</tbody>
</table>

Na, Not available – Cases are not observed under this category.
### Table 2 Summary of various health indicators before matching

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Whether Counselling targeted under ReMiND</th>
<th>Intervention</th>
<th>Control</th>
<th>Change in Intervention Area</th>
<th>Change in Control Area</th>
<th>Difference-in-difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥100 IFA Consumption</td>
<td>Yes</td>
<td>2.2 0.8</td>
<td>14.7 0.6</td>
<td>−14.1</td>
<td>12.7</td>
<td></td>
</tr>
<tr>
<td>≥2 Tetanus Toxoid</td>
<td>Yes</td>
<td>55.6 75.7</td>
<td>60.9 84.2</td>
<td>23.3</td>
<td>−3.2</td>
<td></td>
</tr>
<tr>
<td>≥3 ANC visits</td>
<td>Yes</td>
<td>32.4 34.2</td>
<td>36.9 31.6</td>
<td>−5.3</td>
<td>−7.1</td>
<td></td>
</tr>
<tr>
<td>Full ANC</td>
<td>Yes</td>
<td>0 5.6</td>
<td>4.9 12.6</td>
<td>7.7</td>
<td>−2.1</td>
<td></td>
</tr>
<tr>
<td>Weight</td>
<td>−</td>
<td>35.7 73.2</td>
<td>30.7 77.8</td>
<td>47.1</td>
<td>−9.6</td>
<td></td>
</tr>
<tr>
<td>Blood pressure</td>
<td>−</td>
<td>25.5 51.4</td>
<td>25.6 45.2</td>
<td>19.6</td>
<td>6.3</td>
<td></td>
</tr>
<tr>
<td>Blood test</td>
<td>−</td>
<td>21.7 57.9</td>
<td>18.8 55.9</td>
<td>37.1</td>
<td>−0.9</td>
<td></td>
</tr>
<tr>
<td>Urine test</td>
<td>−</td>
<td>19.1 53.1</td>
<td>26.7 51.4</td>
<td>24.7</td>
<td>9.3</td>
<td></td>
</tr>
<tr>
<td>Self-reporting of illnesses during pregnancy</td>
<td>Yes</td>
<td>42.2 80.9</td>
<td>46.2 72.4</td>
<td>26.2</td>
<td>12.5</td>
<td></td>
</tr>
<tr>
<td>Institutional delivery</td>
<td>Yes</td>
<td>56 90</td>
<td>62.7 91.9</td>
<td>29.2</td>
<td>4.8</td>
<td></td>
</tr>
<tr>
<td>Self-reporting of illnesses after delivery Ambulance usage</td>
<td>Yes</td>
<td>2.4 71.9</td>
<td>1.4 71.9</td>
<td>70.5</td>
<td>−1</td>
<td></td>
</tr>
<tr>
<td>Full immunization*</td>
<td>−</td>
<td>7.7 49</td>
<td>7.1 55.5</td>
<td>48.4</td>
<td>−7.1</td>
<td></td>
</tr>
</tbody>
</table>

*In case of full immunization, the AHS has sample size 124 and 186 mothers and CEAHH survey recruited 1418 and 1473 mothers in intervention and control groups, respectively.

