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Assessment of biosafety and biorisk management practices among medical laboratory students in two institutions in Uganda

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ABSTRACT

Medical laboratory workers handle clinical specimens, which are a threat of exposure to infectious agents. Notably, medical laboratory science students report for internships with only theoretical knowledge of biosafety and biorisk management practices, predisposing them to a higher risk of laboratory hazards. In this study, we assessed the influence of entry-level students' adherence to practices and attitudes towards biosafety and biorisk management during the Internship. An online survey tool was used to explore the practices and attitudes towards laboratory biosafety and risk management. Of the 96 students, 60 (62.5%) anonymous responses were received, and of these, 60.3% were direct entrants, and 32.8% were diploma entrants. Most (91.7%) of the students attended hospital internships, with 60.2% in Biosafety Level (BSL)-2 laboratories and 70.2% rotating in all the core areas of laboratory medicine. The 8.3% who did not attend any internship were under the direct entry category. Exposure to biohazards was not significantly associated with laboratory safety level and student entry category ($P > 0.05$). Recommended laboratory biosafety practices were not significantly associated with the safety level of the laboratory and student entry category ($P > 0.05$). Poor attitudes towards certain laboratory biosafety practices were not significantly associated with the biosafety level of the training laboratory ($P > 0.05$), whereas training ($P = 0.021$) and clean-up procedures ($P = 0.048$) were associated with laboratory safety levels, respectively. The direct entrants had no access to BSL-3 laboratories, and this category of students had a negative attitude towards internship attendance. Therefore, there is a need to create a multi-channel full range laboratory biosafety and biorisk management teaching reforms based on practical application, real case studies, and laboratory simulation to be incorporated into the curriculum to benefit the direct entrant.

1. Introduction

Laboratory medicine is an applied discipline that has developed rapidly with multi-technology, multi-interdisciplinary, and highly comprehensive science [1,2]. Medical laboratories and laboratory personnel form part of the functioning health system capacities necessary for diagnosing, controlling, and preventing diseases. While medical laboratories play essential roles in clinical diagnostics and research settings, there is a significant risk of iatrogenic infections within the facilities as the personnel easily come in contact with pathogens and other hazards [2]. To avoid laboratory-acquired infections and control the spread of potentially hazardous agents such as severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) and Ebola virus, diagnostic and research laboratories must maintain a safe and secure environment [3]. Therefore, this calls for governments, society, and academic and medical research institutions to build the laboratories' capacity through training personnel in biosafety management (BSM) practices to curb emergent public health events [1,2].

The Global Health Security Agenda (GHSA) aims to mitigate risks from emerging and re-emerging infectious agents, which can be achieved through training the personnel, including medical laboratory students, in biosafety and biorisk management before they are rolled out as professionals [4].Biosafety practices are measures designed to prevent and minimize the risks of biohazards [5]. Thus, biosafety aims to protect the worker, the patients, and the environment from contamination with biohazards from the laboratory. In addition, biosecurity

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HIGHLIGHTS

Scientific question

Medical laboratory science students report for internships with only theoretical knowledge of biosafety and biorisk management practices, predisposing them to a higher risk of laboratory hazards.

Evidence before this study

According to a 2014 survey in China, medical laboratory students at specialized levels always have a higher awareness of preventing hospital-acquired compared to direct entrant students. In Uganda, according to a 2017 biorisk management (BRM) survey by the Central Public Health Laboratory (CPHL), insufficient laboratory biosafety and biosecurity measures were found in most of the public and private medical laboratories. However, these facilities are used for medical laboratory students' internships.

New findings

In this study, we assessed the influence of entry-level students' adherence to practices and attitudes towards biosafety and biorisk management during the internship. Most (91.7%) of the students attended hospital internships, with 60.2% in BSL-2 laboratories and 70.2% rotating in all the core areas of laboratory medicine. The 8.3% who did not attend any internship were under the direct entry category. Training and clean-up procedures were associated with laboratory safety levels (P= 0.021 & 0.048, respectively). The direct entrants had no access to BLS-3 laboratories, and this category of students had a negative attitude towards internship attendance.

Significance of the study

Our results indicate that there is need to identify steps to be taken to reform the training of laboratory biosafety and protective consciousness among students. In addition, the training should direct students to operate standardized laboratory procedures and conduct biorisk assessments promptly and correctly, to guarante adherence to biosafety during clinical practice.

measures enhance protection, control, and accountability for valuable biological materials (VBM) within laboratories to prevent unauthorized access, loss, theft, misuse, diversion, or intentional release [4].

