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Feasibility of NepaDengue mobile application for dengue prevention and control: user and stakeholder perspectives in Nepal

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ABSTRACT

Background Dengue has emerged as a significant public health issue in Nepal since 2006, necessitating innovative approaches to disseminating timely information and promoting preventive behaviour. Our study focuses on developing and pretesting a mobile health app called NepaDengue, assessing its acceptance and factors influencing its implementation.

Methods A concurrent triangulation mixed-method design was used, and an intervention was conducted among 228 university students using the mobile application. Acceptability was assessed using the technology acceptance model (TAM) based on user experiences over 1 week. Focus group discussions among students and female community health volunteers and key informant interviews among key dengue stakeholders were conducted to explore facilitators and barriers. Descriptive statistics were calculated, and a thematic analysis was conducted.

Results The high acceptability mean rating scores reported based on the TAM construct indicate that the application is perceived as useful and easy to use and exhibits good functioning and gestural design. The use of the NepaDengue application for dengue prevention and control activities has been perceived as acceptable by users and stakeholders. However, specific barriers were identified, including concerns about sustained usability, illiteracy and limited access to the internet and smartphones. We suggested promoting the application, fostering government ownership and encouraging collaboration to enhance its reach and effective implementation.

Conclusions The NepaDengue application has been perceived as a promising tool for dengue prevention and control in Nepal. Further piloting and implementation of the app in the community setting is recommended.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ There has been an inadequate response to the dengue outbreak in Nepal, requiring an innovative approach to educating the community.

⇒ The use of mHealth applications for preventing, controlling and managing Dengue has been found effective in other developing countries. However, no such intervention for Dengue has been previously implemented in Nepal.

WHAT THIS STUDY ADDS

⇒ The 'NepaDengue' mobile application developed and pretested in our study can potentially serve as a dengue prevention and control tool.

⇒ The application is perceived as acceptable by stakeholders and key users. The application could be promoted as a potential strategy to raise awareness about Dengue in the community.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ This study generates evidence for development and feasibility of mobile health application in dengue prevention and control, prompting further investigation for piloting and implementing of application in different settings of Nepal.

⇒ This study offers practical tool for communities to access information about dengue and adopt preventive measures, enhancing dengue literacy and empowering individuals to take proactive steps against the disease.

⇒ The study further informs policy-makers about the potential of technology integration in public health responses, leading to the development of policies that support the implementation of mobile health interventions for disease prevention and control on a larger scale.

INTRODUCTION

Dengue, a mosquitoborne viral disease, has recently become a global health concern.[1] The dengue prevalence has drastically increased globally over the past decade, resulting in an estimated 390 million cases and 20 000 deaths.[2] Nepal has seen an increase in dengue cases since 2006. Since 2010, several outbreaks have occurred, especially in the lowlands and mid-hills.[3 4] All four serotypes of dengue virus have been reported in Nepal,

and the country experienced its largest outbreak in 2022, with 54 784 cases and 88 deaths. The majority of cases were reported from Bagmati Province (42428), followed by Lumbini Province (5037), Province-1 (2309) and other provinces.[5]

Nepal's response to dengue outbreaks has been ineffective[4] due to low priority and implementation capacity[6] at the provincial and local levels, resulting in a reactive response.[7] In the absence of effective medicine and vaccines, integrated vector management has been a proven method for preventing and controlling dengue.[8] Despite efforts to develop Information Education and Communication (IEC) materials, effective ways to encourage dengue prevention and control are lacking.[9] Studies in Nepal reveal low knowledge regarding dengue symptoms, breeding places, treatment and preventive practices among the community.[10–13] In Nepal, the significant increase in cases in a short period,[14] makes it imperative to use innovative approaches for timely information dissemination to increase awareness and adopt preventive behaviour.

The use of mobile health (mHealth) in the healthcare sector is rapidly emerging around the world. m-Health is an approach to using mobile health technology, including applications, to provide services.[15] Globally, smartphone apps have been developed and scaled to enhance knowledge access and promote health behaviours.[16] The global fight against dengue fever has benefited from innovative mobile solutions, particularly in low-income and middle-income countries.[17] Mobile-based intervention provides dengue-based health information and preventive practices, reducing transaction costs and providing quick access to information.[16 18] Several mobile Health applications with features such as real-time dengue surveillance,[15 19–22] dengue education,[15 19 23] symptoms checker[19 23] and health communication have been widely accepted and considered useful for prompt response and early preparedness.[15]

There is an increasing evidence of mobile technologies and applications on increasing knowledge and preventive behaviours on dengue fever.[16 17] A field experiment in Peru suggested that continuous exposure to dengue-related information through mobile phone technology resulted in a reduction of dengue symptoms, a reduction in vector water container testing positive, significant increases in behavioural practice of covering and cleaning water reservoirs, use of screens in windows and doors, and use of mosquito nets.[24] Mozzify, a real-time surveillance system with health communication and behaviour modification, was highly acceptable and could increase knowledge and change attitudes to practice preventive measures for dengue fever.[15 16]

In Nepal, the internet penetration rate is 37.8%, and smartphone penetration is 73%.[25] Nepal is a member country of the WHO Global Digital Health Partnership for effectively implementing digital health and exchanging the best innovation practices.[26] The National Health Policy 2019, National e-Health Strategy 2017 and National Information Communication Technology Policy 2015 encourage using e-health innovations in the public health sector to reduce disease risk and outbreaks and promote healthy behaviour.[27–29] However, Nepal has yet to experience the technological advancement from digital innovation for dengue.

The utilisation of mobile health applications for dengue prevention and control is unprecedented in Nepal, with no reported or published interventions in community settings. This study introduces a novel approach, marking the first application of such an intervention for dengue prevention and control activities in Nepal. While a 2019 implementation study demonstrated the effectiveness of an SMS-based intervention in improving dengue control practices in Nepal,[18] the current intervention takes a cross-disciplinary perspective, integrating digital health, motivated by the promising outcomes of the prior study. We developed a dengue-based mobile app named NepaDengue that includes features like health awareness, symptoms checker, reminder alert and reporting of breeding sites for dengue fever. Dengue-based applications like Mo-Buzz (Sri Lanka),[19] Mozzify (Philippines),[15] DeFever (Malaysia)[23] and FeverDX (Colombia)[30] are developed and tested in diverse countries. While Mo-Buzz,[19] Mozzify,[15] DeFever[23] and FeverDX[30] primarily focus on aspects such as real-time reporting, disease prediction, awareness and clinical evaluation, NepaDengue uniquely centres around community education, preventive practices and local reporting of breeding sites that place a strong emphasis on creating awareness and encouraging community engagement. NepaDengue is uniquely designed for Nepal, considering the community-centric approach, language, national guidelines and health infrastructure at the local level.

