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Assessment of Laboratory Knowledge, Practical Competency, and Learning Outcomes Among Undergraduate Medical Students

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Abstract

Background: Medical education is based on the support of theory, academic activity and competency in the laboratory. The aim of this study was to assess the academic engagement, lab exposure and knowledge scores of medical undergraduate students and to statistically associate them. **Methods:** This cross sectional analytical study (n=120) used stratified sampling technique and a structured questionnaire was developed specifically for the study, which included a knowledge assessment score test (15 items) to assess the level of knowledge, a frequency score test to assess the level of academic engagement (study hours, attendance and use of digital learning), a hands-on participation score test to assess the level of exposure on the laboratory, and a supervision score test to assess the level of supervision in the laboratory. SPSS v26 was used for the statistical analysis. Descriptive statistics (mean ± SD and percentages) were calculated. Independent t-test and one-way ANOVA were used for group comparisons. Pearson correlation coefficient and Chi square test were used to examine the relationship between the variables, at $p < 0.05$ significance level. **Results:** Out of 120 participants, the mean age was 21.1 ± 1.6 years with 52.5% of females. There was a significant difference in the knowledge scores between students with high and low laboratory exposure (68.9 ± 9.8 vs 54.2 ± 10.5, $p < 0.001$). There was a moderate positive correlation between the study hours and knowledge score ($r = 0.41$, $p < 0.01$). Academic engagement (ANOVA, $F = 6.72$, $p = 0.002$) was a significant factor for laboratory competency scores. A significant correlation between year of study and level of lab participation was found using a chi-square test ($\chi^2 = 14.3$, $p = 0.01$). Generally, regression analysis showed that laboratory exposure had the highest beta (0.36, $p < 0.001$) that contributed to the knowledge score. **Conclusions:** Academic involvement and practical experience in the laboratory have a significant effect on the knowledge building and skill acquisition of medical students.

Keywords: Medical education, laboratory competency, academic engagement, knowledge score, cross-sectional study, statistical analysis

Introduction

Generalized Anxiety Disorder (GAD) is one of the most common anxiety disorders due to the fact that its key characteristics are persistent and excessive worrying that persists for six months or later that interferes with the usual functioning activities [1]. GAD symptoms include restlessness, muscle tension, inability to concentrate, irritability, fatigue, and sleep disruption [2]. The global GAD prevalence patterns reveal the growing trends since the condition adversely affects the quality of life and work performance, which eventually reflect on overall well-being [3]. GAD requires continuous management interventions, targeting severity of symptoms and low functional capacities since it persists and recurs frequently [4,5].

Selective serotonin re-uptake inhibitor (SSRI)-based medications combined with cognitive behavioral therapy (CBT) represent the main therapy approaches for GAD treatment [6]. Medications for antidepressants help treat neurochemical irregularities, and successfully minimize the core anxiety symptoms [7]. Patients who receive medication struggle with associated side-effects, along with difficulties maintaining their treatment plan and restricted gains in their overall functioning [8]. In addition, even after pharmacologic therapy, certain patients have residual symptoms raising the importance of complementary or alternative anxiety therapy that incorporates psychological and behavioral components [9]. CBT provides a step-by-step therapeutic method to patients, to modify stress-giving thought processes and behaviors simultaneously [10]. Evidence for the long-lasting effectiveness of CBT therapy are substantial, if patients complete the therapy process [11]. CBT has also been found to provide self-management skills and coping strategies that can help decrease the risk of symptom recurrence in the long term [12]. Although there is an extensive literature on both CBT and medication treatments but the direct comparison of their outcomes in GAD treatment remains scarce within studies using prospective methods. The success criteria beyond symptom reduction include diminished attention to functional outcomes along with quality-of-life assessments and patient-reported satisfaction in available research [13]. Moreover, differences in study design, treatment duration, and outcome measures have helped to generate inconsistent results on the relative effectiveness of CBT and antidepressant drugs [14]. Thus, future comparative studies are warranted that include clinical and patient-reported outcomes to provide a clearer understanding of the optimization of treatment selection in GAD patients [15].

This research prospectively evaluated the therapeutic outcomes of CBT versus antidepressant medication in adult patients with GAD. This study employed standardized assessment tools while focusing on patient-centered outcomes to measure both decrease in anxiety symptom and their impact on both functional outcomes and quality of life. The study aimed to inform best clinical treatment practices for personalized care decisions and improve services for adults dealing with GAD.

