ORIGINAL ARTICLE

Knowledge, Attitudes, and Practices of Laboratory Biosafety Among Undergraduate Students in a Malaysian Public University: Lab Biosafety KAP among Malaysia Undergraduates

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ABSTRACT

Background: Laboratory biosafety is comprised of a crucial set of rules and regulations to be followed by the laboratory users. However, students' awareness of the biosafety regulations and practices is unknown since there is no current data on laboratory biosafety knowledge. Therefore, this study aims to evaluate the knowledge, attitude and practice (KAP) levels regarding laboratory biosafety among health sciences undergraduates and determine the factors influencing their knowledge. **Methods:** A modified and adapted questionnaire was administered to the voluntary respondent who fulfill the inclusion and exclusion criteria. The questionnaires which consist of 31 questions related to the knowledge, attitude and practice on laboratory biosafety were distributed through online platform and face to face approaches. Spearman's test was used to determine the correlation between the KAP elements, while independent t-tests was used to assess the association between the knowledge and demographic background of the respondent including the gender and briefing status on laboratory biosafety. One way ANOVA and Kruskal Wallis was applied to compare the differences of biosafety knowledge across academic years and faculties, respectively. **Results:** A total of 388 students voluntarily participated in the study. The survey showed that the students have a moderate knowledge on laboratory biosafety whilst have a good attitude and practice towards it. While no significant correlation was found between knowledge and attitude (r=0.046, p=0.371), practice showed a moderate positive correlation with attitude (r=0.417, p<0.001) and weak positive correlation with knowledge (r=0.135, p=0.008). Knowledge levels were significantly associated with the year of study (p<0.001) and briefing status on laboratory biosafety (p=0.013). However, knowledge score did not differ significantly by gender or faculty. **Conclusion:** Undergraduate health science students exhibit moderate knowledge on laboratory biosafety, despite demonstrating good perceptions and adherence to biosafety practices. The observed knowledge gaps may be attributed to insufficient briefing on the subject. Improving laboratory biosafety education could enhance student's preparedness for laboratory work throughout their academic programme.

Keywords:
laboratory biosafety; knowledge, attitude and practice; undergraduate students; health science program

INTRODUCTION

Biosafety refers to the integrated implementation of laboratory practices, protocols and standards, combined with laboratory facilities and safety equipment when working with potentially hazardous biological materials including infectious agents such as bacteria, parasites, fungi, virus and prion (Bayot & Limaiem, 2019; World Health Organization, 2023). Strict compliance with biosafety protocols is essential to prevent laboratory accidents, particularly laboratory-acquired infections (LAIs) – any symptomatic or asymptomatic disease contracted through laboratory work or related activities (Peng et al., 2018; Gugnani & Randhawa, 2020). The LAIs cases have been documented since 1885 and have been reported in various countries. A noble incident in Malaysia involved exposure to Brucella sp., affecting over 50 laboratory workers, with several experiencing adverse health effects. The investigation revealed that primary contributing factors included failure to comply with standard operating procedures (SOPs), absence of a directional airflow system in the laboratory, and improper use of biosafety cabinet (Sam et al., 2012). A parallel case in Singapore demonstrated similar biosafety failures, where insufficient training on Class III biosafety cabinet led to occupational exposure to SARS-associated coronavirus (SARS-CoV) (Lim et al., 2004).

Effective training plays a crucial role in enhancing laboratory biosafety awareness among users, particularly health science students who frequently engage in biological laboratory work. However, biosafety knowledge

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Journal homepage: https://journals.iium.edu.my/ijahs/index.php/IJAHS
EISSN NO 2600-8491

levels vary among these students. A report revealed that most students are familiar with emergency protocols for incidents involving fire, chemical spills and gas leaks, but awareness appears notably lower regarding specific biosafety cabinet procedures and proper Personnel Protective Equipment (PPE) application (Walters et al., 2017).

