Implementing a socio-technical system for computer-aided tuberculosis diagnosis in Peru: A field trial among health professionals in resource-constraint settings

Cesar Ugarte-Gil
Universidad Peruana Cayetano Heredia, Perú

Maria Icochea
Juan Carlos Llontop Otero
Hospital de Huaycan, Ministerio de Salud, Perú

Katerine Villaizan
Nicola Young
Universidad Peruana Cayetano Heredia, Perú

Yu Cao
Benyuan Liu
Terence Griffin
University of Massachusetts, USA

Maria J Brunette
Universidad Peruana Cayetano Heredia, Perú; University of Massachusetts, USA; The Ohio State University, USA

Corresponding author:
Cesar Ugarte-Gil, Instituto de Medicina Tropical Alexander von Humboldt, Universidad Peruana Cayetano Heredia, Av. Honorio Delgado 430, SMP, Lima 15102, Perú.
Email: cesar.ugarte@upch.pe

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Abstract
A major challenge of tuberculosis diagnosis is the lack of universal accessibility to bacteriological confirmation. Computer-aided diagnostic interventions have been developed to address this gap and their successful implementation depends on many health systems factors. A socio-technical system to implement a computer-aided diagnostic tuberculosis diagnosis was preliminary tested in five primary health centers located in Lima, Peru. We recruited nurses (n=7) and tuberculosis physicians (n=5) from these health centers to participate in a field trial of an mHealth tool (eRx X-ray diagnostic app). From September 2018 to February 2019, the nurses uploaded images of chest X-rays using smartphones and the physicians reviewed those images on web-based platforms using tablets. Both completed weekly written feedback about their experience. Each nurse participated for a median duration of 12 weeks (interquartile range = 7.5–15.5), but image upload was only possible at a median of 58 percent (interquartile range = 35.1%–84.4%) of those weeks. Each physician participated for a median duration of 17 weeks (interquartile range = 12–17), but X-ray image review was only possible at a median of 52 percent (interquartile range = 49.7%–57.4%) of those weeks. Heavy workload was most frequently provided as the reason for missing data. Several infrastructural and technological challenges impaired the effective implementation of the mHealth tool, irrespective of its diagnostic accuracy.

Keywords
ehealth, global health, mhealth, primary care, tuberculosis

Background
Tuberculosis (TB) is still one of the most prevalent infectious diseases worldwide with 10 million cases reported in 2018. Across the globe, TB has the highest mortality among infectious causes. Perú, one of the highest TB burden countries in Latin America (123 per 100,000 persons in 2018), has the greatest number of cases of resistant TB, predominantly multidrug-resistant tuberculosis (MDR-TB) (10 per 100,000 persons in 2018). Lima is the city with the highest number of TB cases in the country, with almost 80 percent of the cases reported in Peruvian per year. As one of the most highly inequitable cities in Peru, Lima has areas where TB incidence is much greater than the average national incidence, such as in the northern and eastern parts of Lima, which are overpopulated regions of urban poverty.

One of the gaps identified in the cascade-of-care for TB lies in diagnosis. The process of TB diagnosis outlined by the Peruvian Ministry of Health involves a series of steps. When patients present at any public health center with at least 2 weeks of coughing, they are sent to the center’s TB clinic. There, they provide two sputum samples for bacteriological testing. They also receive a chest X-ray. The patients then must schedule a consult with the TB clinic physician, who synthesizes all of the data (symptoms, bacteriological test, and chest X-ray) to determine the proper diagnosis.

This process is complicated by the fact that the current bacteriological confirmation methods have low sensitivity (i.e. sputum smear test) or are expensive at the primary care level in low- to middle-income settings (i.e. Xpert MTB/Rif). Such barriers cause delays in TB care, during which time TB can worsen clinically, increasing the risk of TB transmission throughout the community. Given these challenges in accessibility and reliability, several patients rely on chest X-rays as an alternative to (rather than in addition to) bacteriological confirmation. In fact, only around 77 percent of TB cases diagnosed in Perú are bacteriologically confirmed, so the remaining cases must be defined under clinical criteria in which chest X-rays play a key role.

