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Use of mobile phones for improving vaccination coverage among children living in rural hard-to-reach areas and urban streets of Bangladesh

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Abstract

In Bangladesh, full vaccination rates among children living in rural hard-to-reach areas and urban streets are low. We conducted a quasi-experimental pre-post study of a 12-month mobile phone intervention to improve vaccination among 0–11 months old children in rural hard-to-reach and urban street dweller areas. Software named “mTika” was employed within the existing public health system to electronically register each child’s birth and remind mothers about upcoming vaccination dates with text messages. Android smart phones with mTika were provided to all health assistants/vaccinators and supervisors in intervention areas, while mothers used plain cell phones already owned by themselves or their families. Pre and post-intervention vaccination coverage was surveyed in intervention and control areas. Among children over 298 days old, full

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Contributors

JU was the Principal Investigator of the study and was involved in every aspect of the study and manuscript from conceptualization to implementation to manuscript writing and submission. MS was involved in study implementation and data analysis. LH and NA were involved in literature review, data analysis and manuscript writing. AL contributed to the adaptation of mTika and manuscript review. MC, LV, and KZ contributed to study implementation and manuscript review. CP and DB are senior professors who were involved in study design and manuscript writing and also provided overall guidance and mentorship for this research. All authors read and approved the final manuscript.

Conflict of interest

The authors report no conflicts of interest.

vaccination coverage actually decreased in control areas – rural baseline 65.9% to endline 55.2% and urban baseline 44.5% to endline 33.9% – while increasing in intervention areas from rural baseline 58.9% to endline 76*8%, difference +18.8% (95% CI 5.7–31.9) and urban baseline 40.7% to endline 57.1%, difference +16.5% (95% CI 3.9–29.0). Difference-in-difference (DID) estimates were +29.5% for rural intervention versus control areas and +27.1% for urban areas for full vaccination in children over 298 days old, and logistic regression adjusting for maternal education, mobile phone ownership, and sex of child showed intervention effect odds ratio (OR) of 3.8 (95% CI 1.5–9.2) in rural areas and 3.0 (95% CI 1.4–6.4) in urban areas. Among all age groups, intervention effects on age-appropriate vaccination coverage were positive: DIDs +13.1–30.5% and ORs 2.5–4.6 ($p < 0.001$ in all comparisons). Qualitative data showed the intervention was well-accepted. Our study demonstrated that a mobile phone intervention can improve vaccination coverage in rural hard-to-reach and urban street dweller communities in Bangladesh. This small-scale successful demonstration should serve as an example to other low-income countries with high mobile phone usage.

Keywords

Child; Immunization; Mobile phone; mHealth; Rural; Urban

1. Introduction

Childhood immunization reduces child mortality from preventable diseases; however, children living in remote rural areas and on urban streets have lower immunization rates and worse health outcomes [1–5]. Bangladesh has a robust Expanded Programme on Immunization (EPI) with full vaccination coverage in 12–23 months old children of 81% nationally, but only 42–60% in 22 rural hard-to-reach districts and 70% in Dhaka city slums [1,6,7]. Prior interventions in Bangladesh to increase vaccinations have included improving EPI services with extended EPI times, additional training for service providers, and active screening for unimmunized children in acute care facilities as well as improving community health-seeking behavior with education, immunization support groups, and health provider outreach to communities [6–9]. These interventions can successfully increase vaccination coverage, however, they are not cost-effective at large scale [9].

One considerable challenge is accurately tracking children and vaccinations, especially in remote rural and urban street dweller populations [2,6]. A recent systematic review found poor agreement between parental recall, EPI cards, and official health records for vaccination history, but only 5 studies were in low-mid income countries (LMICs) [10–12]. A separate review of Demographic and Health Surveys and UNICEF's Multiple Indicator Cluster Sample surveys in 101 countries, mostly LMICs, found only 55% of children had available EPI cards, but good correlation existed between *maternal* report (not general household report) and EPI cards [13]. While mothers without cards can over or underestimate vaccinations depending on social desirability, education, and/or misremembering multiple doses, many studies show consistency in maternal recall and *underestimation* of true vaccination coverage if using only EPI cards [11,13,14]. Moreover, children who have never received vaccines would not have EPI cards. Studies in Asia and

Bangladesh show high correlation between maternal recall and EPI cards, and most EPI programs in LMICs use maternal recall with EPI cards to better track vaccination coverage [1,13,14].

One strategy yet to be researched in Bangladesh is using mobile phones to increase child immunizations by better tracking and reminders. Mobile health (mHealth) programs have gained popularity worldwide to communicate health information at low cost to large groups of people, including hard-to-reach or geographically remote communities [15–19]. Mobile phones have been shown to increase vaccination of underserved populations in Thailand, India, and Brazil [20–22]. Moreover, mobile phone parental reminders linked to electronic medical records and immunization registries can be used in large populations at low cost [23–25]. In Bangladesh, mobile phone ownership increased from 32% in 2007 to 78% in 2011, and mHealth services have increased for several years [26]. However, there is little published research on health impacts of mHealth interventions in Bangladesh [17–19,27,28].

We hypothesized that a mobile phone vaccination registration and reminder system could improve child vaccination coverage in rural hard-to-reach and urban street dweller populations of Bangladesh. Our overall objective was to develop and test a mechanism to use mobile phones to improve child vaccination coverage using the existing Bangladesh public health system, and our specific aims were to assess feasibility and effectiveness of our mobile phone system of vaccination registry, newborn tracking, and parental reminders in rural hard-to-reach and urban street dweller areas.

