Assessment of a Virtual COVID-19 Vaccine Training-of Trainers Course Implemented by an Academic–Humanitarian Partnership

By

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Abstract

Background: The emergency authorization of Sars Cov-2 (COVID-19) vaccines in December 2020 required clinicians, public health leaders, and policymakers to rapidly understand the science of and how to deploy these novel vaccines. In response to this public health crisis, Brown University partnered with Project HOPE® and a multi-national, governmental public health agency to develop and implement a novel virtual COVID-19 Vaccine Training of Trainers (TOT). This virtual training course aimed to educate clinicians and public health and policy leaders on the COVID-19 vaccines.

Methods: A 17-question pre- and post-test survey was administered to participants to assess knowledge acquisition on course content. The three modules covered vaccine immunology; vaccine hesitancy; and vaccine access and distribution. Knowledge scores for the overall assessment and for the three modules were generated by summing the correct responses on the pre- and post-tests. Paired t-Tests assessed the change in mean COVID-19 vaccine knowledge score. A linear regression model examined the change in knowledge score by gender, geographical region, and profession. Four, semi-structured key informant interviews were conducted with Brown University faculty who developed the curriculum and Project HOPE staff who implemented the training to understand key areas of the development and implementation of this virtual educational model.

Results: There was a statistically significant increase in knowledge score between the pre- and post-tests, with a P-value <0.001. The overall mean knowledge score increased 1.04 points from the pre-test to the post-test. There was a statistically significant increase in knowledge score for each of the three modules. In a linear regression model adjusted for gender, geographical region, and profession, a one standard deviation increase in pre-test score was associated with a -0.855 standard deviation change in overall knowledge score from pre- to the post-test; this result was statistically significant ($p < 0.001$). Four recurring themes were identified in the key informant interviews: 1. Each stakeholder in an academic-NGO-government partnership contributes unique expertise and resources; 2. Synthesizing and teaching rapidly changing evidence to a wide audience requires trainers to adapt and constantly revise materials; 3. Virtual trainings have wide reach, but there are doubts about quality and impact; 4. The absence of a plan to monitor the TOT cascade limited the evaluation of study impact.

Conclusions: Virtual trainings have wide reach and result in knowledge gain related to the COVID-19 vaccine. When delivered as part of an academic-NGO-government partnership, trainings may address knowledge and training gaps first identified by local community members. Our findings suggest that a plan should be developed for trainings and materials after the initial training with Master Trainers to monitor and sustain the knowledge cascade.

Introduction

The emergency authorization of Sars Cov-2 (COVID-19) vaccines in December 2020 required clinicians, public health leaders, and policymakers around the world to rapidly understand novel vaccines and to deploy them in their communities. In response, Training of Trainers (TOT) courses were developed to strengthen knowledge on the prevention and clinical management of viruses for which there are effective vaccines, including COVID-19. TOT is a popular form of education and training in public health and follows a knowledge cascade. A master trainer, usually a global leader, technical expert, or practitioner, leads a series of training workshops for national-level trainees. These national-level trainees then implement and lead trainings at the regional and provincial levels. The cascade continues until the training is delivered at local or municipal levels (1,2).

Recently, vaccine education and preparedness TOTs were implemented for various vaccines, including the novel influenza vaccine in 2009, the Pneumococcal Vaccine PCV-10 in Kenya, and the rotavirus vaccine (RVV) in India (2–4). Researchers found that the RVV TOT intervention led to a statistically significant increase in knowledge (3). Participants of the PCV-10 training in Kenya reported retention of key topics, including "vaccine administration" and healthcare workers' communication with caregivers. Training attendees also shared that they would use the PCV-10 training materials to train other healthcare workers (2). These interventions demonstrated that vaccine-directed TOTs have the desired impacts in the field. Elements of these interventions, such as the pre- and post-test assessments from the RVV training and real-world scenarios from the PCV-10 training, were key components of Brown University's COVID-19 TOT courses.

In 2020, the Center for Human Rights and Humanitarian Studies (CHRHS) at Brown University's Watson Institute for International and Public Affairs and Project HOPE® partnered to deliver a novel, virtual COVID-19 TOT course to strengthen knowledge on the prevention and clinical management of COVID-19. This COVID-19 preparedness training included eight modules that covered "infection prevention and control, screening and triage, diagnosis and management, stabilization and resuscitation, surge capacity, surveillance, and risk communication and community education" (5).

Brown University contributed scientific knowledge about COVID-19 management and treatment, and experience in education to the TOT. Project HOPE® contributed expertise in

rapid emergency response, as well as an established network of humanitarian responders and global healthcare workers who were trainees (6). This COVID-19 Preparedness TOT was disseminated to more than 5,000 trainees trained primarily by Brown University faculty and more than 90,000 secondary trainees across 53 countries. Knowledge of key COVID-19 concepts was assessed through voluntary pre- and post-test assessments administered during the training. Kharel et al. (2022) demonstrated a significant improvement in knowledge of COVID-19 preparedness concepts upon completion of the COVID-19 Preparedness TOT program. There was a significant increase in post-test score, and a mean change in score of 1.2 points from the pre- to the post-test upon completion of the COVID-19 preparedness training. The results also showed that there was a statistically significant increase in percent correct for seven of the eight module topics – the increase in percent correct ranged from 1-44% (5).

