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Abstract

Background Human papillomavirus (HPV) vaccination can prevent cancer in low- and middle-income countries (LMICs), but its uptake remains low, especially in Nigeria. Understanding participatory approaches can help identify local strategies to increase, build capacity for, and sustain vaccine uptake. This study evaluated the effectiveness of an innovation bootcamp in enhancing the knowledge and skills of youth implementers about HPV and cervical cancer as a strategy to increase vaccine uptake among Nigerian girls aged 9–14 years. An innovation bootcamp is an intensive training program that engages end users to build capacity and skills.

Methods This was a five-week hybrid bootcamp guided by Youth Participatory Action Research (YPAR) and the PEN-3 cultural model at the Nigerian Institute of Medical Research in Lagos, Nigeria. Data were collected using pre- and post-training surveys to assess sociodemographic characteristics, participant preparation, motivations, support needs, baseline learning barriers, the bootcamp process, and knowledge and implementation science research skills (using 9-item and 22-item self-reported scales, respectively). We conducted descriptive analyses of quantitative data and thematic analysis for qualitative, open-ended responses, and we estimated changes in knowledge and skills using the Wilcoxon Signed-Rank test.

Results Five teams comprised of 16 participants attended the bootcamp, and 13 completed the post-survey. Of the 16 participants, most were female (81%) with an average age of 22 years and resided in the following states: Osun ($n = 5$), Abuja ($n = 4$), Lagos ($n = 2$), Kwara ($n = 2$), Oyo ($n = 2$), and Plateau ($n = 1$). The PEN-3 cultural model highlighted the importance of training and enabling resources. Following the bootcamp, the median knowledge score increased

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from 34 (IQR 31.0–35.0) to 37 (IQR 35.0–40.0), but this change was not statistically significant ($p=0.086$). In contrast, there was a significant increase in research skills score from 54 (IQR 43.0–61.0) to 82 (IQR 73.0–96.0) ($p=0.011$).

Conclusions The bootcamp demonstrated that culturally structured participatory approaches can enhance engagement, knowledge, and skills while cultivating participatory learning communities. Empowering young people with appropriate resources and mentorship can propel sustainable HPV vaccination in Nigeria.

Contributions to the literature

This research underscores the importance of context-specific strategies in promoting HPV vaccination, especially in low- and middle-income countries. Our study highlights the importance of participatory approaches, such as innovation bootcamps, in empowering young people to address local challenges related to HPV vaccination uptake.

Engaging youth implementers enhances their knowledge and skills while fostering a sense of ownership and uptake of evidence-based interventions within the community.

The use of the PEN-3 cultural model to identify local barriers and facilitators can support the development of sustainable vaccination initiatives.

Our research emphasizes the importance of involving diverse stakeholders, including healthcare professionals, religious leaders, and community leaders, and demonstrates the potential impact of youth-led initiatives on public health agendas.

Keywords HPV vaccination, Participatory implementation science, Capacity building, Youth engagement, Cervical cancer prevention

Background

Human papillomavirus (HPV) contributes to about 650,000 new cancer cases globally and remains the leading cause of invasive cervical cancer [1–3]. In Nigeria, HPV causes approximately 11% of all cancers, with cervical cancer predominant among women and anal cancer among men [4]. Nigeria bears the highest cervical cancer burden in Africa, with over 14,900 new cases and more than 10,000 deaths each year, representing an estimated 27% of cases and 20% of cervical cancer-related deaths in West Africa [3].

HPV infection is commonly sexually transmitted [5], including oral HPV infection, which is transmitted through oral sex [1], and normally clears naturally in approximately 12 months through the body's host immune system [6]. However, the duration and clearance of HPV infection vary among individuals, particularly those with underlying conditions such as HIV [7, 8]. In Nigeria, HPV prevalence among young adolescents is about 13.2% [9]. Notably, persistent HPV infection is linked to cervical, anal, vulvar, vaginal, and head and neck cancers, as well as genital warts [3, 10]. HPV vaccination can prevent up to 90% of HPV-related diseases [2]. The two-dose HPV vaccine, administered five to 13 months apart, is effective for preventing the most common HPV genotypes among girls aged 9–14 years [11, 12]. Despite national adoption and recent rollout of a single-dose program in Nigeria [13], and based on available evidence, vaccination coverage remains low (4–12%) [14, 15]. Barriers to HPV vaccine uptake include vaccine hesitancy, limited knowledge and access, inadequate social support, and cultural constraints [13, 16–19], highlighting the

limitations of conventional top-down approaches. The lack of implementation science training opportunities in low- and middle-income countries (LMICs) [20–22], further limits the capacity of local researchers and practitioners to translate evidence into actionable health policies and practices. Community-driven approaches such as participatory research and the PEN-3 cultural model can strengthen locally relevant HPV vaccination strategies.

Youth participatory action research (YPAR) involves bringing together individuals to understand and create solutions for societal issues like HPV and cervical cancer prevention while collaborating with researchers and other community members [23–25]. For example, community-based participatory strategies have been employed to develop mental health interventions through community listening sessions and HPV-related educational programs, as well as to identify context-appropriate solutions for sexual and reproductive health and rights [26–28]. Crowdsourcing has also been utilized to inform research and policies and to develop public health interventions aimed at improving HIV self-testing and condom use, along with the application of designations in co-creating strategies for HPV vaccination and screening [29]. Moreover, the PEN-3 cultural model comprises three interconnected, culturally tailored domains: cultural identity (person, extended family, and neighborhood), relationships and expectations (perceptions or beliefs, enablers, and nurturers), and cultural empowerment (positive, existential, and negative). These domains are essential for identifying resources and assets within the community that can be utilized to improve social issues, such as uptake of HPV vaccines among girls [30,

31]. The applications of the YPAR and PEN-3 models ensure community involvement and perspectives in program design, enhancing program effectiveness and impact.

