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Original Article

Knowledge, Practice, And Perception of Biosafety Measures Among Clinical Laboratory Workers in Lahore, Pakistan: A Cross-Sectional Study

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ABSTRACT

Background: Clinical laboratory workers are routinely exposed to biological, chemical, and physical hazards during specimen handling, testing, waste disposal, and sharps-related procedures, making biosafety compliance essential for occupational safety and diagnostic quality. **Objective:** This study assessed the knowledge, practices, and perceptions of biosafety measures among clinical laboratory workers in Lahore, Pakistan, and examined their associations with selected demographic and workplace-related variables. **Methods:** A cross-sectional observational study was conducted over four months among 326 laboratory personnel from public, private, and teaching hospital laboratories in Lahore. Participants were recruited through convenience sampling and completed a structured self-administered questionnaire covering demographic characteristics and biosafety-related knowledge, practices, and perceptions. Data were analyzed using descriptive statistics, chi-square tests, independent samples t-tests, and one-way ANOVA, with statistical significance set at $p < 0.05$. **Results:** Most participants demonstrated low levels of biosafety knowledge, practice, and perception. Low knowledge was observed in 205 of 322 participants (63.7%), low practice in 182 of 313 participants (58.1%), and low perception in 196 of 313 participants (62.6%). Mean scores were 11.03 ± 4.23 for knowledge, 14.50 ± 6.06 for practice, and 6.85 ± 3.19 for perception. Education and work experience were significantly associated with knowledge level ($p = .003$ and $p = .002$, respectively), while practice and perception showed no significant association with education, experience, gender, or laboratory type. **Conclusion:** Clinical laboratory workers in Lahore showed substantial biosafety deficiencies across knowledge, practice, and perception domains. Although education and experience improved knowledge, they did not translate into stronger practice or perception, highlighting the need for structured competency-based training, institutional monitoring, adequate protective resources, and stronger biosafety culture. **Keywords:** Biosafety; Clinical Laboratory Workers; Knowledge; Practice; Perception; Occupational Safety; Lahore.

INTRODUCTION

Clinical laboratories are essential components of healthcare systems because they provide diagnostic evidence required for disease detection, clinical decision-making, surveillance, treatment monitoring, and infection prevention. Laboratory personnel routinely handle blood, body fluids, tissues, cultures, sharps, contaminated instruments, and potentially infectious clinical specimens, placing them at continuous risk of occupational exposure to biological, chemical, and physical hazards (1,2). These risks are particularly important in diagnostic laboratories where high sample turnover, time-sensitive workflows, and variable adherence to safety procedures may increase the likelihood of accidental

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exposure, specimen spills, needle-stick injuries, and contact with infectious agents such as hepatitis B virus, hepatitis C virus, human immunodeficiency virus, and other pathogenic microorganisms (3,4).

Biosafety refers to the principles, practices, containment strategies, and technologies designed to prevent accidental exposure to hazardous biological materials and to minimize their release into the laboratory environment. Core biosafety measures include correct use of personal protective equipment, hand hygiene, safe handling and disposal of sharps, appropriate biomedical waste segregation, use of biosafety cabinets where indicated, decontamination of work surfaces, vaccination of at-risk personnel, incident reporting, and strict compliance with standard operating procedures (5). International biosafety guidance emphasizes that safe laboratory practice depends not only on infrastructure and equipment but also on worker knowledge, risk perception, institutional supervision, and consistent behavioral compliance during routine procedures (6).

Despite the availability of biosafety guidelines, occupational exposure among laboratory workers remains a persistent concern, especially in low- and middle-income countries where laboratories may face shortages of personal protective equipment, limited biosafety training, weak monitoring systems, inadequate waste-management infrastructure, and inconsistent implementation of standard protocols. Previous studies from developing healthcare settings have shown that laboratory workers may possess partial theoretical awareness of biosafety principles but fail to translate this knowledge into routine practice, creating a knowledge-practice gap that increases occupational and public health risk (7,8). This gap is particularly relevant in clinical laboratories, where even minor lapses in specimen handling, sharps disposal, or disinfection can expose workers and surrounding personnel to preventable hazards.