However, using chest X-rays for diagnostics presents its own challenges, especially at the primary care level in the public sector of the healthcare system. The Peruvian healthcare system is
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divided into a public and private sector. The public sector comprises two systems: (1) Seguro Integral de Salud (SIS), which is funded by the government’s Ministry of Health and attends to populations that live in conditions of poverty or extreme poverty and (2) EsSalud, which is funded by employer contributions and covers salaried individuals and their families. The SIS system is historically underfunded, causing many SIS primary care centers to either lack specialists or health professionals with the appropriate experience to perform accurate and timely readings of chest X-rays. In Peruvian TB clinics, which follow Directly Observed Therapy (DOT) program, a dedicated nurse or nurse technician is responsible for providing TB treatment. Yet, the responsibility to begin treatment falls on physicians, who tend to be overloaded with clinical and administrative duties because of understaffing at the SIS primary care level. Thus, delays in TB diagnosis persist. For this reason, an automated and accessible system to improve the reliability and speed of chest X-ray readings could potentially facilitate TB diagnosis in the Peruvian healthcare system’s public sector.

The use of digital technologies for health (digital health) has become an important mechanism to address health needs. Within digital health, mobile wireless technologies, referred to as mobile health (mHealth), have promising potential for accelerating routine diagnostic processes. We engineered our own mHealth technology, the eRx app, to speed up the TB diagnostic process. The app was designed to both use deep learning technology to evaluate chest X-rays images of patients presenting with TB symptoms and allow TB physicians to evaluate X-rays off-site.

We conducted a field trial to implement socio-technical system with two objectives: (1) to evaluate the utility of the eRx app in a low- and middle-income country (LMIC) and (2) to better understand the intervention implementation challenges from the user’s perspective. This pilot utilized a community-based participatory research (CBPR) design and was made possible by an international collaboration between United States (University of Massachusetts and Boston University) and Peruvian (Universidad Peruana Cayetano Heredia and the Ministry of Health) institutions. Our research framework was anchored in the theory of socio-technical systems, which analyzes elements of the health system and proposes solutions that integrate technology into social settings. While preliminary results of the app’s accuracy and reliability have been published elsewhere, this work examines the users’ experiences when implementing the mHealth system during the intervention. Specifically, this study explores potential barriers and challenges that might inhibit mHealth interventions from achieving their full potential in Lima, Peru.

Methods

Participants

A total of 12 healthcare professionals were recruited to participate in this study. Of these individuals, seven were nurses and five were physicians. They all worked in either a SIS primary care health center (n=4) or an SIS primary level hospital (n=1) in a high-incidence TB area located in Lima, Peru (TB incidence ~2 times the national rate—approximately 312 cases per 100,00 inhabitants). Both the hospital and the health centers had a permanent TB clinic where detection, diagnosis, and treatment (through DOT) were provided. The characteristics of these health centers are displayed in Table 1.

Patient and public involvement

CBPR. This study employed a CBPR design which emphasized the involvement of all participants equally in the research process, recognizing each individual’s unique strengths and assets.
The study team had preliminary meetings with stakeholders (nurses, physicians, community members, TB officials) to discuss the best way to implement this intervention in their community.

**Materials**

**The mHealth technology.** eRx is a mobile app designed to facilitate chest X-ray reading and interpretation during the TB diagnostic process. The app allows for nurses and nurse technicians at TB clinics to upload photographs of chest X-rays and additional patient information (sputum smear results and clinical symptoms such as length of cough, night sweats, and fever) to the eRx mobile database. The database then serves two primary functions: (1) to use a Deep Learning algorithm to identify the presence of lung abnormalities and manifestations of TB and (2) to send this information to a physician at a different location, who can evaluate the incoming data through a computer, smartphone, or Tablet. Considering both the software’s automatic diagnosis and the rest of the patient data (including the chest X-ray images themselves), the physician can diagnose TB remotely. Figure 1 displays the process.

