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| RESEARCH ARTICLE

Impact of an Educational Intervention on Laboratory Technicians' Knowledge of HIV Screening in the Northern Borders Region of Saudi Arabia

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| ABSTRACT

Ensuring the accuracy of HIV screening in blood banks is essential for maintaining transfusion safety and preventing transfusion-transmitted infections. This study evaluated the effectiveness of an educational intervention designed to improve HIV-related knowledge among laboratory technicians in the Central Blood Bank of the Northern Borders Region of Saudi Arabia. A quantitative descriptive design was employed, using a structured questionnaire administered before and after a targeted training program. Thirty laboratory technicians participated, completing assessments covering HIV transmission, diagnostic methods, quality assurance procedures, and biosafety practices. Paired t-test analysis demonstrated a statistically significant improvement in knowledge following the intervention, with mean scores increasing from 11.07 to 14.00 ($p < 0.001$). Effect size calculations indicated a large practical impact (Cohen's $d = 0.842$), and internal consistency of the instrument improved from $\alpha = 0.762$ pre-intervention to $\alpha = 0.794$ post-intervention. Descriptive and frequency analyses revealed notable reductions in misconceptions related to the diagnostic window period, rapid test identification, test sensitivity, and WHO/UNAIDS testing strategies. The findings underscore the critical role of structured, continuous training in enhancing laboratory competency, standardizing testing practices, and reinforcing quality assurance within HIV screening services. Implementing routine, evidence-based educational programs can strengthen national blood safety systems and support alignment with international standards for HIV testing and transfusion safety.

| KEYWORDS

HIV screening; laboratory technicians; Educational Intervention

| ARTICLE INFORMATION

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Background

HIV is a lentivirus within the retrovirus family and is the causative agent of HIV infection, which can progress to AIDS if untreated [1]. AIDS is marked by severe immune dysfunction that increases vulnerability to opportunistic infections and malignancies, and without treatment, individuals with HIV typically survive about 10 years [2]. Transmission occurs through sexual contact, blood transfusion, shared needles, and from mother to child during pregnancy or delivery via exposure to infected blood or bodily fluids. The virus exists in these fluids both as free viral particles and within infected immune cells [3]. HIV originated from West-central African non-human primates and crossed into humans in the early 20th century; HIV-1 was first identified in Cameroon during studies of simian immunodeficiency virus, from which it evolved after repeated cross-species transmission and mutation [4]. Currently, there is no cure or vaccine, and treatment relies on highly active antiretroviral therapy (HAART) [5]. Extensive global research has focused on HIV testing, with HIV testing services (HTS) encompassing pre- and post-test counseling, laboratory processes, and linkage to prevention and treatment [6]. Strengthening these services supports UNAIDS 90-90-90 targets, which aim for 90% of people with HIV to know their status, 90% of those diagnosed to receive sustained therapy, and 90% of treated individuals to achieve viral suppression by 2020 [7]. Although progress has been made, global outcomes remain short of these goals, with about 73% of people living with HIV achieving viral load reduction [8]. The study examines whether focused educational programs can improve laboratory technicians' knowledge and performance, ultimately enhancing the quality of HIV screening. Evaluating these interventions is crucial, as inadequate screening could jeopardize the safety of the regional blood supply and pose persistent public health risks. Thus, this research plays an important role in reinforcing blood transfusion safety and bringing HIV screening practices in the NBR in line with international quality assurance standards.

Literature review

The accuracy and reliability of HIV screening are strongly influenced by the training and proficiency of laboratory personnel. The expertise of lab staff directly impacts the quality of HIV testing. Maintaining high standards of screening necessitates ongoing training and robust quality assurance measures to ensure precise and dependable results. Implementing standardized protocols and comprehensive training programs is crucial for educating all laboratory staff in proper HIV testing procedures. Additionally, regular audits and performance evaluations help identify gaps, reinforce best practices, and support continuous improvement [9].

Blood donation and HIV incidence are influenced by a complex interplay of screening technologies, donor policies, public attitudes, and broader public health interventions. The introduction of nucleic acid testing for blood donors has markedly enhanced HIV detection and reduced the risk of transfusion-related transmission. The accuracy of HIV test results depends heavily on laboratory personnel training, the choice of screening methods, and adherence to quality assurance protocols. HIV prevalence among blood donors is shaped by the effectiveness of public health strategies and the availability of resources. Well-coordinated public health systems and comprehensive screening programs can substantially lower donor HIV prevalence [10].

