One Health 15 (2022) 100442

Contents lists available at ScienceDirect

One Health

journal homepage: www.elsevier.com/locate/onehlt

Strengthening laboratory biosafety in Liberia during the COVID-19 pandemic: Experience from the Global Laboratory Leadership Programme

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ARTICLE INFO

Keywords:
Global laboratory leadership programme
Laboratory biosafety
Workforce development
One health
COVID-19
SARS-CoV-2

ABSTRACT

Background: The Global Laboratory Leadership Programme (GLLP) has biosafety and biosecurity as one of its core competencies and advocates for a One Health approach involving all relevant sectors across the human-animal-environment interface to empower national laboratory systems and strengthen health security. Decentralization of SARS-CoV-2 testing in Liberia coupled with an increase in the number of COVID-19 infections among laboratory professionals raised biosafety concerns. In response, a set of trainings on laboratory biosafety was launched for lab personnel across the country under the framework of the GLLP. The goal was to deliver a comprehensive package for laboratory biosafety in the context of SARS-CoV-2 through active learning.

Methods: Three one-day workshops were conducted between September and October 2020, training personnel from human, animal and environmental laboratories through a One Health approach. Concepts critical to laboratory biosafety were delivered in an interactive engagement format to ensure effective learning and retention of concepts. Pre- and post-training assessments were performed, and a paired *t*-test was used to assess knowledge gain.

Results: Of the 67 participants, 64 were from the human health sector, one from veterinary sector and two from environmental health sector. The average pre-test score was 41%. The main gaps identified were failure to acknowledge surgical antisepsis as a form of hand hygiene and recognition of PPE as the best risk control measure. The average post-test score was 75.5%. The mean difference of pre-test and post-test scores was statistically significant (p-value <0.001). Participants indicated satisfaction with the workshop content, mode of delivery and trainers' proficiency.

Conclusions: The workshops were impactful as evidenced by significant improvement (34.5%) in the post-test scores and positive participant feedback. Repeated refresher trainings are vital to addressing the gaps, ensuring compliance, and promoting biosafety culture. GLLP's approach to cultivating multisectoral national laboratory leaders ready to take responsibility and ownership for capacity building provides a sustainable solution for attaining strong national laboratory systems better prepared for health emergencies and pandemics like COVID-19.

1. Introduction

Laboratories are an essential and fundamental part of health systems and play a critical role in the detection, diagnosis, treatment and control of infectious diseases and their agents [1,2]. Similarly, laboratory biosafety and biosecurity activities are fundamental to protecting the laboratory workforce and the wider community against unintentional or deliberate exposures of pathogenic biological agents [3]. The

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https://doi.org/10.1016/j.onehlt.2022.100442
Received 15 June 2022; Received in revised form 7 October 2022; Accepted 8 October 2022
Available online 10 October 2022

widespread emergence of infectious threats causing extensive outbreaks and pandemics has accentuated biosafety and biosecurity as a fundamental component for resilient national laboratory systems.

Biosafety and biosecurity are one of the "action packages" within the Global Health Security Agenda (GHSA), an international initiative to support the International Health Regulations (IHR) by comprehensively addressing the global health threats posed by infectious diseases [4,5]. Similarly, biosafety and biosecurity has also been identified as one of the core competencies for the Global Laboratory Leadership Programme (GLLP), a fellowship programme fostering and mentoring laboratory leaders to build, strengthen and sustain national laboratory systems in low-and middle-income countries. GLLP embodies a One Health approach and involves laboratory professionals from all relevant sectors across the human-animal-environment interface to empower national laboratory systems and strengthen health security [6,7]. In 2019, Liberia was selected to be a pilot country for the implementation of the GLLP. The programme is mentoring a multisectoral laboratory technical group comprising of human, animal, and environmental laboratory experts, termed as "GLLP mentees", facilitating the development of nine leadership competencies of the competency framework that underlies the GLLP [7]. The mentees are senior laboratory leaders from the national public health, animal, and environmental laboratories.

Liberia reported its first case of COVID-19 on March 16, 2020. Centralized testing for SARS-CoV-2 was initiated at the National Public Health Reference Laboratory (NPHRL). Due to the rising number of COVID-19 infections across the country, compounded by a national-imposed lockdown and curfews, decentralization of testing was rapidly implemented. Ten sites across the country comprised of four regional public health laboratories and six county hospital laboratories were chosen for expansion of testing in a phased manner. With the expansion of testing beginning July 2020, an increased number of COVID-19 infections were reported among laboratory professionals involved in sample collection and processing. Twenty-nine laboratory technicians tested positive for SARS-CoV-2 by the end of August 2020 according to the National COVID-19 situation report number 165 [8]. These cases raised serious concerns over the adequacy of biosafety training and adherence to appropriate biosafety practices among the laboratory staff and highlighted the need for comprehensive training addressing the laboratory biosafety in the context of SARS-CoV-2.