Following the success of the COVID-19 Preparedness TOT, in early 2021, CHRHS and Project HOPE® collaborated to develop a TOT for the COVID-19 vaccine. This course aimed to educate clinicians and public health and policy leaders on the science, the dissemination, and public communication related to the novel COVID-19 vaccine. The COVID-19 Vaccine training included three modules covering three main topics: a) An introduction to vaccine immunology and the technology of COVID-19 vaccines; b) Vaccine hesitancy and public communication about vaccines; and c) Vaccine access and the logistics of vaccine delivery.

To date, researchers have not assessed the success of the COVID-19 vaccine TOT intervention or qualitatively studied how the COVID-19 TOT programs were developed and implemented. Understanding how the TOT was developed from the perspective of key partners provides insight on barriers and opportunities for future similar programs. This mixed methods study aimed to 1) determine whether there was a knowledge gain upon participants' completion of the 2021 COVID-19 Vaccine TOT course, and 2) assess whether the COVID-19 Vaccine TOT may be a model for medical education and training in emergency and resource-limited settings. The study also sought to understand the development and implementation process of the virtual COVID-19 vaccine TOT program. Findings build on the analysis of the 2020 COVID-19 Preparedness training by Kharel and colleagues (2022).

Methods

Sampling and Data Collection

Quantitative Analysis. A total of 1,151 participants completed the pre-test and of these participants, 550 participants completed both the pre- and post-tests. 601 participants completed only the pre-test and 151 participants completed only the post-test. Statistical analyses were limited to the 550 participants who completed both the pre- and post-tests.

Qualitative Analysis. We conducted four, semi-structured key informant interviews to understand key areas of the development and implementation of this virtual educational model. This data collection approach allowed for in-depth accounts of each interviewee's involvement in the COVID-19 Vaccine TOT. The participants were selected using purposive sampling in coordination with the CHRHS program manager. This sampling technique allowed us to capture a breadth of knowledge about and experience with developing and implementing the TOT. The key informants included two CHRHS-affiliated faculty who developed the TOT curriculum, and two Project HOPE® staff members who implemented the training. A semi-structured interview guide was developed in coordination with researchers with expertise in mixed methods research and in global emergency medical education. All interviews were conducted via Zoom® to ensure COVID-19 safety protocol. All participants provided verbal consent for the interview and recording.

Data Analysis

This mixed method study followed a parallel embedded design to address distinct research questions (7). The quantitative methods aimed to determine whether there was a knowledge gain upon completion of the COVID-19 vaccine training course. The qualitative methods aimed to better understand the development and implementation process of the virtual COVID-19 vaccine TOT program from the perspectives of key stakeholders.

Statistical Analysis. A 17-question pre- and post-test assessment was administered to assess knowledge acquisition. Participants were asked to complete the pre-test prior to the start of the training and the post-test immediately upon concluding the training. Knowledge scores for both the overall assessment and module-specific scores were generated by summing the correct the pre- and post-test responses. Paired t-Tests assessed the change in mean COVID-19 vaccine knowledge scores, for both the overall test and for the three modules. A linear regression model

was conducted to examine the change in knowledge score by gender, geographical region, and profession. All analyses were run in R Studio 1.4 and the significance level was set at $\alpha = 0.05$ a priori.

Qualitative Analysis. Initial interview transcripts generated through Zoom® were edited for accuracy to match the audio recording for each interview. Researchers reviewed audio recordings and maintained an audit trail, noting the key concepts and the development and evolution of the key themes throughout the coding process.

Four salient themes were determined from the data utilizing the principles of content analysis and then thematic analysis (8). These themes reflect recurring concepts from the data and were discussed across multiple interviews. Thematic analysis was chosen to identify patterns across interviews and to generate rich, in-depth accounts of the development and implementation of the COVID-19 Vaccine TOT (8). The transcript of the first interview was coded using content analysis. These codes were analyzed and led to the generation of initial, descriptive themes. The first interview transcript was peer coded, and these codes were used to further refine the initial descriptive themes. All four interviews were coded using these refined themes; these themes were continually revised across coding and checking of codes until the final codebook was created. All coding was done in NVivo 12®. The extracts that accompany each theme were selected to offer rich and in-depth perspectives on key ideas mentioned across interviews.

Results

Quantitative

A total of 550 participants completed the pre- and post-test and were included in the final analyses. Most participants identified as female (Table 1). Participants attended from all World Health Organization (WHO) geographical regions and 40 countries, with the largest proportion of participants from the South-East Asia region (27.8%) and the European region (18.7%) (Figure 1; Table 1). More than 80 percent of participants held clinical roles, and about 12 percent worked in public health (Table 1).

