Hybrid mosquitoes? Evidence from rural Tanzania on how local communities may conceptualize and respond to modified mosquitoes as a tool for malaria control

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Abstract

Background: Different forms of mosquito modification are being considered as potential high-impact and low-cost approaches to future malaria control in Africa. Though still under evaluation, the eventual success of these technologies will require high-level public acceptance. Understanding the prevailing community perceptions is therefore crucial for effective public engagement during implementation. This study investigated community perceptions regarding genetically-modified mosquitoes (GMMs) and their potential for malaria control, in Tanzanian villages where no research or campaigns about such technologies have previously been undertaken.

Methods: A mixed-methods design was used, involving: i) structured questionnaires administered to 490 community members to assess awareness, perceptions and support for GMMs, and ii) focus group discussions (FGD) with community leaders to explore in greater depth how these communities frame and would respond to GMMs. Thematic content analysis was used to identify key concepts and interpret the findings.

Results: Nearly all survey respondents were unaware of mosquito modification technologies for malaria control (94.3%), and reported no knowledge of their specific characteristics (97.3%). However, community leaders participating in FGDs offered a set of distinctive interpretive frames to conceptualize interventions relying on GMMs for malaria control. The participants commonly referenced their experiences of cross-breeding for selecting preferred traits in domestic plants and animals. Preferred GMMs attributes included expected reductions in insecticide use and human labour. Population suppression approaches, requiring as few releases as possible, were favored. Common concerns included whether the GMMs would look or behave differently than wild mosquitoes, and how the technology would be integrated into current malaria control policies. The participants emphasised the importance, and the challenges, of educating and engaging communities during technology development.

Conclusion: Understanding how communities perceive and interpret new technologies is crucial in designing effective implementation strategies that enjoy durable public support. This study offers vital clues on how communities with no prior experience of modified mosquitoes might conceptualize or respond to such technologies when deployed in the context of malaria control programs. The existing interpretive frames and the real-life analogies, such as cross-breeding, may provide a basis for effective community engagement to aid the potential deployment of such technologies in the future.

Key words: Malaria elimination; genetically-modified mosquitoes; gene drives, public perceptions; community engagement

Background

Malaria is thought to have killed between 150 million and 300 million people worldwide during the 20th century (1). Although the situation has improved in the last two decades, malaria remains one of the leading causes of death and ill-health globally (2). In 2018 more than 200 million people were diagnosed with malaria and nearly half a million died, more than 90% of whom were in sub-Saharan Africa (SSA) (2). Interventions such as insecticide-treated nets (ITN) and indoor residual spraying (IRS), combined with improved diagnosis and treatment account for most of the reductions in malaria burden (3). Yet these interventions appear to have reached the limit of their efficacy in many regions (4–7). The prospect of achieving further gains require development of novel, complementary interventions (2,8,9).

Mosquito modification technologies have garnered a great deal of public interest, particularly in SSA, where their impact is expected to be highest particularly as a tool for malaria control (2,10–12). While experiments with some of these technologies, particularly the Sterile Insect Technique (SIT), go back several decades (13), significant progress has recently been made in the development and evaluation of novel approaches (14,15) such as Release of Insects carrying a Dominant Lethal genes (RIDL) (16), gene-drive technologies (14,17–20) and release of *Wolbachia*-infected mosquitoes (21–23).

These technologies are at different stages of development, and face specific questions from the perspective of communities considering their introduction. One important distinction is between interventions aiming to eliminate the relevant mosquito species (population suppression), and those intended to permanently introduce into the environment a novel mosquito strain that blocks or interferes with disease transmission (population replacement) (14). These differences suggest the need for distinct communication strategies, and imply a very different expectations on coexistence between modified mosquitoes and the communities hosting the intervention (24).

Given the expectations around these technologies, the purported high-impact and the numerous uncertainties raised by different players, extensive stakeholder engagement will be crucial in ensuring public acceptance and sustainability when the approaches are eventually deployed (14,25,26). Opposition to the release of genetically modified mosquitoes in south-east Asia and the Americas (27–29), and evidence of concerns among stakeholders in Mali (30), Nigeria (31) and Tanzania (32) suggest the importance of proceeding with caution (25,26). Robust social scientific research into how these novel technologies are perceived in regions where they might be deployed is a prerequisite for an effective public engagement strategy (33). A detailed understanding of the prevailing community perceptions will be crucial for effective public engagement during implementation.