**Procedure**

**Field trial design.** Before the trial began, each nurse was given a smartphone with Internet access and each physician was given a Tablet with a data plan. All devices had the eRx app installed. After an initial training for eRx (one session), the study team followed up with health professionals over a 4-week period in May 2018 to receive feedback and resolve potential doubts and questions about eRx, as recommended by previous mHealth interventions.

Once the study began, the nurses were instructed to take photographs of the chest X-rays of patients registered in the clinic who had TB symptoms (cough for more than 2 weeks). These photographs were taken on a negatoscope (X-ray viewer) via the eRx app and then uploaded into the system. After being uploaded, the images were processed by the eRx algorithm, which produced a result for each of the radiological manifestations of TB (cavitation, fibrotic tracts, infiltrate, pleural effusion, military pattern, and lymphadenopathy). The results and the images were also sent to the participating physicians. The physicians were asked to log-in to the application on their Tablet and provide feedback on whether or not the algorithm had correctly identified TB. This information was transmitted to the Deep Learning system in order to continuously improve it throughout the course of the study (these results have been reported elsewhere). Figure 2 displays screenshots of the app and web platform. A diagnosis was never returned to the patient, as the study was the first field trial of eRx.

| Health center | Number of nurses in TB clinic | Number of TB cases registered per year (2017) | Has X-ray machine? |
|---------------|-------------------------------|-----------------------------------------------|--------------------|
| C1            | 1                             | 63                                            | No                 |
| C2            | 1                             | 29                                            | No                 |
| C3            | 1                             | 2                                             | No                 |
| C4            | 1                             | 59                                            | No                 |
| H1            | 3                             | 149                                           | Yes (n = 2; 1 digital) |

TB: tuberculosis.
Data collection. Over the course of the study (16 weeks), at the end of each week both the nurses and the physicians completed written surveys about their experience with the technology and any barriers or complication that had arisen during its use (see Supplemental Appendices B and C). The survey instruments were designed to address the experiences and challenges that other health workers reported during the implementation of past digital health interventions in LMICs.\textsuperscript{15,18,19}

Statistical analysis. Descriptive analysis was done by calculating frequencies (categorical variables) and median with its interquartile range (continues variables). From each weekly feedback survey, explanations and barriers were identified by health care professionals using the standardized survey. Responses were grouped into categories based on overlapping content to try to identify common themes between users.

Ethics

This study was approved by the institutional review board (IRB) at Universidad Peruana Cayetano Heredia (registration number 101992) and permission was obtained from the National TB program, local Health Network, and each health center before the study began. Subjects’ identities were kept confidential through the use of ID codes.

Results

Nurse data

Over the course of the study (September 2018 to February 2019), each nurse ($n = 7$) participated for a median duration of 12 weeks (interquartile range (IQR) = 7.5–15.5, range = 6–16). A total of 303
Figure 2. Screenshots of the eRx App: (a) Tablet screenshot and (b) smartphone screenshot.

X-rays were uploaded to the system during the study period. The majority of nurses (6/7) were unable to upload X-ray images every single week. Table 2-a displays the percentage of weeks photo upload was possible for each nurse, along with the reasons for incompletion. Collectively, upload was only possible at a median of 58 percent (IQR = 35.1%–84.4%) of the weeks. “Too busy” was the most frequently identified reason for inability to upload (53.6% of weeks where upload not possible): it refers to when nurses had too many other tasks to complete and ran out of time to upload the photograph. This trend is consistent with existing literature on challenges with mHealth implementation, which demonstrates that healthcare workers can perceive mobile health programs to add to their routine workload.18,20,21 “X-ray viewer unavailable” alludes to when the
nurses could not photograph X-rays due to the center’s negatoscope (or negatoscope room) being in use, maintenance, or storage for security purposes. “No TB patients” only occurred at health center C3 and “on vacation” only with nurse N4.