There was a statistically significant increase in knowledge score between the pre- and post-tests ($t(549) = 13.917$, $p < 0.001$). The overall mean knowledge score increased 1.03 points (95% CI: 0.88–1.18, $p < 0.001$). The mean knowledge score on the pre-test was 13.39 (SD = 2.21, minimum = 6, maximum = 17). The mean knowledge score on the post-test was 14.41 (SD

= 2.13, minimum = 6, maximum = 17). There was a statistically significant increase in knowledge score for each of the three modules, with the largest increase of 0.52 points for the vaccine immunology module ($t(549) = 3.825$, $p < 0.001$). For the vaccine immunology module, there was 10.93 percent increase in percent correct from the pre- to the post-test.

Across all WHO regions, there was a statistically significant increase in overall knowledge score from the pre- to the post-test. In the Region of the Americas, there was a 1.78 point increase in knowledge score and in South-East Asia, there was a 1.14 point increase in overall knowledge score ($t(36) = 4.7196$, $p < 0.001$; $t(152) = 8.3238$, $p < 0.001$). The largest increase in percent correct was observed in the Region for the Americas (13%), followed by South-East Asia (8.7%), the Eastern Mediterranean Region (8.6%), and the African region (7.9%). The smallest increase in percent correct was observed in the European region (4.8%) and the Western Pacific (6.6%).

There was a statistically significant increase in overall knowledge score across all three aggregate professional categories. Clinicians had a 1 point increase in knowledge score from the pre- to the post-test and public health professionals had a 1.01 point increase in overall knowledge score between the pre- and post-test ($t(446) = 12.234$, $p < 0.001$; $t(66) = 4.4027$, $p < 0.001$). The highest increase of 1.42 points was observed in participants in professions other than clinical work and public health ($t(35) = 4.6146$, $p < 0.001$).

A one standard deviation increase in pre-test score was associated with a -0.855 standard deviation change in overall knowledge score from pre- to the post-test; this result was statistically significant ($p < 0.001$) (Figure 2). Participants from Region of the Americas had a significantly higher change in overall knowledge score from the pre- to the post-test relative to participants from the African region; this result was statistically significant ($p < 0.05$) (Figure 2). The change in the overall knowledge score was not statistically significant for male participants relative to female participants or for participants from the Eastern Mediterranean region relative to participants from the African region.

Qualitative

Four, 30 to 40-minute semi-structured key informant interviews were conducted with Brown University medical faculty (2) and Project HOPE® staff (2) (N = 4). Three participants were female, and one participant was male. Three participants were part of the development

and/or implementation of the Brown University-Project HOPE® COVID-19 Preparedness TOT in 2020. All four participants had prior experience in healthcare workforce development and training in low-and-middle income countries (LMICs).

The four recurring themes identified in the interviews are discussed below (Figure 3).

Theme 1: Each stakeholder in an academic-NGO-government partnership contributes unique expertise and resources.

Academic partners contribute technical expertise and educational resources, and management support for NGO partners.

Academic institutions like Brown University offered "technical support or knowledge or specialty training that maybe the . . . NGOs or the governments don't have" (P1). Experience in direct COVID-19 patient care, for example, informed the material Brown University medical faculty presented in the TOT. Faculty trainers' language expertise also expanded the reach of the training; some trainings conducted in Spanish-speaking countries were taught entirely in Spanish by faculty members who spoke the language. The faculty also applied their extensive experience in developing educational materials, as well as in evaluating scientific evidence – both regular duties for clinical faculty – to develop the three COVID-19 Vaccine TOT modules: "Developing lectures . . . we do [that] for all . . . our educational needs . . . we make lectures and collate information and assess. . . scientific reports on a regular basis, so that's not really a change for us" (P1).

This academic-NGO partnership also allowed Project HOPE® to share some of their usual technical and data management tasks with Brown University. All training sessions, for example, were hosted through Brown University's Zoom® account. Brown University also created and shared event flyers with partners and managed the TOT registration and pre- and post-test assessments. One Project HOPE® staff member reflected that "it was really nice to be able to . . . pass over [the] IT [and] technical components to Brown" (P2).

NGO partners coordinate with academic and government partners and may quickly adapt and resolve issues

Project HOPE® coordinated and relayed key information between academic and government partners. Project HOPE® first engaged Brown University in the TOT and reached

out for technical expertise and educational content/materials. Participants from Brown University shared that Project HOPE® led all aspects of the initiative. Project HOPE® also leveraged their vast global network to recruit participants for the TOT, partnering with both large governmental and non-profit organizations – these partners then disseminated details about the TOT more locally through their member states. Furthermore, sessions were only scheduled following expressed interest from specific countries or member states:

> "And they might say . . . a group of five countries [have] expressed a need for this kind of training . . [W]e would say . . . great . . . [and] ask them to coordinate with the Ministries of Health, and whoever in those countries to suggest . . . a potential date and time . . . usually it was just [a] date." (P2)

NGOs are also able to adapt and resolve issues quickly. Following low participant turnout at a few TOTs, for example, Project HOPE staff disseminated TOT flyers to their NGO partners which ensured sufficient attendance at future trainings. NGO partners may also have the capacity to assign additional staff to a project as needed: Another Project HOPE staff member was brought onto the COVID-19 Vaccine TOT team in response to a Brown University staff member's request for an additional contact person at Project HOPE®.