Clinical practice through Internship is the principal channel for practical and theoretical teaching of the laboratory specialty [6]. According to a 2014 survey in China, medical laboratory students at specialized levels always have a higher awareness of preventing hospital-acquired infections such as disinfection and sterilization and a more heightened awareness of other components of BSM. However, in this survey, all direct entrants had a lower understanding of the laboratory biosafety guidelines for controlling, preventing, and treating biohazards and medical waste handling [5,7]. In Uganda, according to a 2017 biorisk management (BRM) survey by the Central Public Health Laboratory (CPHL), insufficient laboratory biosafety and biosecurity measures were found in most of the public and private medical laboratories [8]. However, these facilities are used for medical laboratory students' internships. Therefore, it is necessary to strengthen the biosafety training aspects among medical laboratory students early before they are rolled out for clinical practice.

Hospital cases involving laboratory biosafety incidents are higher among the front-line hospital staff, including doctors, nurses, and laboratory personnel [9]. There are also many unexplained cases of laboratory-associated infections, which supports that the risk of infection is significantly higher among clinical laboratory personnel than in the general population. The infectious agents may also infect non-laboratory personnel if laboratory workers, including students, are not adequately trained to manage the biological agents. The vast majority of laboratory-acquired infections are caused by operating errors by laboratory personnel or the neglect of compliance with biosafety measures [10]. The primary laboratory accidents that cause almost 80% of infections are spills and splashes, pricks by syringe needles, sharps and broken glass, bites and scratches by laboratory animals and the parasites they carry, and the rest (20%) are caused by failure of the experimental apparatus [5].

This study aimed to assess the practices and attitudes of medical laboratory students towards biosafety and biorisk management during the Internship, which would identify steps to be taken to reform the training of laboratory biosafety, protective consciousness, and BSM among students. In addition, the training should direct students to operate standardized laboratory procedures and conduct biorisk assessments promptly and correctly, increasing competency and proficiency among laboratory professionals and guaranteeing adherence to stipulations on biosafety during clinical practice after the course.

2. Methods and materials

2.1. Study design and participants

This study was cross-sectional, online questionnaire-based, and conducted between June 2021 and September 2021. The study participants included 3rd-year undergraduate medical laboratory students in Makerere and Kampala International University. A sample size of 96 was estimated by the $Z = 4pq/L^2$ formula with a 5% assumed standard error. As the study was conducted using an online platform, only 60 students responded anonymously.

2.2. Questionnaire

Google form was used to formulate the structured questionnaire based on the biosafety and biorisk management guidelines from WHO, the clinical laboratory improvement amendment (CLIA), College of American Pathologists (CAP), Joint Commission (JC), and National Institute of Health (NIH) together with the principles of biosafety in microbiological and medical laboratories (BMBL). The questionnaire was divided into sections that captured socio-demographic profiles, practices, and attitudes towards biosafety and biorisk management.

2.2.1. Socio-demographic profile:

This includes: age, gender, the distance between residence and university, time spent getting to/from the university, height, religion, and student category (direct/diploma entry). The direct entrants are those students who joined directly from high school; diploma entrants are those who were admitted for the undergraduate course with a national diploma in any medical field.

2.2.2. Laboratory practices:

The practices of the participants sought included: eating in the laboratory, applying cosmetics, proper use of personal protective equipment (PPE), prophylactic immunization, hand washing after a procedure and before leaving the laboratory, house-keeping practices, waste disposal, safety symbols and signs, aerosol formation, management of spills, sterilization and disinfection, and emergency communication.

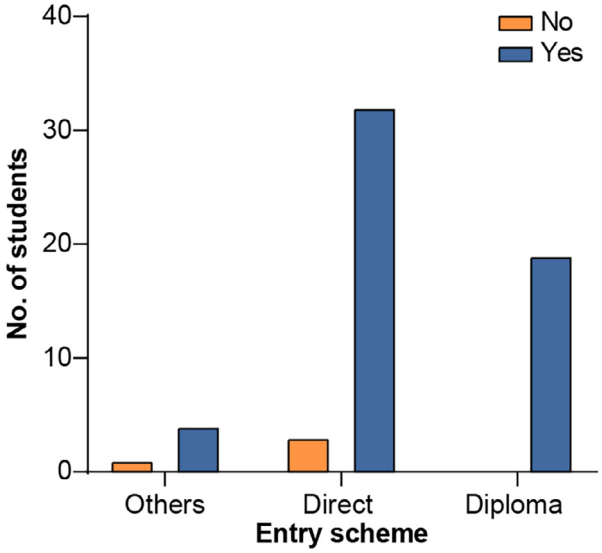

Fig. 1. Attendance of laboratory internship. All diploma students attended internship. Some of the students who missed internship joined the medical laboratory programme under the direct entry scheme.

