 doi:10.20944/preprints202201.0345.v1

Communication

The Africa Phage forum: A new collaborative network for bacteriophage Research in Africa

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Abstract: The problem of antimicrobial resistance has created a new need for alternative/ complementary treatments. To this end, bacteriophages offer an exciting prospect, as they can infect and kill specific bacteria without harming the host. This survey aimed to evaluate the state of applied phage research in Africa, among the members of the Africa phage Forum (APF). This was a cross-sectional survey whereby a google form was created for the members of the Africa Phage forum to fill so as to access the stage of phage research in Africa. Data was collected between June and July 2021

using a structured questionnaire form. A total of 65 out of a total of 101 forum members completed the questionnaire. The survey indicated that a majority 68% of phage researchers in Africa were at the training stages of their career. Some available participants were limited (8%). Most of the members identified funding, lack of skill set, near absence of adequate laboratory infrastructure as major hurdles for phage research. Despite these challenges, 73.3% of APF members work with the ESKAPE group with the majority of its members carrying out research in Phage in Biocontrol (80%), whereas others perform research related to human phage therapy (60%). However, it appeared this research has not yet reached the stage of commercialization. Overall, Phage research is in its infancy in Africa. Key challenges included poor laboratory infrastructure, lack of capacity building in the phage field, and lack of local awareness on the significance of phages for policymakers and governments. APF could, therefore, play a role in creating phage awareness in Africa; mobilizing resources; enhancing networks and collaborations amongst APF members and beyond, especially with more experienced phage mentors in the Western countries, to greatly reduce the gap in knowledge and enhance phage research in Africa.

Keywords:
Africa Phage Forum, Phages, Research, Collaboration, Network, Capacity development.

Abbreviations: APF: Africa Phage Forum, PI: Principal Investigator, TEM : Transmission electron Microscope.

1. Introduction

Each year about 700,000 people die as a result of antimicrobial resistance and unless an urgent action is taken, an estimated number of 10 million deaths annually is expected by 2050 globally, 90% of these deaths are projected to occur in Africa and Asia [1, 2]. According to WHO [3], the persistent failure to develop, manufacture, and distribute effective new antibiotics is further fueling the impact of antimicrobial resistance (AMR) and threatens our ability to successfully treat bacterial infections. In Africa, a combination of several factors makes AMR management a challenge, these problems include lack of infrastructural and institutional capacities, lack of investment and human resources, underutilization of available data, over-the-counter purchase of antibiotics without prescriptions from qualified medical personnel and scarce dissemination to regulatory bodies [4]. The problem of AMR

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has created a new need for alternative treatments. Bacteriophages (phages) are an exciting prospect, as they can infect and kill specific bacteria without harming the host [5]. To date, phage research Africa is still developing. The lack of exposure for African science has made it difficult for Africa to compete with other nations at an international research level. Scientific collaboration is more strikingly prevalent today than it was several decades ago [6]. In today's science, collaboration and formation of research teams are leading to the reduction of solitary researchers and increased funding opportunities and capacity building [7]. Catalyzing collaborative research is increasingly becoming an important area of many biomedical research projects, leading efforts that bring together investigators with diverse scientific backgrounds and perspectives to solve complex biomedical problems that benefit from an interdisciplinary or multidisciplinary approach [8]. Educational programs have been designed to teach the fundamentals in phage biology in Africa and its potential benefits in the reduction of the burden of many bacterial infections throughout the continent [9]. One striking lesson learnt from COVID-19 is the striking collaboration efforts across continents, research groups and scientists resulting, within a short time, to the understanding of the virus that causes COVID-19 and coming up with solutions such as containment measures and vaccines. In phage research, unlike several other areas of research, has emerged with several clusters or forums, with the aim of establishing research hubs, networks and teams. One of these collaborative efforts is the Phage Directory [10]. Phage research in Africa has remained in its infancy due to lack of awareness and availability of handful trained phage scientists who despite their efforts have not been able to bridge phage capacity building gaps. The recently established Africa Phage Forum (APF) is a collaborative network of African phage researchers that aspires to promote and incentivize phage research in Africa with the vision to provide One-health solutions through phage research. The forum offers a platform that encourages scholarship, collaboration and mentorship among researchers and for the advancement of phage research in Africa. Through increased networking and collaborations, APF will play a key role in creating awareness to policy makers and governments leading to mobilization of funding. This survey sought to highlight the current state of research on phages from African scientists and generate a vision to find solutions to the most pressing challenges in maturing its phage research to the highest international standards. More specifically, we aimed to identify the challenges faced by African phage researchers and how these challenges could be dealt with, based on a survey hosted by the APF. Herein, we highlighted the need for (1) improved collaboration among Africa phage researchers by studying different