Between September and October 2020, trainings under the GLLP framework were conducted targeting laboratory professionals from the 15 counties across the country under a One Health approach. The overarching goal of the trainings was to deliver a compendious package for laboratory biosafety in the context of SARS-Cov-2 and equip the laboratory workforce with the skill set required to confidently handle the pathogen.

This paper describes the observations and findings from these trainings and the implications for a professional laboratory workforce.

2. Methods

The training employed a mixture of didactic sessions and hands-on practice sessions. Active learning techniques were adopted for the transfer of learning to workplace practices. Knowledge assessment was conducted through self-administered pre- and post-test questionnaires. Three one-day workshops of seven hours each were conducted in the three major cities in the country (Monrovia, Buchanan and Ganta) between September and October 2020, serving as accessible locations for the trainees located in the neighboring counties. Fig. 1 shows the workshop locations in Liberia. The participants were first administered a pre-test questionnaire to assess their baseline knowledge. This was followed by the training session to impart knowledge to confidently handle SARS-CoV-2 and succeeded by a post-training knowledge assessment.

Fig. 1. Map of Liberia showing the three training locations: Monrovia, Buchanan and Ganta.

2.1. Workshop participants and trainers

A total of 67 participants were recruited for the workshops representing regional public health laboratories, county hospital laboratories, veterinary facilities, food safety and environmental laboratories spanning the country. The group comprised supervisors, technicians, assistants and aides, all with some experience in laboratories dealing with infectious agents. Basic information on job titles and affiliation was collected from each participant. Anonymized questionnaires were used to ensure confidentiality.

The trainers were nine GLLP mentees who, after their GLLP training, underwent a rigorous one-week supplemental training for laboratory biosafety and risk assessment conducted by an International Federation of Biosafety Associations (IFBA) certified biosafety professional from Integrated Quality Laboratory Services (IQLS, Lyon, France). The trainers were actively involved in the national COVID-19 response, had expertise in COVID-19 testing and had displayed advanced skills level in training and facilitation. This highlights the unique approach of the GLLP, fostering and mentoring national laboratory leaders ready to take responsibility and ownership for capacity building when responding to health emergencies and contributing to sustainable national health laboratory systems.

2.2. Workshop content

The workshop content was based upon the COVID-19 laboratory biosafety guidance from the U.S. Centers for Disease Control and Prevention (CDC) [9] and the World Health Organization (WHO) [10], the WHO Laboratory Biosafety Manual [3], and Biosafety in Microbiological and Medical Laboratories [11]. The training program was further refined based on recommendations from the trainers (the GLLP mentees) owing to their better understanding of the national context, needs and existing gaps. Training objectives and outcomes were designed in accordance with the knowledge and skills participants were expected to demonstrate after the course.

The training employed a mixture of didactic sessions, audio visual presentations and practical exercises facilitating integration of the acquired knowledge and good practices into routine laboratory practice. The training sessions focused upon concepts of sample collection, risk assessment and management, biosafety levels, primary and secondary barriers, installation and operation of biosafety cabinets, personal protective equipment (PPEs), hand hygiene, waste management, packaging and shipping samples, decentralized and point of care testing for COVID-19. Alongside the didactic sessions, there were hands-on sessions for donning and doffing of PPE and hand hygiene using the Glo Germ™ kit (Glo Germ Company, Moab, Utah, USA). The participants were divided in groups of 6–8 and facilitated by the trainers to conduct a risk assessment of their respective laboratories for COVID-19 employing the risk assessment template in the WHO COVID-19 laboratory biosafety guidance [10]. They were encouraged to follow the instructions listed in the template, gather and record the required information and subsequently develop a COVID-19 risk control strategy for their labs.

At the end of the workshops, the participants were provided with training materials and posters demonstrating handwashing and use of hand rubs, and the donning and doffing of PPE. Also, the National Biosafety and Biosecurity guide for laboratories [12] was distributed to each of the participating facilities as a template for developing biosafety manuals and standard operating procedures for their respective facilities.

2.3. Workshop assessment

A subject-specific questionnaire was used to assess the knowledge levels related to COVID-19, laboratory biosafety and risk assessment. The questionnaire comprised of 14 objective questions. The maximum possible score for all questions was 21. The same questionnaire was administered before (pre-test) and after (post-test) the workshop to evaluate the participants understanding of key concepts of biosafety related to COVID-19 prior to and after the training.