2. Materials and methods

2.1. Study design and sites

We conducted a quasi-experimental pre-post study to compare vaccination coverage before and after our mobile phone intervention in rural hard-to-reach and urban street dweller populations. We conducted this study through the existing Bangladesh public health system from April 2013 to March 2014. We selected two control and two intervention areas first by geography and then by demographic and health characteristics. We chose two rural hard-to-reach *upazilas* (sub-districts) in Sunamgonj district, which has the most *haors* (wetlands) in Bangladesh and consistently low vaccination rates [1]. We chose two Dhaka city zones from the six zones with the most street dwellers (out of 10 total zones). Hard-to-reach areas were defined as physically remote and difficult to access by health providers. Street children were identified as those who sleep on streets, railway terminals, bus stations, construction sites, parks, and other public places. We matched control and intervention areas based on: population density, total fertility rate, population served by local health facilities, and vaccination coverage.

2.2. Study population

The intervention population included pregnant women, mothers with children age 0–11 months, and EPI service providers in study areas. Women were eligible for participation if they were over 18 years old, gave birth within one year prior to data collection, and were

able to give written informed consent in Bengali. The impact evaluation survey population included children age 0–11 months in study areas.

3. Intervention

We adapted an Android smartphone application connected with a web database named "mTika" created by a research team working with the Bangladesh Ministry of Health and Family Welfare's (MOHFW) Management Information System department. mTika included: (i) smart phone-based registration of pregnant women, (ii) short message service (SMS) birth notifications from mothers, (iii) automated SMS vaccination reminders to mothers, (iv) vaccination reminders for health workers, and (v) smart phone and web-based EPI monitoring by supervisors. mTika was implemented within and by the existing Bangladesh health system in our intervention study areas.

Health Assistants (HAs)/vaccinators under the MOHFW routinely list pregnant women in their catchment areas for health outreach. We provided HAs/vaccinators and supervisors with Android smart phones and mTika training, while mothers used plain cell phones already owned by themselves or their families. HAs/vaccinators recruited from their lists women in the third trimester of pregnancy and registered names, addresses, mobile phone numbers (of women or close contacts), and expected date of delivery into mTika. Upon registration, mothers were assigned a unique code and taught how to send SMS text messages from a regular mobile phone to mTika after childbirth. This birth notification triggered an immediate, server-driven SMS reply as well as generation of a newborn identification number, customized vaccination timetable, and future vaccination reminders on appropriate dates. If registered mothers did not send birth notifications, their children could be registered at time of delivery or at EPI centers. In addition, children could be enrolled directly in mTika at EPI centers without their mothers being registered.

For each routine vaccine dose, mTika sent automatic SMS reminders to mothers about upcoming EPI sessions. In rural areas, EPI sessions are scheduled every 4 weeks and vaccinations are administered for free at government health centers. In urban areas, EPI sessions are scheduled at least weekly and vaccinations are provided for free or small fees from government-contracted non-governmental organizations (NGOs). mTika did not change existing EPI infrastructure, but reminded mothers to take children to EPI sessions at appropriate times based on customized vaccination timetables. mTika sent one SMS *one day before* a scheduled EPI session, a second SMS *at opening time* on the day of the EPI session, and a third SMS two hours *before closing time* on the day of the EPI session. Symbols taught to mothers at registration were used in SMS messages for mothers who were illiterate. EPI providers could access mTika from smart phones to check the number and vaccination details of target children due for a given EPI session. Health workers would log administered vaccines into mTika, and mTika then would update automatically future vaccination timetables and reminders. At the end of an EPI session, mTika would highlight children who did not show. EPI supervisors could access mTika from the web to monitor vaccinators' daily performance.

3.1. Sampling

We conducted cross-sectional baseline and endline surveys of vaccination coverage among children 0–11 months old in control and intervention areas. Different children were sampled at endline than at baseline. In intervention areas, children surveyed at endline included those registered and not registered with mTika in order to evaluate community-wide vaccination coverage. We calculated a sample of 530 children per group was required to detect a 10% increase in full vaccination coverage from a baseline of 56%, with 80% power, 0·05 level of significance, and cluster effect size of 1·5. We used two-stage random cluster sampling first to select community clusters within study areas and then to select households within clusters. We used the World Health Organization (WHO) cluster-sampling methodology to randomly select 40 clusters within each of our two control and two intervention study areas: a cluster consisted of an EPI center with corresponding household catchment area. In rural areas, each *upazila* is divided into 8–10 unions and each union into 24 EPI sites, each covering around 200 households (1000 persons). In Dhaka city, each zone includes about 100 EPI sites. In each cluster, we listed all house-holds with children 0–11 months old and randomly selected 13 households for survey: if a household had more than one eligible child, we randomly selected one child for survey.

We also conducted qualitative interviews on perceptions about mTika. In intervention areas, a total of 30 mothers were randomly selected from full vaccination, drop out (missed doses), and left out (never vaccinated) groups and 30 service providers from HAs, supervisors, and government officials were selected for in-depth interviews. Two group discussions were conducted with vaccinators to assess benefits, barriers, and recommendations about mTika.