Conversely, regions with limited resources may struggle to implement and sustain rigorous screening, leading to higher transmission risks through blood donations. To address these disparities, it is essential to improve blood collection infrastructure and equitable resource allocation worldwide, with international health organizations and partnerships supporting resource-limited countries. Ultimately, HIV prevalence and blood donation safety are shaped by a combination of screening technologies, donor policies, public perceptions, and public health initiatives. The implementation of nucleic acid testing for blood donors has significantly improved HIV detection and reduced the risk of transfusion-related transmission. The accuracy of HIV test results relies on laboratory personnel training, the choice of screening methods, and strict quality assurance practices. HIV prevalence among donors is also influenced by public health strategies and resource availability. Ensuring a safe and adequate blood supply requires addressing social attitudes and misconceptions about donation, particularly in high-risk communities. By accounting for these factors, public health authorities can promote blood donation, minimize HIV transmission, and safeguard the blood supply. Given the complexities of blood donation and HIV screening, a comprehensive, multifaceted approach is essential to protect public health and prevent transfusion-transmitted infections [11].

The accuracy and reliability of HIV screening tests depend heavily on the training and proficiency of laboratory personnel. Continuous training and rigorous quality assurance are essential to uphold screening standards. Laboratory staff must stay informed about the latest testing methods to prevent HIV transmission through blood transfusions. Implementing standardized protocols and comprehensive training ensures that screening facilities consistently maintain accurate and dependable results [12].

Multiple factors influence blood donation and HIV incidence. The use of nucleic acid testing in blood donors has significantly improved HIV detection, reducing the risk of transfusion-related infections. The accuracy of HIV test results depends on laboratory personnel training, the selected screening methods, and adherence to quality assurance protocols. HIV prevalence among donors is shaped by public health strategies and the allocation of resources. Ensuring a safe and adequate blood supply also requires addressing societal attitudes and misconceptions about blood donation, particularly in high-risk populations. By taking these factors into account, public health authorities can promote safe blood donation, minimize HIV transmission, and protect the blood supply. Given the complexity of blood donation and HIV screening, a comprehensive and integrated approach is essential to safeguard public health and prevent transfusion-transmitted infections [13].

The accuracy and reliability of HIV screening tests are strongly influenced by the training and proficiency of laboratory personnel. Staff must be thoroughly trained and adhere to established procedures to minimize errors and maintain high screening standards. Continuous education and quality assurance programs are essential for laboratory personnel to remain up to date with evolving technologies and best practices. Regular audits and performance evaluations further enhance compliance with protocols and support consistent testing quality [14].

Comprehensive laboratory testing is essential for effective HIV diagnosis, treatment, and prevention. Achieving the highest standards in HIV laboratory testing requires rigorous quality control, regular staff training and certification, adherence to standardized protocols, utilization of advanced testing technologies, and robust management and supervision of laboratory processes [15].

High-quality HIV testing depends on thorough training and certification of laboratory personnel. Accurate results require staff to be well-versed in the latest testing methods and protocols. Ongoing education in both the theory and practice of HIV testing is essential, while certification ensures that laboratory personnel maintain proficiency and adhere to established standards. Regular refresher courses and proficiency assessments help sustain skills and uphold quality assurance in HIV testing [15].

High-quality HIV laboratory testing relies on rigorous quality control, comprehensive staff training and certification, standardized protocols, advanced testing technologies, and effective management and supervision of laboratory processes. Essential supporting elements include communication, collaboration, information technology, accreditation, and external quality assessments. The quality of HIV testing is further enhanced through ethical practices, continuous quality improvement initiatives, patient feedback, adherence to regulatory and policy frameworks, ongoing research and development, international collaborations, systematic quality assurance, continuous monitoring and evaluation, capacity building, and strong leadership and governance. Addressing these components improves laboratory accuracy, patient outcomes, and the effectiveness of public health interventions [16].

METHODOLOGY

Research Design

The study adopted a quantitative approach, utilizing descriptive methods to organize observational and statistical data and present them clearly. It focuses on evaluating HIV screening tests for blood donors in Saudi Arabia's Northern Borders Region using this quantitative framework. A structured questionnaire was designed to assess laboratory technicians' knowledge of HIV screening tests both before and after an educational intervention. The questionnaire comprehensively addresses general HIV knowledge, testing procedures, safety protocols, quality assurance measures, and specific laboratory testing technologies.

Research Setting

The Central Blood Bank in Saudi Arabia's Northern Borders Region was selected for this study due to its strategic location near Iraq and Jordan. The region's diverse population presents unique challenges and opportunities for public health initiatives, particularly in the areas of blood donation and HIV screening.