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complementary aspects of phages, (2) continuous training and scientific exchange programs and (3) establishment of productive collaborations in the One-health field based on understanding of each other's successes and challenges. Besides, these findings could form the basis for creation of a phage research center in Africa, providing solutions for a rich ecosystem in an African context.

2. Materials and Methods

This study was a cross-sectional survey. In this study, a survey was conducted using the Africa Phage Forum platform to assess the stage of phage research in Africa. Google form was created for the members of Africa Phage forum to fill voluntarily. Data was collected between June and July 2021 using a structured questionnaire. A total of 65 out of a total of 101 APF members completed the questionnaire (supplied as Supplementary data).

3. Results

From table 1, close to three-quarters of the respondents were male (71%) and less than a third were females (29%). The highest proportion of respondents were from Kenya (45%), followed by Nigeria (25%) and Uganda (11%) (Figure 1). A very small number < 5% was from Egypt, Ghana, Zimbabwe, Benin, India, Poland, Ivory Coast, South Africa, and Pakistan. More than half (58%) of the respondents were affiliated to a university and the rest to a research institution. According to career level, less than a third of the respondents are undergraduate students (29%), master students (25%), research scientists (17%) and PhD students (14%). A minority of the respondents are lecturer/PI (8%), industry professional (6 %) and postdocs (2%). A significant proportion of the respondents are not part of any local phage network (72%) while less than a fifth are part of the Ibadan Bacteriophage Research Team (11%), Institute primate research phage group, International Livestock Research institute, Kenya (8%), PhageTeam Uganda (5%), Ghana phage team (2%), Women In bacteriophage (2%) and PhageAI (2%).

 doi:10.20944/preprints202201.0345.v1

Table 1: Characteristics of respondents according to their gender, institute, career level and phage network.

Variable	Frequency (*N*=65)	Percentage (%)
Gender		
Male	46	71
Female	19	29
Institute		
University	38	58
Research organization	27	42
Career level		
Undergraduate	19	29
Master student	16	25
PhD student	9	14
Lecturer/PI	5	8
Post-doc	1	2
Research scientist	11	17
Industry professional	4	6
Phage network (local)		
None	47	72
Ghana phage team	1	2
Institute Primate Research Phage Biology Group, Kenya	5	8
Ibadan Bacteriophage Research Team	7	11
PhageTeam Uganda	3	5
Women In bacteriophage	1	2
PhageAI	1	2

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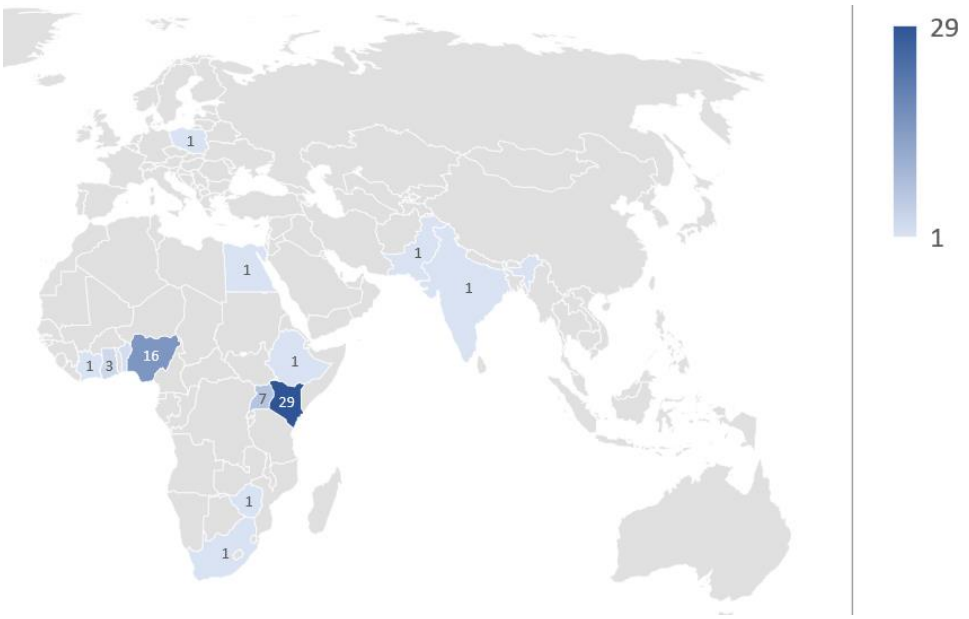