2.2.3. Attitudes towards safety measures:

Case scenarios were used to assess the participants' attitudes towards clinical laboratory safety. A student who scored above four was deemed to have a positive attitude towards safety measures.

The questionnaire was pre-tested by administering it to the medical laboratory technologists at the selected institutions who moderated it before it was administered to students.

2.3. Data analysis

Descriptive statistical analysis was done using the software IBM SPSS Version 22.0. (Armonk, NY, USA: IBM Corp.). Chi-squared test and independent-sample *t*-test were applied to compare the differences in practices and attitudes of students by demographic and laboratory characteristics ($P < 0.05$).

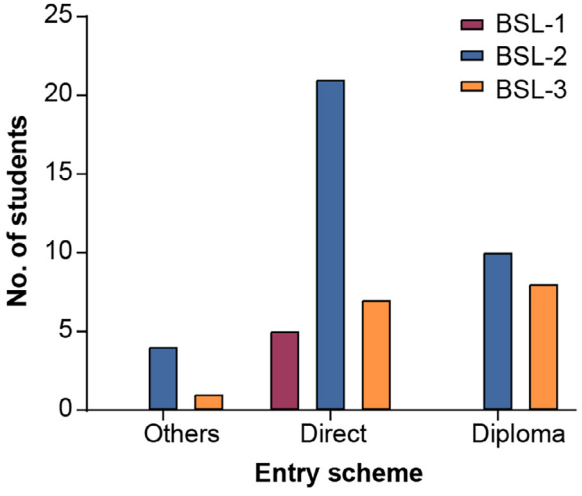

Fig. 2. The number of students trained in laboratories of different biosafety levels. BSL: Biosafety Level.

3. Results

3.1. The study participants

This survey study was instituted amongst medical laboratory students at Makerere University and Kampala International University from June to September 2021. The total number of students who responded to our online survey form was 60 of the 96 expected population; 40 from Makerere University and 20 from Kampala International University (KIU). Sixty percent (60%) of the participants were aged between 20 and 25 years. Most participants (60.3%) were direct entrants, and 32.8% had diplomas in medical laboratory science. The remaining 6.9% of students joined the programme with qualifications other than a diploma.

According to the survey, 91.7% (Fig. 1) of the participants attended hospital internships. About 8.3% who missed the Internship joined the programme under the direct entry category.

3.2. Features and nature of the internship training and training laboratories

This survey also investigated the participants' exposure to VBM and other laboratory hazards. At least 80.3% of the students attended an Internship more than twice, with each rotation duration not exceeding two months (71.4% of students reported that each training lasted < 2 months). Of the 33 direct entrants, 5 (15.2%) attended the hospital rotation only once.

Generally, 70.2% of the medical laboratory students rotated in all the core areas of medical laboratory sciences (hematology, microbiology, clinical chemistry, and pathology). Moreover, 62.5% of the students were trained in BSL-2 laboratories, followed by BSL-3 laboratories (26.8%) (Fig. 2).

Overall, 52.3% of the students reported that their training sites had 4 to 5 trainers, while 18.5% had only 1 to 2 trainers. Regarding the time spent reaching the training sites, 51.8% of students spent less than an hour, of which 66.1% had a distance of < 5 km from their residence to training sites. Proper laboratory training was not significantly associated with entry levels, age, the number of trainers, and distance to and fro the training sites ($P < 0.05$). However, there

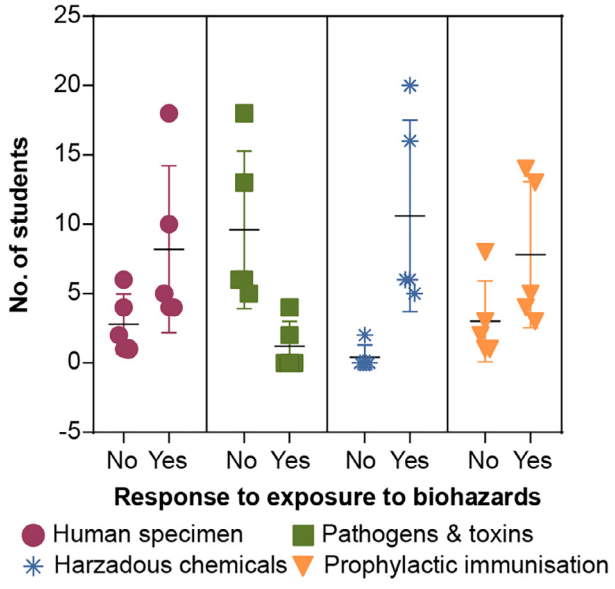

Fig. 3. Exposure of students handling infectious agents to biohazards. Most students attended internship training handle human specimen and pathogens, hence having an exposure to biohazards.

