

Frugal development and deployment of an innovative mobile health platform for COVID-19 in Sri Lanka: the case of SelfShield app

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Received 21 August 2021

Accepted 21 September 2021

Published Online First

28 September 2021

INTRODUCTION

During the early phases of the COVID-19 pandemic, emerging technologies focused largely on strengthening the health system, supporting law enforcement authorities, and enabling researchers to model COVID-19 outbreaks and resource requirements.¹ When the health systems are burdened by the influx of patients with COVID-19, it is neither practical nor rational to treat all patients with COVID-19 in the hospital as many will either be asymptomatic or mildly symptomatic. Thus, home monitoring of patients has been practised in many countries.^{2,3} Respiratory involvement was the first documented site of complications and still continues to be responsible for majority of the deaths.⁴ Therefore, in order to provide effective home care for patients with COVID-19, we recognised the need for a frugal technology tool to monitor patients remotely including monitoring the breathing performance.

Guided by the Commonwealth Centre for Digital Health (CWCDH), a voluntary group of medical doctors, health informaticians and software developers from Sri Lanka embarked on a mission to fulfil this need by developing a smart phone-based self-health checking tool. Named the SelfShield project, the system comprised a smart phone app, a dashboard for medical teams and machine learning algorithms capable of analysing breathing and voice signals.

This report reflects on our early experience with the SelfShield system and we were guided by the following key objectives:

Summary box

What are the new findings?

- ▶ Design of mobile digital health tools using cutting edge technology may be achieved frugally even in low-resource contexts.
- ▶ Repurposing of communities of practice as design teams, digital transformation of evidence-based bedside clinical tests and agile methodologies fitting the purpose may help achieve frugality.

How might it impact on healthcare in the future?

- ▶ Focusing on already validated and tested bedside tests may form the foundation for digital health innovations aimed at patient empowerment in emergency situations.
- ▶ User empowerment is a useful guide for digital health innovations particularly in response to pandemic situations in the future.

1. Identifying already validated bedside clinical tests that may be cost effectively transformed into a mobile platform.
2. Designing and developing a mobile app to capture subjective and objective COVID-19-related data in a user-friendly manner and a dashboard that can help medical professionals assist consenting users.
3. Developing machine learning algorithms capable of analysing sound signals to facilitate decision making related to COVID-19.
4. Deploying the system as a COVID-19 response tool with a focus on citizen empowerment.

METHODS

The SelfShield project evolved at a rapid pace from its conceptualisation in March 2020 and is continuing to evolve even



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To cite: Siribaddana P, Wirasinghe C, Perera S, et al. *BMJ Innov* 2021;**7**:604–608.

after the deployment of its first version in July 2020. We will focus on several key areas related to the method based on its value to the digital health community.

Multidisciplinary team (MDT)

We realised the need for an MDT very early, given that the project required specialised skills. The team, however, was already formed and was working on research and development projects for a considerable period of time. The team consisted of a respiratory physician, medical informaticians, a software engineer and members who had in-depth experience in business process modelling and advising on regulatory requirements related to digital health.

Conceptualisation

We were informed by several guiding principles during the conceptualisation process. Frugality was one such principle, which we perceived as developing a technology with minimal complexity and cost, thereby allowing the same to be scaled in low-resource contexts. We were also informed by the need to be evidence-based, given the nature of the problem we expected to tackle. Empowerment of the citizens was central to our design thinking, given that access to healthcare would become even more limited as the pandemic progresses. Ethical and regulatory needs also guided our thinking, given that the solution was intended to develop handled sensitive data. The overall concept of the SelfShield project is illustrated in figure 1.

As highlighted in figure 1, the project focus has been on enabling users to perform self-health checks and engage in self-initiated care (marked in figure 1 as a dotted circle) by accessing health services such as medical consultation, ambulance services and mental health services. It also created a pathway for the users to seek medical care through voluntary sharing of data with a medical team, who would then be able to refer

the patient to appropriate care services at the right time.