Laboratory incidents have been numerously reported worldwide, some of the cases cause serious injuries, even death (Chen et al., 2023). Incorrect use of chemicals, lack of safety equipment, failure to apply PPE completely are among the factors caused the incidence, which ultimately caused by poor compliance towards safety protocol set for the laboratory. Health science programmes including medicine, dentistry, pharmacy, and allied health sciences highly offer laboratory-based education involving potentially hazardous materials such as biochemistry, haematology, histology, microbiology, parasitology and any biological laboratory practical. Frequent exposure to these hazardous and infectious materials increases the likelihood of health risk for the student, particularly if the safety measures are not adhere up to optimal level.

Although a number of awareness surveys have been conducted at numerous institutions and colleges globally, data remained limited for Malaysian public university undergraduates. This study evaluated laboratory biosafety awareness among health science undergraduates at International Islamic University Malaysia (IIUM). In specific, this study intended to evaluate the level of knowledge, attitude and practice on laboratory biosafety among the student, identify key factors influencing their level of knowledge including gender, faculty, academic year and prior laboratory biosafety training, and analyse correlations between knowledge, attitudes and practices on laboratory biosafety.

The findings provide valuable insight for enhancing biosafety protocols in academic institution offering laboratory-based education, ultimately contributing to improved safety standards for undergraduate laboratory training.

MATERIALS AND METHODS

Ethical Approval

Ethical approval for the survey was granted from IIUM Research Ethics Committee (IREC) (Approval ID: IREC 2024 (UG)-046.

Study Design, Area and Participants

This research employed quantitative cross-sectional approach, involving undergraduate students from all faculties at the IIUM Health Sciences campus.

Sampling

The study applied convenience sampling, targeting eligible undergraduate students at the IIUM Health Sciences campus who had experience handling biological samples or materials during laboratory activities. Postgraduate students and those who worked exclusively with non-biological samples were excluded. The participation was entirely on voluntary basis.

A total of 388 undergraduate students from all faculties were recruited. The sample size was estimated using the Krejcie and Morgan table (Krejcie & Morgan, 1970), estimating 381 respondents with additional 10% non-response rate. This calculation was based on the total population of 3682 registered undergraduate students at the IIUM Health Sciences campus during that academic year.

Questionnaires Development and Distribution

The questionnaire was adapted with minor modifications from six published studies (Burdass et al., 2005; World Health Organization, 2010; El-Gilany et al., 2017; Meechan et al., 2020; Mehta & Diwakar, 2021; Ahmed et al., 2022). The questionnaire underwent rigorous validation, reliability and pilot testing prior to implementation. The questionnaires comprised five sections; Section 1: Informed Consent Documentation, Section 2: Demographic Information (including academic programme and year of study), Section 3: Knowledge Assessment on Laboratory Biosafety, Section 4: Attitude Assessment on Laboratory Biosafety, Section 5: Practice Assessment on Laboratory Biosafety. For Section 3, each correct response (selected from four options) received one mark, while incorrect answers or “I do not know” response were scored zero. Assessment for Section 4 was measured using a 5-point Likert scale ranging (1 point = Strongly Disagree to 5 points = Strongly Agree). Similarly, Section 5 was evaluated using 5-points Likert scale with responses scored as follows: 1 point for ‘never’, 2 points for ‘rarely’, 3 points for ‘occasionally’, 4 points for ‘frequently’ and 5 points for ‘always’. The classification of knowledge, attitude and practice level was established according to the framework developed from Mehta and Diwakar (2021) as presented in Table 1.

Table 1: Classification of score for level of knowledge, attitude and practice

Level of KAP*	Score		
	Knowledge	**Attitude**	**Practice**
Good	8 - 10	38 - 50	42 - 55
Moderate	5 - 7	25 - 37	27 - 41
Poor	0 - 4	0 - 24	0 - 26

**Good level was determined by the ≥75% scores obtained in each category. Moderate level was determined by the 50 to 74% scores obtained in each category. Poor level was determined by the <50% scores obtained in each category.*

The modified questionnaires underwent expert validation and reliability of instruments by two laboratory biosafety specialists, from different faculties within the host institution. Following validation and reliability test (Cronbach's alpha = 0.873), the instrument was administered in a pilot study involving 38 volunteer undergraduate students from the IIUM Health Campus.