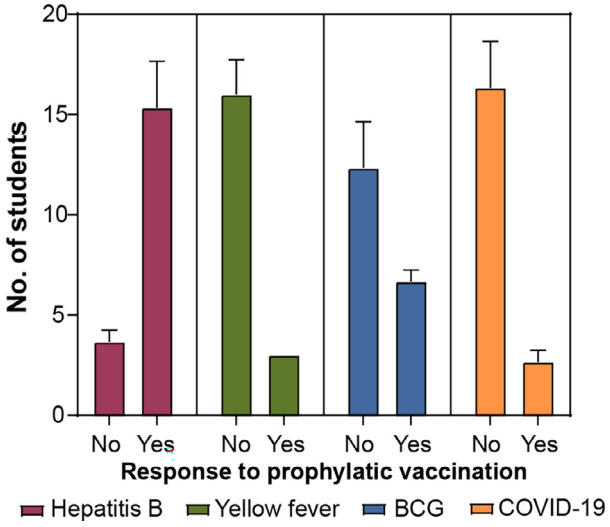

Fig. 4. Prophylactic vaccination status of students. BCG: Bacillus Calmette-Guérin vaccine; COVID-19: Coronavirus disease 2019. Students' response to vaccination against hepatitis B was higher as compared to other vaccines.

was a significant association between the core training area and the entry category ($P = 0.02$). The number of trainers was also significantly associated with the number of times the students attended training ($P = 0.049$).

3.3. Exposure to biohazards

Most participants, from 74.5% to 96.2%, handled specimens containing infectious agents during their internship (Fig. 3). A total of 48 (88.9%) reported to have handled laboratory pathogens, 53 (96.2%) handled hazardous chemicals, and 41 (74.5%) were exposed to human specimens.

Since students were exposed to human pathogens, we investigated if they got any prophylactic vaccines before being deployed for training in the laboratory: thirty-nine (39) (72.2%) of the students had received prophylactic vaccines and 15 (27.8%) had not received any prophylactic vaccine (Fig. 4). Of the 27.8% who did not receive the vaccine, 8 (53.3%) reported having attended internships more than four times. For those who got prophylactic vaccines, 33 (84.6%) received the Hepatitis B vaccine and only 6 (15.4%) reported to have received the COVID-19 vaccine. About 18 (77.8%) of diploma entry students were vaccinated compared to 18 (85.7%) under the direct entry category. The risk of exposure to biohazards was significantly higher in direct entry students ($P = 0.02$) compared to diploma entry students and had no significant association with laboratory safety level ($P > 0.05$). Receiving a prophylactic vaccine was significantly associated with the student entry category ($P = 0.014$).

3.4. Practices toward biosafety

As indicated in Fig. 5, 34.5% − 92.9% of the students reported adhering to most laboratory safety practices. The recommended biosafety practices among medical laboratory students were not significantly associated with the safety level of the laboratory or student entry category ($P > 0.05$).

3.5. Risk assessment practices

According to Table 1 below, 26.8% − 94.5% of participants reported training on managing biorisks in the laboratory. There were 16 (28.6%) of the participants had training on biorisk assessment, 46 (82.1%) had written policies and standard operating practices (SOPs) for performing biorisk assessments, and the majority (48 (90.6%)) had access control in the training laboratories (BSL-2 and BSL-3). About 34 (60.7%) tested autoclaves before use, 45 (81.8%) reported that PPE were provided for all personnel working in the laboratory, and 42 (75%) had safety training prior to commencing any assigned laboratory work. Of those who did fire drill training, 16 (28.5%) and another 49 (87.5%) had training on how to operate, maintain and clean laboratory equipment and spills, and 55 (98.2%) reported that their training laboratories had biohazard signs. Biorisk management practices amongst students were not significantly associated with laboratory biosafety level ($P > 0.05$) but were significantly associated with the student entry categories ($P = 0.03$).

3.6. Attitudes toward biosafety

A negative attitude towards biosafety was interpreted as a mark less then four. 12.5% − 66.1% of the participants (Table 2) had negative attitudes toward laboratory safety. According to the given case scenario, two-thirds of the students had an idea of the importance of biohazard control in the laboratory but did not value certain laboratory biosafety practices. Attitudes toward the use of gloves, medical monitoring, and case reporting were not significantly associated with the biosafety level of the training laboratory ($P > 0.05$); in contrast, training and clean-up procedures were associated with laboratory safety levels ($P = 0.021$ and 0.048, respectively). Furthermore, the attitudes towards biosafety practices were not associated with the student entry category ($P > 0.05$).