As part of YPAR, an innovation bootcamp follows the designathon phase, where individuals, including youth affected by social issues, engage in intensive activities to enhance their capacities and skills. Innovation bootcamps [32], referred to simply as bootcamps, unite teams of youths with diverse ideas aimed at improving various health outcomes, while strengthening their ability to implement their strategies. Innovation bootcamps are part of a broader category of participatory approaches. Previous research has concentrated on conventional training sessions for youth, including crowdsourcing and designathons, examining how these phases support stakeholder engagement, solution identification, educational program development, and the co-creation of tailored strategies to enhance health outcomes, including mental health and well-being [29, 33–35]. Specifically, little is known about the ability of participatory approaches to enhance knowledge and skills concerning health issues and research techniques after crowdsourced open calls and designathons have occurred, aside from their feasibility and acceptability in creating tailored interventions [36]. This research aims to evaluate a culturally structured bootcamp to enhance HPV knowledge and research skills related to HPV and implementation science to improve HPV vaccination uptake among girls aged 9–14 years in Nigeria.

Methods

Study design

We used a descriptive participatory design with a pre-post assessment. Additionally, this research is part of the US-Nigeria Cancer Control Center for Implementation Science Research study, which utilizes YPAR alongside other frameworks, such as the PEN-3 cultural model. In this research, at the beginning of the innovation bootcamp, we used the PEN-3 cultural model to identify community resources that could support the success of the innovation bootcamp and pinpoint barriers to participating in the training. YPAR was utilized throughout the process to generate community-led ideas from young people, engage and bring them together to refine prototypes, and build their capacities to implement their ideas to improve HPV vaccination uptake in their community. YPAR can include phases such as crowdsourced open calls, designathons, and innovation bootcamps (Fig. 1).

Crowdsourcing open calls, participant identification, and recruitment

Participant recruitment and selection were conducted through a participatory open call for submissions promoted on a project-based website; social media platforms (e.g., WhatsApp, Facebook); in-person via flyers distributed in the community, schools, churches, and markets by youth ambassadors; and informational sessions from February 1 to March 17, 2024. Girls, young women, and other relatives and friends aged between 9 and 26 years in Nigeria were eligible to participate in the open call, which included the prompt “How might we promote HPV vaccination among girls in Nigeria?”, to solicit ideas on how

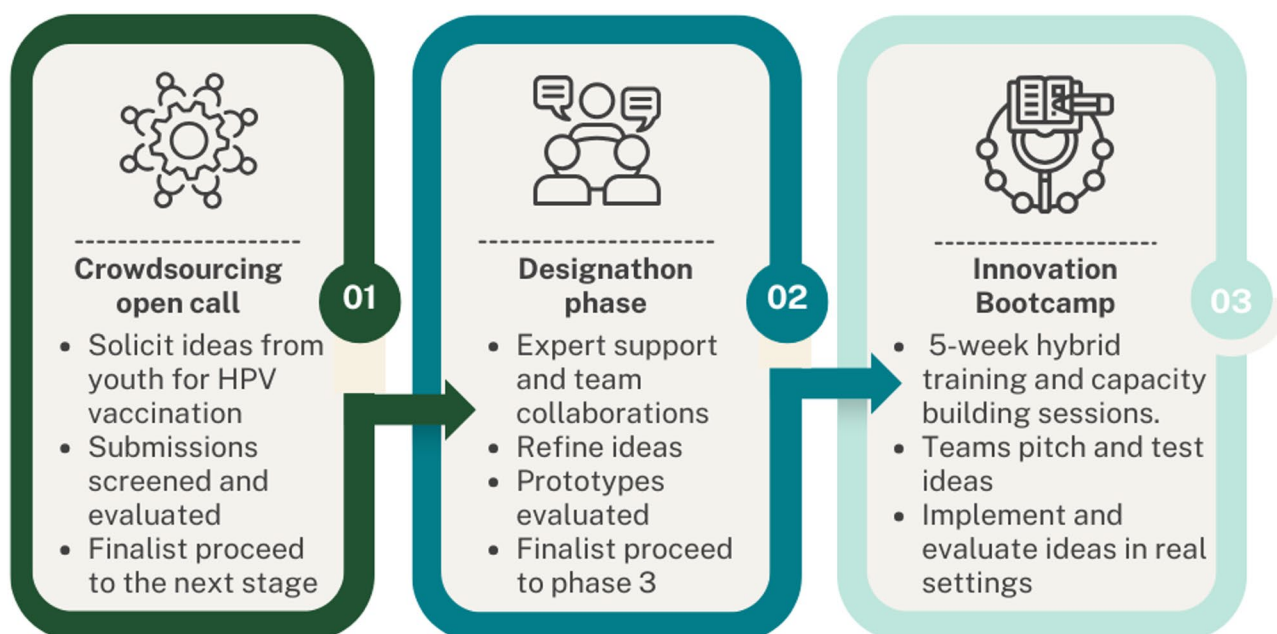


Fig. 1 Youth participatory activities related to cervical cancer prevention in Nigeria

to increase the uptake and sustainment of HPV vaccination among girls aged 9–14 years in Nigeria. Ideas were accepted in diverse formats, including essays, images, posters, personal stories, and video or audio descriptions of the ideas, to encourage participation from diverse young people in Nigeria. Inclusive methods of submission were used, including online submissions through a live link, WhatsApp, and in-person submissions at the Nigerian Institute of Medical Research (NIMR) in Lagos, Nigeria.

Open call submissions, screening, and team selection

We received 418 submissions (Google Form: $n = 365$; WhatsApp: $n = 52$; in-person: $n = 1$) to the open call. The submitted ideas were initially screened for completeness and potential use of artificial intelligence (AI) using ZeroGPT, an AI detector tool. The team's submissions that scored $\geq 10\%$ for AI use did not advance to the subsequent screening stage, to balance sensitivity and specificity. After the initial screening phase, 40 submissions were advanced to judges for further selection. Expert volunteer judges screened the teams' ideas based on a predetermined judging rubric stated in our previous similar work [29]. The rubric included the following categories: clear idea description, innovativeness, novelty, and feasibility. The team of judges included community health professionals, religious leaders, HPV and cervical cancer experts, and education professionals. The top 10 teams were then selected to proceed to the designathon stage.

Designathon phase

A designathon, similar to a hackathon, is a phase in which participants collaborate with experts in the field to refine ideas and develop prototypes [37]. The 10 selected teams refined their ideas during this phase, from April 3 to 6, 2024, and co-created prototypes. The teams pitched their prototypes at the end of the designathon, and the judges provided the teams with feedback to improve them. Then, the judges selected five teams (a total of 16 individuals) whose ideas met all the predetermined judging criteria to proceed to the innovation bootcamp phase for in-depth training and capacity building.