In Pakistan, clinical laboratory services are expanding across public hospitals, private diagnostic centers, and teaching institutions, particularly in major urban centers such as Lahore. However, biosafety systems remain variable across laboratory settings because of differences in institutional policies, workload, training opportunities, resource availability, and regulatory oversight. Earlier Pakistani studies have reported inadequate biosafety awareness, inconsistent use of protective equipment, insufficient training, and barriers to optimal implementation of laboratory biosafety standards among diagnostic laboratory personnel (9). These findings suggest that occupational safety in laboratories cannot be assumed on the basis of professional qualification alone and requires direct assessment of knowledge, practical behavior, and perception of risk among laboratory workers.

Knowledge, practice, and perception assessment provides a useful framework for identifying biosafety gaps because each domain captures a different dimension of occupational safety. Knowledge reflects awareness and understanding of biosafety principles; practice reflects actual compliance with recommended precautions; and perception reflects the perceived importance, seriousness, and personal relevance of biosafety measures. In the PICO framework, the population of interest is clinical laboratory workers in Lahore; the exposure or grouping variables include educational qualification, work experience, gender, and laboratory type; the comparison involves differences across these demographic and workplace categories; and the outcomes are levels of biosafety knowledge, practice, and perception. Evaluating these relationships can help determine whether educational and professional characteristics are associated with safer laboratory behavior or whether institutional interventions are needed beyond formal training.

Although prior studies have examined biosafety awareness and infection-prevention practices in different regions and healthcare groups, limited evidence is available on the combined assessment of knowledge, practice, and perception among clinical laboratory workers across public, private, and teaching hospital laboratories in Lahore. This knowledge gap is important because Lahore contains a large and diverse diagnostic laboratory sector, and findings from this setting may help inform targeted biosafety training, institutional policy development, monitoring systems, and occupational safety interventions. Therefore, the present study aimed to assess the knowledge, practices, and perceptions of biosafety measures among clinical laboratory workers in Lahore, Pakistan, and to determine their association with selected demographic and workplace-related variables.

MATERIALS AND METHODS

A cross-sectional observational study was conducted to assess the knowledge, practices, and perceptions related to biosafety measures among clinical laboratory workers in Lahore, Pakistan. The cross-sectional design was selected because it allowed simultaneous assessment of biosafety-related outcomes and selected demographic and occupational factors within a defined study population. The study was carried out over a four-month period in clinical diagnostic laboratory settings, including public sector laboratories, private diagnostic laboratories, and teaching hospital laboratories in Lahore. These settings were included to capture variation in institutional structure, workload, and laboratory service environments across the city.

The study population comprised clinical laboratory personnel actively working in diagnostic laboratories and directly involved in the handling, processing, testing, or management of clinical specimens. Eligible participants included laboratory workers with at least three months of professional laboratory experience who were willing to participate and provide written informed consent. Laboratory personnel without direct exposure to clinical laboratory procedures, administrative staff, technical support staff not involved in specimen handling, students or interns with less than three months of experience, and non-clinical laboratory workers were excluded. Participants were selected using a non-probability convenience sampling technique from the participating laboratory settings, and recruitment was conducted during routine working hours without interrupting laboratory services.

The required sample size was calculated using Cochran's formula for cross-sectional studies. A 95% confidence level was used with a Z value of 1.96, an expected proportion of 0.50 to maximize sample size in the absence of a fixed prior estimate, and a margin of error of 0.056. This calculation produced a minimum required sample size of 309 participants. To improve statistical precision and account for incomplete or non-response data, 326 clinical laboratory workers were recruited (10). Participants were informed about the purpose of the study, voluntary nature of participation, confidentiality of responses, and their right to withdraw at any stage before completing the questionnaire.

Data were collected using a structured, self-administered questionnaire developed in accordance with the study objectives. The questionnaire consisted of four main components: demographic characteristics, knowledge of biosafety measures, biosafety-related practices, and perception of biosafety measures. The demographic section collected information on gender, educational qualification, years of work experience, and type of laboratory. The knowledge section assessed awareness of biosafety principles, safe handling of biological specimens, use of personal protective equipment, sharps safety, waste disposal, exposure prevention, and standard laboratory precautions. The practice section assessed routine biosafety behaviors, including personal protective equipment use, hand hygiene, safe disposal of sharps and infectious waste, decontamination practices, and adherence to laboratory safety procedures. The perception section assessed participants' views regarding the importance of biosafety, perceived occupational risk, institutional responsibility, and the need for compliance with safety protocols.