4. Discussion

To improve in the field of medical/clinical laboratory sciences in Africa, most institutions enroll different student categories for the programme [11]. This survey reported the same; 60.3% and 32.8% of students were direct and diploma entrants, respectively.

Medical students most often attend hospital internships during their training courses. In this survey, 91.7% of medical laboratory students had internships in the medical laboratory setting, which correlates with a study in Pakistan where 90% of the participants reported to have trained in biosafety [12]. Furthermore, all diploma entrants embraced the importance of hospital laboratory internships, while 8.3% of students from other categories did not attend hospital laboratory training. This concurs with a survey by Hong in China, where students in higher categories attached more importance to biosafety than the direct entrants [5,13].

Students who do not see any importance of hospital laboratory internships as they become practitioners tend to have a negative attitude toward implementing biosafety measures in the laboratory, which could partly explain the results of a study conducted in 2017, indicating that most laboratories in Uganda had insufficient biosafety and biosecurity measures implemented [8].

Medical laboratory science comprises four core areas, i.e., microbiology, hematology, clinical chemistry, histology, and histopathology [14,15]. In this survey, 70.2% of the respondents were trained in all these core areas, which involve close contact with human specimens or patients. However, according to a survey by Hong in China, the direct entry students lacked knowledge of biosafety, which could be due to fear of acquiring laboratory infections because of incompetence in handling specimen and patients [5,13]. Therefore, to support the students to gain confidence and competency, they need to be sufficiently trained in theoretical and practical aspects through simulations and in less infectious laboratories before being sent to a hospital laboratory.

Clinical laboratories are classified into four levels based on the safety equipment, the risk group of infectious agents handled, and

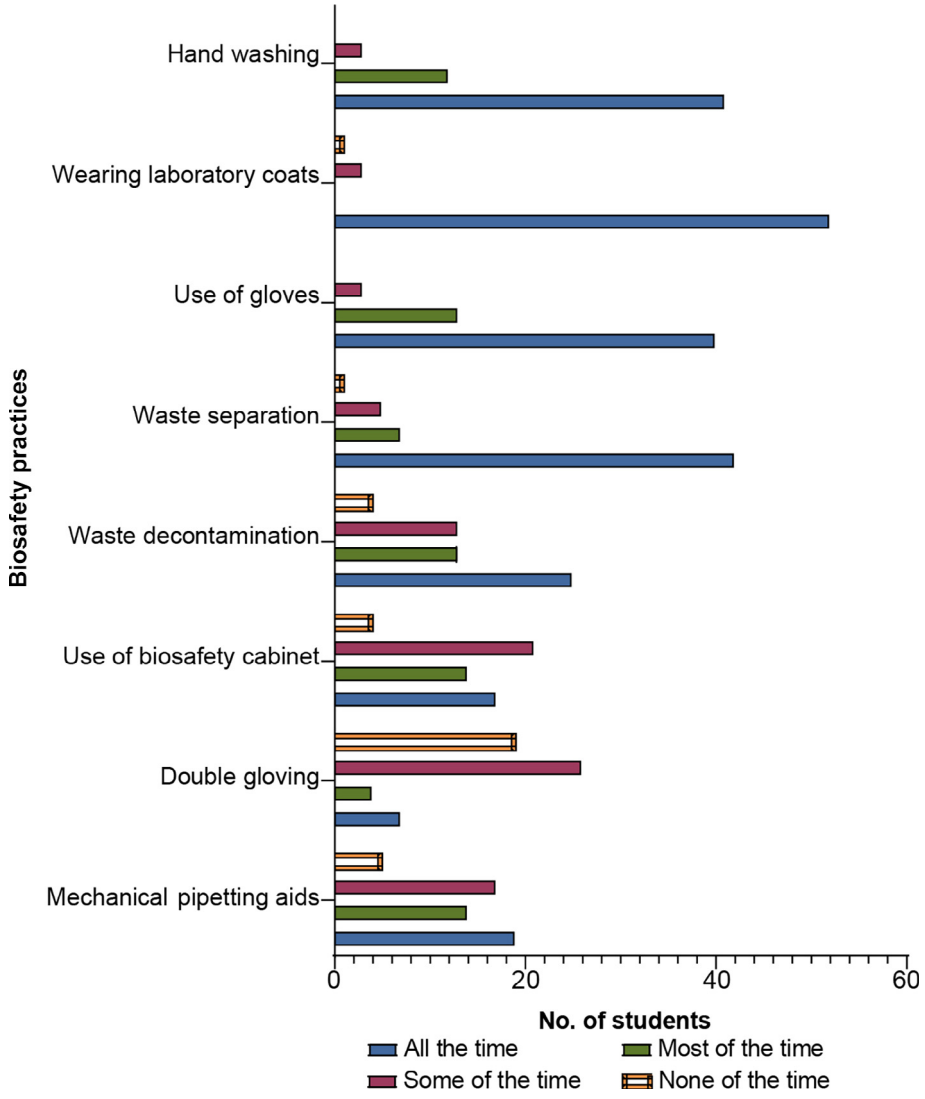

Fig. 5. Adherence to biosafety practices during internship. The most adhered safety practices during internship were hand washing, use of laboratory coats, and waste segregation.