The innovation bootcamp

The innovation bootcamp (the focus of this study) follows the designathon phase, during which individuals affected by social issues and those with co-created community-led prototypes engage in intensive, activity-based training to increase their capacities and skills [32]. This bootcamp brought together teams of youth who had advanced from the prior designathon phase to improve their capacity to implement these strategies. This five-week hybrid bootcamp included a virtual training from June 10 to 15, 2024; fieldwork from June 17 to 21, 2024;

and an in-person bootcamp from June 24 to 30, 2024. The training aimed to enhance knowledge and build implementation research capacity for selected teams at NIMR in Lagos, Nigeria. The in-person bootcamp was designed to include learning agendas and incorporated workshops, group work, networking, collaborative activities, deep reflections, and assignments; all facilitated by experts in HPV, related research skills, and community leaders. Participants learned about HPV and associated risk factors, as well as key implementation science research skills, including conducting community readiness assessments, human-centered design, engaging with the community, conducting qualitative and quantitative research, understanding research ethics, and data analysis (Fig. 2). The teams' deliverables included the People Learning Adaptation Nurture (PLAN) model worksheet for sustainability, a practice brief, a persona page, and a study proposal for each team. Teams pitched their deliverables to a panel of six expert judges, which included university lecturers, youth health advocates, and religious leaders. Five teams were selected and awarded prizes as seed funding to implement their strategies. At the end of the bootcamp, participants evaluated the process, guided by PEN-3 domains. To inform future bootcamps, we synthesized observational notes, participant feedback, and post-bootcamp evaluation data to create a table of practical tips included in this study. The table summarizes key considerations and lessons learned from the planning, delivery, and evaluation of the bootcamp.

PEN-3 cultural model

The PEN-3 cultural model, developed by Dr. Collins O. Airhihenbuwa, served as the foundational framework for implementing the innovation bootcamp. PEN-3 emphasizes culture as an asset to facilitate health decision-making and consists of three interrelated domains: cultural identity, relationships and expectations, and cultural empowerment [38]. At the outset of the bootcamp, a comprehensive assessment was conducted to identify and evaluate community-based training resources, existing assets, and local activities that could enhance participant learning and engagement. This process also involved recognizing potential barriers to training and identifying negative and existential cultural factors that might influence participation. These insights were then deliberately and thoughtfully integrated into the bootcamp design to ensure the training was culturally resonant and responsive to the community's specific needs and context. The bootcamp training materials, resources, and other essential support were tailored based on identified resources, participant dynamics, and feedback to address the needs of the youth participants, ensuring that the bootcamp training could be successfully implemented to enhance

Date/Time	Monday 6/24	Tuesday 6/25	Wednesday 6/26	Thursday 6/27	Friday 6/28	Saturday/Sunday 6/29 and 6/30
9-10	Welcome	Reflection: Community Readiness for Context	Reflection: Community Readiness for Climate	Reflection: Community Readiness for Connections	Reflection: Evaluating Community Readiness	Clinic Observations/Religiou s Practice (Sunday)
10-11	Thematic concentration: Context: Setting the Stage	Research 101	Tentative: Budget and logistics management	Thematic concentration: Connections/ Community Engagement	Qualitative Research	Clinic Observation
11-1	Quantitative Research & ME	Thematic concentration: Climate	Thematic concentration: Connections/Teamw ork	Work on deliverables (data analysis)	Thematic concentration: Work on individual projects	Clinic Observation - HPV Documentary and discussion
1-2	Lunch Break	Lunch Break	Lunch Break	Lunch Break	Lunch Break	Lunch Break
2-4	Interactive workshop: Quantitative data analysis; Monitoring and Evaluation	Interactive workshop: Designing for Context	Thematic concentration: Continue to work on deliverables	Interactive workshop: Work on deliverables (data analysis)	Interactive workshop: Qualitative data analysis	Work on Deliverables
4-5	Team deliverables	Team deliverables	Team deliverables	Team deliverables	Thematic Pitch Preliminary Practice	Work on Deliverables
5-6	Network and Collaboration btw teams	Team deliverables	Team deliverables	Team deliverables	Thematic Pitch Preliminary Practice	Work on Deliverables
6-7	Dinner Break	Dinner Break	Dinner Break	Dinner Break	Dinner Break	Dinner Break

Deep Dive Reflection
Activities
Learning Agendas
Workshop or Group work
Assignment

Fig. 2 Outline of the bootcamp curriculum and key training components

their knowledge of HPV and implementation science research skills.

Data collection tools

A questionnaire was used to collect key data from participants. We collected sociodemographic characteristics, including age, sex, religious affiliation, highest education level attained, and participants' employment status. The questionnaire also included questions about participants' involvement in the designathon (a phase preceding the bootcamp) and whether they had attended a similar bootcamp. Open-ended questions aimed to identify additional training resources needed, assets, and barriers to effective training at the beginning of the bootcamp, and questions to evaluate the bootcamp process at the end were also included. Examples of the open-ended questions administered at the start of the bootcamp include

"What are your motivations for participating in the bootcamp?", "What support do you or your team need to make the bootcamp successful?" and "What are the barriers to achieving your learning goals?". Additional quantitative components of the survey involved assessing resources within their social networks and/or communities, as well as study team support that aided their preparation for the bootcamp. This assessment evaluated prior knowledge of research standards and ethics, as well as individual and team preparation for bootcamp training. The post-bootcamp evaluation questions included "Please explain how the bootcamp did or did not meet expectations," "Please explain how the bootcamp experience expanded your personal/professional goals," and "Is there anything else about the bootcamp experience that you would like to share with the organizing team?"