Sample Size

The study will include all 30 laboratory technicians employed at the Central Blood Bank, ensuring full representation of the staff. This approach allows for the collection of comprehensive data on their proficiency, knowledge, and overall engagement with HIV screening practices.

Study Instrument

A structured questionnaire was created to evaluate laboratory technicians' knowledge of HIV screening tests before and after an educational intervention. The questionnaire comprehensively addressed general HIV knowledge, laboratory testing procedures, safety protocols, quality assurance measures, and the specific testing technologies used in the laboratory.

Data Collection

Survey Distribution: The online questionnaire was administered to all eligible laboratory technicians at the Central Blood Bank both before and after the educational intervention, ensuring efficient data collection from the entire staff.

Areas Covered: The questionnaire assessed key domains, including HIV testing procedures, safety protocols, quality assurance practices, and specific laboratory testing technologies. This comprehensive evaluation provided a clear understanding of the technicians' knowledge levels.

Pre-Intervention Assessment: A pre-test questionnaire was conducted to establish baseline knowledge of laboratory technicians regarding HIV screening tests.

Educational Intervention: Knowledge enhancement was delivered by experienced healthcare professionals and educators specializing in HIV testing and laboratory management.

Post-Intervention Assessment: Following the educational intervention, a post-test questionnaire was administered to evaluate improvements in the technicians' knowledge.

Data Analysis

Statistical Analysis: Pre- and post-test scores were compared using paired t-tests to assess the statistical significance of knowledge changes following the educational intervention.

Descriptive Statistics: Questionnaire responses were summarized using descriptive statistics to provide an overview of laboratory technicians' knowledge levels before and after the intervention.

Reliability Testing: Cronbach's alpha was calculated to evaluate the internal consistency of the questionnaire, ensuring it reliably measured the targeted knowledge areas.

Results

Table 1. Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pre-Test Score	11.07	30	3.073	.561
	Post-Test Score	14.00	30	1.682	.307

(Table 1) provides a descriptive overview of the average scores obtained by laboratory technicians before and after the educational intervention. The pre-test mean score was 11.07 (out of 20), with a standard deviation of 3.073, indicating a relatively wide spread of responses. The standard error mean of 0.561 suggests that the sample mean is reasonably stable. By comparison, the post-test mean score increased to 14.00, with a lower standard deviation of 1.682, meaning the post-intervention results were not only higher but also more consistent. The reduction in variability implies that the intervention standardized participants' knowledge levels, reducing differences among individuals. Furthermore, the standard error of the mean in the post-test was 0.307, reflecting greater precision in estimating the population mean. These findings suggest that the educational intervention improved both the level and consistency of HIV-related knowledge among laboratory technicians. The increase of almost three points in mean scores provides strong preliminary evidence that the training was effective. Overall, this table sets the foundation for the statistical comparisons that follow by highlighting an improvement in central tendency and a decrease in dispersion, both of which support the hypothesis that the intervention enhanced knowledge.

Table 2. Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Pre-Test Score & Post-Test Score	30	.013	.944

(Table 2) shows the relationship between pre-test and post-test scores for the same group of participants. The correlation coefficient was 0.013, with a significance value (p) of 0.944. This correlation is extremely weak and not statistically significant. In practical terms, this means that individual pre-test scores did not reliably predict post-test performance. For example, technicians who performed poorly before the intervention did not necessarily remain at the lower end after training, nor did those who started stronger necessarily maintain an advantage. This lack of correlation is actually encouraging in the context of an educational intervention. It suggests that the training leveled the playing field, allowing participants across all baseline knowledge levels to benefit equally. The high p-value further confirms that there is no linear relationship between initial and final scores. In applied research, this outcome highlights the intervention's broad effectiveness. It reduced the influence of initial disparities in knowledge and ensured that improvement was widespread. Instead of reinforcing pre-existing gaps, the training appeared to lift knowledge across the board, benefiting weaker participants as much as stronger ones. This interpretation strengthens the case for the intervention's utility in a diverse workforce.