Government partners communicate training needs to NGO partners and recruit participants from local communities

Government partners first proposed the idea of the COVID-19 Vaccine TOT to Project HOPE® in response to requests from Departments of Infectious Disease and COVID-19 Vaccination within Ministries of Health. Additionally, government partners engaged and recruited participants, both at the national and local levels, and may thus have a more local reach than NGOs: "And then . . . I would share that flyer with [government partner]. They would share it with their . . . counterparts and whatever countries were being targeted" (P2). Overall, government partners were flexible about training logistics, including timing. Furthermore, since government partners are most familiar with the demographics of their communities, they were tasked with finding translators to offer live translation as needed.

Theme 2: Synthesizing and teaching rapidly changing evidence to a wide audience requires trainers to adapt and constantly revise materials

Both Brown University and Project HOPE® commenced the COVID-19 Vaccine TOT, knowing that the modules would need to be revised given the dynamic evidence on COVID-19 vaccine efficacy and safety. Additionally, both partners aimed to future-proof the training and ensure that the modules and materials remained relevant and applicable over time.

> "It's not like something . . . like HIV, where we already have . . . decades to figure out information . . . this was being developed in real-time with a constantly changing understanding of the virus, how it spread, what the impacts of some of our treatment methodologies were . . . [so we did our] best to . . . future-proof [the] training." (P4)

Regular updates to the TOT slides were integrated into the original work plan—there were scheduled updates to the modules, first daily and then weekly. Over time, however, the updates became inefficient and led participants to question the efficacy of the updates. Following six months of regular updates, the PowerPoint® was quite long and included an extensive discussion of vaccine side-effects: "We continued to update it, probably for maybe six months, and . . . it just got so unwieldy, and the PowerPoint, unfortunately just kept getting longer and longer and longer, because there were so many additional layers of side effects" (P1). The continuous updates led to doubts about the TOT cascade and localization of the TOT; with all the updates, it became challenging to translate the modules into other languages regularly.

Faculty who developed the training referenced a wide array of resources to inform the modules and there was a conscious effort to present information that would be most relevant to participants who were mostly from LMICs: "We tried to use as many diverse sources of information as possible" (P3). Since most COVID-19 Vaccine TOT participants were from LMICs, the faculty synthesized and presented data on vaccine rollout in LMICs as they became available. Brown faculty also learned how to evaluate the validity, rigor, and generalizability of imperfect and non-traditional data: There was an evident lack of peer-reviewed evidence on COVID-19 vaccines. Comparing the various COVID-19 vaccines was also challenging because each vaccine had "different endpoints . . . [and] conclusions" (P1).

> "The data was all very . . . loose at that point, right? It was a lot of pre-publications or data that was getting published in the regular press as opposed to peer-reviewed journals, and so we were . . . looking at all sorts of different resources to cobble together the . . . best information that we could at that point." (P1)

Developing and teaching a single TOT targeted towards both physicians and community health workers was challenging for faculty. Faculty, however, structured the training to be as accessible to participants with varying scientific backgrounds: For example, a color-coding scheme was used to denote more technical slides that may be more difficult for some participants to understand. Different, but related COVID-19 Vaccine TOTs for each profession were proposed as a potential solution because a community health worker and a physician do not always need to know the same information about a COVID-19 vaccine, and individuals in each of these roles have varying educational needs.

> "Your . . . goal is to not bring a community health worker up to the same level of understanding as a physician who runs the vaccine program and so I think, having a potentially, a more narrow scope for who is included in the TOT team with the understanding that as things get rolled out, that material needs to be adapted to cover different populations . . . with different needs." (P1)

Theme 3: Virtual trainings have wide reach, but there are doubts about quality and impact

Wide reach was described as one of the key strengths of virtual trainings. Participants emphasized that virtual training is an effective platform to reach a large, global audience with limited resources. The target audience for the COVID-19 Vaccine TOT was global, rather than limited to a specific geographic location or targeted audience, and Project HOPE® and government partners could therefore invite as many participants as possible. Furthermore, virtual trainings may be recorded and then disseminated broadly for individuals to watch independently. For example, following a few trainings with low attendance, Project HOPE® shared the TOT flyer with other NGOs and encouraged them to disseminate the flyer to their networks; subsequent trainings had sufficient attendance:

> "Then we also started letting our [NGO] colleagues know when the training was scheduled, and . . . what time it would be, what languages it would be, and they would send it out to their networks . . . [W]hen we added them we got . . . a much larger participation rate." (P2)

The overall knowledge improvement, as demonstrated in the average increase in the post-test scores, increased participants' confidence in virtual trainings. Doubts about the quality of the training, as well as the overall impact of the training, remained. Trainings are ubiquitous in global health, and there were doubts about the impact of virtual trainings given how easy it is to become distracted on a virtual platform, especially about an hour into a training: "After you know, an hour and a half, you're . . . on your phone or you're checking email or something, and . . . it can be tough to pay attention" (P2).