The questionnaires were administered both offline and online from April 2024 to May 2024. For offline participation, respondents received printed questionnaire, while the online participants accessed the survey form through Google Form link distributed through Whatsapp or Telegram platform. All respondents were gently reminded that participation was on voluntarily basis and that they were under no-obligation to respond. All collected data were treated in a confidential manner.

Data Analysis

All responses were compiled and statistically analysed using IBM Statistical Package for the Social Sciences (SPSS) software (version 20.0). Normality test was run prior to statistical testing. Descriptive statistics were employed to evaluate respondents' level of knowledge, attitude and practice regarding laboratory biosafety, while correlation analysis examined relationships between these variables.

To determine potential influencing factors (including gender, academic programme, faculty affiliation, and laboratory briefing experience) on biosafety knowledge levels, statistical tests were employed including independent t-test, one-way ANOVA and Kruskal-Wallis tests. The p-value <0.05 is deemed as significant value for all statistical tests.

RESULT

Demographic Data

The study recruited 388 undergraduate students enrolled in various programmes across six faculties; Science (KOS), Allied Health Sciences (KAHS), Pharmacy (KOP), Dentistry (KOD), Medicine (KOM) and Nursing (KON). The majority of respondents were from KAHS (243 students, 62.6%), with a predominant representation of female students (343, 88.4%). Participants spanned all academic years (Year 1 through year 4/ final year), with the highest proportion from Year 2. Approximately one-third of respondents reported having received laboratory biosafety briefing, most of whom were briefed during their first year of study (Table 2).

Table 2: Distribution of students by gender, faculty, year of study, receipt of briefing and the frequency of briefing received

Variable	Frequency, N	Percentage (%)
Gender		
Male	45	11.6
Female	**343**	**88.4**
Kulliyyah		
Allied Health Science	**243**	**62.6**
Dentistry	13	3.4
Medicine	36	9.3
Nursing	44	11.3
Pharmacy	18	4.6
Science	34	8.8
Year of study		
First year	80	20.6
Second year	**129**	**33.2**
Third year	79	20.4
Final year	100	25.8
Have you ever been briefed about biosafety?		
Yes	**297**	**76.5**
No	91	23.5
If yes, how often were these briefings conducted?		
Every year	52	17.1
First year of study	**181**	**59.5**
Other year of study	71	23.4

**The highest frequency and percentage were bold*

Level of Knowledge, Attitude and Practice on Laboratory Biosafety

The study found that the majority of respondents (n = 202, 52.1%) demonstrated moderate knowledge on laboratory biosafety, with a mean score of 7.27± 1.43. However, they exhibited good attitudes (n = 378, 97.4%; mean score = 46.84 ± 6.2) and good practices (n = 304, 78.4%; mean score 45.96 ± 7.2). All scores are reported as mean ± standard deviation (Table 3).

Table 3: Level and mean score of knowledge, attitude and practice on laboratory biosafety

Category		Frequency	Percentage (%)	Mean Score	Standard deviation	Interpretation
Knowledge						
	Good	173	44.6	7.27	1.427	Moderate knowledge
	Moderate	**202**	**52.1**			
	Poor	13	3.4			
Attitude						
	Good	**378**	**97.4**	46.84	6.202	Good attitude
	Moderate	2	0.5			
	Poor	8	2.1			
Practice						
	Good	**304**	**78.4**	45.96	7.197	Good practice
	Moderate	80	20.6			
	Poor	4	1.0			

**The highest frequency and percentage were in bold*

Knowledge of laboratory biosafety

Ten questions were prepared to assess the students' knowledge of laboratory biosafety, covering key elements such as hand hygiene practices, waste management, emergency equipment handling, PPE usage and biosafety cabinet utilisation. Almost all respondents answered the question regarding the function of wearing an eye shield correctly (n = 384, 100%). This was followed by questions related to biohazard waste disposal bin (n = 368, 94.8%) and source of infection in a laboratory (n = 353, 91%).