This study investigated community awareness and perceptions regarding genetically-modified mosquitoes (GMMs) and their potential for malaria control in south-eastern Tanzanian villages where no research or campaigns about such technologies have previously been done. To examine how a typical malaria-endemic community might respond to the introduction of GMMs technologies, this study also explored different frameworks and analogies that communities use in reference to these technologies.

Methods

This study was part of a larger public engagement process aiming to understand and improve public awareness and community evaluation of alternative interventions for malaria control and elimination. This particular study was done in ten randomly selected villages in two districts in south-eastern Tanzania between December 2018 and December 2019 (Fig. 1). Detailed description of the wards is provided by Finda *et al* (5,34), Kaindoa *et al* (35) and Mmbando *et al* (36). Though this area has previously hosted numerous malaria research projects, there had not been any research on modified mosquitoes of any kind. Previous studies in the area have demonstrated high levels of knowledge about malaria transmission and mosquitoes (5,37,38).

Fig.1: Map of the districts and villages where the study was conducted. Map prepared by Najat Kahamba.

Study design and data collection

An explanatory sequential mixed-methods approach (39) was used. A structured questionnaire was administered to community members in the ten selected wards to assess their awareness, knowledge and perceptions of mosquito modification technologies for malaria control. Fifty households were randomly selected in each of the ten wards using household data obtained from the Ifakara Health and Demographic

Survey System (40). The households were visited by the study team, accompanied by community leaders, and one consenting adult in each household was interviewed. The survey was carried out between November and December 2019, and was administered using Kobotoolbox™ software (41) on electronic tablets.

Focus group discussions (FGDs) were held with community leaders from each of the ten wards to explore their perceptions of mosquito modification in more detail. The selected leaders had been elected by the community members every two years, did not belong to any political party and represented community members in various meetings. Their responsibilities included resolving conflicts, authorising property sales and monitoring migrations in and out of their communities. Two community leaders, male and female, were selected per ward. Two FGD sessions were completed (one with women and another with male leaders), and were facilitated by MFF and a research assistant in Swahili language. The FGD sessions also explored different analogies and examples that communities used to express GMMs or similar technologies. Specific attention was paid to vernacular modes of reasoning about the prospect of using modified mosquitoes to combat malaria, and to do so in advance of any concrete plan to introduce these technologies in the region.

Due to the low levels of awareness of mosquito modification technologies, FGD participants were provided with a brief PowerPoint presentation on mosquito modification so as to facilitate informed discussions. The presentation covered different approaches (i.e., sterile insect technique, male RIDL mosquitoes, and gene drive technology). The presentations included basic information on how the mosquitoes are modified then released to the environment and the current stages of the development each approach. However, the presenters avoided value judgments on any approach, so as not to preempt any biases among participants. The discussions were guided to bring out views of mosquito modification technologies for malaria control, including any perceived risks and benefits. Community leaders' recommendations on what needs to be done to secure acceptance in case this technology is implemented were also discussed.

Data processing and analysis

R statistical software version 4.0.0 (42) was used to analyse the socio-demographic characteristics of the survey respondents, and to summarise their knowledge and awareness of GMMs. Since most respondents lacked knowledge and awareness regarding the technology, no further analyses were necessary. Instead lay presentations about the technologies were provided to prime further discussions in FGDs.

Verbatim transcriptions of the FGDs were completed, translated from Swahili to English, and imported into NVIVO 12 Plus software (43) for coding. Both deductive and inductive coding was used. The FGD guide was used to develop deductive codes. However, since the technologies under discussion were new to the participants, most of the codes were generated inductively after extensive reviews and coding of the transcripts. Similar codes were grouped and themes extracted from the emergent patterns. Direct quotes from FGD participants were reported in some selected cases to further describe the themes.

Results

Characteristics of study respondents

A total of 506 people participated in this study, including 16 were community leaders who participated in two FGD sessions and 490 were community members who responded to the questionnaire survey. Three of the FGD participants had secondary school education (12 years of formal education) and the rest had primary school education (7 years of formal education).

Detailed description of the survey respondents is provided on Table 1. Their mean age was 42.5 years (range: 18-88), and were about equally divided between men and women. A majority of the respondents were married, had primary school education and reported farming as their main income generating activity (Table 1). The reported average monthly household income was 132,155 Tanzanian shillings (~60 USD).