3.2. Data collection

We assessed vaccination coverage quantitatively using EPI cards when available and maternal recall with structured questionnaires. We did not rely on the mTika database for vaccination rates because this would miss children not registered in mTika as well as vaccinations not logged into mTika by HAs/vaccinators for logistic or technical reasons. Maternal recall was used to include children with lost EPI cards and children who were never vaccinated. Qualitative data were collected by experienced interviewers using interview and discussion guidelines. Interviews and group discussions were recorded in Bengali, transcribed, and translated into English.

3.3. Data analysis

We analyzed vaccination rates by full vaccination and by age-appropriate vaccination doses to capture community-wide coverage and analyzed data from EPI cards with and without maternal recall to capture more vaccination history. The EPI schedule during the study period included: 1 dose of Bacillus Calmette–Guérin (BCG) vaccine against tuberculosis at birth, 3 doses of pentavalent (Penta) vaccine covering diphtheria, tetanus, pertussis, hepatitis B, and *Haemophilus influenzae* type b at 6, 10, and 14 weeks, and 1 dose of measles rubella (MR) vaccine at 9 months. We added 4 weeks to eligible ages because EPI sessions are held every 4 weeks in some rural areas, thus children over 298 days old (9 months + 28 days) were eligible for “full vaccination”. Other categories for 298+ days were “yet to receive MR” which is the last recommended vaccine at 9 months, “invalid dose” or dose given

earlier than recommended times, “drop out” or missing doses in recommended EPI schedule other than MR, and “left out” or never vaccinated. We defined other EPI-specific ages with a 4-week adjustment: age 70+ days for BCG and Penta1 (due at 6 weeks), age 98+ days for BCG and Penta2 (due at 10 weeks), and age 126+ days for BCG and Penta3 (due at 14 weeks).

Sociodemographic characteristics of mothers and children in rural and urban, control and intervention areas were compared using X^2 tests. Vaccination coverage was compared between baseline and endline surveys using *Z*-tests. Difference-in-difference (DID) estimation was used to track longitudinal differences in coverage from baseline to endline between control versus intervention areas. Use of DID eliminates the influence of individual characteristics correlated with intervention participation and impacts. DID was tested for statistical significance and a 95% confidence interval around the odds ratio (OR) using logistic regression model with an interaction of area and time, adjusting for maternal education, mobile phone ownership, and sex of child. Quantitative data were analyzed using STATA (version 12). Qualitative data were analyzed using thematic content analysis.

3.4. Ethical aspects

The study protocol was approved by the International Centre for Diarrhoeal Disease Research, Bangladesh (icddr,b) ethics review board. Written informed consent was obtained from pregnant women, mothers, and service providers.

4. Results

Sociodemographic characteristics of the study population are shown in Table 1. We sampled between 518 and 522 children across all urban and rural, control and intervention groups at baseline and endline. Approximately half of mothers were under 25 years old and 11–26% had completed primary education or higher. Mobile phones were accessible to over 70% of mothers, with 28–51% owning phones and 42–53% sharing phones. X^2 tests revealed statistically significant differences across groups in maternal age, maternal education, mobile phone ownership, and sex of children, but no obvious patterns emerged.mTika registered a total of 4508 pregnant women and 8360 children and sent 220,105 SMS messages over the 12-month study period (Fig. 1). mTika registered children by: 1) SMS birth notifications from mothers registered during pregnancy, 2) registration at EPI sessions linked to registered mothers, and 3) separate enrollment at EPI sessions not linked to registered mothers. In the rural intervention area, mTika registered 3429 pregnant women: 794 (23%) sent birth notifications, 1019 (30%) did not report births, and 1616 (47%) registered newborns at EPI sessions. mTika ultimately registered a total of 5527 rural hard-to-reach children: 794 (14%) from birth notifications, 1616 (29%) from EPI sessions with registered mothers, and 3127 (56%) from separate enrollment not linked with registered mothers. In the urban intervention area, mTika registered 1079 pregnant women: 515 (48%) sent birth notifications, 513 (48%) did not report births, and 51 (5%) registered newborns at EPI sessions. mTika ultimately registered a total of 2823 urban street dwelling children: 515 (18%) from birth notifications, 51 (2%) were registered from EPI sessions with registered

mothers, and 2257 (80%) children from separate enrollment not linked with registered mothers.

Vaccination coverage among children over 298 days old improved after mTika intervention in rural and urban areas, highlighted by difference-in-difference (DID) calculations (Table 2). EPI programs use full vaccination coverage in children 12–23 months old to evaluate overall program success. In our study, full vaccination coverage was lower in urban areas, 33.9–57.1%, than in rural areas, 55.2–76.8%. In rural areas, baseline full vaccination in the intervention area was 58.9%, lower than in the control area, 65.9%. Full vaccination in the rural intervention area increased from 58.9% to 76.8% while decreasing in the rural control area from 65.9% to 55.2%, resulting in a DID of +29.5% ($p < 0.001$). A similar trend was seen in urban areas, where full vaccination rates in the urban intervention area increased from 40.7% to 57.1% while decreasing in the urban control area from 44.5% to 33.9%, resulting in a DID of +27.1% ($p < 0{\cdot}05$). The rates of invalid dose (vaccinations given too early), drop out (missing doses) and left out (received no vaccinations) all decreased in intervention areas, which is consistent with increases in full vaccination coverage.