Table 4: Students' knowledge of laboratory biosafety

Items	Percentage of correct response to question, n (%)
How many steps of hand washing do you know?	315 (81.3%)
What type of fire extinguisher is the most suitable in the laboratory?	256 (66.0%)
What is the suitable percentage of alcohol should have in alcohol-based hand sanitizers?	254 (65.5%)
Biohazard waste should be disposed in what type of bin?	368 (94.8%)
Which of the following is the most common source of infection in a laboratory?	353 (91.0)
Which Personal Protective Equipment (PPE) are recommended for handling pathogenic microorganisms?	240 (61.9%)
What is the primary purpose of biosafety cabinet?	334 (86.2%)
What are the correct steps to clean a biological spill?	128 (33.0%)
Which glove is appropriate to use when working with potentially contagious materials?	188 (48.5%)
What is the purpose of wearing eye shield?	384 (99%)

The lowest scores were recorded for questions related to the type of gloves to use when handling potentially contagious materials (n = 188, 48.5%) and the correct procedure for cleaning a biological spill (n = 128, 33%) (Table 4). In overall, the data indicated strong student knowledge of eye shield importance but identified significant gaps in understanding the correct biological spill cleanup procedure.

Attitude towards laboratory biosafety

Ten statements assessing attitudes toward laboratory biosafety were employed, covering key areas including hand hygiene practices, waste management, emergency equipment handling, PPE use and biosafety cabinet utilisation. Results showed that the 'Strongly Agree' response was most frequently selected by the students. This was particularly evident for statements emphasising the importance of hand hygiene procedures (n = 334, 86.1%), and biological waste management (n = 334, 86.1%) (Table 5) This demonstrated a notably strong positive attitude, particularly toward hand hygiene and biological waste management.

Practice of laboratory biosafety

The students' practice of laboratory biosafety was assessed using eleven statements representing key areas of hand hygiene practices, waste management, emergency equipment handling, PPE use and biosafety cabinet utilisation. The most consistently reported practice was handwashing after handling potentially infectious materials, with 82.2% (n = 319) of students selecting the 'always' response. This was followed by proper disposal practice of biological waste in designated bins and PPE use during laboratory work (Table 6). However, the majority of students reported never using the fire extinguisher in the laboratory. Overall, the results indicated a strong commitment to core daily safety practices but a lack of engagement with emergency equipment.

Table 5: Students' attitude towards laboratory biosafety

Items	Strongly agree
It is important to follow proper hand hygiene procedures at all times.	334 (86.1%)
Everyone should know how to use fire extinguisher	268 (69.1%)
Alcohol-based hand rub or hand sanitizer should be used every time finish lab work	284 (73.2%)
Using proper methods to handle biological waste is crucial.	334 (86.1%)
I believe a crowded workspace promotes the spread of infections.	265 (68.3%)
I believe wearing PPE could protect me from laboratory hazard	275 (70.9%)
A biosafety cabinet is important for ensuring safety when working with pathogens.	288 (74.2%)
Infectious diseases can be reduced by adhering to proper protocols when managing biological spills.	309 (79.6%)
I believe that wearing gloves is essential for my personal protection when working with germs.	313 (80.7%)
Wearing eye protection is important for my safety when handling pathogens that can cause splashes or sprays.	323 (83.2%)

Correlation between knowledge, attitude and practice on laboratory biosafety

Based on the interpretation of correlation value from Schober et al. (2018) (Table 7), there was negligible correlation observed between knowledge and attitude on laboratory biosafety (r=0.046, n=388, p=0.371). Meanwhile, a weak positive correlation was observed between knowledge and practice (r=0.135, n=388, p=0.008) and attitude and practice (r=0.417, p<0.001) (Table 8). These results indicated that a positive attitude correlated most strongly with safe practices, whereas knowledge had a minimal direct impact on both attitudes and behavior.