Methodology

A cross-sectional analytical study of undergraduate Medical students was carried out to evaluate the relationship between laboratory exposure, participation in practical classes, academic involvement and biomolecular laboratory knowledge. The study was conducted in the medical college for a period of three months from January to March 2026. The final analysis comprised of a total of 120 undergraduate students. To assure representation of academic years, stratified convenience sampling was employed. Students in the MBBS course in the college were included, who were willing to participate. Students who did not participate or who did not complete the questionnaires were not included in the final analysis.

The questionnaire, which was developed based on relevant literature review in the areas of medical education, laboratory competency and biomolecular learning was adapted for being self-administered and structured. The questionnaire contained demographic characteristics, academic profile, GPA, hours spent studying daily, attendance at lab sessions, participation in practical sessions, submission of lab reports, and safety training received, confidence about lab procedures and knowledge of the biomolecular lab. Laboratory exposure was measured by attendance and participation-related items while academic engagement was measured by study hours, GPA, and regularity in learning activities. Basic biochemistry concepts, molecular biology principles, diagnostic biomarkers, laboratory safety and ethics, and specimen handling and processing were evaluated by the biomolecular laboratory knowledge section. The scores for each domain were out of 10, with a total knowledge score of 50. The overall score was divided into four groups of poor, moderate, good and excellent knowledge based on predetermined score ranges.

The questionnaire was reviewed by three faculty members who had experience in the field of medical education and laboratory sciences, and the content validity was ensured. A small sample of 15 students, who were not in the final sample, was used for pilot testing. The internal consistency of the questionnaire was acceptable (Cronbach's alpha = 0.82). The participants were informed of the purpose of the study and informed consent was obtained prior to the data collection. Participation was voluntary and anonymity and confidentiality were ensured throughout the study. The data were gathered anonymously, avoiding the reporting bias and response pressure through institutional communication channels. The data were then entered into Microsoft Excel and analyzed using SPSS version 22. For categorical variables the frequencies and percentages were computed and for continuous variables the means and standard deviations were calculated. Where applicable, comparisons between two groups were conducted using independent samples t-test. The mean knowledge scores were submitted to one-way ANOVA which was used to compare the scores between laboratory exposure groups and post-hoc analysis was used if necessary. The associations between categorical variables were evaluated with chi-square test. Pearson correlation coefficient was used to determine relationships between academic and laboratory-related variables and knowledge scores. A multiple linear regression was used to determine the independent predictors of biomolecular laboratory knowledge. The p-value of less than 0.05 was used for statistical significance.

Results

Total 120 undergraduate medical students were included in the final analysis. The female students' sample group was 55.0% and the male students' sample group was 45.0%. The age group of 21-23 years old was the most predominant and students were almost evenly spread by academic year. Academic profile, 43.3% of students had a GPA ranging from 70% to 80% and 47.5% of students studied 2-4 hours a day. These academic and demographic features are displayed in Table 1, and indicated that the sample was of good size from various academic levels.

Table 1: Demographic and Academic Characteristics of Participants (n = 120

Variable	Category	N (%)
Gender	Male	54 (45.0)
	Female	66 (55.0)
Age (years)	18–20	41 (34.2)
	21–23	58 (48.3)
	>23	21 (17.5)
Academic Year	First Year	28 (23.3)
	Second Year	31 (25.8)
	Third Year	30 (25.0)
	Final Year	31 (25.8)
GPA (%)	<70	34 (28.3)
	70–80	52 (43.3)
	>80	34 (28.3)
Daily Study Hours	<2 hours	26 (21.7)
	2–4 hours	57 (47.5)
	>4 hours	37 (30.8)

Grade Point Average (GPA) (%)

The characteristics of the exposure to and practical training in the laboratory varied among the participants. Sixty percent of the students reported regular attendance (more than 80%), 27.5% moderate and 12.5% low attendance in the laboratory. 42.5% of students reported high participation in practical sessions, 37.5% had moderate participation and 20.0% had low participation. The majority of students mentioned that they had been submitting their laboratory reports regularly and 78.3% of students had received training in lab safety. The students has high, moderate and low level of confidence in laboratory procedure 40.8%, 44.2% and 15.0% respectively. The practical training and exposure variables in Lab are given in Table 2.