Table 1: Socio-demographic characteristics of the survey respondents

Characteristics	Category	n (%)
Age (in years)	18 – 35	186 (37.9%)
	36 – 55	207 (42.3%)
	56 – 88	97 (19.8%)
Marital status	Married	321 (65.5%)
	Not married	82 (16.7%)
	Divorced/separated	39 (8.0%)
	Widow/widower	48 (9.8%)
Educational level	No formal education	43 (8.8%)
	Primary school	358 (73.0%)
	Secondary school	68 (13.9%)
	College/university	21 (4.3%)
Main income generating activities	Farming	413 (84.3%)
	Entrepreneurship	174 (35.5%)
	Fishing	12 (2.4%)
	Animal husbandry	23 (4.7%)
	Formal employment	13 (2.7%)

Community awareness of malaria burden

Previous surveys have shown high levels of awareness among residents of these communities about malaria and its transmission by *Anopheles* mosquitoes (Mapua et al *unpublished*). In this study, two thirds (65.1%, n=319) believed that rural communities experienced higher burden of malaria, 63.9% (n=313) believed that poor communities experienced a higher burden of malaria, and 61.3% believed that transmission occurred mostly outdoors. However, when asked about specific details, only 15.3% (n=75) had a good estimate of current malaria prevalence in the country (as reported in the 2018 Malaria Indicator Survey report (44)). Half (51.6%, n=253) of all respondents believed that the country was making a good progress in malaria control, and 59.6%, (n=292) believed that it was possible to achieve elimination with the current interventions. However, 86.1% (n=422) of the respondents indicated that alternative interventions would be necessary to accelerate elimination efforts.

Community views on novel interventions for malaria control

All respondents reported that any new technologies for malaria control should be effective, affordable, meet in-country regulations and community preferences, and be safe to people, animals and the environment. When asked about trusted sources of malaria-related information, health researchers and health care workers were ranked higher than government officials or politicians (Table 2).

Table 2: Community members' levels of trust for sources of information on malaria control interventions (N = 490)

Variables	Highly trusted	Somewhat trusted	Somewhat distrusted	Strongly distrusted
Health researchers	91.2%	7.6%	0.4%	0.8%
Health care workers	91.2%	8.2%	0.4%	0.2%
Government officials	84.9%	12.7%	1.6%	0.8%
Politicians	55.3%	26.1%	9.0%	9.6%

Awareness regarding mosquito modification technologies for malaria control

A vast majority of survey participants (94.3%, n=462) reported no prior awareness of mosquito modification technologies for malaria control. For the 13 respondents who were aware, the primary sources of information were Ifakara Health Institute staff, and radio or television. Likewise, nearly all participants (97.3% (n=477) reported no knowledge of how any of these technologies worked. When asked if they thought modified mosquitoes had ever been released in their communities, 83.5% (n=409) said they did not know and 16.5% (n=81) said they had not been released.

Community leaders' perceptions of mosquito modification

All community leaders who participated in the focus group discussions reported that they had never heard of the mosquito modification technology before. However, after they were provided with a brief presentation of the technology, they discussed the subject at length and in detail, often expressing a great deal of fascination, preferring it over other malaria control interventions. Key attributes of the technology mentioned to justify this preference were the improvement of environmental safety (as a result of reducing the use of chemical insecticides), and the little effort the technology required from local residents (in contrast to other malaria control methods deemed more labor intensive).

Although three distinct approaches of mosquito modification were presented to FGD participants, i.e., SIT, RIDL and gene drive technologies, all participants showed a preference for discussing gene drive technologies, and in particular the male-biased sex distorter gene drive that, which is being considered for deployment in several sub-Saharan countries at the moment (45). Gene drive technology was preferred because it would require fewer releases of modified mosquitoes compared to the other two, a fact that participants thought would help reduce community skepticism towards the intervention.

> "*It is better if you do not release mosquitoes all the time. Even if people agree that you release mosquitoes, if you do it a lot they may start asking questions again, then you have to spend a lot of time convincing them. But I like this one that does not kill mosquitoes, but makes them have male babies. With this one you can do it just one time, then it is good."* (Female).

Participants were also fascinated by the idea of eliminating mosquitoes by biasing the sexes rather than just killing them directly. This was even considered a humane way of eliminating the mosquitoes.

> *"I really like the idea of making them have just male babies, because, you see, males do not bite, and without females they cannot have babies. This way even your conscious is clean, you have not killed them directly, you have just manipulated them and they will eventually die off. This is a very good and very advance technology"* (Male).