the activities conducted. Biosafety levels range from 1 to 4, with BSL-4 being the maximum containment level [16]. Most students (62.5%) had their training in the BSL-2 laboratory, and only 26.8% at BSL-3. According to the Uganda Academy of Science consensus report, BSL-3 laboratories are a limited number in Uganda, and there is no BSL-4 laboratory [17]. Currently, BSL-3 laboratories are only found within research institutions [18], which explain why most students had their training in BSL-2 laboratories. Though most laboratories in Uganda are BSL-1, only 1.8% of the students attained their training in them. The low attendance in the lowest BSL-1 could be due to the students seeking internships in more advanced laboratories with sophisticated safety equipment.

A medical laboratory is a department prone to laboratory-acquired infections, making the staff contact patients daily and with patients' specimens such as blood, urine, feces, body fluids, and pathological tissues. In this survey, most of the students handled specimens containing infectious agents. As indicated earlier, 88.9% of the participants reported handling laboratory pathogens, 96.2% handled hazardous chemicals, and 74.5% were exposed to the human specimen. Our findings agree with Robert and Hill's commentary that suggests that undergraduate students come into contact with several hazardous chemicals and specimens during their studies and hence need a safety education [19].

In this survey, there was considerable use of vaccines. Through the Ministry of Health (MoH) 2015, the government of Uganda rolled out Hepatitis B vaccination drives in communities, which explains the high rates (72.2%) of prophylactic vaccination among medical laboratory students. The above findings concur with Ssekamatte's study, which found that most health workers within Wakiso in Uganda were fully vaccinated [20]. However, only 27.5% of the students had never received any prophylactic vaccination, and all were direct entrants. The worrying situation is that about half (53.3%) of these students attended hospital laboratory internships more than five times, possibly at risk of contracting laboratory-acquired infections like hepatitis. Therefore, there must be a policy directing all medical laboratory students intending to go for hospital internship to get prophylactic vaccines before commencing their studies; more so, the direct entry students should be educated on the importance of immunization.

Certain practices must be adhered to in a medical laboratory setting to prevent hazards, known as good laboratory practices (GLP), and form the biosafety standard, including proper PPE, decontamination, waste management, and sample handling among others. According

Table 1
Characteristics of biorisk management (BRM) practices.

BRM Practices	Responses to the BRM practices	BSL-1	BSL-2	BSL-3
Risk assessment training	No	3	17	4
	Yes	2	15	11
	Maybe	0	3	1
Written policies and SOPs in place	No	0	2	2
	Yes	4	28	13
	Maybe	0	5	1
Biorisk assessment hands-on practice	No	3	20	7
	Yes	0	8	8
	Maybe	1	7	1
Lab access control in place	No	1	0	0
	Yes	30	15	1
	Maybe	2	0	0
Required PPE in place	No	1	5	2
	Yes	4	28	12
	Maybe	0	2	0
Fire drills performed	No	4	27	8
	Yes	1	7	7
	Maybe	0	1	0
Performed lab equipment maintenance/ troubleshooting	No	0	4	0
	Yes	5	29	15
	Maybe	0	2	1

Abbreviations: SOPs = standard operating practices; PPE = personal protective equipment.

Table 2
Participants' attitudes toward biosafety.

Attitudes	Responses to the attitudes	BSL-1	BSL-2	BSL-3
Adequate training	Positive	4	23	7
	Neutral	1	5	1
	Negative	0	7	7
Application of correct cleanup method	Positive	1	16	5
	Neutral	1	6	1
	Negative	2	13	9
Need to put on gloves or any PPE	Positive	3	32	11
	Neutral	0	1	0
	Negative	1	2	3
Appropriate monitoring of staff	Positive	1	16	7
	Neutral	1	12	2
	Negative	2	7	6

Abbreviations: PPE = personal protective equipment.

to this survey, biosafety practices correlated with the laboratory biosafety level within which students had their Internship. The students who trained in BSL-3 laboratories showed better laboratory practices than those in BSL-2 laboratories. The most adhered to laboratory practices included: the use of gloves (71.4%), wearing of a laboratory coat/gown (92.9%), hand Washing (73.2%), and waste segregation (68.3%). These findings relate to data from a survey conducted by Ahmed Abu-Siniyeh among medical science students at a Saudi Arabia University [21]. The poorly adhered to practices included: the use of a biosafety cabinet when handling infectious material (30.4%), double gloving when handling infectious materials (12.5%), use of mechanical pipetting aids (34.5%), and waste decontamination before disposal. Such poor practices can easily expose students to laboratory infections. In the Colombo district in Sri Lanka, adherence to GLP was 31.9% among medical laboratory workers [21,22] compared to 100% among American laboratories in Kenya [23,24], which can be attributed to the strict policies on GLP and the level of funding. Laboratories found in low-income countries are poorly funded, and the formulation of safety policies is always delayed or never present.