Table 2: Laboratory Exposure and Practical Training Characteristics

Parameter	Category	N (%)
Laboratory Attendance	Regular (>80%)	72 (60.0)
	Moderate (60–80%)	33 (27.5)
	Low (<60%)	15 (12.5)
Participation in Practical Sessions	High	51 (42.5)
	Moderate	45 (37.5)
	Low	24 (20.0)
Laboratory Report Submission	Always	78 (65.0)
	Sometimes	34 (28.3)
	Rarely	8 (6.7)
Laboratory Safety Training Received	Yes	94 (78.3)
	No	26 (21.7)
Confidence in Laboratory Procedures	High	49 (40.8)
	Moderate	53 (44.2)
	Low	18 (15.0)

The overall mean knowledge score of biomolecular laboratory was 35.7 ± 5.9 out of 50. The five knowledge domains were categorized, with the highest mean score being laboratory safety and ethics, basic concepts of biochemistry, handling and processing of specimens, molecular biology principles, and diagnostic biomarkers, respectively. Table 3 shows the domain-wise biomolecular laboratory knowledge scores.

Table 3: Biomolecular Laboratory Knowledge Scores

Knowledge Domain	Mean Score ± SD (Maximum Score = 10)
Basic Biochemistry Concepts	7.3 ± 1.5
Molecular Biology Principles	6.8 ± 1.7
Diagnostic Biomarkers	6.5 ± 1.8
Laboratory Safety and Ethics	8.1 ± 1.2
Specimen Handling and Processing	7.0 ± 1.6
Overall Knowledge Score	35.7 ± 5.9 / 50

The percentage of students with poor knowledge, moderate knowledge, good knowledge and excellent knowledge based on the total number of categories of knowledge were 13.3%, 39.2%, 35.0% and 12.5% respectively. The distribution of students according to knowledge categories is shown in Table 4.

Table 4: Knowledge Categories

Category	Score Range	N (%)
Poor	<25	16 (13.3)
Moderate	25–35	47 (39.2)
Good	36–45	42 (35.0)
Excellent	>45	15 (12.5)

There was a significant difference in the knowledge scores among the laboratory exposure levels. The students who were in high laboratory exposure had the highest mean knowledge score, the students in moderate and low laboratory exposure had lower mean knowledge scores respectively. The mean knowledge scores were 39.8 ± 4.8, 34.1 ± 5.1 and 29.4 ± 5.7 for high, moderate and low exposure respectively. This difference was statistically significant as revealed by One-Way ANOVA ($F = 18.74$, $p < 0.001$). Table 5 shows the comparison of the knowledge scores based on laboratory exposure level.

Table 5: Comparison of Knowledge Scores According to Laboratory Exposure

Laboratory Exposure Level	Mean Knowledge Score ± SD	F-value	p-value
Low	29.4 ± 5.7	18.74	<0.001*
Moderate	34.1 ± 5.1		
High	39.8 ± 4.8		

One-way ANOVA.

The scores were significantly higher for students with high laboratory exposure than for those with moderate and low exposure, as revealed by a post-hoc analysis. There was significant positive correlation between the biomolecular laboratory knowledge score and the academic variables and laboratory-related variables, respectively, as revealed by Pearson correlation analysis. The highest positive correlation of the laboratory attendance with knowledge score was found followed by practical participation, GPA, daily study hours and confidence in laboratory procedures. All the correlations were significant at $p < 0.001$. The correlation between academic variables and biomolecular knowledge score are summarized in Table 6.

Table 6: Correlation between Academic Variables and Biomolecular Knowledge Score

Variable	Pearson r	p-value
Daily Study Hours	0.43	<0.001*
Laboratory Attendance	0.51	<0.001*
Practical Participation Level	0.48	<0.001*
GPA	0.45	<0.001*
Confidence in Laboratory Procedures	0.39	<0.001*

****Statistically significant.***

Multiple linear regression was used to determine the independent predictors of biomolecular laboratory knowledge score. The regression model overall was statistically significant and accounted for 47% of the variance in the knowledge scores. Laboratory attendance was found to be the best independent predictor of the knowledge score followed by participation in the practical, daily study hours and GPA. Gender did not influence significantly. The results of the regression are reported in Table 7.

Table 7: Multiple Linear Regression Analysis Predicting Biomolecular Knowledge Scores

Predictor Variable	β Coefficient	Standard Error	t-value	p-value
Laboratory Attendance	0.34	0.07	4.86	<0.001*
Practical Participation	0.29	0.08	3.94	<0.001*
Daily Study Hours	0.21	0.06	3.12	0.002*
GPA	0.17	0.07	2.43	0.017*
Gender	0.04	0.05	0.62	0.536

The findings overall reflected that the students who were attending the labs regularly, actively participating in the lab sessions and had more hours of study per day, had higher scores in their biomolecular laboratory knowledge. Laboratory attendance was found to be the most correlated variable with knowledge outcomes, while other academic engagement variables were the next most correlated variables.