Framings and analogies used to describe mosquito modification

Although the FGD participants had never heard of mosquito modification technologies, they immediately grasped the concept by reference to their knowledge of cross-breeding and hybridisation. Several participants indicated that the best way to explain this technology to people in the community would be to describe it as a form of '*kupandikiza*', a term that can be literally translated as transplantation but is commonly used to describe hybrid plants. The term was used in both FGD sessions. Participants referred to the hybrid maize seeds that they buy in agricultural shops, which have a relatively higher yield and can better withstand drought than local maize varieties. The leaders also referred to the technology as *'kubadilisha mbegu'* which translates to 'changing seeds'. The term was used to describe the introduction of desirable traits in crop seeds and domestic animals through cross-breeding. They mentioned that they often borrow or pay for their neighbours' male animals with desired characteristics to mate with their female animals in order to get offspring with the desired traits.

"I do it often with my chickens. I don't have a strong rooster, but my neighbour has a very big one. So I ask my neighbour for her rooster to spend time with my chickens, then I can get its seeds. Everyone does that." (Female)

"It is very common with pigs. Sometimes there is one person in the village who has a very big boar, so then if you want to get its seeds you pay that person money so that the boar can mate with your sows. Sometimes you pay money or sometimes you pay him with a litter. But we do that so that we can have the seed for big pigs." (Male)

Will the modified mosquitoes look and behave differently?

Participants expressed curiosity and concern over the modified mosquitoes. They wondered, for example, whether or not the mosquitoes would look the same as local mosquitoes. The leaders drew an analogy here with their experience of selectively-bred animals or hybrid maize, and concluded that the modified mosquitoes would necessarily look different. The leaders were also curious to know if modified mosquitoes would still bite people and whether or not current mosquito control tools could or should be applied to them.

"Yes, they always look different. Even when we plant the hybrid maize, it does not look the same as our local maize, it has better yield, and you can tell just by looking that it is different kind of maize." (Female)

I would like to know, if you want those traits to pass to their offspring, will we still need to kill these modified mosquitoes? Will they still bite people? If they bite, people will still want to kill them, and if they do, then it may not work." (Male)

All mosquitoes are a nuisance; why not just eliminate all of them?

A majority of the FGD participants suggested that technologies of mosquito modification should target all mosquitoes, and not just those transmitting malaria. This line of argument was particularly relevant for genetic modification approaches aimed at population replacement, and participants expressed the fear that modified mosquitoes, if they became a feature of the environment, would still be able to carry other pathogens. Additionally, the participants stressed that mosquitoes are always a nuisance, regardless of the species; their bites are itchy, painful and cause allergies, so it would be beneficial to just eliminate them altogether. The participants drew an analogy with jiggers (*Tunga penetrans*) and lice, which were once prevalent in the region but have been eliminated altogether in their communities. They expected a similar goal should be pursued with mosquitoes.

> *"We should just eliminate all mosquitoes, the way jiggers were eliminated. In the past there were so many jiggers, as kids we had to go to the hospital to get them removed from our feet. But then something was done and they all disappeared. These days you never hear about them, and the children these days do not even know what jiggers are. I would like that to be the case with mosquitoes, all of them. I would be happy if the future generations do not know anything about mosquitoes, maybe they should only see them in the pictures."* (Male)

The FGD participants drew a direct connection between the effectiveness of the intervention and a reduction in the overall density of mosquitoes. They argued that people would only have faith in the merits of the technology if they saw a substantial reduction in nuisance biting. They further noted that most people are unable to distinguish between malaria vector and non-vector mosquitoes, and that they would fail to appreciate the impact of the intervention if it was limited to a single species.

> *"But why would you want the other mosquitoes to remain? For me that is a challenge, that there will still be mosquitoes. People may think that it is not working. The other technologies kill mosquitoes, so then you will know that mosquitoes are not as many. But with this technology there will still be mosquitoes – even if they do not spread malaria, but people will not know that."* (Female)

A few participants, however, did note that mosquitoes also have a place in the ecosystem, and thus supporting the idea of eliminating only those responsible for malaria transmission. They pointed out that it would be impossible to eliminate all mosquitoes, because they had never been to or heard of a place where they are absent. They further expressed that it would be highly important to inform the community that not all mosquitoes would be killed, just the ones that spread malaria, to prevent mistrust of the technology.