**Barriers to image upload.** Table 2-a also exhibits the barriers each nurse identified when photo upload was possible, along with the frequency that these barriers were mentioned. “Upload time” was cited most frequently (46.9% of barriers identified; mentioned at least once by all nurses) and refers to the photographs taking an excessive amount of time to upload into the eRx system. This delay was often caused by a lack of wireless Internet signal, a barrier that has also been identified in several other studies of mHealth interventions.18,22,23 For example, one nurse reported having to walk around the health center (and even into the street outside) in order to find signal to upload the photo. “Proper light unavailable” was mentioned by two nurses as lowering the quality of the X-ray photographs. When the nurses were able to upload photos, “X-ray viewer unavailable” was still considered a barrier due to the delay incurred when waiting for the negatoscope to be free for use. “Challenges with the app itself” refers to frustration because the app did not auto-save patient codes and did not permit the photographs to be edited, centered, or focused. Similar frustrations with the usability of applications have been expressed in past studies of health workers’ experiences with mobile health interventions.18,20,24

**Other responsibilities and suggestions.** Every nurse reported having other responsibilities in addition to their work in the TB clinic. Examples of such tasks include participating in vaccination, anemia screening, and other health campaigns, field work (home visits, for example), nursing staff leadership roles, consults with other health centers, patient intake (DOT for TB), registration and discharge, and administrative responsibilities. Throughout the study, none of the nurses took the eRx photographs during their shift; all images were taken in spare time or after hours. All seven nurses agreed that the eRx app had the potential to be very helpful, especially if it incorporated a notification system that alerted both the doctors and the nurses when information was sent. In addition, every nurse recommended communication with the doctors via a digital messaging system (such as WhatsApp) to facilitate initiation of TB treatment when necessary. This suggestion has promising implications in light of results from other mobile health interventions, which indicate that incorporating direct messaging like WhatsApp between health professionals can improve care delivery.18,25,26 The potential to enhance communication within the workforce also alludes to a particular benefit of implementing a socio-technical system: the capacity to facilitate social interaction.

**Physician data**

Each physician (n=5) participated for a median duration of 17 weeks (IQR = 12–17, range = 8–17). None of the doctors were able to evaluate the X-ray images every single week of their participation. Table 2-b displays the percentage of weeks image evaluation was possible. Collectively, the physicians only managed to review images at a median of 52 percent (IQR = 49.7%–57.4%) of the weeks. “Too busy” was the most commonly cited reason for inability to evaluate the X-rays (72.2% of weeks in which image evaluation not possible) and refers to the physician having too many other pending tasks to carry out the lengthy process of loading images. This finding is consistent with another mHealth intervention that identified understaffing as a challenge for implementation.27 “Tablet technological issues” alludes to the Tablet quitting unexpectedly, not saving work as the doctor added information, or blocking physician log-in. “No X-rays uploaded” and “vacation” only
Table 2. Health professional interview data.

(a) Nurses

| Nurse | Health center | Percentage of weeks photo upload possible | Reasons photo upload not possible | Barriers identified when photo upload possible |
|-------|---------------|------------------------------------------|-----------------------------------|---------------------------------------------|
|       |               |                                          | Too busy (no. of weeks) | X-ray viewer unavailable (no. of weeks) | No TB patients (no. of weeks) | Vacation (no. of weeks) | Upload time (no. of weeks) | Proper light unavailable (no. of weeks) | X-ray viewer unavailable (no. of weeks) | Challenges with app itself (no. of weeks) |
| N1    | H1            | 87.5% (4/16)                             | 2                                |                                       | 2                              | 2                          | 2                          |                                        |                                          |
| N2    | H1            | 100% (6/6)                                | 1                                |                                       | 1                              | 1                          | 1                          |                                        |                                          |
| N3    | H1            | 81.3% (13/16)                             | 3                                |                                       | 2                              | 4                          | 2                          |                                        |                                          |
| N4    | C1            | 58.3% (7/12)                              | 1                                | 1                                      | 3                              | 1                          | 1                          |                                        |                                          |
| N5    | C2            | 41.6% (5/12)                              | 4                                | 3                                      | 7                              | 1                          | 1                          |                                        |                                          |
| N6    | C3            | 25.0% (2/8)                               |                                  | 6                                      | 1                              |                                        |                                          |
| N7    | C4            | 28.6% (2/7)                               | 5                                |                                        | 1                              |                                        |                                          |