Measures assessing knowledge about HPV and implementation science research skills

To assess changes in knowledge and research skills in implementation science before and after the training, we used a 9-item, 5-point self-reported Likert scale to evaluate participants’ knowledge of HPV-related issues. The participants were asked to respond to questions, such as “Please rank how knowledgeable you feel in each of the following competencies,” which examined knowledge regarding the basics of HPV infection and epidemiology among girls and young women in Nigeria, the health effects of HPV on this group, challenges and barriers to HPV vaccination in girls and young women, and the national rollout of HPV vaccinations in Nigeria, among other topics. The response options were 1 = not at all knowledgeable, 2 = slightly knowledgeable, 3 = moderately knowledgeable, 4 = very knowledgeable, and 5 = extremely knowledgeable. Regarding research skills, we used a 22-item, 5-point self-reported Likert scale to ask participants to rate their skill level in various competencies, including research methods in the health sciences, performing SWOT analyses with community data, conducting human-centered design activities, and

engaging stakeholders in research. The response options for research skills included 1 = not at all skilled, 2 = somewhat skilled, 3 = moderately skilled, 4 = skilled, and 5 = very skilled.

Data analyses

Quantitative data analyses were performed using R version 4.4.2. Descriptive statistics, including frequencies and proportions, were performed for sex, religion, education level, employment status, participation in the designathon, and participants’ prior experience attending a bootcamp. The mean and median were calculated for age in years. The sums of scores were generated for knowledge (expected score range: 9–45) and research skills (expected score range: 22–110), with higher scores indicating greater knowledge and skills gained, respectively. Pre-post analyses were performed to assess changes in knowledge and research skills before and after the innovation bootcamp. Specifically, we performed the Wilcoxon signed-rank test (exact) and reported the mean and median differences, along with p-values, between the pre- and post-bootcamp training assessment data, and compared them against a 5% level of significance.

Guided by the PEN-3 cultural model, a thematic analysis was conducted to analyze the qualitative open-ended questions. Themes, sub-themes, and top quotes emerged and were categorized under the PEN-3 cultural model domains by two co-authors. Themes and findings were presented to co-authors, with disagreements resolved through discussions and consensus during regular meetings.

Ethical considerations

The NIMR institutional review board (IRB# IRB/23/066) and the Washington University in St. Louis Institutional Review Board (IRB# 202311163) approved the main study. Participation in the survey was voluntary, and participants were assured of confidentiality. Only participants who provided consent were included.

Results

Participants’ demographic characteristics

Table 1 shows participants’ characteristics at baseline. Of the 16 participants (five teams) invited to the innovation bootcamp, the participants were from states and cities across Nigeria, such as Osun (*n* = 5), Abuja (*n* = 4), Lagos (*n* = 2), Kwara (*n* = 2), Oyo (*n* = 2), and Plateau (*n* = 1). The majority (81%) were female, with a mean age of 22 years (standard deviation [SD] 2.42). Most were identified as Christian (88%), had completed secondary education (75%), and were unemployed (75%). All participants who joined the bootcamp had taken part in the designathon phase, a phase before the bootcamp, organized by the project team to refine and develop prototypes.

Table 1 Participants’ demographic characteristics in the Nigerian bootcamp, 2024 (*N* = 16)

Variable	Overall (<i>N</i> = 16)
State or city	
Osun	5 (31.3%)
Abuja	4 (25.0%)
Lagos	2 (12.5%)
Kwara	2 (12.5%)
Oyo	2 (12.5%)
Plateau	1 (6.3%)
Age	
Mean (SD)	22.0 (2.42)
Median [Min, Max]	22.5 [19.0, 26.0]
Sex	
Female	13 (81.3%)
Male	3 (18.8%)
Religion	
Christian	14 (87.5%)
Muslim	2 (12.5%)
Education	
Bachelor’s Degree	4 (25.0%)
Secondary School	12 (75.0%)
Employment	
No	12 (75.0%)
Yes	4 (25.0%)
Participated in the Designathon in Lagos in April 2024	
Yes	16 (100%)
Ever participated in bootcamp	
No	16 (100%)

No participants had previously attended an innovation bootcamp.

Youth-solicited HPV vaccination strategies

Figure 3 presents the youth-led vaccination strategies solicited through the open call and refined during the designathon and bootcamp phases. Youths 9–26 years old in Nigeria submitted ideas that resonated with their social networks and peers' preferences related to HPV vaccination, taking into account the people or stakeholders (community leaders, healthcare workers, school leaders, the Ministry of Education, ambassadors as gatekeepers, parents, girls, and teachers) they plan to work with, how they plan to learn (assess their knowledge, attitudes, and perceptions, collect feedback, conduct focus group discussions, and hold workshops) from one another and how they plan to adapt and incorporate community feedback into their ideas and nurture everyone involved through educational workshops with stakeholders.

Participants' Preparation for bootcamp training and competencies

Figure 4 includes the survey response distribution administered at the beginning of the bootcamp to assess individual and team preparation for the bootcamp training, including their implementation research skills and

competencies. Specifically, approximately 75% reported that resources from their community or social network helped them prepare, and approximately 69% reported that the bootcamp program team provided them with the necessary resources to prepare ahead of the innovation bootcamp.

Moreover, over 62% of the participants were familiar with research ethical standards, and approximately 50% knew how to ensure that their research adhered to these standards at the beginning of the bootcamp. Additionally, approximately 63% knew how to assess community readiness for change, and about 68% knew who to ask if they had questions about social or ethical issues in research.

Qualitative results

Guided by the relationship and expectations, as well as the cultural empowerment domains of the PEN-3 cultural model, we qualitatively assessed participants' training expectations, motivations, and resource needs before and after the bootcamp.

Pre-bootcamp evaluation

Training motivations, expectations, resource needs, and cultural context

Table 2 presents the themes, subthemes, and top quotes that emerged at the beginning and end of the bootcamp under the different domains of the PEN-3 cultural model.