Remote assessment of breathing performance

At the core of SelfShield design is remote assessment of breathing performance. The team identified two clinical bedside tests, breath-holding test (BHT)^{5 6} and single-breath counting test^{7 8} as useful in assessing respiratory health while having the potential to be transformed into mobile-based tests. BHT (Sabrasez BHT) has been used to measure the respiratory reserve.⁵ On the other hand, single breath count has been used to estimate the slow vital capacity and has been recognised as a useful alternative to peak expiratory flow rate.^{9 10} The use of these time-tested methods meant that the requirement for validation was minimal. The team also identified the usefulness of deep breathing sounds as it provides biomarkers of respiratory distress.¹¹ We recognised some of these biomarkers as breathing-related sounds (eg, cough and wheezing), ratio between inspiration and expiration, breathing patterns, etc. While not all parameters were captured in the initial version, this indicated to us the potential to expand the platform with continuous development. In addition, the subjective assessment of dyspnoea was done using an Adapted Modified Medical Research Council Dyspnoea Score.¹²

Development

During the development, three parallel streams, (1) mobile interface and dashboard development, (2) data collection and signal processing, and (3) testing, were operationalised.

Regular team meetings were held between the developer, medical informaticians and other team members. Personnel working on each stream met almost daily through virtual means. During team meetings, overall architecture was reminded and any new technologies that we could adopt were discussed. In some instances,

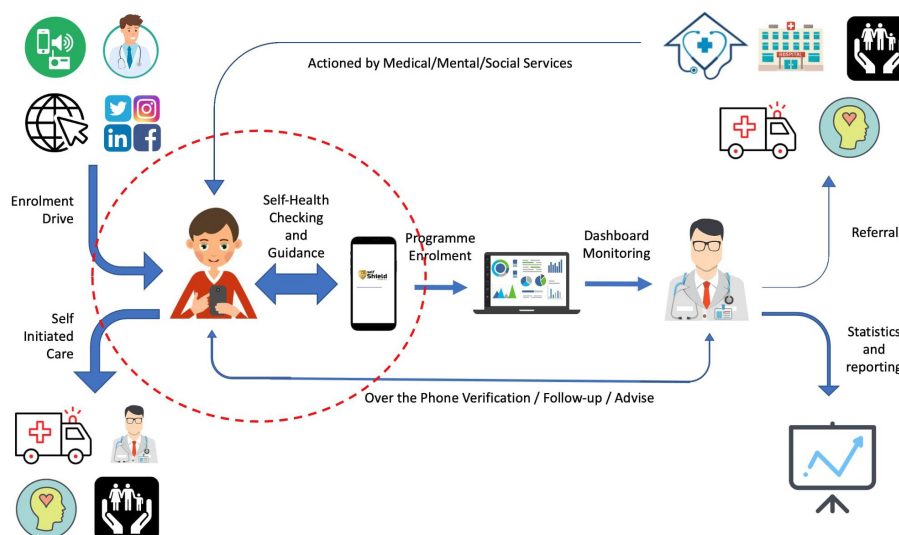


Figure 1 SelfShield project concept.

the overall architecture was modified. The evolving understanding about the pathophysiology and clinical features of COVID-19 also meant that the team had to be up to date and incorporate new knowledge into the design process.

The initial version of the app consisted largely of a text-based questionnaire to identify the COVID-19-related symptoms. However, based on feedback, an icon-based interactive graphical user interface was introduced on subsequent iterations of the design process. Interactive user interfaces to guide users in performing breathing-related tests were also provided.

The team also had to gather enough breathing and voice sounds for designing and testing signal processing machine learning algorithms, and this was achieved by inviting people through social media to donate their sounds—deep breathing, cough and single breath counting sounds via the mobile. These sound files were used to fine-tune the signal processing algorithm. Testing of the product was done iteratively using a network of medical and lay persons also via social media. The process meant that the team gained constant feedback from both medical and lay perspectives throughout the development process as against at the beginning or at the end. The team was able to publish the first version of SelfShield within few weeks. The early version contained minimal functionality but was usable by a user—a functional product. Also, a new version of SelfShield was published at regular intervals and with each new version, the functionality grew, and bugs were fixed. Therefore, the progress of the project was measured based on the new functionalities added—allowing quick progression.

Implementation

In the initial phases of the pandemic, there had been an influx of various apps trying to profit from the interests generated from COVID-19. The popular app publishing platforms therefore had to implement stringent screening processes for COVID-19-related apps while working at a slower pace than usual due to workforce limitations, causing delays.¹³ However, the team was able to overcome this challenge by addressing key aspects related to review such as privacy and confidentiality of users, claims being made and robustness of the technology among others. After publishing, a limited social media campaign was launched to build awareness about the app.