Figure 1: Map showing the distribution of the Africa Phage forum Members

From table 2, three-fifths of respondents have not started phage work while less than a fifth of the respondents work on ESKAPE phages. The minority of respondents have been working on phages specific to *Salmonella* species (2 – 5%), *Acinetobacter* species (5%), *E. coli* (3%), Lambda (2%), APEC, *Aeromonas*, *Edwardsiella* (2%), *Campylobacter* species (2%) and *Listeria monocytogenes* (2%). A diverse range of host bacteria are studied by the respondents. More than two-fifths of the respondents use ESKAPE pathogens (48%) for phage work while less than a fifth (2% - 11%) of the respondents use bacteria species including *Salmonella*, Fish bacterial pathogens, *Actinobacteria*, *Cutibacterium*, *Campylobacter E. coli*, *Helicobacter pylori* and *Listeria monocytogenes*. Less than a third of the respondents are at the stage of bacteriophage isolation (28%), characterization (38%) while some respondents are at the conceptualization stage. Only a small minority are at phage formulation stage (5%) and host bacteria characterization (2%). The potential application of the bacteriophages was for human medicine (74%), Biology (14%) and crop protection (3%). A small number (2%) of bacteriophage work is targeted for aquaculture, diagnosis, livestock, food safety and vaccines.

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Table 2: Bacteriophage, bacteria hosts, research status, and potential applications

Variable	Frequency (N=65)	Percentage (%)
Bacteriophages		
None	39	60
Acinetobacter baumannii	3	5
ESKAPE, *Salmonella typhi*	1	2
Non-typhoidal *salmonella*	2	3
E.coli	2	3
ESKAPE	11	17
Salmonella typhi	3	5
Lambda	1	2
APEC, *Aeromonas*, *Edwardsiella*	1	2
Campylobacter	1	2
Listeria monocytogenes	1	2
Bacteria species		
ESKAPE	31	48
Xanthomonas	2	3
ESKAPE + *Salmonella typhi*	7	11
Non-typhoidal *Salmonella*	4	6
Salmonella typhi	5	8
Fish bacterial pathogens	1	2
Actinobacteria	2	3
ESKAPE + Salmonella typhi + non-typhoidal *salmonella*	4	6
ESKAPE + non-typhoidal *salmonella*	1	2
Mycobacteria	1	2
ESKAPE + *Cutibacterium acnes*	1	2
Campylobacter	1	2

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Escherichia coli	1	2
Helicobacter pylori	1	2
Listeria monocytogenes	1	2
None	2	3
Stage of phage research		
Isolation	18	28
Characterization	25	38
Formulation	3	5
Host characterization	1	2
Conceptualization Stage	18	28
Potential application		
Human Medicine	48	74
Crop protection	2	3
Aquaculture	1	2
Diagnosis	1	2
Biology	9	14
Livestock	1	2
Food safety	1	2
Vaccines	1	2
None	1	2

According to the table 3, a number of challenges were reported. The majority of respondents were constrained by funding (45%), poor laboratory infrastructure (17%), and lack of phage skillset (11%). The rest of the challenges included lack of transmission electron microscope (TEM) services (3%), poor acceptance of phage application by public (3%), procurement delays (2%), novice area (2%) and work in isolation (2%). The highest proportion sought for research collaboration with an established laboratory (37%), funding collaboration (26%), genome sequencing collaboration. A large majority of the respondents would like to be contacted for collaboration (92%) while over two-thirds of the respondents (68%) are willing to mentor students across the continent.