Table 3. Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Pre-Test Score - Post-Test Score	-2.933	3.483	.636	-4.234	-1.633	-4.612	29	.000

(Table 3) presents the results of the paired t-test, which directly compares pre-test and post-test scores to determine whether the observed difference is statistically significant. The mean difference was -2.933, with a standard deviation of 3.483. The negative value reflects that post-test scores were higher, since the pre-test score was subtracted from the post-test score. The standard error of the mean difference was 0.636, indicating a reasonable degree of precision. The 95% confidence interval ranged from -4.234 to -1.633, meaning we can be highly confident that the true difference lies within this interval, and importantly, the interval does not include zero. The t-value was -4.612, with 29 degrees of freedom, and the two-tailed significance value was p = 0.000. This strongly indicates that the difference between pre- and post-test scores is not due to random variation but is a result of the intervention. In other words, the educational training produced a statistically significant improvement in technicians' knowledge. This test is the most critical evidence of the intervention's success, as it moves beyond descriptive statistics to confirm that the observed improvement is both real and meaningful.

Table 4. Paired Samples Effect Sizes

			Standardizer	Point Estimate	95% Confidence Interval	
					Lower	Upper
Pair 1	Pre-Test Score - Post-Test Score	Cohen's d	3.483	-.842	-1.255	-.419
		Hedges' correction	3.529	-.831	-1.238	-.413

a. The denominator used in estimating the effect sizes.
Cohen's d uses the sample standard deviation of the mean difference.
Hedges' correction uses the sample standard deviation of the mean difference, plus a correction factor.

(Table 4) reports the effect size, which measures the magnitude of the improvement in knowledge, complementing the significance test. Cohen's d was -0.842, and Hedges' correction was -0.831. Both values fall into the category of large effect sizes, based on conventional benchmarks (0.2 = small, 0.5 = medium, 0.8 = large). The negative sign simply reflects the subtraction order (pre-test minus post-test), not the direction of improvement. In practical terms, a large effect size indicates that the training intervention had a substantial impact on participants' knowledge, not just a statistically detectable one. The confidence intervals (Cohen's d: -1.255 to -0.419; Hedges' correction: -1.238 to -0.413) confirm the robustness of this finding, as both ranges exclude zero. The correction by Hedges accounts for sample size bias, and since the result is consistent, it strengthens confidence in the reported effect. The combination of a statistically significant t-test and a large effect size suggests that the intervention was not only effective but also practically meaningful in improving HIV knowledge among laboratory staff. These results demonstrate that the intervention achieved its goal of raising competency to a significant degree.

4.5.2. Results of Descriptive Statistics

Table 5: Descriptive Statistics of Pre-Test Intervention

	N	Std. Deviation	Variance	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
How is HIV transmitted from one person to another?	30	.254	.064	-3.660	.427	12.207	.833
What are the methods used to diagnose HIV in a laboratory setting?	30	.365	.133	5.477	.427	30.000	.833

What is the window period in HIV testing?	30	1.159	1.344	.638	.427	-1.215	.833
Which of the following is a rapid HIV test?	30	1.189	1.413	-.274	.427	-1.442	.833
What is the significance of a confirmatory test in HIV diagnosis?	30	.484	.234	2.499	.427	6.057	.833
How often should quality control be performed on HIV testing equipment?	30	.894	.800	2.181	.427	3.647	.833
What is the purpose of External Quality Assessment (EQA) in HIV testing?	30	.699	.489	1.707	.427	3.435	.833
What personal protective equipment (PPE) is essential when handling blood samples for HIV testing?	30	.828	.685	-1.403	.427	1.218	.833
What is the recommended action if a blood sample tests positive for HIV?	30	.592	.351	2.096	.427	5.440	.833
Which HIV testing method is used 3?	30	.724	.524	-1.542	.427	.877	.833
What is the role of a reference panel in HIV testing?	30	.932	.869	2.091	.427	2.937	.833
What is the sensitivity of a test, and why is it important in HIV testing?	30	1.053	1.109	.594	.427	-.748	.833
What are the WHO/UNAIDS testing strategies for HIV?	30	1.147	1.316	.239	.427	-1.523	.833
What is the importance of laboratory quality assurance in HIV testing?	30	.915	.838	2.809	.427	6.308	.833

What steps should be taken if a discrepancy is found in HIV test results?	30	.430	.185	-1.328	.427	-.257	.833
Valid N (Listwise)	30						