In the Sri Lankan setting, the app was first implemented as a support tool for managing specialised quarantine centres. Thereafter, the system was rolled out as part of national response in collaboration with the Ministry of Health of Sri Lanka during the sudden surge of COVID-19 cases in August 2021. In the latter instance, the aim was to help citizens who are showing COVID-19-related symptoms but are not known to be COVID-19 positive. The SelfShield system was also implemented as a workplace safety measure in

a large-scale employer in Sri Lanka and at several settings, including in a community setting for research purposes.

In all instances, the decision to use and generate a check-up report was solely with the user. However, the app generates a notification every 24–72 hours when regular check-ups are not performed. When the user has consented to share the data by enrolling into a designated programme, the shared check-up data appear in the form of alerts for the medical team observing the programme dashboard. The medical team can quickly identify the patients reporting serious symptoms and evaluate their past check-up reports, including breathing performance, in determining the need to follow-up as per a standard operating procedure. If selected to be followed up, the medical team will communicate directly with the user and verify the symptoms, including breathing difficulties before deciding on referral to the next level of care and in providing necessary medical advice.

RESULTS

According to statistics obtained from relevant app publishing platforms (eg, Google and Apple) and the SelfShield aggregated data analytics dashboard, following the launch of the app in July 2020, there were 4637 registered users performing more than 17 000 check-ups over a period of 10 months. However, after the official launch of the App by the Ministry of Health in Sri Lanka in August 2021 there had been a surge in uptake of the SelfShield App by approximately 25 000 new users performing more than 50 000 check-ups within the first month. Approximately 10% of those who register with the app enrol into the national programme by sharing their health data, while other users continue to use the app for self-health checking on their own. In the initial period, the programme generated approximately 1000 daily updates out of which approximately 5%–10% were classified as significant symptom updates. However, it was noted that the number of daily updates gradually lessened with time, maybe due to lower enrolments. It was also noted that approximately 92% of the users were between the ages 16 and 55 years. A gender gap was also noted among the users as the proportion of women using the app was only 30%.

According to the data analytics dashboard of the national COVID-19 programme, 478 red alerts (generated when serious symptoms are disclosed as per Ministry of Health Guidelines) were followed up, and approximately 25% of these were recognised as false alarms that may be due to misinterpretation of mild or already existing symptoms or due to enthusiastic attempts at testing the system. Approximately 50% of the follow-ups ended by providing the user with necessary medical advice to manage themselves at home, including relieving of anxiety, while only 5%

of those who were followed up required referral to the hospital.

According to the analytics dashboard provided to the workplace safety programme, there were approximately 1000 users enrolled in the programme. It was noted that on average, approximately 11 red alerts and approximately 90 other types of alerts were generated and followed up. Approximately 5% of followed-up users were requested to stay home and were monitored. During a review of the workplace safety programme, it was noted that the employer adopted strategies such as sending reminders at regular intervals and implementing policies outlining the use of SelfShield across the organisation to maintain employee motivation.

In the research-oriented community-based implementation, users were enrolled following obtaining their written consent from a cohort of patients suffering from chronic respiratory disorders visiting one of the hospitals in Central Sri Lanka. Participants were asked to perform regular health checks during the study period. The preliminary data suggest that regularity of use increased from 0.6 check-ups per user per 30 days in the workplace safety programme to approximately 6.6 check-ups per user per 30 days. It was also noted that approximately 10% (n=14) reported mild to severe breathing difficulty per 30 days. During a qualitative inquiry using semistructured interviews, it was recognised that patients felt confident in using the app and that they were willing to report their condition knowing that the doctor will be made aware of their status by the app. The medical officers following up these patients observed that patients were motivated to use the app soon after being seen by a doctor or immediately after being discharged from the hospital. Final results pertaining to the community-based implementation will be presented in a separate paper.

DISCUSSION

During the COVID-19 pandemic, an exponential number of digital health tools were rapidly implemented and scaled.¹⁴ SelfShield Project was one such initiative, which was able to sustain its commitment to patient empowerment despite enduring many challenges. We recognised some of the key challenges as resource oriented, sociotechnical and regulatory and ethical.