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Table 3: Respondent research challenges and needs

Variable	Frequency (N=65)	Percentage (%)
Research challenges		
Funding constraints	29	45
Lack phage skillset	7	11
Laboratory Infrastructure	11	17
Procurement delays	1	2
Novice research area	1	2
Work in isolation	1	2
Poor acceptance of phage application	2	3
Lack of TEM facilities	2	3
No response	11	17
Collaboration type		
Phage genome sequencing and bioinformatics	11	17
Grant writing skill training	2	3
Research collaboration with established phage laboratory	24	37
Funding	17	26
Phage training in isolation and characterization	5	8
Phage conferences	1	2
Scientific writing and publication	2	3
No response	3	5
Would you like to be contacted for possible collaboration?		
Yes	60	92
No	5	8
Student mentorship		

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Yes	44	68
No	21	32

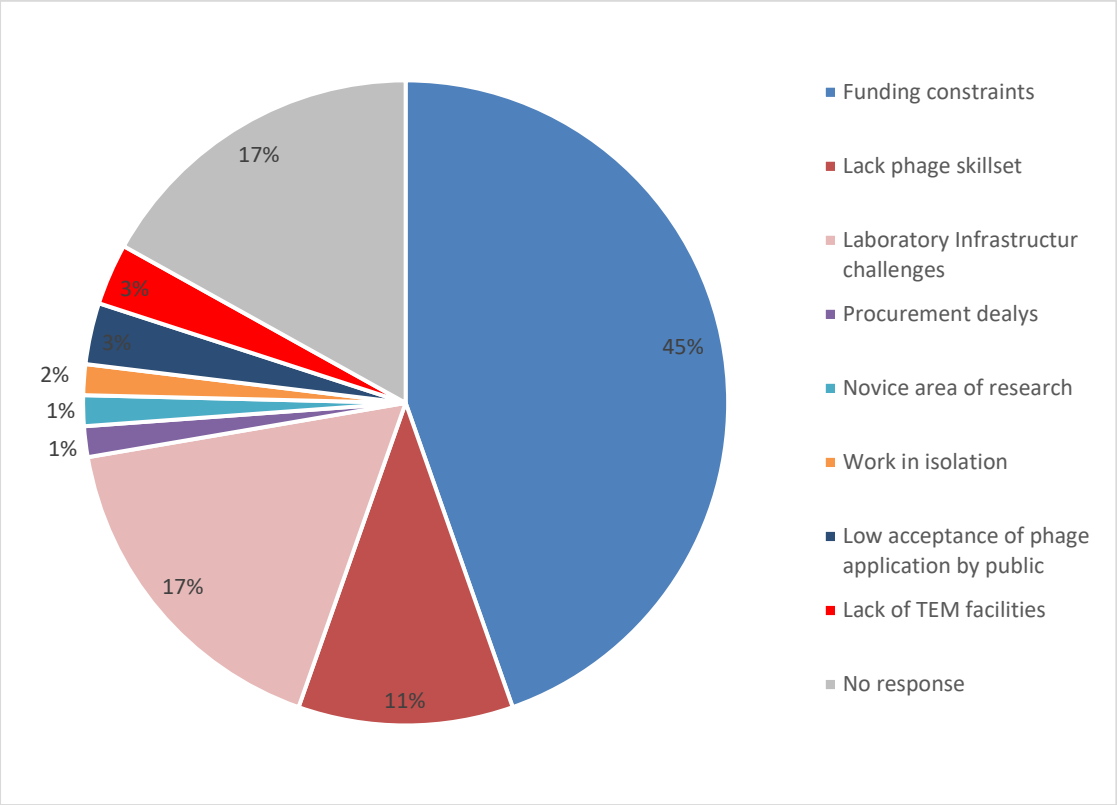

Figure 1. Pie chart showing categories of challenges limiting phage research in Africa