2.4. Statistical analysis

Data were analyzed using the Statistical Packages for Social Sciences (SPSS) version 24.0. The paired Student's *t*-test was used to compare pre- and post-test scores. A p value of <0.05 was considered significant. As the participants in the three workshops received similar training content, participants' data were considered homogeneous and the results of the three workshops were combined and analyzed together.

2.5. Workshop evaluation

An end-of-session feedback was obtained from the participants to evaluate their satisfaction with the quality and content of the workshop, facilitators competency and the general impression of the session.

3. Results

A total of 67 laboratory professionals were trained across the country: 64 (95.5%) were from human health, one from the veterinary sector and two from environmental health. About half (48%) of the participants were technicians, 18 (27%) were supervisors, 13 (19%) were assistants and 4(6%) were aides.

Participants mean scores displayed a marked improvement from 9 (41%) in the pre-test to 16 (75.5%) in the post-test results (Fig. 2).

Distribution of correct responses in the pre-test and post-test questionnaires is shown in Table 1.

Analysis of the pre-test questionnaires revealed that all the trainees correctly understood that risk assessment is a continuous process and handwashing with soap and water is a form of hand hygiene. The main gaps identified in the pretest were failure to acknowledge surgical antisepsis as a form of hand hygiene (4.4%) and recognition of PPE as the best risk control measure (6%).

The post-test analysis showed the highest scores for correct practices for wearing laboratory coats (100%) and hand hygiene incorporating alcohol-based hand rubbing in addition to handwashing with soap and water (100%).

The gap pertaining to PPE being the best risk control measure persisted and recorded lowest score in the post-test and least improvement. The greatest improvement was noted for the concepts related to the recommended timing for hand hygiene followed by Biosafety Cabinet Class II serving an ideal choice for handling COVID-19 samples.

The difference between the pre-test and post-test means indicated an overall 34.5% increase in understanding by the participants. Further analysis through a paired *t*-test yielded a highly significant result (p value <0.001, 95% CI) (Table 2).

In the end-of-session feedback all the participants found the workshop content to be educational and informative. The exercises were reported to be engaging, enabling better retention of concepts and putting theory into practice. The participants were particularly enthused to learn about the concept of risk assessment and how to put it into practice as shown by this quote: *'Risk assessment is a totally new concept. This training has exposed us to and we are looking forward to apply it in our settings'*. They found the timing of the training to be appropriate with the ongoing decentralization of COVID-19 testing in the country. A majority (90%) of the trainees reported that the facilitators met their expectations. Being trained by a pool of national experts was described as an empowering experience. Approximately 12% of the trainees pointed out the duration of training was too short and wanted it to be extended.

4. Discussion

Biosafety is an area of utmost concern in every medical and

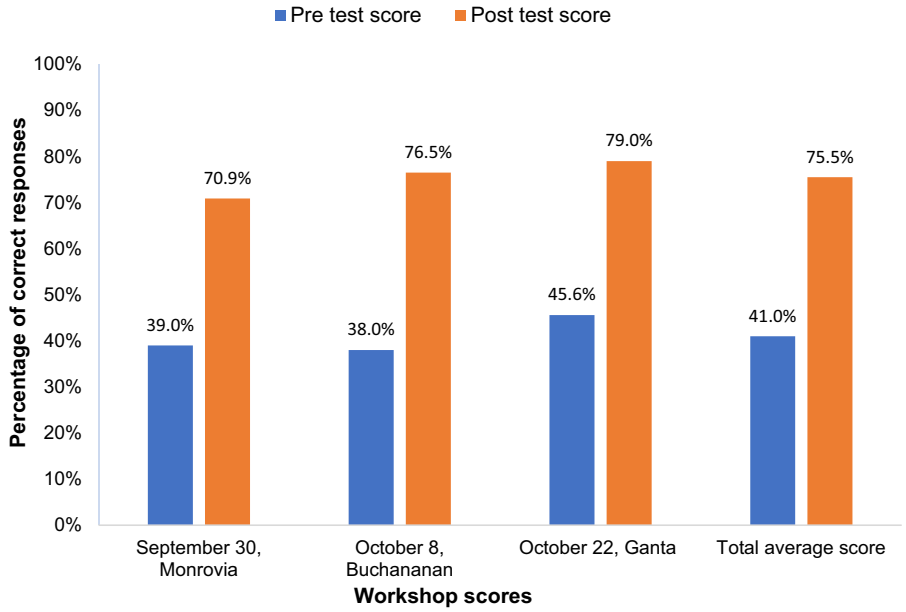

Fig. 2. Bar graph displaying the average pre-test and post test scores for the workshops.