The main outcome variables were knowledge, practice, and perception scores related to biosafety measures. Responses from each domain were converted into composite scores and analyzed as continuous variables. For categorical analysis, each domain was further classified into low, moderate, and high levels according to predefined scoring thresholds. The independent variables included gender, educational qualification, professional experience, and laboratory type. Educational qualification was categorized according to reported academic or professional laboratory training, work experience was grouped by duration of laboratory employment, and laboratory type was categorized as public/government, private diagnostic, or teaching hospital laboratory.

To reduce response bias, participants completed the questionnaire independently and were not required to provide identifying information. Completed questionnaires were checked for completeness before data entry. Data were coded, entered, cleaned, and reviewed for missing or inconsistent responses before analysis. Incomplete responses were excluded from analyses requiring complete data for the relevant variables. Data integrity was maintained through careful coding, verification of entered responses, and secure storage of all study records. The same questionnaire format and data collection procedure were used across participating sites to maintain consistency and reproducibility.

Statistical analysis was performed using descriptive and inferential methods. Categorical variables, including gender, education, experience category, laboratory type, and categorized knowledge, practice, and perception levels, were summarized using frequencies and percentages. Continuous KAP scores were summarized using means, standard deviations, minimum values, and maximum values. Chi-square tests were applied to examine associations between demographic or occupational variables and categorized knowledge, practice, and perception levels. Independent samples t-tests were used to compare mean knowledge, practice, and perception scores between male and female participants. One-way analysis of variance was used to compare mean KAP scores across educational qualification groups, work experience categories, and laboratory types. Where overall group differences were identified, post hoc comparisons were conducted to examine pairwise differences between groups. Statistical significance was assessed using a p-value threshold of less than 0.05.

Potential bias was addressed through anonymous self-administration of the questionnaire, standardized data collection procedures, predefined eligibility criteria, and systematic checking of completed questionnaires before data entry. Selection bias was minimized by recruiting participants from different categories of laboratories, including public, private, and teaching hospital settings. Information bias was reduced by using structured questions and allowing participants to complete responses independently. Confounding was explored by assessing the relationship of KAP outcomes with key demographic and occupational variables, including education, experience, gender, and laboratory type.

Ethical approval and permission for data collection were obtained from the relevant institutional and laboratory authorities before commencement of the study. Written informed consent was obtained from all participants. Confidentiality and anonymity were maintained throughout the study by avoiding personal identifiers and using the collected data only for research purposes. Participation was voluntary, and no laboratory worker was coerced or penalized for declining participation. The study procedures were conducted in accordance with ethical principles for research involving human participants.

RESULTS

A total of 326 clinical laboratory workers participated in the study. Valid responses varied across some variables because of incomplete responses, with 322 valid cases for knowledge, 313 for practice, and 313 for perception analyses. Female participants represented a slightly larger proportion of the sample than males, and most respondents had Bachelor-level professional training in Medical Laboratory Technology. Nearly half of the participants had less than one year of work experience, and more than half were employed in private laboratories.

Table 1. Demographic Characteristics of Clinical Laboratory Workers

Variable	Category	n	%
Gender	Male	146	45.6
	Female	174	54.4
Education	Diploma in MLT	56	18.1
	Bachelor in MLT	193	62.3

Variable	Category	n	%
	General bachelor's degree	32	10.3
	Master's in MLT	25	8.1
	Undergraduate	4	1.3
Work experience	<1 year	152	47.9
	1–3 years	131	41.3
	4–6 years	27	8.5
	>6 years	7	2.2
Laboratory type	Private laboratory	169	53.8
	Public/Government laboratory	105	33.4
	Teaching hospital laboratory	40	12.7

Most participants were professionally trained laboratory workers, with 193 respondents (62.3%) holding a Bachelor in MLT and 56 (18.1%) holding a Diploma in MLT. The sample was dominated by early-career professionals: 152 participants (47.9%) had less than one year of experience, while 131 (41.3%) had 1–3 years of experience. Private laboratories contributed the largest subgroup, accounting for 169 participants (53.8%), followed by public/government laboratories with 105 participants (33.4%) and teaching hospital laboratories with 40 participants (12.7%).