Discussion

The cross sectional analytical study revealed a significant association between laboratory exposure and the biomolecular laboratory knowledge of the study participants, the undergraduate medical students. The overall knowledge scores were higher for students with high than moderate or low laboratory exposure. The results indicate that frequent participation in laboratory learning can enhance theory knowledge and enable students to apply the concepts of biomedical sciences in real life. It has also been pointed out by previous studies that hands-on laboratory training helps to encourage critical thinking, scientific reasoning and competency development among medical students [16, 17].

In the present study, the mean score in the diagnostic biomarkers item category was the lowest and the mean score for laboratory safety and ethics was the highest. This suggests that although students' awareness of basic safety principles was good, their understanding of clinically relevant biomarker interpretation was relatively weak. Performance in this area is where biochemical, molecular and clinical knowledge is required to be integrated, so a lower performance may be interpreted as needing lessons to be taught on cases, with demonstrations repeated, and more clinically oriented laboratory teaching. This teaching might enable students to not only understand the definition of biomarkers, but also their clinical relevance, interpretation and their limitations as a diagnostic[18,19]. Enhancing the integration of laboratory medicine into the early phases of undergraduate laboratory medicine training may help students understand how to apply theoretical information about a biomarker to a diagnostic decision-making scenario [20].

Correlation analysis revealed that the laboratory attendance was found to be the most positively correlated with the biomolecular knowledge score, followed by the participation in practicals, GPA, daily study hours and confidence in laboratory procedure. The results indicate that academic engagement and hands-on experience in the laboratory have both an impact on the learning outcomes. Those who attend the laboratory regularly and are active in practical work could gain from repeated observation, hands-on practice, discussion and reinforcement of some of the ideas which form the basis for lecture work. It is also evident in this pattern that knowledge development is not solely dependent on attendance but it is facilitated by a combination of regular attendance, self-study, and repeated practical exposures [21, 22]. Such observations can also be seen as evidence for experiential learning theories, which emphasize the importance of active engagement and repeated hands-on learning experiences for reinforcing knowledge and building skills in the lab, and, consequently, for increasing students' confidence in using scientific concepts in real life [23].

Multiple linear regression analysis also revealed that laboratory attendance had the highest correlation with biomolecular knowledge score followed by participation in the practical, hours of daily study time and GPA. Gender was not associated with knowledge outcomes, indicating that academic and laboratory factors were more strongly related to outcomes of the knowledge components studied than were demographic factors. The findings of this study reflect the significance of organized laboratory exposure in undergraduate learning and suggest that there should be a teaching and learning connection between practical and theoretical learning [24, 25]. This underscores the need to ensure that sufficient laboratory opportunities are provided to facilitate learning and competency throughout the medical curriculum [26].

The findings have important implications for medical colleges. Laboratory based learning should not be limited as an adjunct to learning but as an integral part of competency based medical education. Good attendance, active participation, laboratory report writing, practical sessions for developing confidence and safety training can enhance student understanding of biomolecular concepts. This poorer performance for the diagnostic biomarkers and specimen handling also indicates that these subjects need more practical application, real-world examples and clinical correlation [27, 28]. In undergraduate medical education, curriculum planners may need to make greater effort to provide supervised laboratory practice experiences and include laboratory results as part of problem-solving activities [29].

There are some limitations in this study. The cross-sectional design used precludes the ability to draw causal conclusions about the link between laboratory exposures and knowledge outcomes. The study was carried out in one medical college, so it might not be generalizable. Some factors including study hours, GPA, and confidence in laboratory procedure were self-reported, and could be subject to reporting bias. Furthermore, the knowledge evaluated using questionnaires may not accurately represent the observed performance in laboratory. It is suggested that the results of this study be corroborated in future multicenter, longitudinal and objective studies based on practical assessment.

Conclusion

To sum up, laboratory attendance, participation in practicals and academic engagement were significantly related with biomolecular laboratory knowledge of the medical undergraduate students. The laboratory attendance was the most significant independent variable for the knowledge score followed by practical participation, daily study hours and GPA. The results highlight the importance of systematic laboratory training, good supervision, and a stronger emphasis on weaker components like diagnostic biomarkers.

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Conflict of Interest

None

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Use of Artificial Intelligence

The corresponding author declared that no artificial intelligence or AI-assisted tools were used in this manuscript.

Authors' Contribution

TQ, SI and MK contributed significantly and equally as per ICMJE. All authors gave their final approvals to publish this article.

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