### Table 3 Summary of the various health indicators after matching

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Whether Counselling targeted under ReMiND</th>
<th>Intervention</th>
<th>Control</th>
<th>Change in intervention area</th>
<th>Change in control area</th>
<th>Difference-in-difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥100 IFA consumption</td>
<td>Yes</td>
<td>2.00 1.00</td>
<td>14.10 0.40</td>
<td>−13.70</td>
<td>12.7</td>
<td></td>
</tr>
<tr>
<td>≥2 TT</td>
<td>Yes</td>
<td>2.00 85.20</td>
<td>9.10 88.10</td>
<td>79.00</td>
<td>4.2</td>
<td></td>
</tr>
<tr>
<td>≥3 ANC visits</td>
<td>Yes</td>
<td>32.30 37.90</td>
<td>34.30 30.20</td>
<td>−4.10</td>
<td>9.</td>
<td></td>
</tr>
<tr>
<td>Full ANC</td>
<td>Yes</td>
<td>0.00 0.40</td>
<td>1.00 0.40</td>
<td>−0.60</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Weight measurement Blood pressure</td>
<td>−</td>
<td>19.20 53.50</td>
<td>14.10 48.20</td>
<td>34.10</td>
<td>2.</td>
<td></td>
</tr>
<tr>
<td>Blood test</td>
<td>−</td>
<td>14.10 58.80</td>
<td>11.10 61.70</td>
<td>50.60</td>
<td>−5.9</td>
<td></td>
</tr>
<tr>
<td>Urine test</td>
<td>−</td>
<td>12.10 53.30</td>
<td>15.20 54.50</td>
<td>39.30</td>
<td>1.9</td>
<td></td>
</tr>
<tr>
<td>Self-reporting of illnesses during pregnancy</td>
<td>Yes</td>
<td>40.40 84.80</td>
<td>45.50 76.70</td>
<td>31.20</td>
<td>13.20</td>
<td></td>
</tr>
<tr>
<td>Institutional delivery</td>
<td>Yes</td>
<td>55.60 94.60</td>
<td>60.60 95.70</td>
<td>35.10</td>
<td>3.90</td>
<td></td>
</tr>
<tr>
<td>Self-reporting of illnesses after delivery Ambulance usage</td>
<td>Yes</td>
<td>34.30 50.60</td>
<td>38.40 35.20</td>
<td>−3.20</td>
<td>19.5</td>
<td></td>
</tr>
<tr>
<td>Full immunization*</td>
<td>−</td>
<td>1.00 82.70</td>
<td>0.00 79.20</td>
<td>79.20</td>
<td>2.5</td>
<td></td>
</tr>
</tbody>
</table>

*In case of full immunization, the matched sample for intervention and control area 1019 cases each.
Discussion

We undertook a quasi-experimental study with a control group to assess the impact of an m-health application used by village-level community health workers for improving knowledge and care-seeking of beneficiaries for utilising MNCH services. Overall, our findings suggest that out of eight services which were targeted for improvement, the ReMiND project significantly improved IFA supplementation, identification and self-reporting of illnesses during pregnancy and after delivery. The latter could be a result of an improvement in knowledge level of pregnant women for recognition of danger signs. The coverage of three or more ANC visits, tetanus toxoid vaccination, full ANC care and ambulance usage also increased in the intervention area relative to control area by 10.3%, 4.28%, 1.1% and 2.05%; however, the changes were statistically insignificant. We did not find any change in institutional deliveries despite the service being targeted for change as part of ReMiND project. This could be a result of several other demand-side and supply-side interventions being implemented in Uttar Pradesh state which were contributing to an overall improvement in institutional delivery. These interventions were being implemented in intervention and control area alike, and as a result the incremental effect of m-health intervention was not significant.

The ReMiND project primarily serves to increase the capacity of ASHA workers to deliver quality counselling to pregnant women. The effect of better counselling reflects in the generation of demand for ANC services and its utilisation thereof. The findings are also congruent with the theoretical understanding of this model. The project also aimed at improving the knowledge and awareness levels of the pregnant women for recognition of danger signs, which is again reflected in the results, wherein women from intervention area reported significantly higher recognition of complications during pregnancy and after delivery. Alongside, as a result of improved care-seeking, we also find a reduction in the unmet need for care during pregnancy for these complications, as well as a shift in care-seeking to public sector. Together with increased recognition of problems during pregnancy, demand for its care and greater contact with the public sector, probably explains the increased reported use of abdominal examination during ANC care. This may not be necessarily an intended effect of the project, but an associated effect.