Table 2. Distribution and Descriptive Statistics of Knowledge, Practice, and Perception Scores

Domain	Level	n	%	Valid N	Mean ± SD	Minimum–Maximum
Knowledge	Low	205	63.7	322	11.03 ± 4.23	2–24
	Moderate	105	32.6			
	High	12	3.7			
Practice	Low	182	58.1	313	14.50 ± 6.06	6–30
	Moderate	85	27.2			
	Highss	46	14.7			
Perception	Low	196	62.6	313	6.85 ± 3.19	3–15
	Moderate	65	20.8			
	High	52	16.6			

Low levels were predominant across all three biosafety domains. For knowledge, 205 of 322 participants (63.7%) were classified as having low knowledge, while only 12 participants (3.7%) reached the high-knowledge category. Practice showed a similar pattern, with 182 of 313 participants (58.1%) categorized as having low biosafety practice and 46 (14.7%) categorized as high. Perception was also mostly low, with 196 of 313 participants (62.6%) in the low category, although the proportion classified as high perception (16.6%) was slightly greater than the high categories for knowledge and practice. Mean scores were 11.03 ± 4.23 for knowledge, 14.50 ± 6.06 for practice, and 6.85 ± 3.19 for perception.

Table 3. Association Between Demographic Variables and Categorized KAP Levels

Independent Variable	Outcome Domain	χ^2	df	p-value	Approx. Cramer's V
Education	Knowledge level	22.91	8	.003	0.189
	Practice level	15.47	8	.051	0.157

Independent Variable	Outcome Domain	χ^2	df	p-value	Approx. Cramer's V
	Perception level	11.33	8	.184	0.134
	Knowledge level	21.46	6	.002	0.183
Work experience	Practice level	2.19	6	.901	0.059
	Perception level	2.46	6	.873	0.063
	Knowledge level	0.61	4	.962	0.031
Laboratory type	Practice level	3.68	4	.452	0.077
	Perception level	1.69	4	.793	0.052

Education and work experience were significantly associated with biosafety knowledge level. The association between education and knowledge was statistically significant (χ^2 = 22.91, df = 8, p = .003), with an approximate Cramer's V of 0.189, indicating a small-to-moderate association. Work experience also showed a significant relationship with knowledge level (χ^2 = 21.46, df = 6, p = .002; Cramer's V ≈ 0.183). In contrast, education was not significantly associated with practice (p = .051) or perception (p = .184), although the education-practice association approached the conventional threshold for significance. Work experience showed no meaningful association with practice (p = .901) or perception (p = .873). Laboratory type was not significantly associated with any KAP domain, with p-values ranging from .452 to .962.

Table 4. Comparison of Mean KAP Scores by Gender

Domain	Male Mean ± SD	Female Mean ± SD	Mean Difference	t	df	p-value
Knowledge score	10.96 ± 4.48	11.02 ± 4.02	-0.06	-0.12	317	.902
Practice score	14.36 ± 6.24	14.53 ± 5.93	-0.17	-0.24	308	.812
Perception score	7.13 ± 3.20	6.56 ± 3.15	0.57	1.59	308	.112

Mean KAP scores were comparable between male and female participants. Knowledge scores were nearly identical between males and females (10.96 ± 4.48 vs. 11.02 ± 4.02; p = .902). Practice scores also showed minimal difference, with males scoring 14.36 ± 6.24 and females scoring 14.53 ± 5.93 (p = .812). Although males had a slightly higher mean perception score than females (7.13 ± 3.20 vs. 6.56 ± 3.15), this difference was not statistically significant (p = .112). Overall, gender did not significantly influence knowledge, practice, or perception scores.