This paper delves into the application's pretesting and feasibility assessment phases, focusing on user and stakeholder perspectives regarding application acceptability scores and identifying facilitators and barriers to its implementation.

METHODS

Study design, setting and time

The study is an implementation study using a concurrent triangulation mix method design. We conducted our study in Butwal Sub-Metropolitan City, situated in the Lumbini Province of Nepal. It has been among the highest-hit areas for dengue cases in recent years. Butwal Sub-Metropolitan City is an urban economic trade hub connecting to the open Indian border. The study was conducted between November 2022 and May 2023. Figure 1 shows our study site, province-wise dengue cases and smartphone penetration in 2021.

Study population

The study involved a survey among 228 university students, 10 key informant interviews with stakeholders, 2 focus group discussions with university students and 1

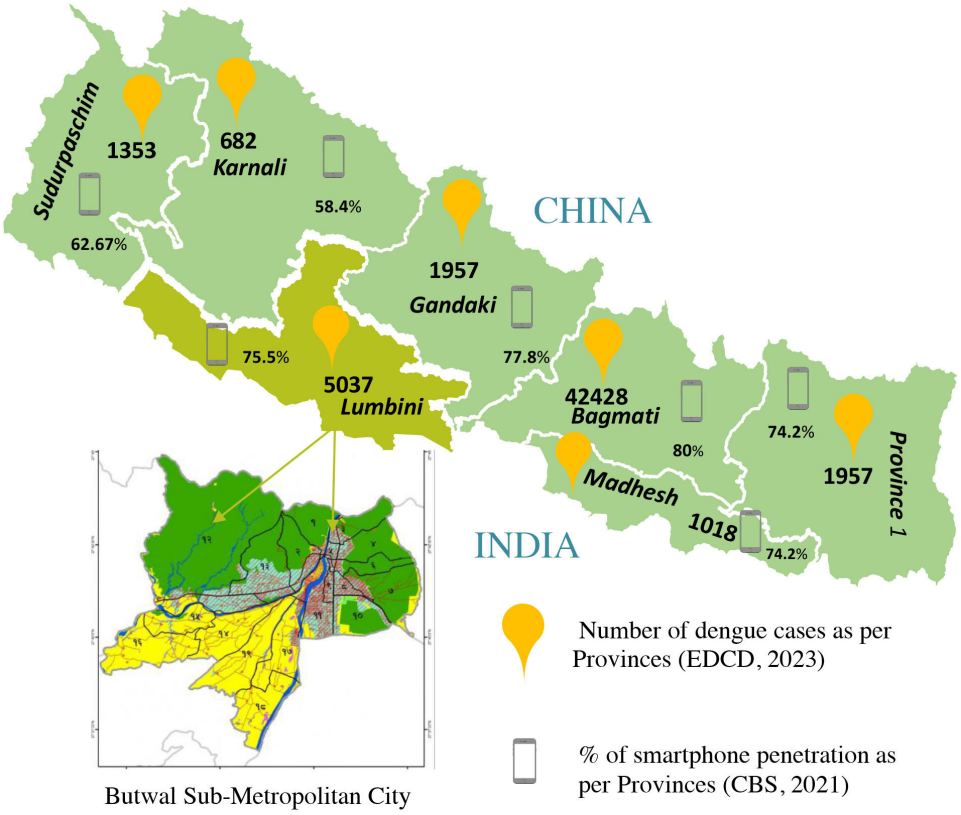

Figure 1 Number of dengue cases and smartphone penetration in seven provinces of Nepal (EDCD, 2023),[5] (CBS, 2021).[25] EDCD, Epidemiology Disease Control Division, CBS, Central Bureau of Statistics.

focus group discussion with Female Community Health Volunteers (FCHVs). Stakeholders involved dengue focal persons and planners from the Epidemiology Disease Control Division (EDCD), National Health Education Information and Communication Center (NHEICC), Vector Borne Disease Research Training Center (VBDRTC), Lumbini Provincial Health Directorate (PHD), District Health Office Rupandehi (DHO) and Butwal Sub-Metropolitan City (BMC). University students are undergraduate students from two campuses.

Conceptual framework

The study used the Technology Acceptance Model (TAM) (online supplemental figure 1) and the Practical, Robust, Implementation and Sustainability Model (PRISM) (online supplemental figure 2) to develop a conceptual framework.[31 32] The TAM (online supplemental figure 1) emphasises that an individual's behavioural intention to use the technology is determined by two aspects, which are perceived ease of use and perceived usefulness.[31] We used the PRISM (online supplemental figure 2) model in our study to gain a comprehensive perspective of our intervention study from stakeholders' and users' perspectives focusing on implementing factors, key facilitators and barriers in implementing the app in a community setting. Refer to (figure 2) for detail description of the conceptual framework.

Intervention

Phase I: design and development of mobile health application

A mobile health application named NepaDengue was developed by an IT team based in Nepal. NepaDengue is an informative mobile application designed to make people aware and assist the health system in dengue prevention and control. The application is designed based on the Android platform and comprises both English and Nepali languages. The development team worked in close coordination and guidance with researchers. The application was released on Google Play Store on 9 November 2022.

The application comprises major features such as health education, reminder notifications, symptoms checker, hospital contacts, health news and reporting a breeding site (online supplemental figure 3). Health education comprises information on signs and symptoms, breeding sites and preventive measures for dengue. Reminder notifications allow users to set the time and date for preventive activities. Users can check the likelihood of dengue infection through the symptoms checker feature. Reporting a breeding site allows the user to take a picture of the site and report where the respective municipality can take action based on reports. The reporting of a breeding site feature is aimed to increase community engagement to report the breeding site and assist the health system in taking action like search and destroy campaigns in the community. The contents of the application were prepared and adopted based on the