Assessment of attitudes was carried out using the clinical laboratory case scenario to naturally demonstrate and simulate actual laboratory incidents to a new trainee in the laboratory. The direct entrants were unaware of the dangers a new trainee would face if left to work alone in the laboratory unsupervised compared to the diploma entrants, which calls for simulation classes about biosafety to be incorporated into the medical laboratory curriculum in Uganda.

5. Conclusion

This survey indicates that some students who attend internships in various laboratories were aware of the biosafety practices, but most of the direct entrants had negative attitudes towards biosafety and biorisk management. Therefore, there is a need to reform the teaching of biosafety to benefit direct entrants by integrating biosafety management classes into every core course of the medical laboratory sciences programme. Furthermore, the training laboratories should give students a rigorous orientation on biorisk management before they can independently perform any task during their internships.

Ethics statement

This was a continuous curriculum evaluation program for improvement in the delivery of medical laboratory science programme in Muni University. Consent was sought from students before they answered any questionnaire. The identities of the subjects were not revealed.

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Conflict of interest statement

The authors declare that there are no conflicts of interest.

Author contributions

John Roberts Padde: Conceptualization, Methodology, Visualization, Investigation, Writing – Original Draft, Writing – Review & Editing. **Winnie Akiteng:** Conceptualization, Methodology, Investigation, Visualization, Writing – Original Draft, Writing-Review & Editing. **William Edema:** Writing – Original Draft, Writing – Review & Editing. **Saad Mahjub Atiku:** Formal Analysis and Visualization. **Julius Tibyangye:** Validation. **Job Tekakwo and Cosmas Andruga:** Methodology, Writing – Review & Editing. **Benson Musinguzi, Derrick Hope, Jean Brenda Gesa, Lawrence Amadile, Robert Agondua:** Writing – Review & Editing.

Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.bsheal.2022.08.005.