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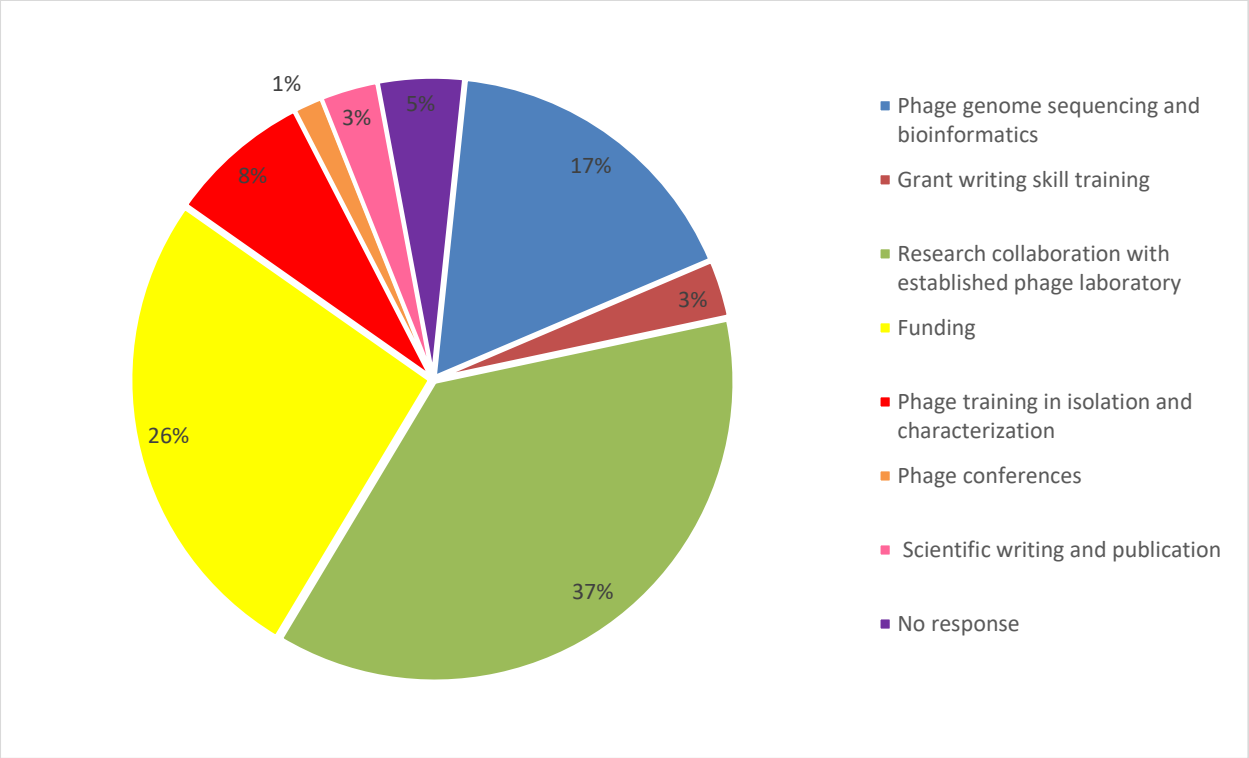

Figure 2: Type of collaboration and support for research improvement

The members of Africa Phage forum comprised of majorly students 53.3% at various stages of studies with only 46.6% are at postgraduate level. The number of critical manpower to provide mentorship was accessed and we found 26.6% either as research scientists or lecturers. None within APF had reached the stage of commercialization of phages. However, most members were at the characterization stage (60%) followed by the isolation stage (40%). Considering the bacteria of interest Most members 73.3% work with the ESKAPE group with most members research in Phage in biocontrol (80%) while others research in phage therapy in humans (60%).