Age-appropriate vaccination also increased with mTika in rural and urban areas, shown with a logistic regression model of DID adjusted for child's sex, maternal education and mobile phone ownership (Table 3). The intervention effect on age-appropriate vaccination was positive for all age groups, with DIDs ranging from +13.1% to +30.5% and ORs ranging from 2.5 to 4.6 ($p < 0.001$ across all rural versus urban comparisons per age group). The ORs of left out rates were correspondingly lower across all age groups. The largest intervention effect was on age-appropriate vaccination for children over 70 days, OR 4.6 in the urban intervention area ($p < 0.001$, 95% CI 2.1–7.8).

Using EPI cards only does not include left out never vaccinated children, and EPI card-only analysis shows urban and rural study areas have similar trends in age-appropriate vaccination coverage (Table 4). Among all children irrespective of mTika intervention, 98–100% received the BCG vaccine appropriately by age 70 days. Full vaccination rates were 60–78% in rural areas and 48–57% in urban areas. In control groups, full vaccination declined from baseline to endline surveys in both rural and urban areas, although this was not statistically significant. In intervention groups, nearly all categories of age-appropriate vaccinations increased or remained similar from baseline to endline surveys across both rural and urban areas. Appropriate vaccination coverage for children over 98 days (BCG + Penta2) increased in the rural intervention area from 88% to 94% ($p < 0.001$) but also in the rural control area from 93% to 98% ($p < 0.05$). Vaccination coverage in children over 126 days (BCG + Penta3) also increased in the rural intervention area from 75% to 85% ($p < 0.001$).

Qualitative data showed that most interviewed mothers perceived mTika as good or excellent in helping them vaccinate their children in a timely manner. Mothers liked the multiple SMS reminders about EPI sessions and easily understood SMS messages and symbols. Service providers who were interviewed considered mTika user-friendly, time-efficient, and helpful in reducing their workload. mTika helped service providers and

supervisors tally missed vaccinations and drop out cases, identify target children for door-to-door visits, and easily monitor EPI performance on the web.

5. Discussion

This quasi-experimental pre-post intervention study demonstrated that use of a mHealth approach to strengthen routine immunization programs in the existing public health system in Bangladesh was acceptable and successful in increasing vaccination coverage among children in rural hard-to-reach and urban street dweller communities. Using information and communications technology for health systems strengthening is a fast-growing arena of global health, but many interventions lack rigorous research on implementation processes, outcomes, and health impacts [18–20,29,30]. Several mHealth interventions have been implemented in Bangladesh since the 1990s, with one recent analysis reporting at least 26 mHealth programs underway since March 2012 [29]. Among these initiatives, 4 were created by the public sector, 19 by private entities, and 4 by NGOs, with health targets ranging from breast cancer screening to health-care access [29]. Published studies on mHealth interventions' impact, cost, and sustainability are gradually increasing globally, although there remains an imbalance between the novelty of mHealth programs and the paucity of robust supporting evidence, particularly when opportunities for financial gain are high [29,31,32].

Our study is a useful first example of robust implementation research demonstrating health impacts from a mobile phone immunization intervention in Bangladesh. Our findings are generalizable to other hard-to-reach remote rural and slum areas in Bangladesh given that 1) full vaccination coverage in our study was similar to the 42–70% found in prior studies and 2) mobile phone ownership in our study was similar to the 75–89% found in prior studies [1,27,28]. Mobile phone access and ownership have increased dramatically worldwide – 60% of sub-Saharan Africa has mobile phone coverage – which has created a wide array of new development, banking, and economic opportunities for all socioeconomic strata in many LMICs [33]. Whether or not LMIC governments will harness mobile technology to improve their public health systems should not depend on mobile phone access, but instead on demonstrated impact, cost-effectiveness, and sustainability at large scale [18,28].

We observed vaccination coverage among children living on urban streets was markedly lower than in remote rural areas, highlighting how urban street dwellers are even harder to reach with health services than other communities. Half of the world's population currently lives in cities, and migration with rapid urbanization will result in a projected increase of 2.5 billion people in cities by 2050, with 90% of this growth in Asia and Africa [34]. Bangladesh is the world's most densely populated country with 16 million people living in its capital Dhaka and approximately one-third of city residents living in slums [34,35]. Slum residents lack reliable access to housing, water, sanitation, and health, and migrants are generally poorer, less educated, less knowledgeable about locally available services, and suffer worse health outcomes [3,5,8,36]. In this study, the majority of urban street children registered with mTika were *not* linked with registered mothers, but despite the challenge of migration and tracking families over time, vaccination coverage did increase in urban

intervention areas. mHealth interventions could be a powerful low-cost tool for health outreach to slums by linking residents to nearby health services.

Study limitations include constraints surrounding study design and challenges in mTika intervention implementation. Due to time and funding constraints, we were unable to examine a large number of children eligible for full vaccination as this would have required a 12-month intervention period plus a 12-month follow-up period for children to reach appropriate age for full vaccination. While examining age-appropriate vaccination allows a comprehensive view of community-wide vaccination coverage, compliance decreases over time as children age, families move, and follow-up becomes difficult. Furthermore, because the mTika intervention was implemented by the existing public health system, we were unable to rigorously standardize implementation procedures, randomize EPI centers or service providers, or use contemporaneous controls. The quasi-experimental pre-post design, however, did allow us to research feasibility and acceptability of integrating mTika into the existing Bangladesh EPI infrastructure and better assess future scalability and sustainability. Using maternal recall for vaccination history is not as accurate as EPI cards, but is a necessary reality in many LMICs. More than one-third of parents could not show EPI cards during our surveys either because they lost the cards or their children were never vaccinated and never received cards. Ultimately, a larger scale and longer duration study would allow more accurate analysis of mTika's health impacts and cost-effectiveness.