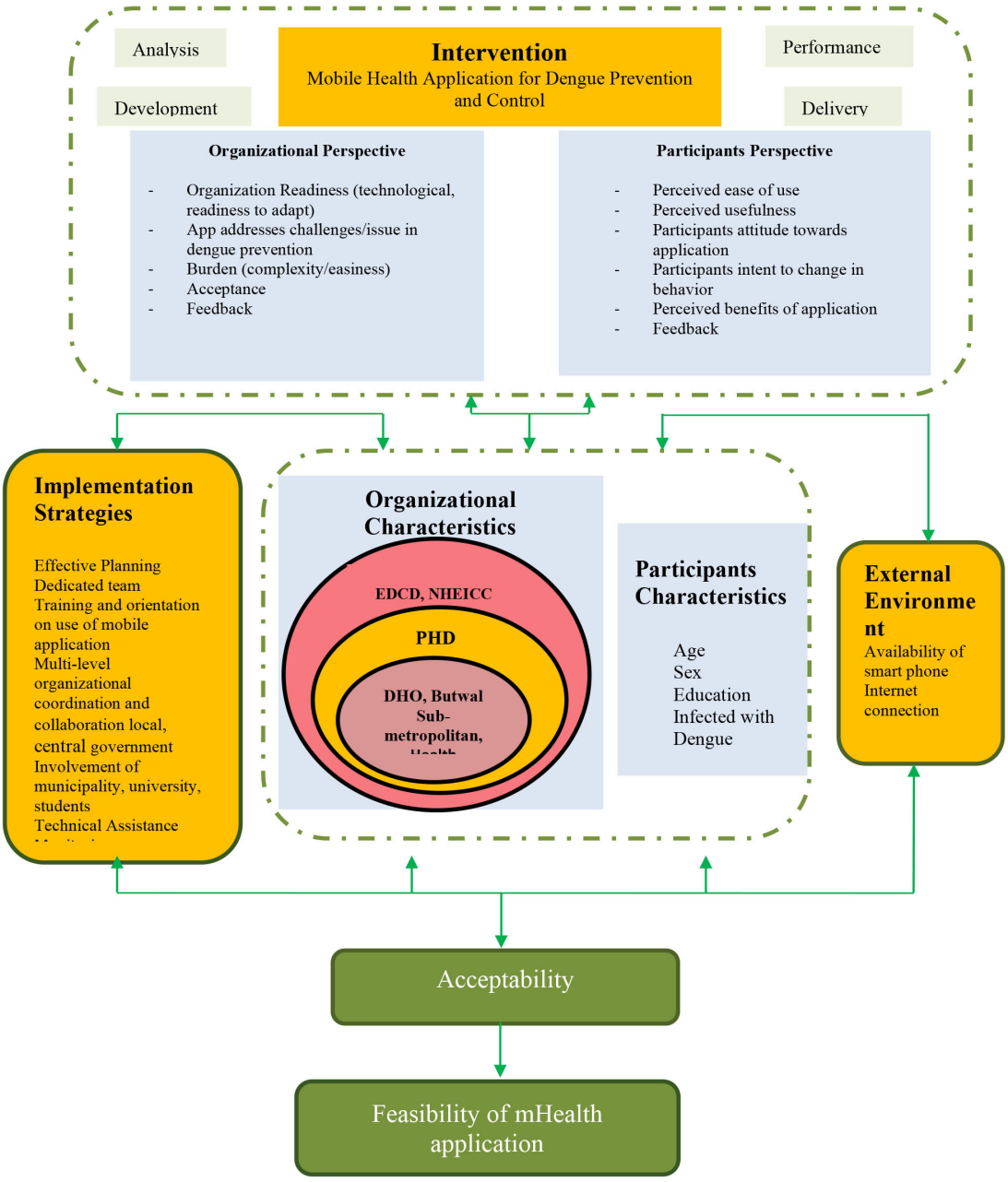

Figure 2 Conceptual framework on feasibility of mobile health application for dengue prevention and control based on TAM (Davis,1989)[30] and PRISM (Feldstein and Glasgow, 2008).[31] EDCD, Epidemiology Disease Control Division; NHEICC, National Health Education Information and Communication Center; PHD, Provincial Health Directorate; PRISM, Practical, Robust, Implementation and Sustainability Model; TAM, technology acceptance model.

National Guideline on Dengue Prevention and Control and IEC materials prepared by NHEICC, Nepal (figure 3).

Phase II: pretesting of mobile health application

Recruitment process

The pretesting phase of the mobile health application involved 228 university students purposefully selected from two campuses within ward no. 13 of Butwal Sub-Metropolitan City. Official approval was obtained from the respective campuses, which are known for being in a dengue hotspot area. This choice aimed to gather data from an environment with a higher risk of dengue transmission, enhancing the study's relevance. Participants were selected based on their eligibility, which included being 18 years or older, possessing Android smartphones and having access to the Internet, either Wi-Fi or mobile data (online supplemental figure 4).

A sampling frame of 390 eligible students was prepared with the assistance of campus faculties, with 270 from campus A and 120 from campus B. Based on the proportionate sample size, 170 students from campus A and 90 students from campus B were approached to participate in the study. Among those approached, consent to participate was obtained from 159 students from campus A and 69 from campus B. The campus management team and students