(b) Physicians

| Physician | Health center | Percentage of weeks image evaluation possible | Reasons image evaluation not possible | Barriers identified when evaluation possible |
|-----------|---------------|-----------------------------------------------|--------------------------------------|---------------------------------------------|
|           |               |                                              | Too busy (no. of weeks) | Tablet technological issues (no. of weeks) | No X-rays uploaded (no. of weeks) | Vacation (no. of weeks) | Sickness/injury (no. of weeks) | Poor Internet connection at health center (no. of weeks) | Image quality (no. of weeks) | Propaganda (no. of weeks) | Insufficient Tablet data (no. of weeks) | App terminology (no. of weeks) | App programming (no. of weeks) |
| P1        | H1            | 52.3% (9/17)                                | 4                                  | 1                                         | 1                            | 2                          | 4                          | 2                          | 2                          |                                            |                                            |                                            |
| P2        | H1            | 47.1% (8/17)                                | 9                                  |                                           |                              |                            |                            |                            |                                    |                                        |                                            |                                            |
| P3        | C3            | 62.5% (5/8)                                 | 1                                  |                                           |                              |                            |                            |                            |                                    |                                            |                                        |                                            |
| P4        | C1            | 52.3% (9/17)                                | 7                                  |                                           |                              |                            |                            |                            |                                    |                                        |                                        |                                            |
| P5        | C2            | 52.3% (9/17)                                | 5                                  |                                           |                              |                            |                            |                            |                                    |                                        |                                        |                                            |

TB: tuberculosis.
occurred with P1 at H1. “Sickness/injury” refers to doctors reporting either having been out of the office due to sickness or physical injury and thus inability to use the technology.

**Barriers to X-ray evaluation.** Table 2-b also displays the barriers each physician identified even when evaluation was possible, along with the frequency that these barriers were mentioned. “Poor Internet connection at health center” (29.7% of barriers reported) refers to the delay that occurred when physicians tried to use the Tablet (or even their own personal cell phones) at the health center to load the images on the eRx app. As aforementioned, other studies have also documented poor network connectivity as a challenge that health workers have experienced when using mobile devices.18 “Image quality” denotes dissatisfaction that physicians identified in the images they were receiving. Several commented that the photos were not centered, focused properly, or correctly oriented, or that their lighting made their reading difficult. “Propaganda” refers to advertisements that were constantly appearing on the Tablet and interrupting the physician’s X-ray evaluation. “Insufficient Tablet data” alludes to delays in image loading due to too little Tablet data to overcome the poor wireless Internet access, which is consistent with previous reports of barriers to successful implementation of an mHealth intervention.18,28 “App terminology” refers to the issues some physicians encountered with the terms used in the app. Certain terms were translated incorrectly or were out of date. One lobe of the right lung was also missing from the options during the diagnostic evaluation. Finally, “app programming” encompasses frustration due to the app quitting unexpectedly and not auto-saving information as it was aggregated by the physicians.

**Other responsibilities and complications.** Similar to the nurses interviewed, all the physicians had responsibilities in addition to their contributions to the TB clinic. Examples of these roles include consults in other medical departments of the health center, consults in private practices, teaching, meetings, domiciliary field visits, and referrals. Every doctor resorted to using a personal laptop or cell phone because the Tablet loaded images so slowly. In fact, all of the doctors reported preferring to evaluate the images at home outside of their shift, either at night or over the weekend. Utilizing mobile health technology outside of working hours has not been observed in recent, effective mHealth interventions,18 and seemingly contradicts the goal of a socio-technical system: to implement technology in a social setting. The physicians’ advice for improvement was in line with the barriers they identified.