biomedical laboratory and has been identified as one of the prerequisites to respond effectively to infectious disease threats as shown by the GHSA and the GLLP. The training workshops were conducted in Liberia to provide laboratory biosafety and risk assessment education to laboratory personnel involved in the national COVID-19 response adopting active learning principles and evaluating knowledge gain. Regardless of the past work experience and laboratory setting type, the baseline knowledge of all participants concerning biosafety and risk assessment was low. Similar results were reported in other biosafety training programs in different settings [13–16]. Our workshops were effective in delivering the fundamental concepts of biosafety in the context of SARS-CoV-2 as evidenced by the significant improvement in the post test scores. This is in concordance with several published reports establishing the usefulness of biosafety-associated educational training sessions [16–20].

The increases observed in the domain of hand hygiene can be explained by the various practical group exercises which allowed to put theory into practice, enabling better retention. Also, there was a significant improvement reported for the knowledge relating to the use of biosafety cabinets for handling COVID-19 samples. This knowledge gain can be attributed to the videos presented during training displaying different types of BSCs, best practices for safe use, incident management, maintenance and certification of BSCs, followed by group discussions and problem-solving exercises.

The interactive and engaging nature of the workshop was well-aligned with the participants preferred learning styles. Incorporating active learning techniques by engaging participants in collective brainstorming, group problem solving, practical demonstrations made the training content relevant, practical and enjoyable.

Repeated refresher trainings integrating behavioral insights methodology might prove worthwhile in addressing these misconceptions. In conjunction with theoretical content, incorporating relevant hands-on practices might also serve as a tool to increase topic specific knowledge and facilitate positive behavior change that may actively influence organizational culture around biosafety [21].

In summary, the GLLP's commitment to building a pool of multisectoral competent laboratory leaders capable of effectively cascading knowledge and skills to help build human resource capacity across all sectors of the laboratory system offers a promising approach to empowering and advancing national laboratory systems exhibiting better preparedness for responding to outbreaks and health emergencies.

4.1. *Strengths and limitations*

The workshops predominantly focused on addressing the concepts and practices of biosafety in the context of SARS-CoV-2 employing principles of active learning. Participants were actively engaged and exhibited substantial knowledge improvement and expressed a high level of satisfaction with the workshop content and facilitator's competency. Alongside theory, practical hands-on exercises were integrated into the training content to enable retention and encourage adherence with positive behaviors. Additionally, the workshops were conducted by a pool of GLLP mentees with an understanding of the local needs that helped tailor the workshop content to best meet existing needs while simultaneously ensuring national leadership and ownership. However, restricted representation from the animal and environmental health laboratories was a limitation.

COVID-19 infections among the laboratory workforce were followed up for a year after the workshops. Six additional cases were positive for SARS-CoV-2 by the end of October 2021 for a total of thirty-five cases [22]. This finding corroborates the practical effectiveness of the trainings and reflects the translation of knowledge gain into good behaviors and laboratory practices pertaining to biosafety.

5. Conclusions

Laboratory biosafety and biosecurity is a critical and fundamental component for resilient national laboratory systems. The biosafety and risk assessment trainings were impactful as confirmed by the significant improvement in the post-training evaluations, positive trainee feedback as well as fewer COVID-19 infections reported in the follow-up period. These findings highlight the significance of relevant education and practical demonstrations in augmenting knowledge and understanding pertinent to laboratory biosafety and biosecurity. GLLP's approach to multisectoral laboratory workforce development and cultivating national laboratory leaders for a critical component of global health security provides a logical, sustainable and strategic model that can enable resource-limited settings attain and sustain strong national laboratory systems.

Table 1
Distribution of correct responses in the pre- test and post-test questionnaires.