As per our knowledge, there has been no robust impact analysis of the m-health intervention from India [21]. Few studies from southern India have assessed the acceptability and feasibility of mobile phones [28, 29], whereas others have studied the impact of m-health as clinical guide for management of diseases such as fever, diarrhoea, respiratory infections [30], HIV consultation [31], etc. A systematic review which assessed the effect of m-health on the coverage of antenatal, postnatal and immunisation services reported a majority (80%, n = 8) studies from African region with only two from Asia [32]. Hence, our study bridges this important gap in evidence. Moreover, with close to one million ASHA workers in India, the question of whether or not such m-health interventions could bolster the extent and quality of health service delivery is an important policy question. Studies around the world report that mobile health messages were better perceived and accepted in the communities. For instance, knowledge about the minimum number of ANC visits increased from 10% to 37% after receiving

Table 4 Impact of m-health intervention on various health indicators in district Kaushambi from 2011 to 2015

| Indicator                                      | Estimate | Std. Error | t value | Pr(>|t|) | Lower Limit of CI | Upper Limit of CI |
|------------------------------------------------|----------|------------|---------|---------|-------------------|-------------------|
| ≥100 IFA                                       | 0.1258   | 0.0202     | 6.361   | <0.0001 | 0.086208          | 0.275196          |
| ≥2 Tetanus Toxoid                              | 0.0428   | 0.0503     | 0.852   | 0.3942  | -0.055788         | 0.68534           |
| Three or more ANC                             | 0.103    | 0.0725     | 1.42    | 0.156   | -0.0391           | 0.988408          |
| Full ANC                                       | 0.0105   | 0.00988    | 1.062   | 0.288   | -0.0088648        | 0.1346928         |
| Weight measurement                            | -0.1068  | 0.0598     | -1.785  | 0.074544| -0.224008         | 0.81353           |
| Blood pressure                                | 0.0075171| 0.073664   | 0.102   | 0.919   | -0.1368643        | 1.003684          |
| Blood test                                    | -0.05668 | 0.07188    | -0.789  | 0.430556| -0.1975648        | 0.97936           |
| Urine test                                    | 0.0236   | 0.0733     | 0.323   | 0.74677 | -0.120068         | 0.9994            |
| Self-reporting of illnesses during pregnancy  | 0.1311   | 0.06385    | 2.053   | 0.0402  | 0.005954          | 0.869998          |
| Institutional delivery                        | 0.04023  | 0.04333    | 0.928   | 0.3533  | -0.0044698        | 0.590562          |
| Self-reporting of illnesses after delivery    | 0.196    | 0.07575    | 2.588   | 0.00977 | 0.004753          | 1.03223           |
| Ambulance usage                               | 0.0206   | 0.05571    | 0.37    | 0.7112  | -0.0885916        | 0.759154          |
| Full immunization                             | -0.06439 | 0.07397    | -0.869  | 0.3812  | -0.2093712        | 1.032606          |
text messages for health promotion on mobile phones in Tamil Nadu [29]. In Afghanistan, the use of m-health resulted in a 20% improvement in antenatal attendance and a 22.3% improvement in the number of women receiving skilled deliveries at a health facility [33]. In terms of quality of counselling, that is whether a client receives complete and accurate information, a study in India showed that after a period of 4 months of use of m-health application, front-line workers had increased their knowledge retention of at least three to five danger signs across all key health categories from 48% at baseline to 70% [34]. Mobile phones thus have not only been used for data collection in field, receiving alerts and reminders, but also to facilitate health education sessions, community education and trainings, and person-to-person communication to strengthen health service delivery [4].