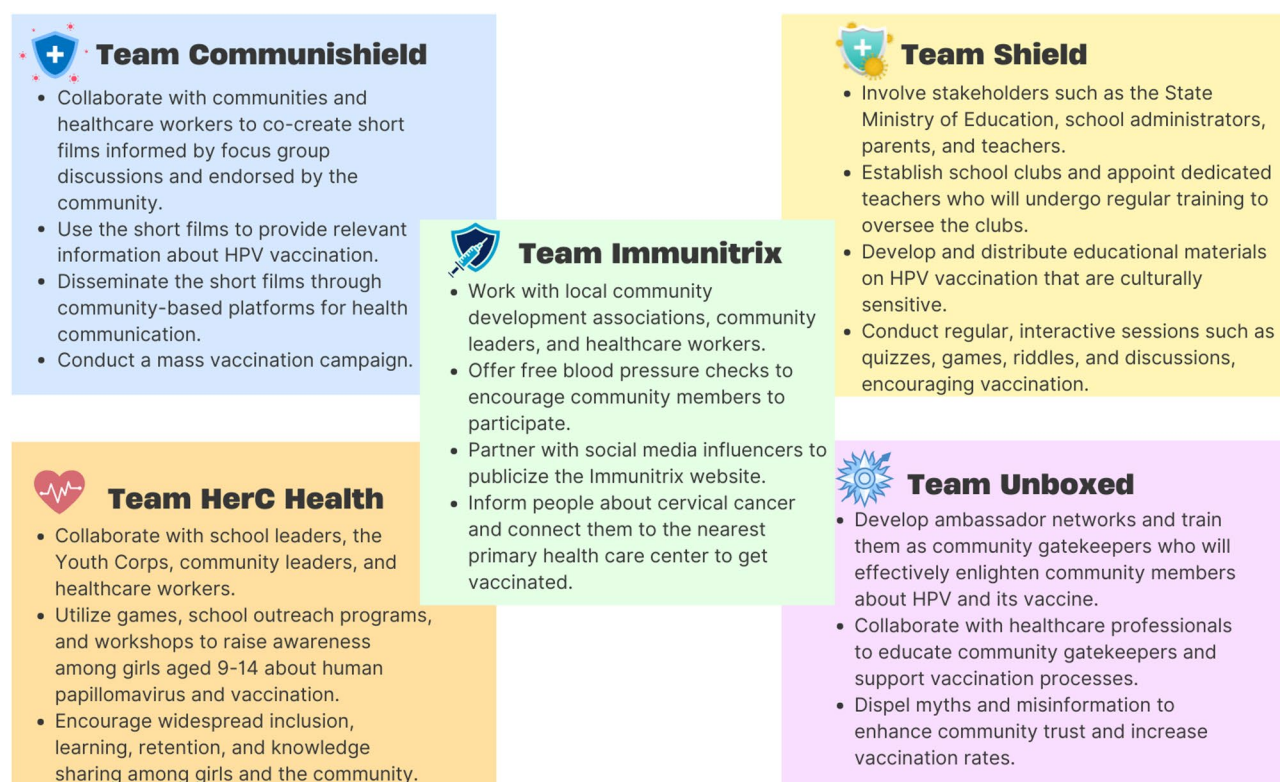


Fig. 3 HPV Vaccination Interventions Strategies Proposed in Nigeria, 2024

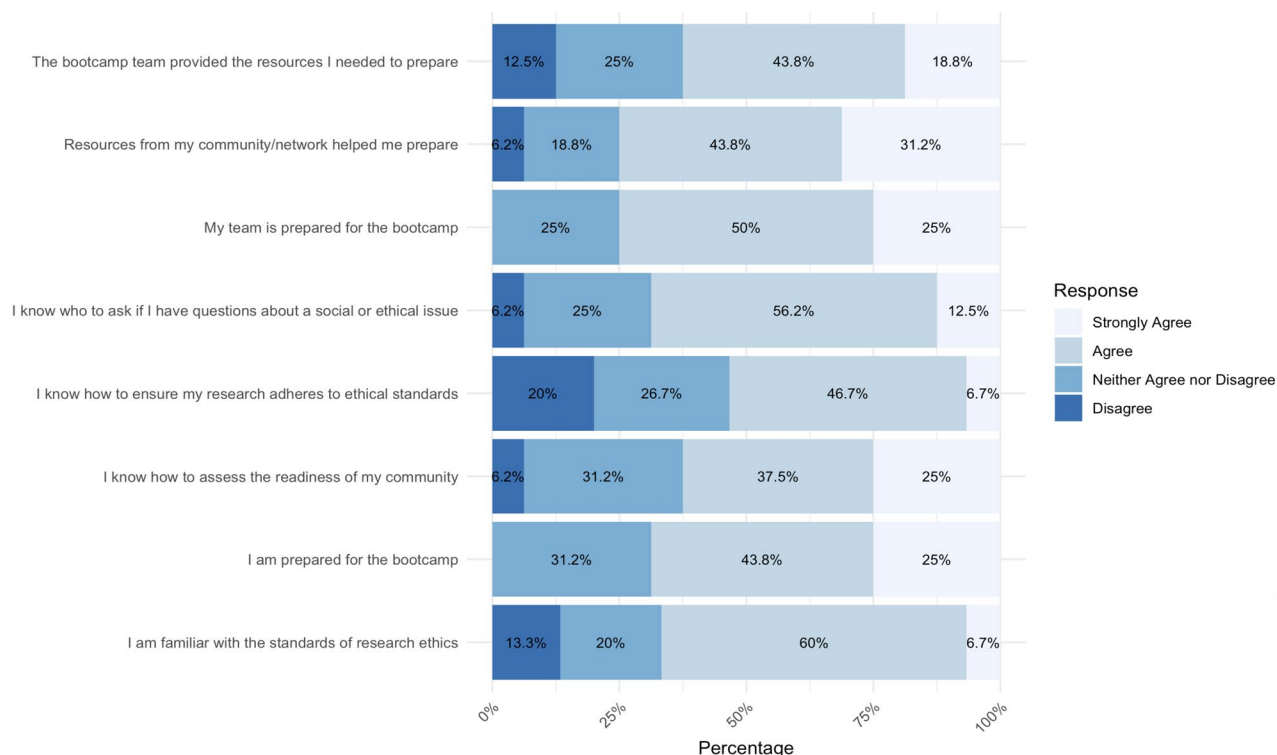


Fig. 4 Preparation, learning resources, and assets for the bootcamp training in Nigeria, 2024

Perceptions and training expectations

Our qualitative thematic analyses revealed that most participants were motivated to participate in the bootcamp because they wanted to learn and network with professionals to prevent cervical cancer. Specifically, participants were interested in gaining new insights to complement the little information they knew about HPV and support them in refining their proposed interventions for increasing HPV vaccination uptake and sustainability among girls aged 9–14 years in Nigeria, as stated by participants:

“My greatest motivation for participating in this Bootcamp and also at the Designathon is the opportunity to actually make a positive contribution to the health of people...” (Table 2, Quote 1.1).

and.