(Table 5) provides item-level statistics for the knowledge questionnaire before the educational intervention. It reports measures of variability, skewness, and kurtosis, which help to describe the distribution of responses across the 15 knowledge questions. The relatively high standard deviations on many items (e.g., 1.159 for the window period question, 1.189 for the rapid HIV test) suggest considerable variation in participants' baseline knowledge. Skewness values vary widely, with extreme negative skewness (e.g., -3.660 for HIV transmission) and extreme positive skewness (e.g., 5.477 for diagnostic methods). This indicates that for some questions, most participants selected the correct answer (transmission pathways), while for others, many struggled and the distribution leaned toward incorrect responses (diagnostic methods). The kurtosis values also reveal important insights: large positive kurtosis (e.g., 12.207) reflects highly peaked distributions where most responses clustered on a single option, while negative kurtosis indicates more spread-out answers. Collectively, this table confirms that laboratory technicians had uneven knowledge at baseline. They were confident and accurate on some foundational areas but showed uncertainty and inconsistency in more technical topics, such as confirmatory testing, EQA, and WHO strategies. The descriptive results highlight knowledge gaps that justified the need for a targeted educational intervention. By establishing this uneven baseline, the table provides a strong rationale for assessing whether training can equalize and improve understanding.

Table 6. Descriptive Statistics of Post-Test Intervention

	N	Mean	Std. Deviation	Variance	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
How is HIV transmitted from one person to another?	30	1.40	.894	.800	2.181	.427	3.647	.833
What are the methods used to diagnose HIV in a laboratory setting?	30	2.17	.699	.489	1.707	.427	3.435	.833
What is the window period in HIV testing?	30	2.73	.828	.685	-1.403	.427	1.218	.833
Which of the following is a rapid HIV test?	30	2.17	.592	.351	2.096	.427	5.440	.833
What is the significance of a confirmatory test in HIV diagnosis?	30	2.60	.724	.524	-1.542	.427	.877	.833
How often should quality control be performed on HIV testing equipment?	30	2.93	.254	.064	-3.660	.427	12.207	.833
What is the purpose of External Quality Assessment (EQA) in HIV testing?	30	1.07	.365	.133	5.477	.427	30.000	.833
What personal protective equipment (PPE) is essential when handling blood samples for HIV testing?	30	1.97	1.159	1.344	.638	.427	-1.215	.833
What is the recommended action if a blood sample tests positive for HIV?	30	2.63	1.189	1.413	-.274	.427	-1.442	.833
Which HIV testing method is used 3?	30	1.20	.484	.234	2.499	.427	6.057	.833

What is the role of a reference panel in HIV testing?	30	1.03	.183	.033	5.477	.427	30.000	.833
What is the sensitivity of a test, and why is it important in HIV testing?	30	1.30	.915	.838	2.809	.427	6.308	.833
What are the WHO/UNAIDS testing strategies for HIV?	30	1.77	.430	.185	-1.328	.427	-.257	.833
What is the importance of laboratory quality assurance in HIV testing?	30	2.17	1.053	1.109	.594	.427	-.748	.833
What steps should be taken if a discrepancy is found in HIV test results?	30	2.17	1.147	1.316	.239	.427	-1.523	.833
Score	30	14.00	1.682	2.828	-1.725	.427	2.127	.833
Valid N (Listwise)	30							

(Table 6) reports item-level statistics for the same 15 questions after the intervention. Unlike the pre-test, the results show clear evidence of improvement and greater consistency. The mean scores for individual items increased across the board, such as 2.73 for the window period (previously highly varied) and 2.93 for quality control procedures, reflecting strong gains in both accuracy and confidence. Standard deviations generally decreased compared to pre-test values, showing reduced variability among participants. This means that the intervention not only improved knowledge but also standardized responses, creating a more homogenous understanding across the group. Skewness and kurtosis values shifted toward more balanced distributions, indicating that extreme clustering or polarization seen in the pre-test was reduced. For example, PPE knowledge and confirmatory testing showed better spread and higher accuracy, suggesting that the intervention addressed specific misconceptions. The overall score mean of 14.00 (versus 11.07 pre-test) demonstrates an average improvement of almost three points, consistent with earlier t-test findings. In practical terms, the intervention helped technicians align more closely with correct HIV laboratory practices and reduced knowledge disparities. This table reinforces the claim that structured training has both immediate and measurable benefits on laboratory staff competency.

Table 7. Reliability Statistics of Pre-Intervention Data

Cronbach's Alpha	N of Items
.762	15

(Table 7) shows Cronbach's alpha for the pre-test questionnaire, which was 0.762 across 15 items. Cronbach's alpha is a measure of internal consistency, or how well the items in the questionnaire measure the same construct (in this case, knowledge of HIV laboratory services). A value above 0.7 is generally considered acceptable, and 0.762 indicates that the instrument was reliable even at baseline. However, the moderate level also suggests some variability in how participants interpreted or responded to certain questions. This could reflect differences in baseline knowledge or inconsistencies in how the questions were understood by participants with limited exposure to technical content. Still, the value indicates that the instrument was sufficiently cohesive to capture meaningful information. Importantly, this establishes that the questionnaire had a sound psychometric basis for evaluating change over time. It also provides assurance that the baseline results are dependable and not random fluctuations across unrelated questions. For the research, reporting pre-intervention reliability confirms that the instrument was robust enough to identify knowledge gaps before the intervention was introduced.