	Questions	Pre-test scores (%)	Post test scores (%)	Improvement (%)
1	Transmission routes for COVID-19	44 (65.6%)	59 (88.0%)	15 (22.4%)
2	Biosafety level recommended for COVID-19 routine testing	18 (26.8%)	59 (88.0%)	41 (61.2%)
3	Disinfectants active against COVID-19	24 (35.8%)	51 (76.1%)	27 (40.3%)
4	Recommended time for handwashing with soap & water	15 (22.3%)	59 (88.0%)	44 (65.7%)
5	Ideal class of biosafety cabinets for handling COVID-19 samples	11 (16.4%)	55 (82.1%)	44 (65.7%)
6	Wearing PPE is the best risk control measure	4 (6.0%)	14 (20.9%)	10 (14.9%)
7	Labelling of patient samples from suspected /confirmed COVID-19 cases for transport	10 (14.9%)	32 (47.8%)	22 (32.9%)
8	Surgical masks are effective at protecting lab personnel against aerosols	26 (38.8%)	45 (67.1%)	19 (28.3%)
9	Correct sequence of putting on PPE	39 (58.2%)	60 (89.6%)	21 (31.4%)
10	Lab risk assessment is an ongoing continuous process	67 (100.0%)	67 (100.0%)	0 (0.0%)
11	Frequency of certification of a BSC	21 (31.4%)	36 (53.8%)	15 (22.4%)
12	Hand hygiene applies to surgical antisepsis	3 (4.4%)	31 (46.2%)	28 (41.8%)
13	Hand hygiene applies to cleaning hands with an alcohol- based hand rub (ABHR)	43 (64.2%)	67 (100.0%)	24 (35.8%)
14	Hand hygiene applies to cleaning hands with soap and water	67 (100.0%)	67 (100.0%)	0 (0.0%)
15	ABHR is more effective at killing microorganisms than soap & water	65 (97.0%)	65 (97.0%)	0 (0.0%)
16	ABHR takes less time to clean hands than soap and water	14 (20.9%)	60 (89.6%)	46 (68.7%)
17	ABHR doesn't require sinks, water or towels	19 (28.4%)	59 (88.1%)	40 (59.7%)
18	ABHR can be placed directly at the point of care	14 (20.9%)	49 (73.1%)	35 (52.2%)
19	Always use the correct size of lab coats and aprons	40 (59.7%)	67 (100.0%)	27 (40.3%)
20	Lab coats should be disinfected before cleaning	26 (38.8%)	45 (67.2%)	19 (28.4%)
21	Lab coats should not be worn outside the lab	47 (70.1%)	67 (100.0%)	20 (29.9%)

Table 2
Paired sample t-test analysis of pre- and post-test assessment.

Paired Samples Test	Paired Differences				df	P value
	Mean	Standard Deviation	95% Confidence Interval of the Difference			
			Lower	Upper		
Pre Test -Post Test	−22.818	14.604	−29.294	−16.341	21.00	0.000

6. Recommendations

Given the variety of infectious disease threats the laboratory professionals are exposed, biosafety and biosecurity should be prioritized and regular refresher trainings should be conducted to reinforce the concepts, encourage proper behaviors and ensure maximum compliance. Trainings and assessments should be incorporated as a part of routine competency assessment for laboratory professionals. Furthermore, a key goal and responsibility of laboratory leadership as part of capacity building is to address laboratory biosafety and biosecurity gaps and implement a sustainable and proactive management system at the country level [23].

Disclaimer

The findings and conclusions in this report are those of the author(s) and do not necessarily represent the official position of the U.S. Centers for Disease.

Control and prevention

"Use of trade names is for identification only and does not imply endorsement by [the Centers for Disease Control and Prevention/the Agency for Toxic Substances and Disease Registry], the Public Health Service, or the U.S. Department of Health and Human Services."

Ethical approval

For this study no ethical approval was obtained. No personal identifiers were collected and anonymized questionnaires were used to ensure confidentiality.

Funding

The funding for the work done as part of this manuscript was supported by the United States Centers for Disease Control and Prevention [grant number 6 NU2GGH001804–03-06].

CRediT authorship contribution statement

Shruti Malik: Conceptualization, Methodology, Formal analysis, Writing – original draft, Writing – review & editing. **Fahn M. Taweh:** Investigation. **Maxwell Freeman:** Investigation. **John B. Dogba:** Investigation. **Grace O. Gwesa:** Investigation. **Melvin Tokpah:** Investigation. **Prince P. Gbondin:** Investigation. **T. Henry Kohar:** Investigation. **John Y. Hena:** Investigation. **Jane A. MaCauley:** Investigation. **Antoine Pierson:** Conceptualization, Writing – review & editing. **Mark A. Rayfield:** Visualization, Writing – review & editing. **Leonard F. Peruski:** Visualization, Writing – review & editing. **Adilya Albetkova:** Visualization, Writing – review & editing. **Amanda Balish:** Visualization, Writing – review & editing, Supervision.

Declaration of Competing Interest

The authors declare no conflict of interest with respect to the research, authorship, and/or publication of this article.

Data availability

Data will be made available on request.

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