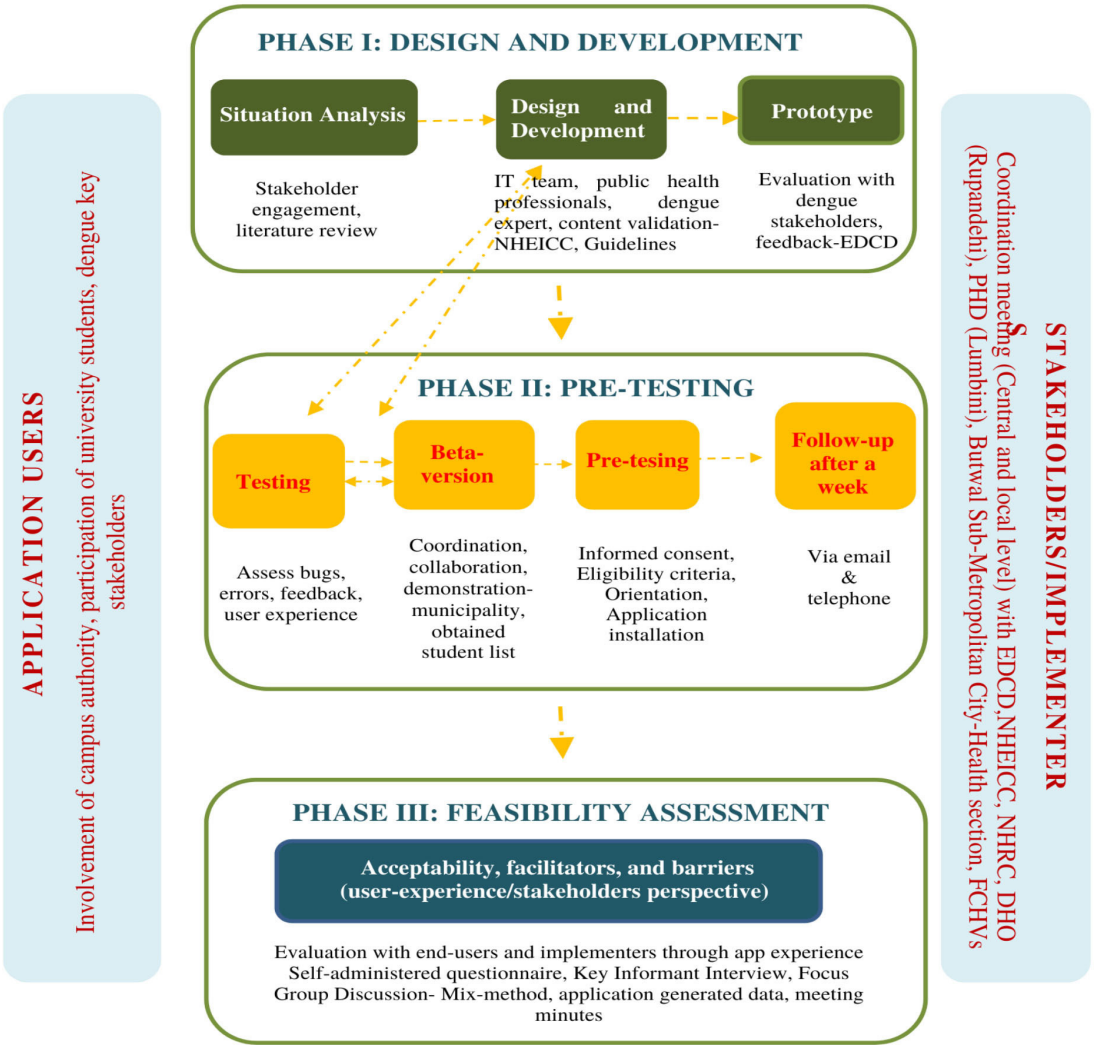

Figure 3 Phases of mobile health intervention. DHO, District Health Office; EDCD, Epidemiology Disease Control Division; FCHVs, Female Community Health Volunteers; NHEICC, National Health Education Information and Communication Center; NHRC, Nepal Health Research Council.

were involved directly in the intervention. We chose university students because university students are identified as early adopters of information, technology and knowledge who can quickly disseminate health education to peer groups and families. They are also among the groups that represent the community as a significant part and who have easy access to smartphones and are used to digital innovation, making them suitable for testing the feasibility of the application.

Informed consent, orientation and application download

Prior to participation, written informed consent was obtained from all eligible participants. An orientation session was conducted to demonstrate a comprehensive understanding of the study's purpose and the features of the mobile health application. Eligible students were requested to download the mobile health application from the Google Play Store using a QR code or an APK file. The APK file was provided to facilitate easy download. Campus facilities, including Wi-Fi, were available for download, and a mobile data hotspot was provided to ensure accessibility. In addition, recharge cards and stationery items were provided to the participants as part of the compensation for their participation. Overall, guidance was provided by researchers on the application download process.

Stakeholder orientation

In parallel, an initial consultation meeting and orientation was conducted with key stakeholders involved in dengue management at central, provincial and local levels to establish a collaborative approach and gain insights from experts in the field. Stakeholders were invited to actively use the mobile health application during and after the orientation session. This hands-on experience allowed stakeholders to explore the application's interface, functionalities and content.

Phase III: assessment of the feasibility of mobile health application

Follow-up

Participants were instructed to engage actively with the application for a week. They were followed up after 1 week to assess their interaction with the application and gather

feedback. This follow-up evaluated the acceptability score, overall user experience, facilitators and barriers to the mobile health application among the pretested cohort. Students' perspective on acceptability was assessed through a self-administered questionnaire and focus group discussion, whereas organisational perspective on mobile health applications was assessed through key informant interviews with stakeholders. Additionally, a focus group discussion was done among FCHVs of Ward 3 of Butwal Sub-Metropolitan City (online supplemental figure 4). Throughout the follow-up process, participants were reminded of their voluntary participation, and the confidentiality of responses was assured. Participants were informed about the research objectives, and consent was obtained before taking recordings for qualitative data. Any concerns or questions raised by participants were addressed promptly (figure 3).

Study instrument

The TAM questionnaire was used to assess the acceptability of the application. The construct of TAM includes perceived usefulness, perceived ease of use, attitude and intention to use. The instrument used in this study comprised 21 items measured on a 5-point Likert scale. The points ranged from 1 to 5, given as 1 indicates strongly disagree, 2 indicates disagree, 3 indicates neutral, 4 indicates agree and 5 indicates strongly agree. Seven items for perceived usefulness and seven items for perceived ease of use were adapted originally from Davis,[31] four items for attitude were adapted from Taylor and Todd[33] and Park,[34] three items for behavioural intention to use were adapted from Taylor and Todd,[33] Agrawal and Prasad,[35] Venkatesh.[36] We assessed Cronbach alpha coefficients for adapted TAM that obtained 0.86. We used KII and FGD guidelines (online supplemental figure 5) to assess stakeholders' and user perspectives, key facilitators and barriers to using the application.

Data analysis

For quantitative data, STATA V.14.0 was used for data analysis. Descriptive analysis was done for the sociodemographic information of participants. The mean score obtained in each construct of the Likert scale tool of the TAM questionnaire was calculated. A mean score >3 (out of 5) was considered a high mean rating score. A cut-off at >3 was set to simplify the interpretation, considering the score above this threshold indicates a positive response.

For qualitative data, thematic analysis (online supplemental figure 6) was conducted using NVivo V.12, where participants' responses were categorised and subcategorised as per the frequency based on our predetermined variables based on the TAM conceptual framework questionnaire. A coding framework was developed, incorporating both predetermined and inductively derived codes. Responses were further analysed based on frequency to identify prominent themes and patterns.

Analysed quantitative and qualitative data were merged in the later phase to answer our research questions. Findings were interpreted in light of both quantitative metrics and qualitative narratives.

Table 1 Characteristics of participants (students)

Variable	Frequency	Per cent
Age of respondents		
<20 years	119	52.19
>20 years	109	47.81
Sex		
Male	64	28.07
Female	164	71.93
Previously infected with dengue		
Yes	25	10.96
No	203	89.04
Total	228	100

Patient and public involvement

The study did not incorporate patient or public involvement in the design, execution, reporting or dissemination strategies.

RESULTS

Based on the results and findings from the study, we generated five themes: theme 1: perspective on the application, theme 2: challenges application addresses, theme 3: implementation challenges of the application, theme 4: implementation strategies and theme 5: suggestions and improvements (online supplemental figure 6).

Characteristics of the participants

The study included 228 students, with 164 females and 64 males. Students were aged between 18 and 32 years, with a median age of 20. Over half (119) were below 20 years old, accounting for 52.19%. A total of 25 (10.96%) reported a history of dengue within a year (table 1).

Theme 1: perspective of the application

Based on TAM, the figures below provide information on four constructs related to the perceived usefulness, perceived ease of use, attitude and intention to use the mobile application.

Perceived usefulness

The mobile app obtained a mean score rating >4 (out of 5), SD (0.51) for perceived usefulness (figure 4). Students found the application useful for obtaining health education on signs and symptoms, transmission, prevention, health news and hospital contacts. Additionally, stakeholders noted the app's potential to assist in early planning and preparation. Stakeholders from EDCD highlighted the significance of a reminder notification feature aligned with the government campaign to clean breeding sites at least once a week and remind communities to adopt dengue preventive measures.