Table 5. Comparison of Mean KAP Scores Across Education, Experience, and Laboratory Type

Independent Variable	Outcome Domain	F	df	p-value	Approx. η^2
	Knowledge score	2.45	4, 304	.046	0.031
Education	Practice score	0.91	4, 295	.459	0.012
	Perception score	1.70	4, 295	.151	0.023
	Knowledge score	3.23	3, 313	.023	0.030
Work experience	Practice score	0.41	3, 304	.745	0.004
	Perception score	0.51	3, 304	.677	0.005
	Knowledge score	2.50	2, 311	.084	0.016
Laboratory type	Practice score	0.23	2, 302	.796	0.002
	Perception score	0.04	2, 302	.961	<0.001

One-way ANOVA showed statistically significant differences in knowledge scores across educational groups ($F = 2.45$, df = 4,304, $p = .046$; $\eta^2 \approx 0.031$) and experience categories ($F = 3.23$, df = 3,313, $p = .023$; $\eta^2 \approx 0.030$). These findings indicate that education and experience were associated with variation in biosafety knowledge scores, although the estimated effect sizes were small. Practice and perception scores did not differ significantly across education, experience, or laboratory type categories. Laboratory type showed no statistically significant difference for knowledge ($p = .084$), practice ($p = .796$), or perception ($p = .961$), indicating broadly similar KAP score patterns across private, public/government, and teaching hospital laboratory settings.

Overall, the findings show that most clinical laboratory workers had low categorized levels of biosafety knowledge, practice, and perception. Education and professional experience were significantly related to knowledge, but these factors did not show significant relationships with biosafety practice or perception. Gender and laboratory type were not significantly associated with any KAP domain. This pattern indicates that improved educational or experiential exposure may increase biosafety knowledge, but it did not translate into significantly better reported practice or perception within the study sample.

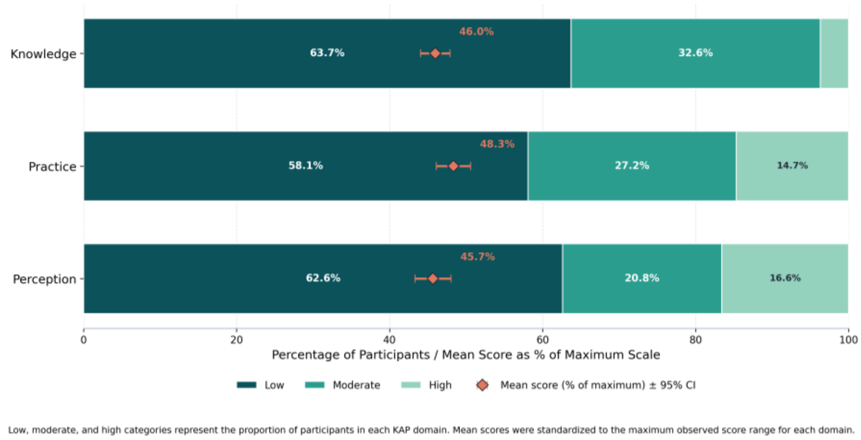

Figure 1. Biosafety Deficit Profile Across Knowledge, Practice, and Perception Domains

Knowledge demonstrated the greatest biosafety deficit, with 63.7% of participants classified in the low category, 32.6% in the moderate category, and only 3.7% in the high category, while the standardized mean score reached 46.0% of the maximum scale (95% CI: 44.0%–47.9%). Practice showed the highest standardized mean performance at 48.3% (95% CI: 46.1%–50.6%), yet 58.1% of participants still remained in the low-practice group, compared with 27.2% moderate and 14.7% high, indicating limited translation of biosafety knowledge into routine implementation. Perception showed a similarly unfavorable pattern, with 62.6% low, 20.8% moderate, and 16.6% high responses, and a standardized mean of 45.7% (95% CI: 43.3%–48.0%). Overall, all three domains were characterized by a predominance of low-level responses exceeding 58%, whereas mean standardized scores clustered narrowly between 45.7% and 48.3%, highlighting a clinically important pattern in which modest average performance coexisted with a persistently high burden of suboptimal biosafety status across the workforce.