mTika implementation challenges included difficulties with developing entirely new software, multiple other groups working in this space, growing capacity of health workers and field staff to use smart phones, low active mTika usage by mothers, and inability to track SMS notifications by different vaccination coverage categories. Frequent initial trainings were held to improve staff competence and capacity early in implementation. Low active engagement with the system by mothers, as evidenced by low rates of birth notifications, is a challenge also observed in other mHealth field sites (Labrique, personal communication, January 2015). However, low rates of birth notifications by mothers did not indicate complete lack of engagement by mothers as vaccination coverage and qualitative data showed mothers responded to mTika SMS reminders. Ultimately, implementation challenges were mitigated by continuous monitoring of field activities, brainstorming among project and technical staff, and refining technology as per project needs. Future iterations of mTika should focus on promoting active mTika use by pregnant women, following up registered mothers who did not send birth notifications to enroll their children into mTika, and reaching mothers of newborns not registered during pregnancy.

6. Conclusions

Use of mobile phone for improving vaccination coverage in rural hard-to-reach and urban street dweller communities in Bangladesh is feasible and has measurable health impact. Key next steps are research in mechanisms to increase mTika intervention's health impacts, scalability, sustainability, and cost-effectiveness. This small-scale successful demonstration could serve as an example to other low-income countries with high mobile phone usage and robust EPI programs.

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References

[1]. Directorate General of Health Services (DGHS). EPI coverage evaluation survey. Expanded Programme on Immunization, Ministry of Health and Family Welfare, the Government of Bangladesh; Dhaka: 2011.

[2]. Uddin MJ, Koehlmoos T, Ali A, Saha NC, Hossain M. Health needs and health-care-seeking behaviour of street-dwellers in Dhaka, Bangladesh. Health Policy Plan. 2009; 24:385–94. [PubMed: 19535539]

[3]. Perry H, Weierbach R, El-Arifeen S, Hossain I. A comprehensive assessment of the quality of immunization services in one major area of Dhaka City, Bangladesh. Trop Med Int Health. 1998; 3:981–92. [PubMed: 9892283]

[4]. Mutua MK, Kimani-Murage E, Ettarh RR. Childhood vaccination in informal urban settlements in Nairobi, Kenya: who gets vaccinated? BMC Public Health. 2011; 11:6. [PubMed: 21205306]

[5]. Agarwal S, Bhanot A, Goindi G. Understanding and addressing childhood immunization coverage in urban slums. Indian Pediatr. 2005; 42:653–63. [PubMed: 16085966]

[6]. Uddin MJ, Larson C, Oliveras E, Khan AI, Quaiyum MA, Saha NC. Child immunization coverage in rural hard-to-reach haor areas of Bangladesh: possible alternative strategies. Asia-Pacific J Public Health. 2009; 21:8–18.

[7]. Uddin MJ, Larson C, Oliveras E, Khan AI, Quaiyum MA, Saha NC. Effectiveness of combined strategies to improve low coverage of child immunization in urban slums of Bangladesh. International Centre for Diarrhoeal Disease Research, Bangladesh (ICDDR, B). 2008

[8]. Uddin MJ, Larson C, Oliveras E, Khan AI, Quaiyum MA, Saha NC. Child immunization coverage in urban slums of Bangladesh: impact of an intervention package. Health Policy Plan. 2010; 25

[9]. Hayford K, Uddin MJ, Koehlmoos TP, Bishai DM. Cost and sustainability of a successful package of interventions to improve vaccination coverage for children in urban slums of Bangladesh. Vaccine. 2014; 32:2294–9. [PubMed: 24631083]

[10]. Miles M, Ryman TK, Dietz V, Zell E, Luman ET. Validity of vaccination cards and parental recall to estimate vaccination coverage: a systematic review of the literature. Vaccine. 2013; 31:1560–8. [PubMed: 23196207]

[11]. Murray CJ, Shengelia B, Gupta N, Moussavi S, Tandon A, Thieren M. Validity of reported vaccination coverage in 45 countries. Lancet. 2003; 362:1022–7. [PubMed: 14522532]

[12]. Luman ET, Ryman TK, Sablan M. Estimating vaccination coverage: validity of household-retained vaccination cards and parental recall. Vaccine. 2009; 27:2534–9. [PubMed: 18948158]

[13]. Brown J, Monasch R, Bicego G, Burton A, Boerma JT. An assessment of the quality of national child immunization coverage estimates in population-based surveys. MEASURE Evaluation, Carolina Population Center, University of North Carolina at Chapel Hill. 2002

[14]. Khan A, Khan A. Validating measures of immunization coverage: lessons from international experience. Research and development solutions, policy briefs series No. 2012; 10

[15]. Vodopivec-Jamsek V, de Jongh T, Gurol-Urganci I, Atun R, Car J. Mobile phone messaging for preventive health care. Cochrane Database Syst Rev. 2012; 12

[16]. Lemaire, J. Advanced Development for Africa; Geneva: 2011. Scaling up mobile health: elements necessary for the successful scale up of mHealth in developing countries.

[17]. Kahn JG, Yang JS, Kahn JS. 'Mobile' health needs and opportunities in developing countries. Health Aff. 2010; 29:252–8.