“I expect to learn and gain new insights that would help refine my team’s intervention plans” (Table 2, Quote 1.2).

Enablers

Participants said essential bootcamp training resources, such as internet connections, PCs, tablets or laptops, and food, would be needed.

Participants requested honesty during the training, listening ears, and understanding mentors and trainers to

openly communicate and interact with during the bootcamp, including other essential support, such as financial and mental health support:

Nurturers

Participants attended the bootcamp training to network and build professional connections with expert and diverse facilitators, who provided continuous mentorship and guidance throughout the training. Specifically, participants emphasized the importance of ongoing training and support in delivering their pitches effectively and achieving their professional goals.

“To network with professionals” (Table 2, Quote 3.1).

and

“More training, I believe, mentorship and guidance from the professionals too!” (Table 2, Quote 3.2).

Negative and existential factors

In addition to participants’ preparation, readiness, expectations, and resource needs, they identified barriers that could hinder their full participation in the bootcamp training. These included a lack of learning resources, personal trauma, stress, time constraints, and academic workload. The participants expressed difficulty balancing their school responsibilities with the bootcamp,

Table 2 The PEN-3 cultural model: relationships and expectations and cultural empowerment

Theme	Quote Number	Supporting quotes
PEN-3 Cultural Model Domain: Relationship and expectations		
Perceptions		
Learn new insights	1.1	"My greatest motivation for participating in this Bootcamp and also at the Designathon is the opportunity to actually make a positive contribution in the health life of people..."
The bootcamp was a hard work	1.2	
The bootcamp was fun	1.3	"I Expect to learn, gain new insights that would help refine my team's intervention plans"
Different perception about food and accommodation	1.4	"I didn't know it had so much work in it like that" "It was more fun and intense than I imagined"
Enablers		
Basic learning resources	2.1	"Money, food, internet access, PC tablet or laptop"
Honesty during the bootcamp	2.2	"Total and raw honesty on how to go about everything, the things to look out for and the best course of action that would bring about our success."
Listening ears	2.3	"Financial and mental support"
Financial and Mental support	2.4	"Just like designathon, the overall bootcamp experience was well put together"
Bootcamp training well put together	2.5	"In 2020, my mum battled Cervical Cancer, and since then, I have sought a platform to lend my voice to the fight against this disease."
The bootcamp a platform to voice health concerns	2.6	"The bootcamp has shaped my confidence as a social innovator and empowered me to reach my goals"
Social networking among teams	2.7	"The bootcamp equipped us with more skills than expected"
Team building	2.8	"Through the series of lectures, I gained lots of knowledge that has helped me understand the world of research better"
Acquired skills and knowledge	2.9	"I think a counselor should be made available that teams can approach when facing conflicts"
The bootcamp enables the contributions to improve public health outcomes		
Conflict resolution during the bootcamp		
Acquired discipline and fueled interest in future career		
Nurtures		
Learn and network with professionals to prevent cervical cancer	3.1	"To network with professionals"
Mentorship and guidance	3.2	"More training I believe, mentorship and guidance from the professionals too!"
The facilitators and ambassadors key to bootcamp training success	3.3	"We need guidance from facilitators on how to properly arrange and deliver our pitch"
	3.4	"The facilitators and ambassadors were amazing"
	3.5	"I was able to meet people that I believe would be helpful in attaining my professional goals"
PEN-3 Cultural Model Domain: Cultural Empowerment		
Negative, Existential		
Lack of learning resources	4.1	"Lack of Adequate learning tools/Gadgets"
Personal trauma and stress	4.2	"Too much Stress, too much overwhelming information."
Time limitation	4.3	"My personal traumas"
Workload	4.4	"School workload. Combining schooling and preparing for exams whilst participating in bootcamp doesn't seem easy. But it's a challenge I'm willing to take on."

acknowledging it as a demanding but worthwhile challenge, as stated by some participants.

"Lack of adequate learning tools/gadgets" (Table 2, Quote 4.1),

"Too much stress, too much overwhelming information" (Table 2, Quote 4.2),

and

"School workload. Combining schooling and preparing for exams while participating in a bootcamp does not seem easy. However, it is a challenge I'm willing to take on" (Table 2, Quote 4.4).

Post bootcamp evaluation

After the bootcamp, the PEN-3 domains were utilized to assess participant evaluations of the bootcamp process. Key factors emerged within the relationships and expectations domain, which included participants' perceptions of the bootcamp at its conclusion, as well as the enablers and nurturers.

Perceptions

The participants stated that the bootcamp training was hard work but more fun than expected.

"I did not know it had so much work in it like that" (Table 2, Quote 1.3).

and

"It was more fun and intense than I imagined"
(Table 2, Quote 1.4).

Enablers

Overall, the bootcamp training was perceived to be well planned and effective in enabling participants' learning and building their capacity to implement their ideas, as stated by one participant.

"Like the designathon, the overall bootcamp experience was well put together" (Table 2, Quote 2.4).

The bootcamp acted as a place for participants to openly discuss and share personal experiences, stories, and health concerns with experts in the field and their team members, creating a great learning environment, as stated by a participant.

"In 2020, my mum battled Cervical Cancer, and since then, I have sought a platform to lend my voice to the fight against this disease" (Table 2, Quote 2.5).

Participants reported acquiring skills and knowledge from the bootcamp training, which fueled their ability to implement strategies to improve public health outcomes.

"The bootcamp has shaped my confidence as a social innovator and empowered me to reach my goals"
(Table 2, Quote 2.6),

"The bootcamp equipped us with more skills than expected" (Table 2, Quote 2.7),

and

"Through the series of lectures, I gained a lot of knowledge that has helped me understand the world of research better" (Table 2, Quote 2.8).

Nurturers

The expert facilitators and bootcamp program teams were essential in the learning process, from planning the bootcamp to delivering appropriate learning resources and information to participants, as noted by participants.

"The facilitators and ambassadors were amazing"
(Table 2, Quote 3.4).

and

"I was able to meet people who I believe would be helpful in attaining my professional goals" (Table 2, Quote 3.5).