Table 7: Interpretation of the correlation value

Correlation value	Interpretation
0.00-0.10	Negligible correlation
0.10-0.39	Weak correlation
0.40-0.69	Moderate correlation
0.70-0.89	Strong correlation
0.90-1.00	Very strong correlaion

Note. The range was adopted from Schober and Schwarte.

Table 6: Students' practice on laboratory biosafety (n=388)

Items	Always
I wash my hands with soap and water after wearing glove.	222 (57.2%)
I use a fire extinguisher in the laboratory according to the specified guidelines.	67 (17.3%)
I use alcohol-based hand rub before and after handling laboratory equipment and samples	195 (50.3%)
I properly discard biomedical waste in the right color-coded bins.	288 (74.2%)
I wash my hands after handling potentially infectious materials or biomedical waste.	319 (82.2%)
I wear personal protective equipment when collecting and working with samples.	258 (66.5%)
I organize my workplace from the clean side to the dirty side in the biosafety cabinet.	225 (58.0%)
I handle biological spills by following proper procedures.	208 (53.6%)
I change gloves whenever they are contaminated or their integrity is compromised.	250 (64.4%)
I wear an eye shield when performing activities that involve the splash or spray of hazardous materials.	174 (44.8%)
I use biosafety cabinet when handling microbiological sample and conducting relevant test.	217 (55.9%)

Table 8: Correlation coefficient and p-value for knowledge, attitude and practices scores for laboratory biosafety (n=388)

Variables	Correlation coefficient, r	*p*-value	Inference
Knowledge score- Attitude score	+0.046	0.371	Negligible and not statistically significant correlation
Knowledge score- Practice score	+0.135	**0.008**	Weak positive and statistically significant correlation
Attitude score- Practice score	+0.417	**<0.001**	Weak positive and statistically significant correlation

**Significant results (p <0.05) were bold.*

Association between knowledge level and demographic factors

The study found no significant association between the knowledge of laboratory biosafety and students' gender or faculty. However, knowledge levels varied significantly across different years of study (p<0.001) (Table 9). Post hoc Bonferroni tests revealed significant differences between first and final year (p = 0.019), second and third year (p = 0.002) and second and final year (p<0.001) (Table 10). These findings suggest that biosafety knowledge was determined more by academic progression than by demographic factors.

Table 9: Association analysis between knowledge scores and demographic outcomes

Parameter	n	Knowledge score		Statistics (df)	*p*-value
		Mean	SD		
Gender				t-statistics 1.328 (386)	0.185
Male	45	7.53	1.34		
Female	343	7.23	1.44		
Faculty				Chi-square statistics 2.173 (5)	0.825
KAHS	243	7.34	1.41		
KOD	13	7.46	1.13		
KOM	36	7.19	1.62		
KON	44	7.16	1.26		
KOP	18	7.11	1.71		
KOS	34	7.00	1.56		
Year of study				F-statistics 9.275 (3, 384)	**<0.001**
First year	80	7.11	1.47		
Second year	129	6.84	1.53		
Third year	79	7.54	1.36		
Final year	100	7.73	1.11		
Briefing status				t-statistics 2.48 (386)	**0.013**
Received briefing	297	7.37	1.35		
Did not received briefing	91	6.95	1.61		

Table 10: Multiple comparisons (Post Hoc) of knowledge scores regarding laboratory biosafety using Bonferroni test for different year of study

Variable	Year of study	Year of study	*p*-value
Knowledge score	First year	Second year	0.977
		Third year	0.299
		Final year	**0.019**
	Second year	Third year	**0.002**
		Final year	**<0.001**
	Third year	Final year	1.000

**Significant results (p <0.05) were bold.*

DISCUSSION

Laboratory biosafety is essential for health sciences students, either undergraduate or postgraduate level, who handle biological samples, including hazardous and infectious materials, genetically modified specimens and related waste. Since students frequently work with such materials during lab sessions and research, understanding biosafety guidelines helps prevent lab accidents, protecting both individuals and the surrounding environment.