[18]. Mehl G, Labrique A. Prioritizing integrated mHealth strategies for universal health coverage. Science. 2014; 345:1284–7. [PubMed: 25214614]

[19]. Agarwal S, Labrique A. Newborn health on the line: the potential mHealth applications. JAMA. 2014; 312:229–30. [PubMed: 24953141]

[20]. Kaewkungwal J, Singhasivanon P, Khamsiriwatchara A, Sawang S, Meankew P, Wechsart A. Application of smart phone in 'Better Border Healthcare Program': a module for mother and child care. BMC Med Informat Decis Making. 2010; 10:69–69.

[21]. Malviya, S. Text messages to boost immunization. Available at: http://www.kiwanja.net/database/article

[22]. United Nations Foundation – mobile phones to help meet health needs in Brazil's indigenous communities. Available at: <http://www.unfoundation. org/news-and-media/press-releases/2011/info-as-care.html>

[23]. Irigoyen MM, Findley S, Earle B, Stambaugh K, Vaughan R. Impact of appointment reminders on vaccination coverage at an urban clinic. Pediatrics. 2000; 106:919–23. [PubMed: 11044144]

[24]. Stockwell MS, Kharbanda EO, Martinez RA, Vargas CY, Vawdrey DK, Camargo S. Effect of a text messaging intervention on influenza vaccination in an urban, low-income pediatric and adolescent population: a randomized controlled trial. JAMA. 2012; 307:1702–8. [PubMed: 22535855]

[25]. Stockwell MS, Kharbanda EO, Martinez RA, Lara M, Vawdrey D, Natarajan K, Rickert VI. Text4Health: impact of text message reminder–recalls for pediatric and adolescent immunizations. Am J Public Health. 2012; 102:e15–21. [PubMed: 22390457]

[26]. Government of Bangladesh, Bureau of Statistics. Bangladesh demographic and health survey. Government of Bangladesh, Bureau of Statistics; 2011.

[27]. Ahmed T, Lucas H, Khan AS, Islam R, Bhuiya A, Iqbal M. eHealth and mHealth initiatives in Bangladesh: a scoping study. BMC Health Serv Res. 2014; 14:260. [PubMed: 24934164]

[28]. Chib A. The promise and peril of mHealth in developing countries. Mob Media Commun. 2013; 1:69–75.

[29]. Khatun F, Hanifi SMA, Iqbal M, Rasheed S, Rahman MS, Ahmed T, et al. Prospects of mHealth services in Bangladesh: recent evidence from Chakaria. PLoS One. 2014:9.

[30]. Ahmed T, Bloom G, Iqbal M, Lucas H, Rasheed S, Waldman L, et al. e-Health and m-health in Bangladesh: opportunities and challenges. Institute of Development Studies. 2014

[31]. Hoque M, Mazmum M, Ahsan F, Bao Y. e-Health in Bangladesh: current status, challenges, and future direction. Int Technol Manag Rev. 2014; 4:87–96.

[32]. Vassallo DJ, Hoque F, Roberts MF, Patterson V, Swinfen P, Swinfen R. An evaluation of the first year's experience with a low-cost telemedicine link in Bangladesh. Journal of Telemedicine and Telecare. 2001; 7:125–38. [PubMed: 11346472]

[33]. Aker JC, Mbiti IM. Mobile phones and economic development in Africa. Center for Global Development Working paper. Center for Global Development. 2010

[34]. United Nations. World urbanization prospects: the 2014 revision, highlights. Department of Economic and Social Affairs, Population Division. 2014

[35]. Martine G, Marshall A. State of world population 2007: unleashing the potential of urban growth. UNFPA. 2007

[36]. Ahmed SM, Hossian A, Khan MA, Mridha MK, Alam A, Chowdhury N, et al. Using formative research to develop MNCH programme in urban slums in Bangladesh: experiences from MANOSHI BRAC. BMC Public Health. 2010; 10:663. [PubMed: 21044335]

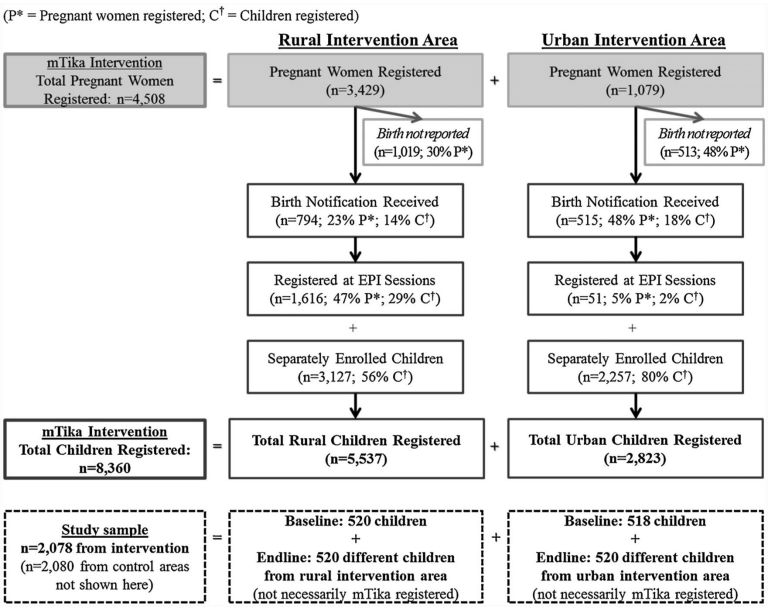

Fig. 1.