Decreased knowledge retention and loss of knowledge over time was another concern. There was an underlying belief that the hands-on nature of in-person training, combined with the face-to-face interactions with colleagues, facilitates more knowledge retention, especially over time – perhaps participants retained the information when filling out the post-test immediately after the training, but that knowledge may be lost over time. There may also be more loss of knowledge following virtual training if this knowledge is not applied regularly: "You know, maybe if you don't get pulled for a vaccination campaign for . . . another few months, . . . you might not remember all of it" (P2). Additionally, in-person trainings may be more appropriate for more sensitive topics, such as vaccine hesitancy, which was covered in the third module of the COVID-19 Vaccine TOT – in-person trainings may facilitate more dynamic engagement and open conversation about these topics.

To increase the quality of virtual training, participants suggested there could be more discussion throughout the session. There should be an effort to develop interactive and engaging training materials: "I think just trying to make it not like death by PowerPoint®, and try to incorporate as much discussion or other activities as possible is really important" (P2). One strategy to facilitate participant engagement in a virtual training could be to place participants into Breakout Rooms. It is unrealistic to expect 50-100 attendees to engage in an open discussion with the entire group – smaller Breakout Rooms will at least allow trainees to meet someone new and "be a little more engaged" (P2). Other strategies to encourage participant engagement

include integrating quizzes and interactive videos throughout the training so that faculty are not speaking for multiple hours.

Training quality also includes accessing the training in one's own language and including trainers from local communities and who are familiar with local contexts. One participant reflected that in future virtual trainings, it would be helpful to have a faculty trainer from the African continent deliver a training to participants from Africa: "It's nice to be hearing from someone who is . . . more familiar with the context that you're operating in" (P2). Furthermore, there were challenges in translating materials into local languages and identifying an interpreter who would accurately communicate material in English in other languages.

While virtual trainings expand potential reach to participants across the globe, access remains limited to communities without reliable Internet connection. Participants also need equipment like monitors and computers. These resources may be difficult to access individually if they are not available at a workplace. Overall, there were concerns that virtual trainings do not reach – and perhaps exclude – participants from rural communities for whom the training may have a larger impact. One participant reflected that participants in rural areas may have access to fewer resources on COVID-19 relative to participants from urban areas.

Theme 4: The absence of a plan to monitor the TOT cascade limited the evaluation of study impact

All four participants noted the absence of a plan to monitor the TOT cascade as a key limitation of the training. The impact of the TOT depends upon whether Master Trainers who attended the Brown University-Project HOPE® training were able to implement the TOT within their own communities. One participant shared that there is a loss of control unless an institutional partner like Project HOPE or Brown University remains closely involved in the knowledge cascade: "Once you train the trainers, unless it's under a program where you, as an institution, are deeply involved, or you as . . . a partner institution, are deeply involved . . . you lose a level of control" (P4).

Participants noted that there was a system to monitor the contact information and demographics of individuals who participated in the TOT, but there was no system to monitor whether the training was cascaded. Monitoring the TOT cascade data and TOT follow-up, more

generally, was part of Project HOPE's® duties. Follow-up with TOT participants was informal: Project HOPE® staff inquired about whether participants had conducted any training sessions via email and estimated about a 10 percent response rate to these emails. Participants who responded to these email inquiries shared data about the TOT cascade with varying levels of detail: "Some people would send . . . a whole Excel sheet with . . . all of the hospitals they'd gone to and . . . a list of participants. And then some people were just like yeah, we did two other trainings" (P2).

The absence of a plan to systematically track the TOT cascade limited partners' ability to evaluate the impact of the training. Some participants also doubted whether there was sufficient support for participants to initiate the TOT cascade. For example, training materials were not available in all local languages and partners were unable to provide translation support, so participants had to translate all the materials themselves before implementing the TOT within their own communities.

One participant reflected on how one key takeaway from the COVID-19 Vaccine TOT is the need to establish a system, as well as resources to monitor the TOT cascade data: "There should be ways to measure the TOT cascade, even if TOT partners like Project HOPE® are neither directly nor intimately involved in the cascade itself. This participant has ensured that there are systems to monitor cascade data for TOTs they have since managed.

Discussion

The present study assessed whether there was knowledge gain upon completion of a virtual, global training about a novel vaccine for an emerging, global infectious disease (COVID-19). To our knowledge, this is the first qualitative study about a TOT virtual training program implemented in response to the COVID-19 pandemic. Findings offer an in-depth perspective on TOTs, and expands on quantitative studies of TOT trainings that focus on knowledge gain through analyses of pre- and post-test scores (5).