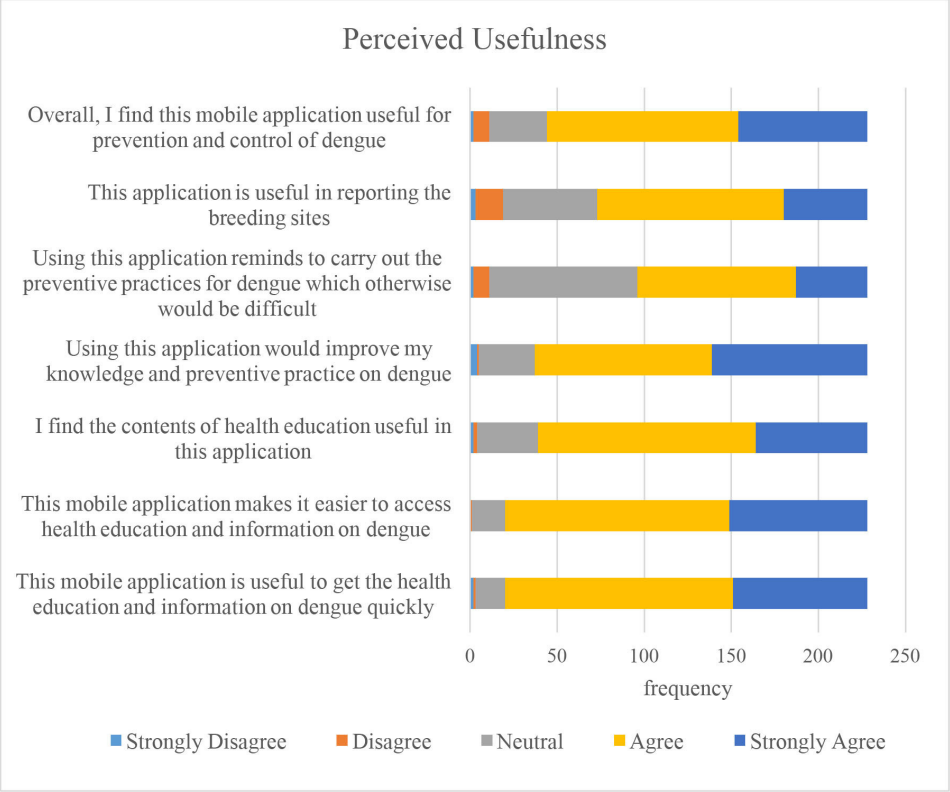

Figure 4 Constructs of perceived usefulness.

> I find this application useful because most of the information on Dengue is given there. The measures that should be taken when infected with Dengue are also included. If we are out of reach or alone and need a doctor's consultation, we could contact you through the application.—P5, CCT

> The one which I liked is the reminder alert. The Nepal government has recently made a policy to clean our surroundings and look after the water storage area and breeding sites. Do it regularly, if not possible, at least a week. And we are marketing that thing currently. So, those who have downloaded the application can get a notification about the time to clean their surroundings. Even if a person forgets, the application reminds them to conduct the activities, which is a positive thing.—DFP, EDCD

Perceived ease of use

The descriptive finding suggests a mean rating score of >3.8 (out of 5), SD (0.52) for perceived ease of use (figure 5). The finding implies that the application was clear and understandable and learning to use the application was not difficult. Both students and stakeholders found the application easy, informative and understandable. Stakeholders perceived that using both languages (English and Nepali) made the application easy to use. Observation and discussion among FCHVs in the community revealed that they could easily download and navigate through the application. However, one stakeholder stated that the ease of use depends on the exposure to the technology.

> Usually what happens is, at first, when you say mobile application, it is thought to be a complicated thing for the community level. There is a misconception that using Android mobile applications is complex for a community. Even I thought that way. But, when I went through this application, it is comfortable, easy to use, and get access to information easily.—Health Section In-charge, BMC

Attitude

The descriptive statistics reported a mean score rating of >4 (out of 5), SD (0.5) for the construct attitude (figure 6). The findings suggest that participants have a positive attitude towards using the application for dengue prevention and control. They perceive the application as innovative and relevant to the current dengue situation in Nepal.

> The application that is developed at the preliminary stage is very good. During the orientation, I appreciated it very much. …Otherwise, there are several other applications and software, but the application that you have developed is effective. Overall, the concept is perfect. – DFP, EDCD

Intention to use

The construct intention to change obtained a mean rating score of >3.5 (out of 5) and SD (0.65) (figure 7). Participants reported they would use the application in the future and would recommend others to use it. However, a few participants agreed they are not actively using the application as there are no dengue cases. However, they believe they would use it as needed in the

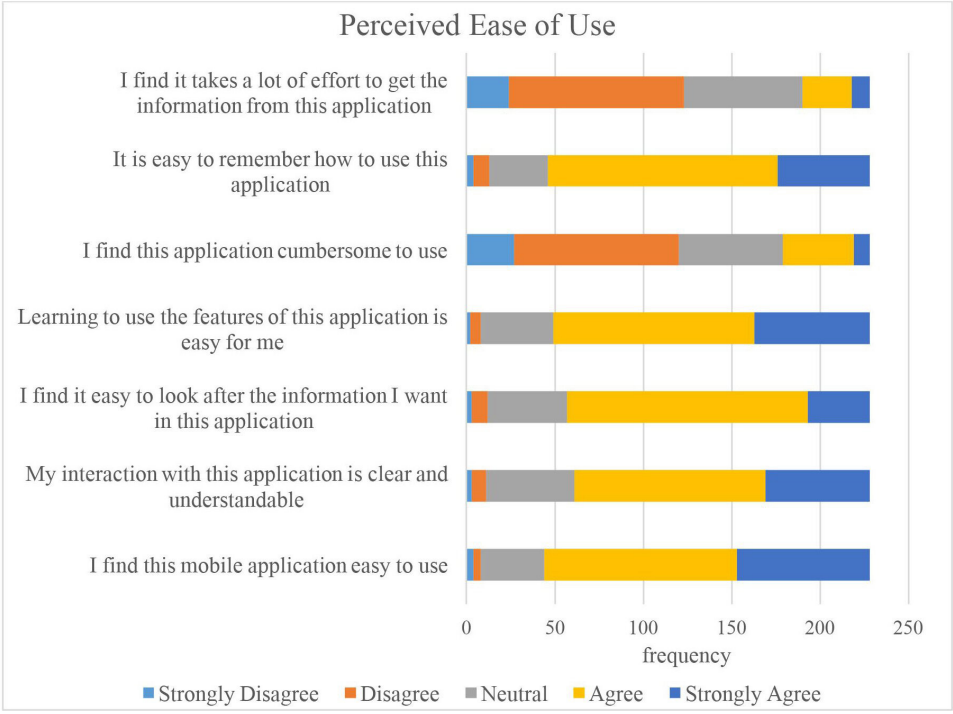

Figure 5 Constructs of perceived ease of use.

future. The stakeholders at the district level believe that if there are no cases of dengue, people might not use the application.