Number of pregnant women and children registered in mTika intervention and study sample (P* = Pregnant women registered; C† = Children registered).

Table 1

Sociodemographic characteristics of mothers and children in rural hard-to-reach and urban street dweller, control and intervention areas.

Characteristics	Rural hard-to-reach						Urban street dweller					
	Control area			Intervention area			Control area			Intervention area		
	Baseline % (*n* = 520)	Endline % (*n* = 520)	χ^2-value (*p*-Value)	Baseline % (*n* = 520)	Endline % (*n* = 520)	χ^2-value (*p*-Value)	Baseline % (*n* = 520)	Endline % (*n* = 522)	χ^2-value (*p*-Value)	Baseline % (*n* = 518)	Endline% (*n* = 520)	χ^2 -value (*p*-Value)
Age of mothers (years)												
< 25	42	52	10.2 ($p < 001$)	41	45	2.4 ($p < 0\text{-}31$)	57	56	2.9 ($p < 0.23$)	61	56	5.3 ($p < 0.07$)
25-29	34	26		34	30		26	23		24	24	
≥ 30	24	22		25	25		17	21		15	20	
Respondent's education												
None	36	29	7.2 ($p < 0.05$)	40	30	24.7 ($p < 0.01$)	41	43	14.0 ($p < 0.01$)	46	33	18.4 ($p < 0.01$)
< Primary	42	45		46	46		40	46		39	45	
≥ Primary	22	26		14	24		19	11		15	22	
Mobile phone ownership												
Yes, self	30	42	30.8 ($p < 0.01$)	28	37	21.1 ($p < 0.01$)	34	35	0.3 ($p < 0.88$)	28	51	73.0 ($p < 0.01$)
Yes, family	43	45		45	47		48	47		53	42	
None	27	14		27	16		18	18		19	7	
Sex of child												
Male	51	52	0.02 ($p < 0.90$)	50	53	0.7 ($p < 0.42$)	46	53	5.3 ($p < 0.05$)	55	50	2.4 ($p < 0.12$)
Female	49	48		50	47		54	47		45	50	

Table 2

Vaccination coverage[a] among children over 298 days old in intervention and control, rural and urban areas with difference-in-difference (DID) and logistic model odds ratio (OR).

Vaccination coverage in children age 298+ days	Intervention: rural			Control: rural			DID[b] OR (95% CI) (*n* = 393)
	Baseline % (*n* = 131)	Endline % (*n* = 69)	Difference (95% CI)	Baseline % (*n* = 126)	Endline % (*n* = 67)	Difference (95% CI)	
Fully vaccinated: BCG + Penta3 + MR	58.9	76.8	18.8** (5.7, 31.9)	65.9	55.2	−10.7** (−25.2, 3.9)	29.5 3.6** (1.5, 8.9)
BCG + Penta3 (Yet to receive MR)[c]	26.7	18.8	−7.9 (−19.8, 4.1)	26.2	38.8	12.6* (−1.4, 26.6)	−20.5 0.4** (0.1, 0.9)
Invalid dose[e]	4.6	2.9	−1.7 (−7.0, 3.7)	6.3	3.0	−3.4 (−9.3, 2.5)	1.7 1.4 (0.1, 13.7)
Drop out: missing doses[e]	1.5	0	−1.5 (−3.6, 0.6)	0	0	0 NA	−1.5 NA
Left out: never vaccinated	9.2	1.4	−7.7** (−13.4, −2.0)	0.8	3.0	2.2 (−2.2, 6.6)	−9.9 0.04* (0, 0.9)
	Intervention: urban			**Control: urban**			
	(*n* = 150)	**(*n* = 98)**		**(*n* = 110)**	**(*n* = 112)**		**(*n* = 470)**
Fully vaccinated: BCG + Penta3 + MR	40.7	57.1	16.5** (3.9, 29.0)	44.5	33.9	−10.6** (−23.4, 2.2)	27.1 2.3* (1.1, 5.5)
BCG + Penta3 (Yet to receive MR)[c]	48.6	41.8	−6.8 (−19.5, 5.8)	44.5	52.7	8.1** (−5.0, 21.2)	−14.9 0.5 (0.3, 0.8)
Invalid dose[d]	3.3	0	−3.3 (−6.2, −0.5)	1.8	4.5	2.6 (−1.9, 7.2)	−5.8 0(−)
Drop out: missing doses[e]	0.7	0	−0.7 (−2.0, 0.6)	2.7	2.7	0 (−4.3, 4.2)	−0.7 0(−)
Left out: never vaccinated	6.7	1.0	−5.6** (−10.1, −1.2)	6.4	6.3	−0.1 (−6.5, 6.3)	−5.5 0.2* (0, 2.0)

[a] According to Expanded Programme on Immunization (EPI) card and/or maternal recall.

[b] DID = difference-in-difference estimate of difference between the intervention group's change from baseline to endline and control group's change from baseline to endline.

[c] Yet to receive MR = not yet received MR which is the last dose of the routine immunization schedule;

[d] Invalid dose = any dose given before correct date in routine immunization schedule.