Limitations of human, technical and financial resources are inherent problems for digital health initiatives particularly in low-income and middle-income country contexts.¹⁵ However, the case highlights the possibility of overcoming human resource and technical challenges to a large extent by mobilising a highly motivated and highly trained MDT, which may be described as a community of practice (CoP).¹⁶ In this case, the MDT members were already part of an innovations drive, thus creating a 'sense of community'. They had a shared domain of interest in the form of 'digital health', while a shared repertoire of

resources indicated a 'shared practice'. These are characteristic features of a CoP, which Wenger described as 'groups of people who share a concern or a passion for something they do and learn how to do it better as they interact regularly'.¹⁶ In our view, mobilising an already established CoP with a repurposed goal meant it lessened the time for team formation and thereby improved the efficiency of the work being done.

We also focused on frugal technologies and methods. For instance, we used already validated bedside clinical tests and transformed them into digital procedures as against trialling new clinical procedures. Focus on already existing mobile technologies also meant that the final product would be affordable and scalable even in low-resource contexts. We kept the solution simple and focused on optimising the functionality through an iterative process similar in nature to agile development.¹⁷ Use of free and open-source tools and using offers given by technology companies such as Amazon and Google enabled fast tracking of development activities and keeping the costs down. Thus, we fulfilled the three criteria as recognised by Weyrauch and Herstatt on frugal innovations, including substantial cost reduction, concentration on core functionalities and optimised performance level.¹⁸

In line with characteristics recognised by Emery, we consider sociotechnical challenges as the challenges that arise when an information and communication system such as a medical app is being used by people, communities and by organisations.¹⁹ We believe these challenges to be some of the most difficult to overcome. When self-empowering digital health tools are introduced, it is vital that the message to the users is clear and communicated effectively through contemporary media.¹²⁰ We observed the reluctance from the citizens to disclose certain information as the repercussions may not be desirable (eg, enforced quarantine at a centre when exposure to COVID-19 is disclosed). We also recognised that creating buy-in among stakeholders for a context-independent medical app, which deals with personal data, may be slow and complex. However, stakeholder buy-in is known to be a catalyst for scaling digital health tools.¹⁵ Therefore, a strong focus on sociotechnical aspect including involvement of stakeholders from the very beginning is recommended for similar endeavours in the future.

We also recognised that when it comes to personal health records, greater investment in terms of time and resources must be made on regulatory and ethical compliance. We strived to strengthen security of the system, ensure privacy and confidentiality of the data, and provide users a choice. Informed consent at enrolment and when sharing data with a medical team were also used as compliance mechanisms. However, we realised that when robust regulatory and ethical frameworks are largely absent, ad hoc measures may prevent innovations from taking place as well as gaining its full potential.

We also noted several limitations of the app. People from extremes of ages and with disabilities such as vision, hearing or confusion may not be able to self-administer the app. A gender gap among the users were also noted, which may be related to cultural barriers in terms of using technology among women.²¹ SelfShield in its current form is also not able to cater to people who do not have access to the internet or a smart phone. Therefore, work is in progress to extract the essence of the SelfShield project and distil it to the most efficient components capable of delivery through a 'land line' or 'dumb phone'.

CONCLUSIONS

This report highlights an innovative smart phone-based home monitoring solution that was developed with minimum resources in a low-resource context. It demonstrates the transferability of bedside clinical tests for respiratory assessment into digital form and the usability of such a tool in COVID-19 pandemic response for multiple scenarios including as part of a national response. Further studies are needed to ascertain its impact on patients, organisations and care pathways. The diagnostic potential of the tool is also an area needing further research. However, the report illustrates how an idea can be transformed into functional solutions at a rapid pace using multidisciplinary inputs, commitment to a common vision, focus on frugality and evidence base, and through agile methodologies fitting a particular context, goals and the changing circumstances.

Contributors PS conceptualised and drafted the initial manuscript; and CW and SP expanded relevant sections. PS, DG and VHWD edited the final manuscript.

Funding The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests None declared.

Patient consent for publication Not applicable.

Provenance and peer review Not commissioned; externally peer reviewed.

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