This study assessed awareness of laboratory biosafety among undergraduate students from various faculties and academic programmes related to health sciences. Results indicated that most students had a moderate level of knowledge, with an average score of 7.27 out of 10, consistent with the moderate-range framework established by Mehta & Diwakar (2021). These findings align with a similar 2021–2022 study in Vietnam, where 69% of medical laboratory students demonstrated basic lab safety awareness (Ngoc et al., 2024). The reason for this gap may be due to a lack of training on laboratory biosafety. This fact is supported by a study conducted by Keshan et al. (2020) in which they found a significant difference between pre- and post-training knowledge scores on biosafety (p<0.001). This implies that knowledge could be improved by proper training.

This study evaluated laboratory biosafety awareness among undergraduate students who frequently engaged in biological laboratory work. This assessment focused not only on their knowledge of biosafety but also their attitudes and practices related to it. These aspects were examined across five fundamental areas including hygiene, waste management, emergency equipment handling, PPE usage, and biosafety cabinet operation.

Among the knowledge-based questions, the highest score was recorded for the PPE-related item, which is the purpose of wearing eye shields. This suggests a strong understanding among students regarding the importance of this particular item. However, their understanding of PPE usage was inconsistent; while they recognised the importance of eye protection, their responses faltered on other PPE-related questions, such as identifying the correct PPE for handling pathogens or selecting the appropriate glove type.

Regarding the correct PPE items for pathogen handling, most students chose lab coats, face masks and gloves, but frequently omitted safety goggles. This oversight may be attributed from limited exposure to high-risk lab sessions involving pathogenic strains, reducing the perceived need for goggles. This assumption is supported by the low percentage (44.8%) of students who wore eye shields when handling hazardous materials, despite the fact that 80.7% acknowledge their importance.

The gap in practical compliance may reflect varying levels of lab experience across student cohorts. For instance, first-year students typically engage in low-risk lab sessions, resulting in reduced familiarity with full PPE requirements.

As a result, even though safety goggles are available, their perceived necessity remains minimal. Furthermore, since laboratory assistants typically prepare the chemicals and handle tasks involving potential splashes, students have even fewer opportunities to use safety goggles. This limited exposure to the use of eye shields and other PPE may affect students' practical habits, as supported by Rofifa et al. (2019) which suggest that PPE usage tends to increase with greater familiarity and experience in laboratory settings. Inadequate knowledge might be resulted from insufficient safety equipment in the lab, as reported by Goh (2018), where lack of safety goggles in the lab led to a decline in the awareness level due to rare use of the item in routine lab sessions.

Another PPE-related knowledge gap appeared in glove selection, where many respondents incorrectly chose 'plastic glove' over 'non-sterile glove'. This may reflect confusion between common latex gloves and plastic alternatives. Despite this, students demonstrated strong adherence to PPE principles in practice, recognising their importance when handling potentially hazardous materials. It can be evidenced by the fact that many of them change gloves when they become contaminated or when their integrity was compromised. This response demonstrated that the students strongly believed gloves could protect them from infection, although they were unaware of the type of gloves that should be used in the lab. The students' gap in theoretical knowledge likely stems from the routine practice of using provided gloves (e.g., latex) in the lab without receiving formal information about their material composition and the alternatives, leading them to use the available gloves without considering their specific type or properties. This may be due to lack of training, as proven by Mehta and Diwakar (2021), who reported that knowledge improved after training sessions. The data reveals that 23.5% of the students never receive a briefing, and only 17.1% of the students do receive it annually. This suggests that laboratory biosafety training is still inadequate, leading to insufficient knowledge. All of these responses indicated that positive practices and attitudes towards PPE commitment were interrelated but not linked to the knowledge component. This assumption was supported by the moderate positive correlation between attitude and practice, whereas knowledge showed only a weak or non-significant correlation with them.