**Discussion**

**Summary of findings**

This field trial of an mHealth intervention in Lima, Peru, revealed that socioecological factors at the health worker, health system, and general infrastructural level hindered the technology from realizing its full potential to accelerate the TB diagnostic process. At the health worker level, an extremely heavy workload prevented both nurses and physicians from utilizing the technology consistently throughout the trial. At the health system level, the availability of resources (such as X-ray viewers) complicated efficient use of the eRx app. At the general infrastructural level, access to Internet connectivity also delayed the app’s functioning, discouraging its usage. Although the health professionals identified specific issues with the programming of the eRx app itself, the underlying reasons reported for their frequent inability to perform the desired tasks on the app were separate from such design complications. This finding emphasizes the importance of a socio-technical approach when both designing and evaluating the effectiveness of an mHealth intervention.
Why Lima should be good candidate for mHealth intervention

In general, the implementation barriers identified in this study are consistent with those defined by the World Health Organization’s (WHO) 2016 Chest Radiography (CXR) in Tuberculosis Guideline as relevant issues to be addressed. For example, this report recommends that existing infrastructure, current workload, and Internet connectivity capacity for eHealth/telemedicine options be considered when intending to institute a CXR intervention.29 Similarly, a report in digital health in 2019 corroborates that poor connectivity in rural areas of LMICs and lack of basic computing infrastructure like laptops and mobile devices hinder potential mHealth interventions.19

However, at its current level of development, Lima does seem to pass many of the qualifications for a successful mobile health intervention. For instance, in terms of Internet connectivity and access to basic computing infrastructure, statistics from 2019 suggest that of the 78 percent of the Peruvian population living in urban areas, 73 percent uses the Internet and the number of mobile subscriptions surpasses the total urban population count.30 Given such high Internet usage and mobile phone subscription, one might expect Lima to be well suited for eRx, especially if the necessary mobile devices and data plans are provided. Similarly, in terms of existing health system infrastructure, it is standard for health centers in Lima to have negatoscopes for X-ray viewing. This light table being the only additional resource necessary to carry out the mHealth intervention, the city would appear to be good candidate for the eRx app, according to general guidelines.

Unsuspecting details that complicated the intervention

Nevertheless, this field trial revealed that details specific to Lima and the Peruvian health care system encumbered the socio-technical mHealth intervention even though the city seemed to qualify as a good candidate for implementation. For example, though the statistics on Internet connectivity and mobile device usage are promising, signal blockage due to the characteristic hills of Lima’s terrain is unaccounted for. This geographic factor likely contributed to the health professionals’ reports of delayed image upload and download. Not to mention, the availability of general Internet connection does not necessarily ensure that the connection speed is fast enough to accommodate the extremely busy schedules of both nurses and physicians in the often-understaffed Peruvian health centers. This finding is consistent with a previous report that identifies that interventions introduced in a resource-rich setting may need a different surrounding technical ecosystem than those introduced in a resource-limited setting.31 In addition, the prevalence of mobile phones across Lima does not necessarily imply that nurses are proficient in such technology usage. In fact, over the course of 2018, the number of Internet users in urban Perú rose by 9.1 percent (2 million people) and the number of social media users by 15 percent, with the majority of such users between the ages of 18–34.30 This rapid growth and user age might not include the nurse population, whose possible lack of experience with mobile technology might have also delayed maneuver of the eRx app and inhibited its efficient implementation. Accordingly, previous studies of mHealth interventions corroborate that low digital literacy can negatively impact health workers’ experience and perceptions of the use of mobile devices.18,32