HPV-related knowledge and implementation research skills

Table 3 presents pre- and post-innovation bootcamp questions assessing participants' HPV-related knowledge and implementation science research skills. There was a small increase in the median HPV-related knowledge score from 34 (IQR 31.0–35.0) pre-bootcamp to 37 (IQR 35.0–40.0) post-bootcamp ($V=20.5$, $p=0.086$). Additionally, the median implementation science research skills score increased from 54 (IQR 43.0–61.0) pre-bootcamp training to 82 (IQR 73.0–96.0) post-bootcamp ($V=10$, $p=0.011$), indicating a significant improvement in the implementation science research skills of youth implementers following the innovation bootcamp to implement their interventions. Although HPV-related knowledge increased, the improvement was not statistically significant after the training.

Discussion

We applied an innovative approach to developing novel strategies for increasing HPV vaccination uptake among young girls by employing crowdsourcing, designathon, and bootcamp methodologies. We organized and implemented a bootcamp to increase the capacity of Nigerian youth to execute ideas from a previously conducted designathon. The crowdsourced open call focused on strategies to improve HPV vaccination uptake among Nigerian girls aged 9–14 years. This participatory approach provided an opportunity for Nigerian communities to collaborate with local stakeholders to develop and refine their innovative ideas. The inclusive engagement of the bootcamp highlights the potential of youth-driven innovations in addressing public health issues. By equipping bootcamp participants with the necessary tools, mentorship, and refined strategies, the bootcamp fostered creative problem-solving techniques and empowered the

Table 3 Changes in participants' knowledge of HPV and implementation research skills before and after the bootcamp in Nigeria, 2024

Variable	Pre-bootcamp (N= 13)	Post-bootcamp (N= 13)	p-value
HPV-related knowledge score			0.086
Mean (SD)	32.9 (4.35)	37.2 (5.51)	
Median [Min, Max]	34.0 [23.0, 40.0]	37.0 [23.0, 45.0]	
25th Percentile	31.0	35.0	
75th Percentile	35.0	40.0	
IQR	4.00	5.00	
Implementation science research skill			0.011
Mean (SD)	54.2 (14.9)	80.5 (17.8)	
Median [Min, Max]	54.0 [34.0, 87.0]	82.0 [43.0, 102]	
25th Percentile	43.0	73.0	
75th Percentile	61.0	96.0	
IQR	18.0	23.0	

next generation of public health advocates dedicated to improving HPV vaccinations within their communities.

First, our findings suggest that youth involvement in participatory design processes, such as open calls, designathons, and innovation bootcamps, can sustain momentum and deepen their commitment to public health initiatives, such as vaccination programs. Specifically, the bootcamp successfully engaged five teams of young Nigerians to refine, test, and present strategies for increasing HPV vaccine uptake. This supports prior research demonstrating the effectiveness of participatory models, such as crowdsourced open calls and youth-led designathons, in public health innovation [33, 35]. Our study combined capacity building with real-world applications, enabling participants to turn abstract ideas into practical solutions. The importance of this “so what” is notable: innovation bootcamps can provide scalable pathways for youth to become active agents of health promotion, particularly in low-resource settings where formal research infrastructure may be limited.

Second, our bootcamp highlighted the value of engaging stakeholders across sectors, including healthcare workers, educators, and faith-based leaders, in mentoring youth and shaping community-relevant interventions. Workshops led by community religious leaders and university faculty bridged the gap between cultural, educational, and health systems. These cross-sector collaborations produce strategies grounded in local realities, which prior evidence suggests increases intervention uptake and sustainability [39, 40]. For example, many team proposals have incorporated school-based education, faith leader advocacy, and parent-focused awareness sessions. These findings support existing calls for co-creation with trusted community figures to increase vaccine confidence and delivery [18, 41]. Future public health campaigns can benefit from similar bootcamp models that facilitate early and continuous stakeholder involvement.

Third, participants generated innovative ideas rooted in their communities, such as engaging school leaders, market heads, and religious figures to promote vaccine uptake. This affirms research showing that young people are well-positioned to identify relevant mobilization pathways [28]. Equipping youth with skills in human-centered design, implementation science, and stakeholder engagement enhanced their capacity to address vaccine hesitancy and low awareness. For example, most teams emphasized education-focused campaigns tailored to adolescent girls and their caregivers, acknowledging Nigeria's strong cultural emphasis on formal education. The bootcamp structure allowed these ideas to be refined and tested through peer feedback, mentorship, and pitching sessions. This finding suggests that training young

community innovators and implementers can drive both individual learning and collective health action.

Fourth, the innovation bootcamp training model provides a practical framework for building the capacity of local stakeholders and young researchers, especially in LMICs. Building on previous studies [21, 32], it enhances our understanding of how participatory learning approaches can facilitate the translation of evidence-based research to practice. Formal implementation science training remains scarce in many LMICs, particularly for young people. Participatory methods, like innovation bootcamps, can help close that gap by embedding ethics, research design, data collection, and community engagement into a practice-based curriculum. Additionally, the bootcamp emphasized continuous feedback and mentorship, which participants credited with increasing their confidence and professional clarity. As such, innovation bootcamps should be considered a viable tool for national public health institutions and global health funders aiming to strengthen local research ecosystems. Engaging youth through such models not only boosts local ownership but also improves the cultural fit and sustainability of interventions. Future efforts should prioritize expanding access to similar programs and rigorously evaluating their long-term health outcomes.

Practical tips for conducting future innovation bootcamps

To support future researchers and implementers interested in participatory training methods, such as innovation bootcamps, we synthesized key lessons from our experience, including insights from previous research into practical tips [42–44]. Table 4 presents practical tips that can be used or adapted to conduct a participatory innovation bootcamp. These tips can guide replication or adaptation across different subjects, including public health issues, especially in low-resource or youth-focused settings. The table also provides recommendations for participant recruitment, stakeholder engagement, flexible training formats, feedback loops, and formal certification. By offering structured yet flexible pathways for community participation, bootcamps can serve as critical platforms for addressing public health priorities with local insight and innovation.