Regarding the key aspect of waste management, nearly 95% of students knew the yellow bin is the appropriate container for discarding biohazardous waste. In addition to recognising its importance, they also demonstrated this understanding in practice, with 74.2% reporting that they consistently dispose biological waste correctly after lab work. This positive behaviour may be attributed to the availability and clear labelling of bins in the laboratory, regular briefings and reminders from lab personnel, and prior training or orientation. Similar findings have been observed in other studies, such as those involving students in Uganda (Padde et al., 2022), Saudi Arabia (Abu-Siniyeh & Al-Shehri, 2020) and South Delhi (Singh, 2022), albeit with slight variations in percentages across studies. The latter study demonstrated that students consistently practised proper waste management techniques after attending biomedical waste management class.

In contrast, knowledge related to handling biological spills was notably lower, with only 33% of students answering correctly. Over half either provided incorrect answers or were unsure. Despite this, most students believed that following proper spill management procedures could reduce the risk of infection spread. In fact, over half claimed that they always follow proper procedures in such situations. This discrepancy raises concerns about whether students may be unknowingly practising incorrect steps while believing they are following the right procedures. A closer look at the responses revealed that many students believed the correct approach was to directly apply disinfectant before wiping and discarding it, often omitting the crucial step of first covering the spill before applying disinfectant. This suggests gap training or hands-on experience, possibly because the spill incidents are rare or typically handled by lab managers. Proper spill management is critical for minimising lab-acquired infections (LAIs), one of the most significant risks in laboratory work. These infections could escalate to a global scale if improper cleaning of biohazardous materials becomes a consistent practice (Demaneuf, 2020). Notably, students appeared to be aware of the potential for infection from contaminated biological materials and acknowledged the risk of greater spread in crowded environments. Crowded workspaces can increase the risk of transmission infection due to close contact and the chances of encountering items strewn across the table (Alshammari et al., 2021).

Encouragingly, the present study revealed that the students possessed relatively high levels of knowledge and awareness regarding the procedures and importance of proper handwashing, whether using soap or alcohol-based hand sanitisers. While most students reported that they frequently washed their hands after lab sessions, many did not always use soap. Furthermore, the use of alcohol-based hand rubs after lab sessions was less common among the students in this study, contrasting with findings from India, where students demonstrated higher adherence to such practices (Modi et al., 2017). Inconsistent training may contribute to poor compliance, as evidenced by Dutta et al. (2020), who found a strong link between hand hygiene training and practice. Students who received training were more likely to wash their hands consistently after removing gloves and completing lab sessions. The practices of hand hygiene are crucial in preventing incidents of cross-contamination caused by unclean hands during lab activities, regardless of the level of awareness and belief. Therefore, the biosafety unit responsible for these protocols should reinforce the importance of hand hygiene through regular training and highlight the potential consequences of improper practices. This proactive approach not only prevents harm to individuals but also helps minimise risks and prevent broader impact at the community level.

Another critical aspect of biosafety regulation in the biology laboratories is adherence to proper biosafety cabinet (BSC) usage procedures. A high percentage of respondents demonstrated good understanding of the function of a BSC, which is to protect personnel, environment and products when handling risk items, and they believed in the importance of the biosafety cabinet in ensuring safety. Practically, half of the students claimed that they use biosafety cabinet when handling microbiological samples, even they manage to organise the workplace appropriately, which is to separate the clean and dirty sides in the biosafety cabinet to reduce cross contamination during the lab activities. This score is among the lowest scores obtained for the questions in the survey. This low score could be due to the nature of experiments set up for undergraduate students who frequently practise on open bench due to low-risk research activities (Meechan & Paul, 2020). However, the importance of using biosafety cabinet should get appropriate concern by the institution, as previous case have shown a great health impact on the lab users who are exposed to pathogenic Brucellosis's infectious agents due to failure to adhere to the utilisation of biosafety cabinet (Sam et al., 2012). In essence, students' knowledge and attitude regarding BSC were good; however, their practice did not align with these strengths.