References

[1] D.M. Morens, G.K. Folkers, A.S. Fauci, The challenge of emerging and re-emerging infectious diseases, Nature 430 (2004) 242–249, https://doi.org/10.1038/nature02759.
[2] A.K. Feehan, J. Garcia-Diaz, Investigator responsibilities in clinical research, Ochsner J 20 (2020) 44–49, https://doi.org/10.31486/toj.19.0085.
[3] J. Muhammad, S. Sarwar, T. Khan, S.A. Qasmi, A. Ikram, A cross-sectional survey to assess biorisk management system in research and diagnostic laboratories in Khyber Pakhtunkhwa, Pakistan, Front. Public Health 766162 (2021), 9. https://doi.org/10.3389/fpubh.2021.766162.
[4] WHO, Biorisk management: laboratory biosecurity guidance, World Health Organization, Geneva. https://apps.who.int/iris/handle/10665/69390, 2006 (accessed 1 May 2022).
[5] J. Cohen, Alarm over biosafety blunders, Science (New York, N.Y.) 345 (2014) 247–248, https://doi.org/10.1126/science.345.6194.247.
[6] F.A. Ali, L.A. Pulido, M.N. Garza, M.H. Amerson, et al., A professional development model for medical laboratory scientists working in the core laboratory, Am. Soc. Clin. Lab. Sci. 25 (2012) 67-73, https://doi.org/10.29074/ascls.25.2.67.
[7] L. Huang, L. Cheng, Q. Cai, R.O. Kosik, Y. Huang, X. Zhao, G.T. Xu, T.P. Su, A.W. Chiu, A. P. Fan, Curriculum reform at Chinese medical schools: what have we learned?, Med Teacher 36 (2014) 1043–1050, https://doi.org/10.3109/0142159x.2014.918253.
[8] A.K. Atek, A. Baguma, P. Okwalinga, J. Opio, et al., Biorisk management practices in public and private laboratories in Uganda: A nationwide baseline survey, J. Bioterr. Biodefense 9 (2018), 2. https://doi.org/10.4172/2157-2526.1000164.
[9] A.F. Monegro, V. Muppidi, H. Regunath, Hospital acquired infections, StatPearls Publishing LLC., Treasure Island (FL). https://www.ncbi.nlm.nih.gov/books/NBK441857 2022 (accessed 1 May 2022).
[10] D. Gillum, P. Krishnan, K. Byers, Asearchable laboratory-acquired infection database, Appl. Biosafety 21 (2016) 203–207, https://doi.org/10.1177/1535676016683194.
[11] I.N. Okeke, Towards a fiercely urgent expansion of laboratory medicine in Africa, Afric. J. Lab. Med. 10 (2021) 1785, https://doi.org/10.4102/ajlm.v10i1.1785.
[12] M. Sahrish, Laboratory biosafety and biosecurity related education in Pakistan: engaging students through the Socratic method of learning, J. Biosafety Biosecur. 3 (2021) 22–27, https://doi.org/10.1016/j.jobb.2021.03.003.
[13] L. Hong, R. Zhang, R. Zhao, H. Shen, Investigation of the awareness in laboratory biosafety among teachers and students of medical colleges in Jiangsu Province, Chin. J. Disease Control Prev. 14 (2010) 447–450.
[14] F.A. Ali, L.A. Pulido, M.N. Garza, M.H. Amerson, et al, A professional development model for medical laboratory scientists working in the core laboratory, Am. Soc. Clin. Lab. Sci. 25 (2012) 67–73, https://doi.org/10.29074/ascls.25.2.67.
[15] J.M. Deboy, A.J. Beck, M.L. Boulton, D.H. Kim, M.D. Wichman, P.F. Luedtke, Core courses in public health laboratory science and practice: findings from 2006 and 2011 surveys, Public Health Rep. 128 (Suppl 2) (2013) 105–114, https://doi.org/10.1177/00333549131280s215.
[16] M.L. Bayot, K.C. King, Biohazard Levels, StatPearls Publishing, StatPearls Publishing LLC., Treasure Island (FL). https://www.ncbi.nlm.nih.gov/books/NBK535351, 2022 (accessed 1 May 2022).
[17] Uganda National Academy of Sciences, The Scope of Biosafety and Biosecurity in Uganda: a consensus study report, policy recommendations for the control of associated risks. https://unas.org.ug/wp-content/uploads/2022/01/The-Scope-of-Biosafety-and-Biosecurity-in-Uganda-Policy-Recommendations-for-the-Control-of-Associated-Risks-A-Consensus-Study-Report-UNAS.pdf, 2010 (accessed 1 May 2022).
[18] B. Muriithi, M. Bundi, A. Galata, G. Miringu, E. Wandera, C. Kathiiko, E. Odoyo, M. Kamemba, E. Amukoye, S. Huqa, et al, Biosafety and biosecurity capacity building: insights from implementation of the NUITM-KEMRI biosafety training model, Trop. Med. Health 46 (2018), 30. https://doi.org/10.1186/s41182-018-0108-7.
[19] R.H. Hill, Undergraduates need a safety education!, J Chem. Educ. 93 (2016) 1495–1498, https://doi.org/10.1021/acs.jchemed.5b00825.
[20] T. Ssekamatte, T. Mukama, S.P.S. Kibira, R. Ndejjo, J.N. Bukenya, Z.P.A. Kimoga, S. Etajak, R. Nuwematsiko, E. Buregyeya, J.C. Ssempebwa, et al, Hepatitis B screening and vaccination status of healthcare providers in Wakiso district, Uganda, PLoS One 15 (2020), e0235470. https://doi.org/10.1371/journal.pone.0235470.
[21] A. Abu-Siniyeh, S.S. Al-Shehri, Safety in medical laboratories: perception and practice of university students and laboratory workers, Appl. Biosaf. 26 (2021) S-34-S-42, https://doi.org/10.1089/apb.20.0050.
[22] A.J. Abhayaratne, Y. Samarasinghe, U.M. Francis, An assessment of the knowledge, attitudes practices among medical laboratory technicians on biosafety precautions in selected government healthcare institutions in Colombo district Sri Lanka, Int. J. Sci. Healthcare Res. 5 (2020) 78–85.
[23] E. Hunsperger, B. Juma, C. Onyango, et al., Building laboratory capacity to detect and characterize pathogens of public and global health security concern in Kenya, BMC Public Health 19 (2019) 477. https://doi.org/10.1186/s12889-019-6770-9.
[24] F. Lestari, A. Kadir, T. Miswary, C.F. Maharani, A. Bowolaksono, D. Paramitasari, Implementation of bio-risk management system in a national clinical and medical referral centre laboratory, Int. J. Environ. Res. Public Health 18 (2021), 2308. https://doi.org/10.3390/ijerph18052308.