DISCUSSION

The present study demonstrated that clinical laboratory workers in Lahore had suboptimal biosafety knowledge, practices, and perceptions, with low-level responses predominating across all three assessed domains. More than half of the participants were categorized as having low knowledge, low practice, and low perception, indicating that biosafety gaps were not limited to one dimension of occupational safety but were present across awareness, behavioral implementation, and perceived importance of biosafety measures. Although the mean scores suggested moderate overall performance when treated as continuous variables, the categorical distribution showed that a large proportion of laboratory workers remained below desirable biosafety standards. This pattern is important because clinical laboratory workers routinely handle blood, body fluids, sharps, contaminated materials, and potentially infectious specimens, where inconsistent adherence to biosafety principles can increase the risk of occupational exposure, laboratory-acquired infections, and unsafe diagnostic work environments (11,12).

The predominance of low biosafety knowledge among participants suggests that many laboratory workers may not have sufficient understanding of standard precautions, hazard identification, risk assessment, sharps safety, spill management, waste segregation, and correct use of personal protective equipment. This finding is consistent with evidence from comparable low- and middle-income healthcare settings, where gaps in biosafety knowledge have been linked to limited structured training, weak institutional safety culture, inadequate refresher education, and variable enforcement of laboratory safety protocols (13). In the present study, only a small proportion of participants achieved high knowledge levels, showing that formal employment in clinical laboratory settings does not necessarily ensure adequate biosafety competence. This is particularly relevant in settings where laboratory personnel may enter the workforce with variable levels of professional preparation and may not receive standardized biosafety orientation after appointment (14).

Education was significantly associated with biosafety knowledge, indicating that participants with higher or more relevant educational qualifications had better awareness of biosafety measures. This association is expected because formal laboratory education usually includes basic instruction in infection control, specimen handling, personal protective equipment, biomedical waste management, and occupational safety. However, the effect appeared limited because high knowledge remained uncommon despite the majority of participants having professional laboratory qualifications. This suggests that academic exposure alone may be insufficient unless reinforced through practical demonstrations, competency-based training, continuing professional development, and routine workplace assessment. Similar findings have been reported in studies where higher educational attainment improved theoretical awareness but did not consistently produce strong biosafety performance in routine laboratory practice (15,16).

Work experience was also significantly associated with biosafety knowledge, suggesting that professional exposure may contribute to improved recognition of laboratory hazards and safety requirements. Laboratory workers with longer experience are more likely to encounter occupational risks, safety audits, institutional protocols, and peer-based learning, which may gradually improve knowledge. Nevertheless, experience did not show a significant association with practice or perception, indicating that time spent in laboratory work does not automatically result in safer behavior or stronger risk perception. This finding highlights the possibility that workers may become familiar with laboratory hazards over time but may also normalize unsafe practices if institutional monitoring, supervision, and accountability are weak. In occupational safety research, this phenomenon is often reflected as a gap between knowing what should be done and consistently doing it under routine workload conditions (17,18).

The absence of significant associations between demographic variables and biosafety practice is one of the most important findings of the study. Although education and experience were related to knowledge, they were not significantly related to practice, showing a clear knowledge-practice gap. This means that better awareness did not necessarily translate into consistent use of personal protective equipment, hand hygiene, safe sharps disposal, waste segregation, decontamination, or adherence to standard operating procedures. Such a gap may be explained by system-level barriers, including insufficient availability of protective equipment, workload pressure, inadequate supervision, lack of biosafety audits, limited institutional enforcement, and weak reporting systems for exposure incidents. Therefore, improving biosafety practice requires more than educational intervention; it requires organizational commitment, accessible resources, monitoring mechanisms, and a workplace culture in which safety compliance is expected and reinforced.

The finding that perception levels were predominantly low is also clinically and operationally meaningful. Perception influences whether workers consider biosafety measures necessary, urgent, and personally relevant. If laboratory workers underestimate occupational risk or view safety precautions as optional, inconvenient, or secondary to workflow speed, compliance is likely to remain inconsistent even when knowledge is present. The lack of significant association between perception and demographic variables suggests that low risk perception may be a shared problem across different groups of laboratory workers rather than being limited to a particular gender, education level, experience category, or laboratory type. This indicates the need for behavioral and institutional interventions that strengthen risk awareness, promote accountability, and make biosafety an embedded part of routine laboratory culture rather than an occasional training topic.