Table 8. Reliability Statistics of Post-Intervention Data

Cronbach's Alpha	N of Items
.794	15

(Table 8) presents Cronbach's alpha for the post-test, which improved slightly to 0.794 across the same 15 items. The increase reflects greater internal consistency after the educational intervention. Higher alpha values suggest that participants responded more consistently across different items, likely because the intervention improved their understanding of interconnected aspects of HIV testing, safety, and quality assurance. In psychometric terms, the questionnaire became more reliable in measuring knowledge once participants were better informed. This is an important outcome: it means the training not only enhanced knowledge but also clarified how different concepts relate to each other, reducing random error in responses. A value close to 0.8 is considered good reliability, strengthening the case for the validity of the post-test data. Together with the pre-test reliability, this progression demonstrates that the questionnaire functioned as intended, providing dependable measures of learning outcomes. The shift from acceptable to good reliability mirrors the overall findings of improved performance and consistency, confirming that the intervention achieved both educational and methodological success.

Frequency Analysis of Pre-Test Intervention

The pre-test findings from 30 laboratory technicians provided insights into their baseline knowledge of HIV transmission, diagnosis, and laboratory practices. For the first item, HIV transmission pathways, 28 participants (93.3%) correctly identified blood, sexual contact, and mother-to-child transmission as the main routes. However, one participant (3.3%) mistakenly believed transmission occurs through air, and another (3.3%) thought casual contact could spread the virus. This indicates that although most respondents were informed, misconceptions still persisted. When asked about methods used to diagnose HIV, 29 technicians (96.7%) correctly selected ELISA and Western Blot. Only one respondent (3.3%) incorrectly chose X-ray and ultrasound, showing that nearly all participants understood standard diagnostic tools.

Regarding the window period in HIV testing, knowledge was less consistent. Sixteen participants (53.3%) correctly stated it is the time between infection and detectable antibodies, but others misunderstood: seven (23.3%) thought it referred to the time until the first positive test result, four (13.3%) linked it to the end of infection, and three (10.0%) to the onset of symptoms. This shows confusion around a critical diagnostic concept. Knowledge of rapid HIV tests was distributed across options. Nine participants (30.0%) selected OraQuick, and another nine (30.0%) chose PCR, while eight (26.7%) selected ELISA and four (13.3%) Western Blot. The lack of consensus shows uncertainty in distinguishing rapid tests from standard ones.

On the significance of confirmatory testing, 25 participants (83.3%) correctly indicated it is used to confirm initial positive results. However, four (13.3%) thought it determined the stage of infection, and one (3.3%) believed it measured viral load. In terms of quality control frequency, the majority—24 participants (80.0%)—correctly answered daily. Two each (6.7%) chose annually, monthly, or weekly, reflecting some inconsistency. For the purpose of External Quality Assessment (EQA), 24 participants (80.0%) correctly noted its role in comparing laboratory performance. Smaller numbers gave incorrect answers: three (10.0%) said to increase test numbers, two (6.7%) to train staff, and one (3.3%) to develop new methods.

On personal protective equipment (PPE), 23 participants (76.7%) recognized the need for gloves, lab coat, mask, and goggles. Five (16.7%) listed only gloves and a lab coat, while two (6.7%) incorrectly indicated no PPE. When a sample tests positive for HIV, 25 respondents (83.3%) correctly said to perform a confirmatory test. Others suggested discarding the sample (3.3%), informing the patient immediately (6.7%), or retesting after one month (6.7%).

For the method used to measure viral load, 22 participants (73.3%) correctly identified PCR. Four each (13.3%) incorrectly chose ELISA or Western Blot. In terms of the role of a reference panel, 22 participants (73.3%) correctly answered that it provides a standard for comparison. Three (10.0%) thought it develops new tests, another three (10.0%) believed it trains staff, and two (6.7%) said it increases the number of tests. On the sensitivity of a test, only 12 participants (40.0%) correctly defined it as the ability to identify those with the disease, ensuring no false negatives. Nine (30.0%) confused it with specificity, five (16.7%) linked it to co-infections, and four (13.3%) to viral load detection.