Strengths and limitations

We used standard robust methods to undertake impact evaluation. To control for known confounders, we used propensity score matching. Demand-side factors influencing service utilisation are controlled in propensity score matching of intervention and control areas. Several supply-side interventions were being implemented in district Kaushambi as part of National Health Mission to improve coverage of MNCH services, such as augmentation of health care infrastructure of public health facilities, strengthening the number and capacity of human resources through contractual recruitment and training, initiation of a referral transport service, conditional cash transfer (JSY), free cashless institutional deliveries to reduce financial and geographical barriers to access [35]. Since the district is a basic entity in governance of health care delivery system in India, each of these interventions was implemented in all community development blocks of district Kaushambi uniformly. However, differences in sub-district level performance of between different blocks cannot be ruled out. To address this possibility, we matched the two intervention community blocks with two control blocks from the same district similar in terms of baseline coverage for full ANC coverage and institutional delivery. Matching only takes care of observed heterogeneity across the treated and control samples. However, if unobserved heterogeneity is time invariant and uncorrelated with the treatment over time, then difference-in-difference model estimates are same as the estimates obtained by employing fixed effect regression models [36–38]. So, on one side, we did assume the presence of unobserved heterogeneity in the model; on the other side, it was treated as fixed effect and thus balanced out by use of the double-difference method. To clarify further, we also tried to control the same observed socio-demographic variables used for matching in the DID specification. As a result of this inclusion, there were minuscule changes in the estimates of the DID coefficients. The DID estimates remain same with or without the inclusion of observed socio-demographic variables in DID specification which have already been used at matching stage, assuring the robustness of the matching in adjusting for these individual confounders. In the context of such a study design, with application of PSM and DID, we believe that the analysis adjusts for both the known and the unknown confounders [36–40] and any change in the coverage is attributable to m-health intervention. However, we do acknowledge that having observations at multiple time points rather than two is even better as it reinforces the strength of the conclusion from mere association towards causation. But there is evidence that followed this approach and evaluated the impact based on two time periods [41, 42].

Our study has a few design and methodological limitations. Firstly, allocation of intervention was not randomised. However, we attempted to account for this potential selection bias in our analysis where the demand-side factors at household level were controlled using propensity score matching. Similarly, supply-side health system factors other than m-health application were controlled using DID estimator. The DID method along with PSM technique is good enough to deal with the time invariant heterogeneities but the DID model cannot circumvent time variant unobserved heterogeneity. Also, there may be some individual-level unobserved heterogeneity which cannot be removed even after matching. Such bias cannot be removed completely as unobserved heterogeneities are unknown and cannot be tested [43, 44].

Furthermore, we chose to use calliper method for selecting a matched control participant for every participant in the treated arm. The reason for choosing the calliper method was to get a good match and to avoid the inexact match for the participants in the treated group based on their observed characteristics. As is evident from Figures S1A & B, propensity score densities before matching are significantly different among intervention and control arms. In such a situation, it is advisable to use the calliper method, which chooses the participants from the common support and provides the good match [45–48]. For this, nearest neighbour matching with a calliper automatically uses individuals in (or close to) the area of common support. Also, calliper matchings with widths of 0.2, 0.02 and 0.03 have been reported to have superior results [49], which prompted us to use this method.
The major drawback of using any weighting methods (stratification or full matching or kernel) is an arbitrary assignment of weights to the participants of control group. More importantly, however, our data before matching show significant variation in the propensity score densities between intervention and control groups. In such a situation, these weighting methods are likely to assign extreme weights to the participants of comparison group given that the distribution of the propensity scores is quite dispersed. As a result, the variance produced by this method in such a scenario is actually higher in contrast to theoretical assumption of maintaining the lower variance by these techniques [48, 50–53].

Finally, we would like to state that choosing the best method out of the available techniques remains a contentious issue. A number of methods can be used for matching purposes including stratification and kernel method. However, there is no strict criterion available for the use of one particular method [54]. Most of the literature suggests that the calliper method outperforms other methods such as nearest neighbour with and without replacement and optimal matching [55] and gives better results if it is difficult to find the matches from the control group [56]. Some authors also justify the use of kernel matching and other weighting techniques over the other [57]. In view of the advantages and disadvantages of the various matching techniques and due to the small number of available possible covariates, we consider that the choice of calliper method for the matching purpose in the present study is valid [48].