Our study had two important findings. First, quantitative findings suggest a significant increase in overall COVID-19 vaccine knowledge score upon completing this virtual training course. Statistically significant increases in post-test knowledge scores were observed for each of the three training modules (vaccine immunology; vaccine hesitancy; and vaccine distribution), and across professions and WHO geographical regions. This study supports prior research that

showed a significant knowledge gain upon completing a virtual, global COVID-19 preparedness TOT course (5). Together, these statistically significant increases in knowledge score suggest that there is a gain in knowledge upon completion of a virtual TOT course about novel vaccines and treatments for these infectious diseases. The virtual COVID-19 Vaccine TOT was taught in both English and Spanish, indicating that these virtual trainings may be delivered to a global audience in both languages.

The qualitative findings offer in-depth accounts on the development and implementation of the COVID-19 Vaccine TOT from the perspectives of key stakeholders. To our knowledge, this is the first qualitative study about this training program, and offers an in-depth perspective on TOTs by expanding on quantitative studies of TOT trainings that focus on knowledge gains through analyses of pre- and post-test scores (5). The qualitative methodology offered key informants an opportunity to elaborate on their perspectives of and experiences with the training. The four recurring themes from this study offer practical steps to improve future COVID-19 Vaccine TOTs, such as devising a clear plan to monitor the knowledge cascade and creating opportunities for small group engagement and discussion through Break Out rooms on a virtual platform. Key informants included Brown University medical faculty and Project HOPE staff, offering two distinct perspectives on the development and implementation of the training.

These in-depth accounts from both academic and NGO key informants demonstrated that academic, NGO, and government stakeholders contribute unique expertise and resources to a virtual TOT like this COVID-19 vaccine training (6). Our findings highlight how government partners may serve as liaisons and communicate their communities' desire and/or need for training with NGO partners who have human and financial resources and academic partners with educational expertise. Engaging government and local partners in TOT development may help ensure that trainings address knowledge and capacity gaps identified within and by communities. Teaching a rapidly evolving topic like COVID-19 vaccines requires flexibility and creativity from trainers and program staff. TOTs should integrate knowledge from target communities, such as data on COVID-19 vaccine trial results and outcomes in LMICs as this data becomes available.

A key strength of the COVID-19 Vaccine TOT was the wide reach offered through a virtual platform like Zoom®. This finding is aligned with existing literature about how virtual training may address limitations in local technical expertise and access to trainers (9). Trainers

and staff, however, must define and implement strategies to ensure the quality and impact of virtual trainings. High-quality trainings may be offered in local languages and be interactive. The impact of a TOT relates to the knowledge cascade – all TOTs should include a feasible plan to monitor the knowledge cascade, which should be developed at the outset of the study. While Project HOPE® monitored the knowledge cascade for the COVID-19 Vaccine training, government and local partners may be better suited to both monitor and support the TOT cascade. These local partners could even support trainers and ensure that they have all the required resources to implement the TOT locally (1).

The doubts about long-term knowledge retention and application raised in this study are consistent with concerns that there may not be a full transfer of knowledge within the one to three-day TOT (1). Knowledge of COVID-19 vaccine was only assessed at one-time point through a post-test administered immediately upon completion of the training. While knowledge gain was observed immediately upon completion of the training, there is no way to know that there was long-term knowledge retention. Future TOT courses should assess long-term knowledge retention through virtual post-test assessments disseminated to training participants three to six-months after the initial training. Like the COVID-19 Vaccine TOT, medical education and public health trainings were held on Zoom® due to the COVID-19 pandemic – this virtual platform facilitated increased reach, but there were doubts about engagement and application of the material (9). Equitable access concerns for the COVID-19 Vaccine TOT that was targeted towards audiences in LMICs are consistent with challenges health professions students in the United States faced with virtual learning: Students struggled to find regular Internet access and nearly 60 percent of students reported loss of concentration with more than four hours of daily virtual learning (10).

Limitations

The present study does not assess long-term knowledge retention and application of topics and concepts from the virtual COVID-19 Vaccine TOT course. Post-training COVID-19 vaccine knowledge was assessed at a single time point through a post-test administered upon immediate conclusion of the training. Less than half of the participants who completed the pre-test also completed the post-test. This limits our ability to assess long-term knowledge retention from the training. Furthermore, the COVID-19 Vaccine TOT was delivered as a single day

training, which may have led to participant fatigue and therefore lower completion rates for the post-test assessment. Although the COVID-19 vaccine training was delivered in both English and Spanish, the pre- and post-test assessments were administered in English, which may have limited participants' ability to understand the questions. The training course offered participants opportunities to engage in interactive problem-solving. The pre- and post-tests, however, included only multiple choice and true/false questions and did not assess participants' application of key concepts from the COVID-19 vaccine training to real-world scenarios.