Study limitations

Our study had limitations. First, the expert panel of judges evaluated the selected ideas for implementation based on their feasibility as presented in the pitches. There were no outcome pilot data to support the proposed ideas. However, a pilot study will be conducted after the bootcamp phase. Second, the teams that participated in the bootcamp came from diverse backgrounds, but owing to Nigeria's vast population and limited resources, bootcamp participants were not representative

Table 4 Practical tips for organizing a participatory innovation bootcamp

Key Component	Tip	Why It Matters
1. Define Clear Objectives	Clearly articulate the purpose, learning goals, and expected outcomes of the bootcamp at the start	Guides curriculum design and helps participants stay focused on results.
2. Recruitment and Selection	Use crowdsourcing open calls promoted through multiple channels (e.g., social media, in-person) and accept flexible submission formats (e.g., video, text, audio)	Ensures inclusivity and encourages diverse, community-driven ideas.
3. Screening Process	Establish a transparent selection process using a judging panel and criteria such as clarity, innovation, and feasibility	Helps identify strong, original, and implementable ideas.
4. Pre-Bootcamp Activities	Include a designathon or idea refinement phase to prepare participants and co-create solutions with support from mentors, including CITI training, and field assessment activities	Boosts participant readiness and idea quality before the main training.
5. Structured Agenda and Handbook	Develop an agenda with interactive sessions, peer learning, fieldwork, mentoring, and networking opportunities, including a bootcamp handbook	Enhances engagement, accommodates various learning styles, and builds team cohesion.
6. Flexible Learning Format	Blend in-person and virtual formats, ensuring cultural and contextual relevance	Adapts to participant needs and ensures accessibility in low-resource settings.
7. Core Learning Topics	Focus on implementation skills like community engagement, research methods, ethics, design thinking, communications, and sustainability planning	Equips participants with versatile, cross-sector competencies.
8. Feedback Loops	Integrate continuous feedback from participants and facilitators throughout the bootcamp (surveys, check-ins, reflection)	Allows iterative improvement and enhances engagement and satisfaction.
9. Logistical and Emotional Support	Provide internet, learning devices, meals, stipends, and mental health resources	Removes participation barriers and supports overall well-being.
10. Facilitation and Mentorship	Recruit cross-sector facilitators and assign mentors to each team to provide guidance throughout the bootcamp and after during implementation	Fosters deeper learning, real-time problem-solving, and long-term relationships.
11. Deliverables and Pitching	Require concrete outputs (e.g., project briefs, personas, proposals, community engagement plans) and conduct final presentations (pitch) to expert judges	Promotes application of learning and encourages professional presentation skills.
12. Monitoring and Evaluation	Conduct pre- and post-assessments (both quantitative and qualitative) to track skill acquisition and participant experience	Demonstrates impact and informs future bootcamp improvements.
13. Post-Bootcamp Support	Provide follow-up mentorship, link participants to funding or partner organizations, other opportunities and support project implementation	Increases sustainability and real-world impact of bootcamp outcomes.
14. Formal Certification and Seed Funding	Offer certificates of completion (co-branded by partner organizations, if applicable) that validate learning and participation, including seed funding to implement ideas	Adds credibility, boosts morale, and can enhance participants' educational or career portfolios

of the entire country. Future bootcamps could increase the number of teams selected for the bootcamp phase to improve representativeness. Third, we did not collect data from bootcamp organizers, which could also help to iteratively improve this model. Fourth, reported changes in HPV knowledge and implementation science research skills are based on participants' self-ratings and could be strengthened with additional assessments of participant performance and deliverables, including the use of objective measures. Fifth, since the study involved a participatory process that included a crowdsourcing open call, designathon, and then bootcamp, the sample size during the bootcamp phase was small, consisting of only five teams (16 participants) with evaluated ideas, which reduces generalizability. The results support further investigation with a larger sample size.

Following the bootcamp, five teams launched pilot studies focused on increasing HPV vaccination uptake. Each team has been assigned a supervisor with expertise in HPV vaccination. While we have engaged and encouraged some youths to help increase the uptake of HPV

vaccination among Nigerian girls, there is still room for further research and policy implementation.

Conclusion

The innovation bootcamp enhanced the knowledge and research skills of youth implementers in implementation science. It also supported community innovation, capabilities, and eagerness to develop community-driven interventions to promote HPV vaccination uptake. The bootcamp led to five community-focused innovations to promote the uptake of HPV vaccination among young girls in Nigeria. The strategies identified in the bootcamp will be formally examined in a series of pilot trials. The pilot findings will help assess the feasibility and sustainability of solutions to increase HPV vaccination among Nigerian girls aged 9–14 years. The findings will then inform a subsequent stepped-wedge cluster-randomized trial.

An innovation bootcamp shows potential for adoption into national HPV vaccination strategies and can offer a participatory approach for broader youth-led implementation science initiatives in LMICs. Empowering young

people to lead change in their own ways can promote local ownership, accelerate innovation, and support sustainable ways to enhance vaccine coverage and other health outcomes.

Abbreviations

HPV	Human papillomavirus
LMICs	Low- and middle-income countries
YPAR	Youth Participatory Action Research
PLAN	People, Learning, Adapting, and Nurturing
NIMR	Nigerian Institute of Medical Research

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Author contributions

PK, OAO, AS, NO, MAA, JO: Conceptualization, study methodology, design, data analysis, drafting of the manuscript, project management, manuscript writing, reviewing, and editing. TO, FTA, UN, TG, PAK, CNN, SY, OO, IAO, JSS, KAO, RJW, BA, COA, and AB: Manuscript review and editing. HX, AZM, JJO: Data management, manuscript writing, reviewing, and editing the manuscript. JI, JDT, and OCE: Project conceptualization and administration, manuscript review and editing, and overall project supervision. All the authors contributed equally to the review, editing, and approval of the final manuscript.

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Data availability

The data and materials used in this study are available upon reasonable request from the corresponding author. Access may be subject to ethical and confidentiality considerations.

Declarations

Ethics approval and consent to participate

The Nigerian Institute of Medical Research (NIMR) approved the main study (IRB# IRB/23/066). Participation in the survey was voluntary, and participants were assured of confidentiality. Only participants who provided consent were included.

Consent for publication

All the authors have consented to the publication of this manuscript.

Competing interests

The authors declare no competing interests.

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