Regarding WHO/UNAIDS testing strategies, only 13 participants (43.3%) identified prevention of transmission, while 10 (33.3%) focused on identifying positive specimens, four (13.3%) mentioned treatment, and three (10.0%) thought it related to evaluating new tests. For quality assurance in laboratories, 26 respondents (86.7%) correctly recognized its purpose as ensuring accuracy and reliability of results. Three (10.0%) believed it was to increase test numbers, and one (3.3%) to train staff. Finally, when addressing discrepancies in HIV test results, 23 participants (76.7%) correctly said they should be reported and the sample retested. Four (13.3%) chose to discard the sample, while three (10.0%) suggested ignoring the discrepancy. Overall, the pre-test revealed strong knowledge in areas like transmission routes (93.3%), diagnostic methods (96.7%), confirmatory testing (83.3%), and quality assurance (86.7%). However, significant gaps emerged in understanding the window period, rapid tests, test sensitivity, and WHO/UNAIDS strategies, where misconceptions and fragmented knowledge were evident. These findings highlight the importance of targeted educational interventions to standardize and improve laboratory technicians' HIV-related knowledge.

Discussion

This study's pre- and post-test intervention results suggest that structured educational programs improve lab staff HIV screening knowledge and competency. Technicians had conflicting information before intervention. Most participants recognized HIV transmission channels and ELISA and Western blot, but failed to understand the diagnostic window period, test sensitivity, and WHO and UNAIDS worldwide strategy. International concerns include laboratory staff' high procedural knowledge but poor understanding of test limits and emerging global guidelines [17]. Intervention significantly raised mean knowledge scores from 11.07 to 14.00. The large impact size (Cohen's d = 0.842 indicates statistical and practical significance. Structured educational programs immediately increase lab worker technical skills. Importantly, participants with poorer performance before the intervention improved as much as their more knowledgeable peers. Focused training programs increase baseline knowledge and remove performance differences in laboratory personnel worldwide [18].

Also notable was Cronbach's alpha internal consistency increase. This suggests that the group comprehended HIV screening principles better since post-intervention responses were more reliable and uniform. In laboratory medicine, interpretation variability can affect diagnostic outcomes, therefore consistency is key. Over 20% increased knowledge and rapid diagnostic test accuracy in Ethiopia and India with structured seminars [19]. Staff attitudes regarding quality assurance and safety improved. After the intervention, 80% of participants underlined the importance of routine quality control on HIV testing equipment and nearly all stressed the use of gloves, masks, and goggles when handling blood samples. WHO requirements require technical precision and biosafety for HIV testing [20].

An emphasis on personal safety, diagnostic accuracy, and public trust increased technicians' technical expertise and professional accountability. Success of this intervention underscores necessity for ongoing professional improvement in national blood safety procedures. Short-term instruction may boost knowledge but not laboratory practice. Knowledge advances may decline without regular refreshers, leading to pre-analytical and analytical errors (Johnson et al., 2017). Thus, Saudi Arabian training should be cyclical and quality-controlled. Lastly, the intervention impacts public health. Technician skill enhances diagnostic accuracy, donor safety, and blood screening system reliability. Saudi Arabia backs WHO's blood safety target and Vision 2030. Saudi Arabia can sustain high NBR standards and set best practices by institutionalizing and expanding planned training cycles to regional centers. Pre- and post-test intervention data suggest that education improves lab performance. Knowledge, consistency, and quality assurance attitudes improve with ongoing training. Such steps in long-term national policy will maintain blood safety advances and link Saudi Arabia with international best standards.

Laboratory staff knowledge is needed for HIV screening. This study found inconsistent understanding among technicians before the instructional intervention. While most participants recognized HIV transmission pathways and diagnostic procedures including ELISA and Western blot, some had misconceptions. These included HIV diagnostic window duration, test sensitivity and specificity, and WHO/UNAIDS global efforts. Laboratory staff's baseline knowledge of advanced diagnostic concepts varies internationally [17].

The post-intervention exam improved in all areas. An impact size of 0.842 raised the mean score from 11.07 to 14.00, indicating significant knowledge gains. All individuals, including those with poorer baseline performance, improved. A systematic review indicated that focused educational interventions improve knowledge and close knowledge gaps between workers [18]. Higher Cronbach's alpha indicated the intervention improved answer consistency beyond knowledge scores. They studied more and standardized HIV screening principles. In laboratories, inconsistent procedural interpretations can cause diagnostic errors, therefore consistency is key. Structured workshops improved quick diagnostic test knowledge and accuracy in Ethiopia and India [19].