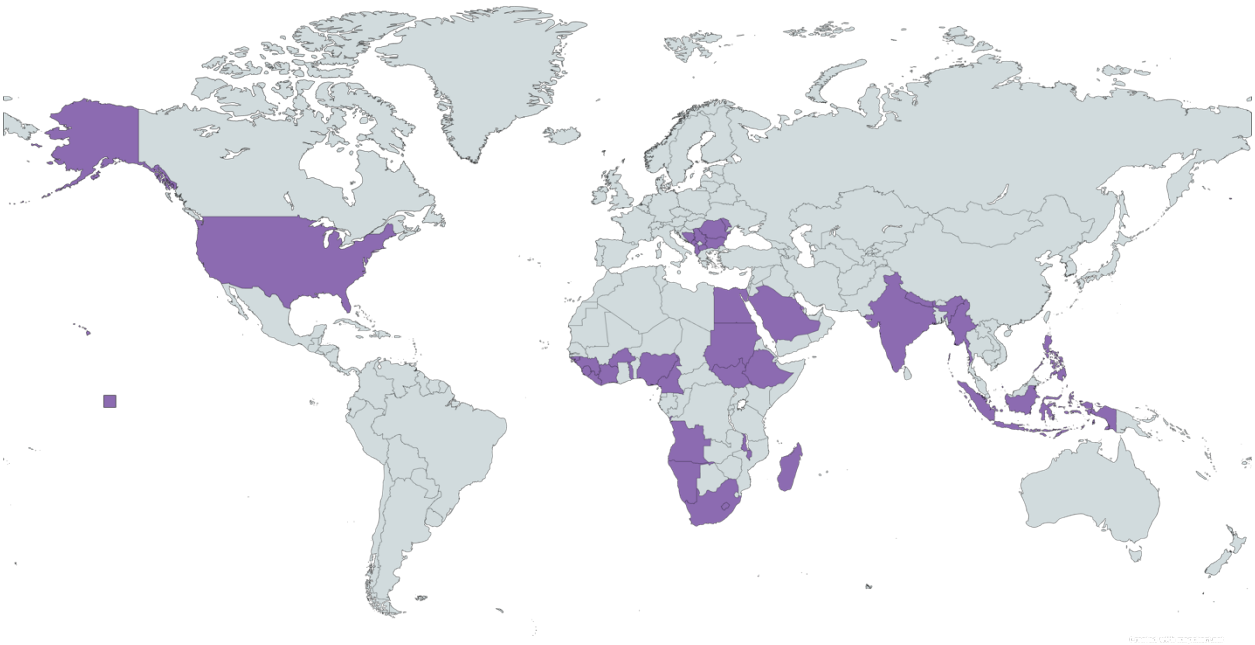
The primary author's affiliation with Brown University may have limited key informants', especially Project HOPE® staff's, critique of Brown's involvement in the COVID-19 Vaccine TOT. TOT participants were not interviewed for this study, and there may be differences in what trainers/staff and participants value and seek from a virtual training. The small sample size is a limitation of this study. Recruitment of Project HOPE® staff was limited because some key staff who supported the TOT were unavailable for an interview due to their involvement in the humanitarian response to the Russia-Ukraine War. Since key informant interviews were conducted more than a year after the training, there could be recall bias. There may also be overlap between reflections on the COVID-19 Preparedness TOT and the COVID-19 Vaccine TOT since three out of four key informants were also involved in the first COVID-19 TOT in 2020.

Conclusion

Virtual trainings on novel vaccines for emerging infectious diseases like the novel COVID-19 vaccine have wide reach. These trainings may address knowledge and training gaps first identified by local community members when delivered as part of an academic-NGO-government partnership. Stakeholders implementing future virtual COVID-19 Vaccine TOT courses must clearly define and ensure quality of virtual trainings. Our findings suggest that a plan to monitor and sustain the knowledge cascade after the initial training with Master Trainers should be developed alongside the training materials. Government and local partners, rather than international NGOs, may be able to better support the local knowledge cascade. Future TOTs should assess long-term knowledge retention and application through post-tests administered to participants three to six months after the initial training course.

Tables and Figures

Figure 1: Map of participants' country of residence.*



** Map created using MapChart.*

Table 1: Demographics of participants who completed both the pre- and post-tests.

	Overall (N=550)
Gender	
Female	381 (69.3%)
Male	169 (30.7%)
WHO Region	
African	61 (11.1%)
Eastern Mediterranean	96 (17.5%)
European	103 (18.7%)
Region of the Americas	37 (6.7%)
South-East Asia	153 (27.8%)
Unknown	3 (0.5%)
Western Pacific	97 (17.6%)
Profession	
Clinical	447 (81.3%)
Other	36 (6.5%)
Public Health	67 (12.2%)

Figure 2: Percent change in knowledge score from the pre- to post-test by WHO region.