> Right now, we are not actively using it because we do not feel the necessity. It might be because there are no cases of dengue or dengue outbreaks currently, but it is useful in the future and is a good app.—P4, BBC

Theme 2: stakeholders perception on challenges that app addresses in dengue prevention and control

Awareness raising

Stakeholders noted the low level of awareness regarding dengue among people and the misleading information circulated in the media. They stated that even though people know the term dengue at the community level,

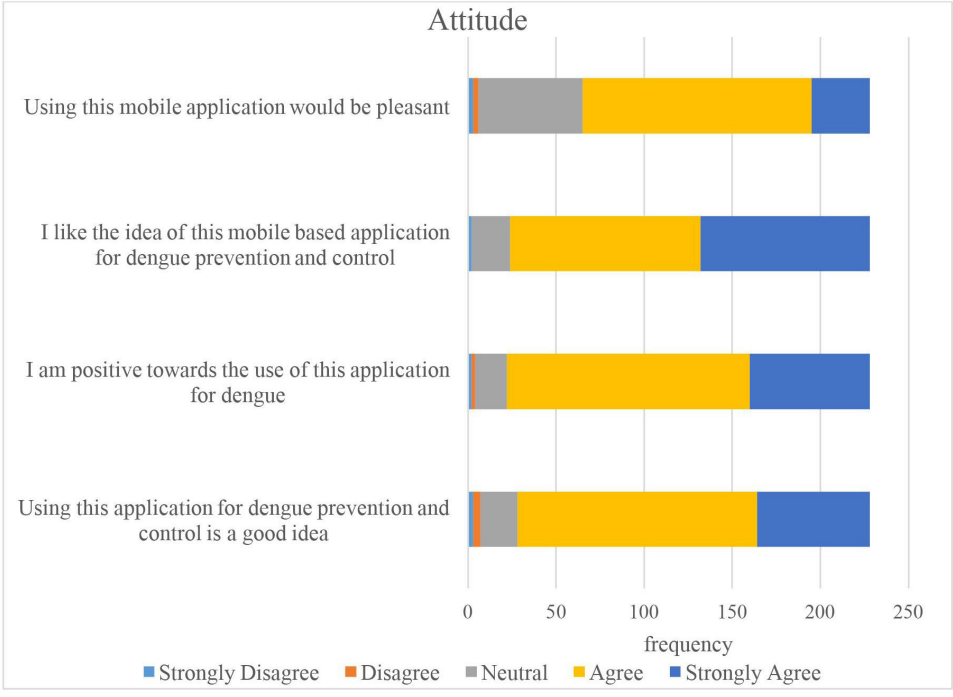

Figure 6 Constructs of attitude.

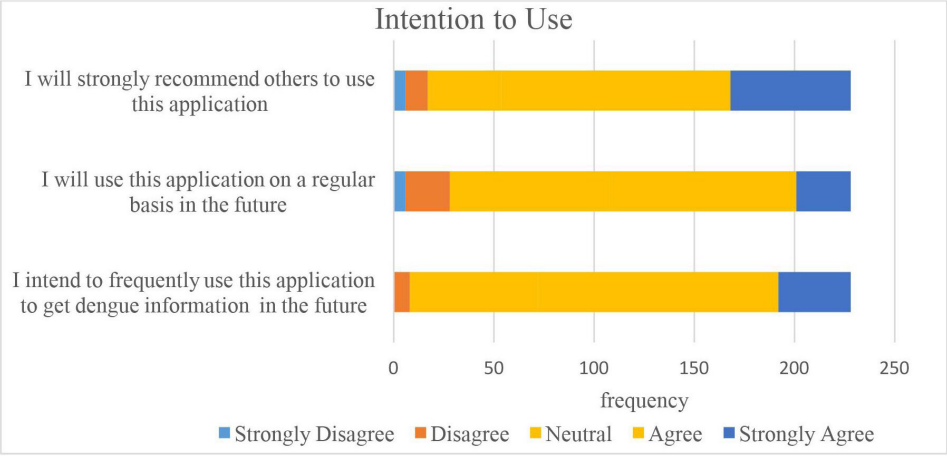

Figure 7 Constructs of intention to use.

they do not know the transmission, symptoms and preventive measures. Using the application would address their major challenge to raise awareness and possibly be a reliable source to disseminate the correct information to the public.

> … if we use this application, I think there will be a good level of awareness because people have access to smartphones. One thing is that those interested can get in-depth information about Dengue. Secondly, those who are infected, affected can use this application.—Dengue Expertise, VBDRTC

Search and destroy campaign

While the search-and-destroy campaign has been perceived as an effective strategy by stakeholders, it has been conducted as a part of a reactive response to the outbreak. It was stated that although the risk factors are present in the community all around the year, the community engagement for search and destroy is low. Stakeholders perceive this application would assist the campaign as there is direct communication with the community through which they can quickly locate the reported breeding sites.

Despite their perception of the application addressing their challenges, some stakeholders in the municipality believe the combination of printed materials and application would be appropriate in the community context.

> Search and destroy have been found effective in the community. We can track people's location for search and destroy campaigns. The app can make our work easier to conduct search and destroy. Through this app, we can orient/provide information about the dengue suspicion area for the representative of that particular community/location. We can inform them of their location in the app by telephone to the word representative, health workers, and FCHV. We can ask them to take action in those areas. It is good.—DFP, DHO, Rupandehi

> Only using the conventional method will not work. We have to use the application and printed media as per the context of the population.—Health Section In-charge, BMC

Cost-effective means

The key informants reported that there is a limited budget allocated, resulting in increased expenditure on developing and updating IEC materials each year. At the community level, the challenge was to reach a wider population as people discarded pamphlets or printed sources. People are inclined towards the use of mobile phones. Stakeholders believe delivering information through an app would be convenient and accessible, making it a cost-effective choice for enhancing dengue awareness efforts.

> Currently, we are using the conventional method for dengue awareness. If we use this application, it will be more cost-effective.—Dengue Expertise, VBDRTC

> We feel we cannot reach a wider population other than this means because information through radio has been less effective these days. People do not use television much these days. So, if pamphlets are also given, people keep them in their pockets and throw them away. So, through the application, it is easy to reach the community in terms of cost. I think it will be cost-effective.—Health Section Staff, BMC

Theme 3: challenges for implementation of the mobile application make people use the application

To make people use the application has been identified as one of the challenges by stakeholders. They believe the development of the application might not be significant unless people use it. The informant from EDCD raised concerns about whether the application could cover and engage all target audiences in the community.