Another limitation of our matching method is the limited number of variables used for matching. The choice of variable for matching in our study was guided by two factors – relevance of the variable for matching and availability of the same variable in both the datasets. Preference was given to the variables believed to be related to the outcome of interest; thereby reducing the variance engendered due to the inclusion of variables which are unrelated to the outcome [48, 58]. Secondly, this process of variable selection can be based on previous research [59]. Occupation, caste, education of mother and religion have been reported to be associated with utilisation of maternal and child health services [60–65]. In addition, income or wealth status has also been reported to be associated with outcomes; however, there was no variable related to income or consumption expenditure in the AHS data, so the latter could not be included in matching. In light of this, we included all possible relevant variables available for matching, and did not have further scope to include any other variable to address the observed heterogeneity among treatment and control.

Secondly, the sample of women dropped after matching, especially in the AHS (2011) dataset. Based on retrospective power calculation for the matched sample, we found that our study had a power of 80% to detect a difference of at least 10% for four indicators, that is coverage of IFA consumption, coverage of ≥2 Tetanus toxoid, full ANC and ambulance usage. For rest of the indicators, it had an 80% power to identify the minimum difference of 10–20%. In this regard, it is important to highlight that intervention studies have different implications for researchers and policy-makers or programme managers. Although researchers may be keen to detect even minimum possible differences in the outcomes, programme managers would be interested in scaling up interventions which have some programmatically relevant improvement in coverage of services. Hence, we believe that while our study may be underpowered to detect very small changes between intervention and control groups, it is powered enough to detect programmatically relevant change in coverage. Hence, our evaluation takes a much more pragmatic viewpoint of the intervention’s success.

Thirdly, the reference period which we used for estimating coverage of ANC and PNC services in the CEAHH (2015) survey was 6 months, which was 1 year in the AHS (2011) survey. However, this was done to reduce the chances of recall bias which could be possible when using longer reference periods for recall. Moreover, since the methodology used for data collection in each of the surveys was the same for women in both intervention and control areas during a given survey, there is no possibility of a systematic bias in findings as a result of these differences.

We would like to acknowledge that some of the endpoints being evaluated as part of this study, such as quality of ANC care, postnatal care coverage and immunisation, were not directly targeted using the m-health intervention. However, we considered evaluating these endpoints as such to evaluate whether there be spin-off benefits of the intervention which aims at improving the coverage of services in antenatal period by bringing the pregnant women in contact health system. This greater contact with health system could lead to increase in utilisation of services even beyond pregnancy.

Conclusion

To conclude, our study fills an important gap in evidence of literature, which is relevant not only in context of India, but also for similar low- and middle-income countries. Overall, our findings suggest that out of eight services which were targeted for improvement by the ReMiND project, coverage of iron–folic acid
supplementation, identification, self-reporting and care-seeking of complications during pregnancy after delivery registered a significant improvement as result of m-health intervention. The increase in coverage of ANC visits, TT vaccine and ambulance use was not statistically significant. In light of these findings, we recommend an assessment of the costs to understand whether the improvements in service utilisation justify the increase in investments on account of m-health. The Government of Uttar Pradesh and the Government of India could consider replication of such an intervention in the entire state or country.

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References


**Supporting Information**

Additional Supporting Information may be found in the online version of this article:

**Figure S1.** Distribution of propensity score before matching.

**Figure S2.** Distribution of propensity score after matching.

**Table S1.** Overall balance test for Impact Assessment of ReMiND project

**Table S2.** Socio-demographic profile of the study population under AHS, 2011 and CEAHH Survey, 2015 in the intervention and control blocks of district Kaushambi before propensity score matching.

**Appendix S1.** Theory of change.

**Appendix S2.** Difference in difference.