The final key area of biosafety assessed was the use of fire extinguishers as emergency equipment in the lab. Approximately 66% of students correctly identified the Class ABC fire extinguisher as the appropriate tool for handling fire incidents in the lab. However, a significant number of students, which is 120 of them, either provided incorrect answers or were unsure. Despite this gap, nearly 70% strongly agreed that everyone should know how to use a fire extinguisher. Yet, almost half reported that they never or rarely used one in the laboratory. This situation is similar to findings from Saudi Arabia, where students lacked opportunities to use fire extinguisher simply because no real fire incidents requiring them to use them (Abu-Siniyeh & Al-Shehri, 2020). In emergency situations such as fires, students' ability to respond effectively using a fire extinguisher is very crucial. To bridge this gap, institutions should implement regular fire drills and hands-on training, allowing students to learn, observe and practices proper fire extinguisher use.

The study also examined potential factors influencing students' understanding of laboratory biosafety. Key variables assessed included gender, academic programme, year of study, and prior exposure to laboratory biosafety training. The results revealed significant differences in knowledge scores based on academic year and pre-laboratory training.

Multiple comparisons analyses showed significant score disparities between first-year and final-year students, as well as between second-year students and their senior counterparts (third-year and above). This finding aligns with the initial assumption that junior students possess less laboratory experience than seniors. Furthermore, most academic programmes typically schedule off-campus practical sessions for third-year students and above, suggesting that senior students may acquire both formal and informal biosafety knowledge through their academic progression. This correlation has been consistently reported in previous studies. For instance, research demonstrated that while first-year students often struggle to identify chemical and biohazard symbols, internship students perform significantly better (Walters et al., 2017; Abu-Siniyeh & Al-Shehri, 2020; Geraldez et al., 2023; Ngoc et al., 2024).

Prior training emerged as a primary determinant of biosafety comprehension. The current findings corroborate earlier studies emphasising the importance of early biosafety instruction (Abu-Siniyeh & Al-Shehri, 2020; Dutta et al., 2020; Mehta & Diwakar, 2021; AlWaqfi et al., 2022). While traditional methods such as passive instruction and verbal briefing demonstrate moderate effectiveness, active students' engagement during safety training yields significantly better knowledge retention. Recent innovative approaches show particular promise, as demonstrated by Li et al. (2024), who reported medical students exhibited enhanced biosafety understanding through a blended experiential and mobile learning approach using WeChat. Given students' increasing technology proficiency, incorporating AI and similar technologies could potentially optimise biosafety compliance and adaptation in laboratory settings.

CONCLUSION

This study evaluated laboratory biosafety awareness among undergraduate students at IIUM who regularly engage in biological laboratory work. Among 388 students, the majority demonstrated moderate biosafety knowledge levels. While students showed satisfactory understanding of five key elements, particularly PPE utilisation, waste management and hygiene practices, this knowledge inconsistently translated into practical application. The concerning disconnect between theoretical knowledge and actual practice highlights a critical area for intervention. These findings underscore the urgent need to bridge this implementation gap, particularly for students who spend significant time in laboratory settings. Future biosafety initiatives should prioritise behavioural compliance alongside knowledge acquisition, ensuring that safety protocols become ingrained in routine laboratory practice. Furthermore, the study reveals that awareness alone is insufficient for ensuring biosafety compliance. Institutional efforts should focus on developing targeted training programmes that emphasize hands-on application, regular reinforcement of safety protocols and accountability measures to transform knowledge into habitual safe practices. This approach would be particularly impactful in academic settings where students develop their foundational laboratory habits that may persist throughout their professional careers.

ACKNOWLEDGEMENT

This research was not funded by any grant.

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