> To aware the community about the availability of this application is the biggest challenge. Just disseminating the information is not a big thing, but to make people use the application is another challenge. Overall, the application is beneficial, but to make people use it might be a challenge.—DFP, EDCD

Illiteracy and availability of smartphone

Stakeholders highlighted that people have varying levels of digital literacy and smartphone usage.

Not everyone in the community is literate and uses smartphones, which creates a barrier to implementing the application. People without internet facilities and smartphones might not benefit from the application.

> When this app is taken to the community level, the first thing we need to know is the smartphone-friendly population. How much is the coverage?—Dengue Expert, VB-DRTC

> Another challenge is not all people in the community use smartphones.—DFP, EDCD

Organisational challenges

At the central level, stakeholders anticipate challenges arising from the government's inability to purchase the application outright and the need for ongoing updates, modifications and validation to align with the national programme. They express that the lack of ownership and control over the application's development might restrict making necessary changes for nationwide implementation.

> The application is already developed, and if you sell it, the government cannot purchase it. Moreover, if we need to update in between, bring new changes, or modify, then that would be a challenge.—DFP, EDCD

According to the municipality health section staff, they feel if the contents, IEC materials, in the application will have to be designed by themselves, they lack expertise. They would probably face technical issues with updating content. However, they are confident that an orientation or training would assist them.

> If the contents have to be developed by us then, there could be challenges like designing IEC materials and putting them in the application. That expertise might not be with us. We could make it, but it might be compromised quality. In terms of updating contents, basic orientation and training would be enough for us.—Health Section Staff, BMC

Theme 4: suggested implementation strategies by stakeholders

Application promotion

Key informants emphasise that no matter how good the application is, it should be promoted widely for effective implementation and utilisation. Recognising that promoting the application during outbreaks might be challenging, they advocate for proactive dissemination of information beforehand. The promotion activities suggested are orientation targeting health workers representing health facilities in each administrative unit (Palika) and FCHVs, utilisation of diverse media outlets such as local FM radio stations, webpages, websites and social media platforms to amplify awareness, using official platforms, like the Ministry of Health and Population's Viber group, which connects nearly a million individuals. The potential of media and digital platforms has been suggested as a means to reach a wider audience. However, stakeholders acknowledge that these promotion efforts would require time.

> …when I dig further, why don't people use apps? Because we do not promote apps. The people who develop apps know about the application but not the users. We need to teach people in different places how to use the app, and promotion should be done widely.—Health Education Promotion Focal Person, NHEICC

Government ownership

For the effective implementation and public acceptance of the application, stakeholders emphasise government ownership. They stress the necessity of app ownership by the National Dengue Control Programme to allow it to make necessary modifications and officially endorse for nationwide dissemination.

> …ultimately the application must be owned by the national government. Only after the government owns it can we market the application. …rather than just developing an application, if the Ministry of Health and Population and Program Division can adopt and request the public to use it, it will be great. If the national program owns that application and disseminates it widely, the public will own and accept the information.—DFP, EDCD

Collaborative approach

Rather than an individual effort, stakeholders suggest a collaborative approach for effective implementation and long-term sustainability of the application. At the central level, an agreement between the national programme team and the application designer team is recommended. Stakeholders stated that they are optimistic about adopting the application with some modifications. They emphasise the coordination between institutions, application developers, and EDCD for continued implementation and improvement of the application.

> We must discuss and collaborate with the program division and technical expert. If there is collaboration, only we can easily use it as an effective tool. After the national program owns it, it wishes to take the property alone. How can we do it? If the approach is made institutionally, it is easier for the government to adopt it. If you approach individually, there might be issues in technicality regarding the backup, update, software, and server.—DFP, EDCD

Theme 5: suggested improvements on the application

Addition of dengue case reporting feature

As stated, the major challenge in the national dengue control programme has been in recording and reporting the number of cases. The existing Early Warning, Alert and Response System (EWARS) relies on hospitals to report cases, leaving gaps in assessing the overall case scenario in the community. Stakeholders believe incorporating a dengue self-case reporting feature would allow individuals to report the cases. They recognise that while

not everyone may use the self-reporting feature, a significant portion could choose to do so. Moreover, even if only half of the diagnosed individuals report their cases through the app, it could significantly enhance understanding of the country's dengue scenario.

> If there is any sort of self-reporting mechanism from the app, it will be effective. Just like the IMU app for our COVID-19, if there is a name, a record of every patient. If the person is confirmed a dengue case, he/she can enter their details in the app; it will be more effective because there is no exact report of dengue cases with anyone… If only half of the diagnosed people report the case, we can know the scenario of our country.—DFP, PHD, Lumbini

Audio-visual aid

Both stakeholders and students suggested the integration of audio-visual aids like audio messages and linked videos to facilitate better understanding among the elderly and remote populations.

> If we can make more pictorial messages, I think it will be good. For older people, it is good if we prepare audio messages.—Representative, EDCD

> If there could be audio-visual information, it would be better. In the part of prevention, if we can include an audio message, the people in the rural part can easily understand.—P3, CCT

Update in line with the programme

According to the central level (EDCD), the emphasis was on the update of contents by recent changes regarding the alternative ways of vector control and atypical symptoms of dengue. Valuable insights from the National Health Research Council's documentation of last year's epidemic are also expected to provide valuable guidance for preparedness. Specifically, stakeholders recommend refining the health education contents of the application. The Nepali term for 'dengue' was expected to be consistently presented to ensure clarity and uniformity in spelling. Additionally, the suggestion to update the Nepalese name of the dengue mosquito to 'Baage laamkhutte' or 'tiger mosquito' was made to establish a relatable context for the user.

> And recently, we have updated something in our program. We are also planning for alternative vector control methods like targeted indoor residual spray in some places and biological larvae sights. We are updating the complementary ways, too. Atypical classical symptoms and other risky symptoms have been observed, so NHRC is documenting the experiences of dengue patients from last year. That might also provide some insights. In addition to that, we need to update the program. Moreover, what we have planned is Dengue is one part, along with this, for other vector-borne diseases, we can focus on the vector control part of the application.—DFP, EDCD

Other suggestions

One key informant suggested incorporating a case alert system that would be instrumental in notifying and alerting people about the cases in their location, including suspected cases and trends.

Integration of additional vectorborne diseases could enhance the application's usefulness and provide a comprehensive resource for public health awareness. Moreover, students highlight the offline availability of content, allowing users to access it even without internet connectivity. Likewise, when asked about what would make it attractive for them to use this application in the future, they responded that integrating educational games would engage them better.