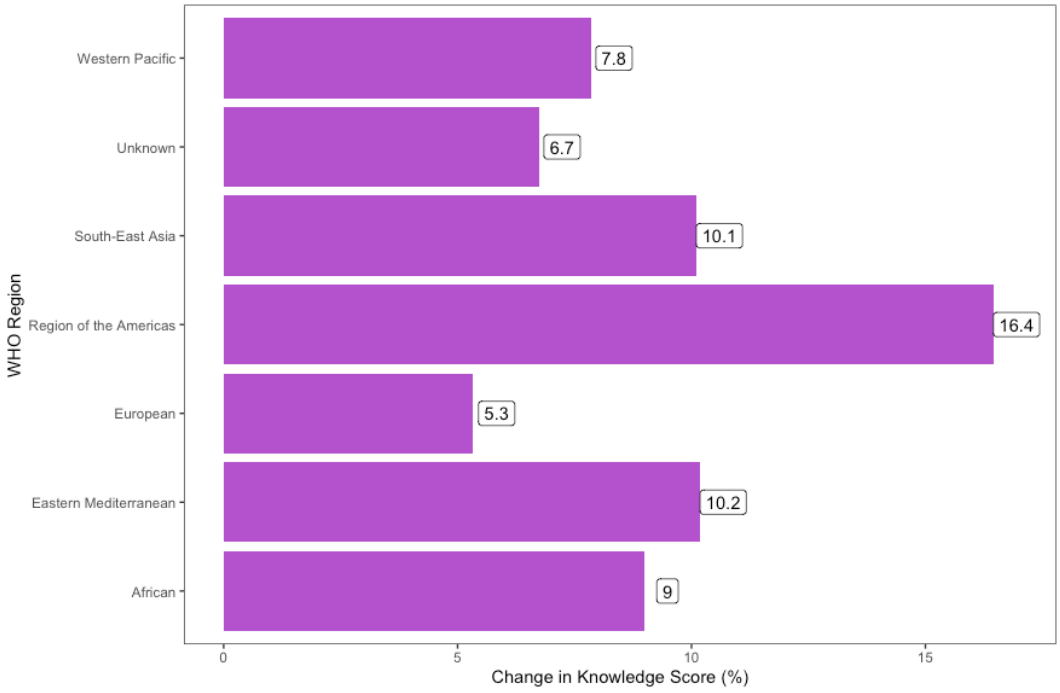


Table 2: Multivariable regression model of change in knowledge score.

Characteristic	Standardized Coefficients (95% CI) (N = 550)
Pre-Test Score	-0.855*(-0.995 – -0.714)
Gender	
Female	[Reference]
Male	-0.119 (-0.419 – 0.182)
Profession	
Clinical	[Reference]
Public Health	0.109 (-0.347 – 0.565)
Other	0.020 (-0.581 – 0.621)
WHO Region	
African	[Reference]
Eastern Mediterranean	-0.533 (-1.11 – 0.0389)
European	0.039 (-0.498 – 0.577)
Region of the Americas	0.853* (0.143 – 0.156)
South-East Asia	-0.016 (-0.535 – 0.502)
Unknown	-0.928 (-2.76 – 0.904)
Western Pacific	0.171 (-0.381 – 0.723)

*$p < 0.05$

Figure 3: Summary of key themes from key informant interviews.

Theme	Key Findings
Each stakeholder in an academic-NGO-government partnership contributes unique expertise and resources.	• Academic partners contribute technical expertise and educational resources, as well management support for NGO partners. • NGO partners coordinate between academic and government partners and may quickly adapt and resolve issues. • Government partners communicate training needs to NGO partners and recruit participants from local communities.
Synthesizing and teaching rapidly changing evidence to a wide audience requires trainers to adapt and constantly revise materials.	• All stakeholders commenced the COVID-19 Vaccine TOT, knowing that the modules would need to be revised given the dynamic evidence on COVID-19 vaccine efficacy and safety. • Faculty learned how to evaluate the validity, rigor, and generalizability of imperfect and non-traditional data since there was an evident lack of peer-reviewed evidence on COVID-19 vaccines. • Developing and teaching a single TOT for both physicians and community health workers was a challenge for faculty. Faculty structured the training to be as accessible to participants with varying scientific backgrounds.
Virtual trainings have wide reach, but there are doubts about quality and impact.	• Participants emphasized that virtual training is an effective platform to reach a large, global audience with limited resources. • The overall knowledge improvement, as demonstrated in the average increase in the post-test scores, increased participants' confidence in virtual trainings. • To increase the quality of virtual training, there should be an effort to develop interactive and engaging training materials.
The absence of a plan to monitor the TOT cascade limited the evaluation of study impact.	• All four participants noted that the impact of the TOT depends upon whether attendees implement the TOT within their own communities. The absence of a plan to systematically track the TOT cascade limited partners' ability to evaluate the impact of the training. • Monitoring the TOT cascade data was part of Project HOPE's® duties. Follow-up with TOT participants was informal.

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