> *"I do not think there is a need to eliminate all the others if they are not transmitting anything. Remember, there are other birds and other insects that feed on mosquitoes, so it is no use to kill something that is harmless. You know, even in countries that do not have malaria there are still mosquitoes. I know this. So then it is okay to have mosquitoes that do not have malaria. You just need to teach people to differentiate malaria mosquitoes from other mosquitoes so that they know the difference."* (Male)

Importance of engaging and educating community members

All FGD participants stressed the importance of educating and engaging the community in the development of these technologies. It was emphasized that this should be done not just once but repeatedly until their level of awareness and knowledge was such that they could participate in any decision to bring the technology into the community.

> *"It is just very important to make sure that people are well aware of this technology. You have to educate them well. Tell people the benefits of this science, and the risks of continuing to have malaria mosquitoes. I think people should know what can happen if people agree to have these mosquitoes released, and what will happen if they do not. For example, you can talk to people maybe two or three times every month, and do it like that until it becomes a common thing that people talk about. That is when you can come with the modified mosquitoes. It is like that. If you do not do this then it may bring very big problem, and people may even attack you, chase you or embarrass you"* (Female)

In addition to education people, it was also noted that developers must also demonstrate the effectiveness and safety of this technology in a way that communities would understand. The FGD participants advised that, in order to win the trust of people, researchers would need to come up with means to show people the attributes of this technology rather than just tell them. The leaders explained that more efforts would also be needed to educate people on different mosquito species, and on how to differentiate between malaria-transmitting and other mosquitoes. Without a degree of familiarity with these issues, it was noted that it would be impossible to convince people that the mosquitoes being released are harmless.

> *"When you go there with your mosquitoes and tell them that you want to release them, they will ask you if the mosquitoes can harm them, and you will say that these are harmless mosquitoes. They will then ask you to prove it. How will you do that? You will have to find a way of demonstrating to people that these mosquitoes are harmless. If you just tell people that any mosquitoes are harmless you are in for trouble. We all know that all mosquitoes spread diseases, and that all mosquitoes are bad."* (Male)

Discussion

Historically, the release of modified mosquitoes has received a mixed response from the communities hosting these interventions (46,47). Current research projects that involve the release of modified mosquitoes include extensive campaigns of public information and engagement (29,48–50). It has become abundantly clear that these campaigns must start well in advance of the deployment of the technology, and that they must be preceded by research into the concerns, expectations and interpretive frames that local residents bring to bear on the prospect of making disease control reliant on the introduction of altered mosquitoes into the environment (12,26,51).

This study attempted to explore perceptions of mosquito modification technologies in a region of southern Tanzania where no trials of modified mosquitoes have yet taken place, but where epidemiological characteristics might in the near future recommend their use to combat malaria. This is a region, moreover, where many other malaria control interventions have been pioneered or piloted in the past, and where a significant proportion of the population is familiar with entomological research thanks to the long-term presence of the Ifakara Health Institute (5,52). This study provides the first social scientific evidence on public perspectives on mosquito modification in Tanzania.

Nearly all community members that responded to the survey reported no knowledge or prior awareness of mosquito modification technologies for malaria control. This is understandable, since no trials have been conducted in Tanzania to date, and local and national media have offered very limited coverage of debates on this issue elsewhere in the region. Similar findings have been observed in Mali and Nigeria (31,53), for example, as well as in high-income countries such as United States of America, where a 2016 survey indicated that 46% of respondents reported having received no information about gene-edited mosquitoes (54). The generalized lack of knowledge and awareness made it difficult to assess in detail public perceptions of the technology, at least through a standardized survey questionnaire. FGDs were introduced to allow us to discuss mosquito modification technologies in some detail with a select group of local residents, so as to study in depth the specific conceptual frames that might be used to make sense of the technology.

Although all FGD participants had never before heard about mosquito modification, they all expressed a great deal of fascination over it once the discussions got underway. The FGD participants associated the technology to several aspects of their lived experiences, specifically the practice of cross-breeding domestic animals to select for preferred traits, or the use of hybrid crops that provide better yield and withstood drought. The prospect that similar techniques could be used to eliminate malaria appeared therefore intuitively plausible, even before the specific principles of each form of mosquito modification were discussed. The analogy with forms of biological modification familiar to local residents also shaped their initial consideration of risk, as it allowed them to balance any potential hazards of the technology with the promise of a direct benefit. Similar findings are also reported in the US, where support for genetic modification increased once the potential risks and benefits of the technology were communicated to the people (55). A study by Widmar *et al* (2017), for example, indicated that genetic modification was most acceptable when used in human medicine and in disease control (56). In our case, participants were relatively supportive once mosquito modification was contrasted with other malaria control interventions, partly because it was seen as requiring less direct participation from the community, and because it was thought to reduce environmental risks they associated with other interventions (i.e. extensive use of chemicals in IRS, ITNs, or larviciding).