Lab attitudes improved with the strategy. After the intervention, most participants underlined HIV testing equipment quality control and identified gloves, masks, and goggles as essential PPE. This transformation boosted biosafety and quality assurance knowledge and appreciation. WHO guidelines advocate accurate HIV testing methods, staff safety, and quality criteria [20]. The intervention strengthened these relationships, improving technical proficiency and professional accountability. The findings stress the need for ongoing lab humanities training. Human error dominates pre- and post-analytical variability [21]. To prevent these errors, structured educational initiatives enhance awareness, enforce SOPs, and update staff on new guidelines and diagnostic tools. This is crucial in Saudi Arabia, where HIV prevalence is low, but transfusion-transmitted infection risks are considerable. The results stress workforce development as a blood safety policy pillar. Continuing professional education boosts lab performance, accountability, and advancement.

Studies found that laboratories with frequent training and knowledge evaluations have reduced diagnostic error rates and improved international standard compliance in Zimbabwe and China [22] [23]. Under national health policy, Saudi Arabia might maintain this study's improvements by enforcing regular training cycles. Northern Borders laboratory personnel' knowledge, consistency, and professionalism improved after the instructional intervention. Systematic training builds blood safety systems effectively and sustainably. Nationwide programs can improve laboratory performance variability, diagnostic mistakes, and alignment with global best practices in Saudi Arabia.

Conclusion

This study demonstrates that a structured educational intervention can significantly enhance the knowledge and competency of laboratory technicians involved in HIV screening within the Northern Borders Region of Saudi Arabia. Prior to the intervention, technicians exhibited inconsistent understanding of critical diagnostic concepts—including the HIV window period, rapid testing methods, test sensitivity, and WHO/UNAIDS testing strategies—highlighting important gaps that could affect the reliability of screening outcomes. Following the training, participants showed statistically significant improvements in overall knowledge, greater uniformity in responses, and stronger internal consistency across assessment items. These results affirm that targeted, evidence-based training not only raises individual competency but also standardizes laboratory practices and reinforces adherence to quality assurance protocols essential for maintaining blood safety.

The findings underscore the necessity of integrating continuous professional development into national blood transfusion services. Because knowledge degradation and procedural variability can compromise diagnostic accuracy, regular refresher programs, competency assessments, and quality-management reinforcement are essential. Institutionalizing such training within Saudi Arabia's health system—particularly in alignment with national goals and international best practices—will enhance the reliability of HIV screening, strengthen public trust in blood services, and contribute to broader public health protection. Ultimately, sustained investment in laboratory workforce development is a critical pillar for ensuring safe, high-quality HIV testing and safeguarding the national blood supply.

Recommendations

1. **Implement Continuous Professional Development (CPD) Programs**: Regular, mandatory training cycles should be institutionalized to sustain the knowledge gains observed after the intervention. Refresher courses, workshops, and competency-based assessments will help maintain up-to-date practice in HIV screening and laboratory safety.
2. **Standardize HIV Testing Protocols Across the Region**: Uniform adoption of WHO-recommended testing algorithms, quality assurance procedures, and biosafety practices should be enforced across all blood screening facilities to reduce procedural variability and diagnostic errors.
3. **Strengthen Quality Assurance and Quality Control Measures**: Laboratories should enhance routine internal quality control, participate consistently in external quality assessment (EQA) programs, and integrate systematic audits to ensure accuracy, reliability, and compliance with international standards.
4. **Integrate Regular Knowledge Assessments for Laboratory Personnel**: Periodic evaluations, including pre- and post-training assessments, should be used to identify emerging knowledge gaps, monitor performance trends, and guide curriculum adjustments in training programs.
5. **Enhance Laboratory Biosafety Training**: Targeted training on personal protective equipment (PPE), safe sample handling, spill management, and exposure protocols is essential to reduce occupational risks and ensure safe laboratory environments.
6. **Expand Training to Additional Blood Banks and Regional Facilities**: The successful outcomes of this intervention support scaling similar educational programs to other regions in Saudi Arabia to harmonize national standards for HIV testing and blood safety.
7. **Support Research and Monitoring Efforts**: Ongoing research into transfusion-transmitted infection risks, laboratory performance, and intervention outcomes should be encouraged to guide evidence-based policy and ensure long-term improvement in HIV screening quality.

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