> The majority of information has been included in the application. In addition to the features, we can add an alert system based on location. Like the number of suspected cases in my area or particular location. Are cases rising? Is this the time to be aware? A type of warning for people. I think this is all… —Representative, EDCD

> I think we can incorporate educational games so that we use them often.—P1, BBC

DISCUSSION

Our study presents evidence that the mobile health application NepaDengue has the potential to serve as an effective tool for Dengue Prevention and Control in Nepal. The evidence from university students and dengue key stakeholders indicated the application's acceptability and usefulness within the community and healthcare system. The development of the mobile-based application NepaDengue, aimed to raise awareness and support dengue prevention, is the first application to be developed and pretested in Nepal.

Facilitators

Our study reported a high acceptability mean score rating based on TAM constructs among university students. The findings are consistent with previous studies conducted in Sri Lanka and Japan on similar applications like Mozzify and FeverDx, which reported high acceptability scores based on the MARS assessment.[15 30] The high acceptability ratings observed can be attributed to factors such as the participant's familiarity and exposure to technology, as our study comprised participants who used smartphones. Comparatively, younger participants find the mobile application more straightforward[19] than older ones.

Our study participants viewed NepaDengue as an innovative, simple and relevant tool. The findings are consistent with the similar application Mozzify in Japan, where participants highlighted its positive attributes.[15] Participants found the NepaDengue app helpful in educating communities, promoting preventive behaviours and supporting the government's search and destroy campaigns. Similar positive results were observed with the Mozzify app piloted in Japan and the Philippines,

recognising it as a potential technology for improving knowledge and encouraging the practice of preventive measures against Dengue.[15] Several such applications have been identified as significant to reduce dengue risk in many countries.[19 37] The positive findings in our study reinforce the objective of developing our application.

Lack of community engagement, stated by participants, has been identified to restrict[19] the dengue control activities. Meanwhile, participants in our study perceive NepaDengue as a means to engage the community through reporting a breeding site feature and facilitating timely identification, preparedness and planning for effective dengue control activities.

Likewise, mobile applications have been identified as feasible for conducting participatory surveillance[17] and engaging the community in preventing and controlling dengue fever.[38] On the other hand, the mapping system has assisted the government with information on identifying breeding sites[19] and dengue risk areas, alerting people,[20 21] and implementing control measures on time.[38]

With technological advancement, people are used to smartphones. In contrast, radio, television and printed means are limited, and health education media such as printed materials and pamphlets are often misplaced and lost.[38] In contrast to the conventional method, the NepaDengue app is perceived as a cost-minimisation strategy that could reduce yearly design and printing costs, offering a one-time investment with minimal yearly maintenance expenses. Some stakeholders suggest that applying conventional methods could be appropriate depending on the context. Studies have shown the effectiveness of combined methods in positive change in the knowledge and practice of people for dengue in Nepal.[18]

Barriers

One of the findings highlighted in our study is the sustained use of the application. The absence of dengue cases, digital literacy, internet and smartphone availability might hinder the active use of the application. A similar concern has been raised by participants for the Mozzify application, where they felt the need to sustain the engagement of the users with the application.[37] Studies suggest that the motivation to use such technology depends on the immediate benefit the user receives,[39] which involves complex psychosocial considerations.[19] The perceived severity and susceptibility are significant predictors of intention to use.[40]

Additionally, the intention to use might differ based on social trust, participatory intervention[40] and direct response of health authorities to reports from the application. Students recommend integrating educational games and quizzes to encourage sustained usage, while stakeholders suggest including other vectorborne diseases in the application. Similar suggestions were reported for the Mozzify application piloted in the Philippines.[37] These recommendations highlight the importance of considering engagement strategies and increasing user interaction to maximise the application's impact.

Strategies

For the successful implementation of the NepaDengue application, the study emphasised the significance of government ownership, application promotion and collaborative efforts.

Despite challenges relating to the government's purchasing power, IT expertise and rights to update, there is a consensus among stakeholders from the central to local levels that the application should be owned by the national programme to ensure wide dissemination and acceptance among the public. This aligns with the idea that government ownership lends credibility and authority to the application, making it more likely to be accepted and used effectively.[41] It is emphasised that despite having a good application, its success relies on promoting it extensively within the community. Suggestions are made on promoting and leveraging existing digital platforms and Neglected Tropical Diseases (NTD) networking groups.

It is acknowledged that the current stage of dengue being observed is relatively mild, but it is predicted that in the coming years, dengue could cause significant havoc. The stakeholders also highlighted the underreporting of dengue cases, emphasising that not all cases are captured in the existing EWARS. Incorporating a self-reporting feature as part of future preparedness plans to improve case reporting and identify the dengue scenario in the country would be beneficial. While the user interface, colours and graphics are appreciated, high image resolution and short load time are recommended, along with the integration of audio-visual aids to increase the usability of the application by users.

Limitations and strengths of the study

Our study was a pretesting study only, and responses were based on using the application for a short period in a particular group and setting.

The acceptability scale was assessed among university students in a particular setting based on specific socioeconomic status and behaviour. This might limit the generalisability of the findings to a more diverse population in Nepal. The application is restricted to Nepal because of its context-based development and the National Guideline on Dengue Prevention and Control. The application has not been pretested or piloted in any other setting.

While stakeholder consultations were conducted, it is essential to note that these may not entirely capture the sentiments of the broader community. The perspectives gathered from key stakeholders may be influenced by their specific roles and may not fully represent the diverse opinions within the community.

While our study represents a pretesting phase, it contributes valuable insights into developing and assessing mHealth applications for future implementation and improvements in Nepal. This further emphasises the

study's pretesting phase, role and applicability to similar settings.

Conclusion

The NepaDengue application has been perceived as a promising tool for supporting dengue prevention and control efforts in Nepal. Dengue key stakeholders from all levels are receptive and ready to adopt the application with the necessary revisions and modifications aligned with the National Dengue Control Programme. We believe this app could be one of the strategies in the future for increasing awareness and translating dengue prevention knowledge into practice.

Recommendation

The piloting and evaluation of the application in community settings, particularly during actual dengue outbreaks, is recommended to assess user experiences in different contexts. Additionally, landscape analysis and effectiveness studies are recommended to assess the actual mean difference in knowledge and attitude before and after the implementation of the application. Further, developing a strategic intervention package and engaging dengue key stakeholders to pilot the application are essential. Based on our findings, the government's adoption of the application could be a strategy for comprehensive promotion. Agreement with the government counterpart for the app's adoption, revision and timely update is recommended. The Epidemiology and Disease Control Division (EDCD) could play a crucial role.

Current progress and future direction

From the date of the app's first release in the Google Play Store on 9 November, 2022, we have updated the offline availability of major content, updated health education content and fixed errors and bugs. We are currently updating our old version and releasing others. We have started to plan and design a self-reporting mechanism and work on user engagement. We aim to collaborate with the Nepal government and concerned stakeholders for the piloting of this application in the future.

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