[e] Drop out = missing any doses in routine immunization schedule other than MR; BCG = Bacillus Calmette–Guérin vaccine against tuberculosis (1 dose); Penta = pentavalent vaccine covering diphtheria, tetanus, pertussis, hepatitis B, and *Haemophilus influenzae* type b (3 doses); MR = measles rubella vaccine (1 dose); NA = not applicable.

* $p < 0.05$.

** $p < 0.001$.

Table 3

Intervention effects on vaccination status[a] at different ages in rural and urban intervention areas adjusted for maternal education, mobile phone ownership, and sex of child.

Vaccination status by age of child	Rural + urban		Rural		Urban	
	DID[b]	ORc (95% CI)	DID[b]	OR[c] (95% CI)	DID[b]	OR[c] (95% CI)
70+ days	**(*n* = 3593)**		**(*n* = 1754)**		**(*n* = 1839)**	
Appropriately vaccinated: BCG + Penta1	13.5	4.2** (2.7, 6.6)	13.1	4.1** (2.1, 7.8)	14.1	4.6** (2.5, 8.6)
Left out: never vaccinated	−11.3	0·2** (0.1, 0.3)	−12.0	0.2** (0.1, 0.5)	−10.6	0.1** (0.1, 0.3)
98+ days	**(*n* = 3262)**		**(*n* = 1583)**		**(*n* = 1679)**	
Appropriately vaccinated: BCG + Penta2	18.0	3·1** (2.2, 4.4)	14.6	2.7** (1·6, 4·5)	21.1	3.6** (2.3, 5.9)
Left out: never vaccinated	−10.4	0·2** (0.1, 0.3)	−9.8	0.2** (0.1, 0.5)	−10.9	0.1** (0.1, 0.3)
126+ days	**(*n* = 2849)**		**(*n* = 1360)**		**(*n* = 1489)**	
Appropriately vaccinated: BCG + Penta3	22.9	2·9** (2.1, 4.0)	24.2	3.3** (2.1, 5.4)	20.8	2.5** (1.7, 3.9)
Left out: never vaccinated	−10.2	0·1** (0.1, 0.3)	−7.7	0·2** (0.1, 0.6)	−12.2	0.1** (0.02, 0.2)
298+ days	**(*n* = 863)**		**(*n* = 393)**		**(*n* = 470)**	
Fully vaccinated: BCG + Penta3 + MR	30.5	3.5** (1.2, 6.1)	29.5	3·8** (1.5, 9.2)	27.1	3.0** (1.4, 6.4)
Left out: never vaccinated	−8.2	0·1* (0.2, 0.5)	−9.9	0* (0, 0.9)	−5.5	0.1 (0, 1.5)

[a] According to Expanded Programme on Immunization (EPI) card and/or maternal recall.

[b] DID = difference-in-difference estimate of difference between the intervention group's change from baseline to endline and control group's change from baseline to endline.

[c] OR=odds ratio of intervention effect which is the interaction between intervention (versus control) and endline (versus baseline) calculated with logistic regression; BCG = Bacillus Calmette–Guérin vaccine against tuberculosis (1 dose); Penta = pentavalent vaccine covering diphtheria, tetanus, pertussis, hepatitis B, and *Haemophilus influenzae* type b (3 doses); MR = measles rubella vaccine (1 dose).

* $p < 0.05$.

** $p < 0.001$.

Table 4

Vaccination coverage using EPI card only[a] among children age 0-11 months in rural and urban, intervention and control areas.

Vaccine antigen by dose and by age of child	Intervention				Control			
	Baseline		Endline		Baseline		Endline	
Rural	***n***	**%**	***N***	**%**	***n***	**%**	***n***	**%**
BCG (70+ days)	321	100	352	100	345	100	238	100
BCG + Penta1 (70+ days)	321	99	352	99	345	99	238	100
BCG + Penta2 (98+ days)	296	88	344	94**	324	93	233	98*
BCG + Penta3 (126+ days)	259	75	318	85**	287	85	222	87
Fully vaccinated: BCG + Penta3 + MR(298+ days)	106	72	68	78	116	70	57	60
BCG + Penta3 (Yet to receive MR;[b] 298+ days)	106	22	68	19	116	22	57	37
Drop out: missing doses[c] (298+ days)	106	1	68	1	116	0	57	0
Urban	n	%	*N*	%	n	%	n	%
BCG (70+ days)	335	100	428	99	308	100	319	98
BCG + Penta1 (70+ days)	335	96	428	97	308	97	319	95
BCG + Penta2 (98+ days)	307	83	389	88	278	88	294	80**
BCG + Penta3 (126+ days)	265	72	359	76	230	73	262	66
Fully vaccinated: BCG + Penta3 + MR(298+ days)	102	48	88	57	80	54	65	48
BCG + Penta3 (Yet to receive MR;[b] 298+ days)	102	47	88	43	80	40	65	46
Drop out: missing doses[c] (298+ days)	102	1	88	0	80	4	65	2

[a] According to Expanded Programme on Immunization (EPI) card only and not using maternal recall to improve accuracy.

[b] Yet to receive MR = not yet received MR which is the last dose of the routine immunization schedule.

[c] Drop out = missing any doses in routine immunization schedule other than MR; BCG = Bacillus Calmette–Guérin vaccine against tuberculosis (1 dose); Penta = pentavalent vaccine covering diphtheria, tetanus, pertussis, hepatitis B, and *Haemophilus influenzae* type b (3 doses); MR = measles rubella vaccine (1 dose).

* $p < 0.05$.

** $p < 0.001$.