Regarding access to negatoscopes, it was true that every center included in this study did have its own device. However, the location of this X-ray viewer and the details of its maintenance complicated the eRx procedure. Five of seven nurses reported delays due to the negatoscope because it was either located in an occupied room or undergoing maintenance (which was not a brief process in itself). Thus, simply having the proper resources on site did not ensure their availability.
The importance of mHealth adaptability

Taken together, our findings confirm that mHealth interventions must be adapted to their unique implementation setting in order to achieve their intended utility. In particular, socio-technical systems, which by nature rely heavily on social factors, must cater to the condition of the individuals in their particular geographic site of use. This conclusion is consistent with other studies that call for implementers of computer-aided TB detection software to conduct their own pilot studies on the specific population being tested, irrespective of the current WHO guidelines focusing only on predefined threshold scores. Although our results certainly corroborate the fact that human factors, technical elements, healthcare ecosystems, program characteristics, and extrinsic ecosystems must be considered before implementation, they also shed light on the importance of always performing field trials in each unique setting of a socio-technical mHealth intervention. As the literature begins to call for the scale up of digital health interventions, we urge implementers to proceed with caution since the health system of every LMIC is not built the same.

Limitations and future work

eRx. In the specific case of eRx in Lima, both nurses and physicians agreed that apart from the infrastructural challenges discussed, with small programming modifications, the app could be very helpful in accelerating the TB diagnostic process. This positive attitude toward the mobile technology is consistent with the WHO’s recommendations for digital interventions for health system strengthening in 2019, which reports that health workers appreciate the opportunity to communicate with each other and reduce their professional isolation through provider-to-provider telemedicine. To improve the eRx app itself, aggregating auto-save and image zoom/rotate properties would address the shortcomings identified by the health professionals in this study. Although large infrastructural changes would certainly be out of the scope of an mHealth intervention, a larger Tablet data plan and accompanying wireless network for the smartphones might reduce image upload and download delays. If feasible, these changes in the eRx protocol could overcome some of the barriers addressed by the health professionals in this study. In an ideal world, however, each regional network of Peru’s public health system would be able to provide their primary care centers and hospitals with the economic resources to fortify their wireless Internet connection and to hire more health professionals so that each location was not so understaffed.

This research. To our best knowledge, this study is the first to evaluate the social factors involved in an mHealth intervention of an X-ray diagnostic tool for TB. It also sheds light on barriers that can arise during the implementation of a socio-technical system in Lima and other similar cities in LMICs. However, our research was limited in the number of hospitals and professionals included, making it difficult to apply our findings to larger populations. The small sample size was a result of our own financial constraints (e.g. we did not have sufficient funds to purchase more smartphones and Tablets to distribute to health professionals), however, despite this small sample size, include all the health personnel available in TB program, so the evidence collected here can be used in the preparation and feasibility evaluation of mHealth intervention in similar settings. This study also could have benefited from in-depth interviews with the health professionals, on top of the written surveys, to allow for a qualitative analysis. Future work could examine another field trial of an updated version of the app in different health centers in Lima in order to render more generalizable results. In addition, next steps should consider bringing the intervention to scale and addressing the challenges that come with Ministry of Health policy change.
Conclusion

This study confirmed that socio-technical mHealth interventions must be adapted to their intended setting in order to prove effective. Unexpected barriers at the health worker, health system, and general infrastructural level hindered the utility of the eRx chest X-ray TB diagnostic tool in Lima, Peru. Although new technologies may be user-friendly and well accepted by health professionals, our work emphasizes that field trials must be conducted in the context of their implementation site in order to determine whether the health system can support a specific mHealth operation. As technical innovations to improve diagnostic speed become more accessible and desirable to the global health community, the most successful mHealth interventions will be those with the flexibility to adapt to complex health systems with few resources.

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ORCID iD

Cesar Ugarte-Gil https://orcid.org/0000-0002-2833-9087

Supplemental material

Supplemental material for this article is available online.

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