4. Discussion

4.1. Phage researchers in Africa comprises of diverse career background

Seeking solutions to the common challenges faced by phage scientists in the developing world/third world, the Africa Phage forum was created based on a Collaborative Network of African phage researchers that focuses on promoting and sensitizing phage research in Africa. To achieve this,

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APF encourages phage researchers in Africa to engage (share ideas, experiences, resources, opportunities) and network with a common goal of improving human life. To this end, APF has grown and cut across all Africa and is gaining acceptance as an umbrella for all phage researchers in Africa. Majority of members cut across, West Africa, East Africa, North Africa and Southern Africa. Three countries, Kenya, Nigeria and Uganda are leading sites for phage research in Africa. Although not all phage researchers are on-board, phage field is gaining acceptance among African researchers. Most of the research is focused on isolation and characterization while a handful have dived into phage product formulation stage. However, not every phage enthusiast has started phage research as some are still at the conceptualization phase of their research. Moreover, researchers involved in phage research are at various stages of career with most being students. Phage research in Africa is responding to the challenge posed by ESKAPE pathogens taking the lead in phage research especially in human pathogens. Nonetheless, a small number are interested in studying phage biology, phage application in crop protection, phages for aquaculture, diagnosis, livestock, food safety and vaccines.

4.2. Mentor training Critical area of need

Mentorship has been underlined as being central to academic advancements and has long played critical roles in the training and career development of scientists [11]. Mentorship is critical to developing the next generation of phage leaders. According to the principles developed by Knowles, Candy, Bandura, and Schon suggest that professionals should be active contributors in the educational process so that learning is work-situated, or shaped by their knowledge and experience, and teachers or role models should facilitate learning by providing guidance, support, and constructive feedback [11]. Effective mentorship is key to the development, success, and retention of early career investigators in research settings [12]. The situation of phage research in Africa may be related to the quality of mentorship provided. From this survey, lecturers or Principal investigators who participated depict that the poor state of phage researchers in Africa may be inclined to the fact that there are few faculty members actually researching on phages.

The majority of phage researchers in Africa are at the training stages of their career. More than half of the members of APF are either at their undergraduate level or postgraduate level of training. The combination of low faculty and several students possibly shows two things 1.) That phage research in Africa, if given the correct push will serve as a major research aspect in Africa and contribute to

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tackling the threat of antimicrobial resistance 2.) Mentor recruitment training is key in driving phage research in Africa. APF is therefore set to encourage collaborations that will help drive mentor capacity developments. Previous efforts to training manpower in Africa is greatly acknowledged [9].

4.3. Major Hindrances to Phage Research in Africa

Apart from the mentorship, the lack of facilities to conduct phage research hinders the progress of phage research. This is because of the limited number of laboratories equipped for phage research leading to research being outsourced causing huge delays, results that cannot be replicated and data is not enough to inform policy. The major hindrances to phage research in Africa highlighted in this study include poor funding, lack of laboratory infrastructure, the lack of sensitization phage research. The phage adoption is being advocated across the globe, with a number of *in vivo* animal studies and clinical trials on-going in many countries. To date, there is no single country in Africa that has participated in phage clinical trials and the lack of coordinated phage biobanks plays a role in the lack of concerted efforts for collaborations between the African countries.

Álvarez *et al.,* (2019) [13] in their paper identified lack of regulatory framework on phage therapy, inadequate funding from government and pharmaceutical companies as well as getting volunteers as major hindrances to phage therapy research . These issues are particularly true for Africa.

4.4. Tackling the hurdles of phage research in Africa

Phage research in Africa is gaining interest triggered by the growing interest among students creating a unique but interesting area of research in future. However, the observed challenges unless solved could continue hindering phage research in Africa at the nascent stage. Some solutions include advocating for adequate funding for phage research in Africa, collaborations that lead to capacity and infrastructural development and sensitizing the public towards phage research and its possible applications.

5. Conclusions

Members are actively involved in phage research at various stages of their careers and are open to collaboration that will lead to the establishment of phage in Africa. Africa Phage Forum is a good initiative that creates a platform for sharing of phage knowledge. The APF can help propel phage

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research by tackling the challenges highlighted such as funding, capacity building, creating awareness and being the voice of African phage researchers in various forums.

Acknowledgments

Africa Phage Forum is grateful to Phage Directory for their logistic support and their assistance in publicizing our webinars.

Conflict of Interest

The authors declare no conflict of interest

Author Contributions:

NFM, NEN, RN and AM conceived and designed the study and prepared the manuscript. All authors reviewed, edited and have approved the final manuscript for publication.

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Supplementary: A structured questionnaire

https://docs.google.com/forms/d/14M5d4-tF17nbZfqxJ5e9K2yAWX8KCajrBtyevRFRyTQ/prefill