After being presented with several forms of modification, participants expressed the greatest interest in the male-biased sex-distorted gene drive. This was due to the low perception of risk associated with male mosquitoes and the high perception of risk associated with female mosquitoes, findings that have been previously documented from the same study site; there is near universal perception in the community that malaria is transmitted by female *Anopheles* mosquitoes, and that male mosquitoes do not transmit any diseases (37,57). The participants also pointed out that the gene drive approach would require fewer and smaller releases compared to the other mosquito modification technologies, a fact that is one the advertising attributes of gene drive technology (14,17).

The FGD participants contemplated the possibility that modified mosquitoes would look or behave differently than local mosquitoes, and sought further clarification on this particular point. These concern, although expressed mildly in this case, have led to some of the major controversies associated with mosquito modification technologies, and include fears of mutations in the mosquito itself (or in the pathogen), and the possibility that sterile mosquitoes might cause sterility through biting (31,58,59). It is crucial that these concerns are given careful consideration, and that researchers and sponsors of these technologies can allay these fears with adequate scientific evidence.

Participants in our FGDs also expressed the concern that eliminating just one mosquito species would not be enough, and would fail to garner sufficient public support. This concern can be explained by the fact the effectiveness of most other malaria vector control interventions is often assessed against a reduction of overall mosquito density, and people are generally unable to differentiate between malaria vectors and other mosquito species. It is estimated that malaria vectors in this region only account for less than 10% of the overall mosquito population (5,60). Even if the technology in question worked, the community would feel little difference in terms of the overall mosquito nuisance. This fact will also need to be given a thorough consideration as it may affect perception of the effectiveness of the technology in the future.

The participants emphasized that it would not be enough to just raise awareness of people about this technology; people needed to be fully engaged in order to make sense of the technology in their specific context. They stressed the need to demonstrate, rather than tell, the safety and effectiveness of this technology. Similar findings were observed in the studies in Mali and Nigeria, where the respondents asked that evidence of the technology's safety and effectiveness be shown before they could allow it in their settings (31,53).

This study is not without limitations. The community leaders that participated in the FGDs represent a particular segment of the population, and their views on the subject might not be generalizable. Yet our findings provide the first social scientific evidence on public perspectives on mosquito modification in Tanzania. The FGDs generated a wealth of qualitative data on the preferred interpretive frames and the most salient concerns expressed by an important sub-population of local residents. This data can serve as a baseline from which to design further studies and start developing effective tools for public engagement.

Conclusion

Understanding how communities perceive and interpret new technologies is crucial in designing strategies of public outreach and generating durable support for the technologies. This study offers vital clues on how communities without any previous experiences regarding genetically-modified mosquitoes might conceptualize or respond to such technologies when deployed for malaria control. Despite the low levels of awareness about GMMs as observed in these Tanzania villages, the FGD participants described distinctive interpretive frames to conceptualize technologies relying on GMMs for malaria control, referring to their experiences with cross-breeding to select preferred traits in domestic plants and animals. These interpretive frames and the real-life analogies may provide a basis for effective community engagement to address any salient concerns, support vital research and development, and possibly aid future deployment of such technologies for malaria elimination. The findings of this study may find broader application in other settings where GMMs or similar approaches are being planned.

Declarations

Ethical considerations

Ethical approvals for this project was obtained from Ifakara Health Institute's Institutional Review Board (Protocol ID: IHI/IRB/EXT/No: 015 - 2018) and the Medical Research Coordinating Committee (MRCC) at the National Institute for Medical Research (Protocol ID: NIMR/HQ/R.8a/Vol.IX/2697), in Tanzania, as well as University of the Witwatersrand (UW) in

South Africa (Clearance certificate No. M180820). Written consent was obtained from all participants of this study, after they had been informed of the purpose and procedure of the discussions. Permission to publish this study was obtained from NIMR, ref: NIMR/HQ/P.12 VOL XXXI71.

Authors' contributions

MFF was involved in study design, data collection, entry and analysis, interpretation of the results and writing the manuscript. NC, FOO, AHK and JL were involved in study design, supervision and critical revision of the manuscript revision. EGM, RN, WMP, BT and PC were also involved in data collection and revision of the manuscript. All authors read and approved the final manuscript.

Availability of data and material

All data for this study will be available upon request.

Competing interests

The authors declare no competing interests.

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