Gender was not significantly associated with knowledge, practice, or perception scores. Male and female participants had comparable biosafety profiles, suggesting that biosafety deficiencies were broadly distributed across the workforce. This finding supports the interpretation that the observed gaps are more likely related to training quality, institutional systems, and workplace practices than to individual demographic characteristics. Similarly, laboratory type was not significantly associated with any KAP domain, despite participants being recruited from private, public/government, and teaching hospital laboratories. This may indicate that biosafety challenges are widespread across laboratory settings in Lahore. However, the lack of statistical difference does not necessarily mean that all laboratory settings have identical safety infrastructure; rather, it suggests that the measured knowledge, practice, and perception scores were similarly suboptimal across institutional categories.

The study findings carry important implications for laboratory management and occupational health policy. First, biosafety training should be structured, recurring, and competency-based rather than limited to theoretical instruction. Training should include demonstration of personal protective equipment use, spill response, biomedical waste segregation, sharps injury prevention, biosafety cabinet use where applicable, and post-exposure procedures. Second, institutions should implement routine biosafety monitoring through checklists, audits, incident reporting, and feedback mechanisms. Third, availability of essential protective resources must be ensured because laboratory workers cannot comply consistently with biosafety standards if gloves, masks, gowns, disinfectants, sharps containers, and waste-disposal systems are insufficient or inconsistently supplied. Fourth, laboratory supervisors should play an active role in reinforcing safe practices through observation, correction, and positive safety culture development.

The results also suggest that interventions should target both individual and system-level determinants of biosafety compliance. Individual-level strategies may improve knowledge and risk perception, whereas system-level strategies are needed to improve actual practice. For example, educational sessions may increase awareness of sharps injury prevention, but safe practice requires puncture-resistant sharps containers at point of use, written protocols, immediate reporting pathways, and post-exposure management systems. Similarly, knowledge of PPE is unlikely to improve compliance unless PPE is available, comfortable, appropriate for the task, and reinforced through institutional expectations. A combined model involving education, infrastructure, supervision, and accountability is therefore more likely to improve biosafety outcomes than isolated training alone.

The study has several limitations that should be considered when interpreting the findings. The cross-sectional design limits causal inference, so associations between education, experience, and knowledge should not be interpreted as proof of causation. The use of convenience sampling may limit generalizability beyond the participating laboratories. Self-reported questionnaire responses may be affected by recall bias or social desirability bias, particularly for practice-related items where participants may overreport safe behavior. In addition, some analyses involved fewer valid cases than the total sample because of incomplete responses, which may have influenced precision. Despite these limitations, the study provides useful evidence on biosafety gaps among clinical laboratory workers in Lahore and identifies specific domains requiring improvement.

Overall, the findings show that biosafety among clinical laboratory workers requires urgent attention, particularly because low knowledge, practice, and perception were common across the study population. Education and experience were associated with knowledge but did not significantly improve practice or perception, emphasizing that biosafety compliance is not achieved through awareness alone. The study supports the need for integrated biosafety programs that combine continuous professional training, adequate protective resources, institutional monitoring, practical competency assessment, and a stronger culture of occupational safety. Strengthening these areas may reduce preventable laboratory exposures, improve worker protection, and enhance the safety and quality of diagnostic laboratory services.

CONCLUSION

The present study concluded that clinical laboratory workers in Lahore demonstrated substantial deficiencies in biosafety knowledge, practices, and perceptions, with most participants falling into the low category across all three domains. Although higher educational qualification and greater work experience were significantly associated with improved biosafety knowledge, these factors did not produce corresponding improvements in reported biosafety practices or perceptions, indicating a clear gap between awareness and practical implementation. Gender and laboratory type showed no significant association with knowledge, practice, or perception, suggesting that biosafety limitations were broadly distributed across the laboratory workforce rather than confined to specific demographic or institutional groups. These findings emphasize that improving biosafety compliance requires more than academic training or workplace exposure alone; it demands structured and repeated competency-based training, consistent availability of personal protective equipment, effective supervision, routine biosafety monitoring, clear institutional policies, and a stronger safety culture within clinical laboratories. Strengthening these measures is essential to reduce occupational exposure risks, improve adherence to standard laboratory precautions, and ensure safer diagnostic laboratory environments for healthcare workers and patients.

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