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Assessment of Infection Control Practices and Biosafety Compliance Among Medical Laboratory Professionals: A Comparative Study of Public and Private Sectors

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A B S T R A C T

Background: Medical laboratories function as highly critical environments where personnel are routinely exposed to severe biological hazards. Consequently, strict adherence to biosafety protocols is a fundamental requirement to mitigate the risk of laboratory-acquired infections.

Aim: To thoroughly dissect the occupational safety climate within medical laboratories.

Methods: Employing a cross-sectional descriptive-analytical design, the study surveyed a purposive sample of 100 laboratory professionals operating in the two municipalities of Msallata and Al-Khums, Libya. Data were gathered using a validated, 24-item structured questionnaire assessing hygiene practices, personal protective equipment (PPE) usage, waste management, and administrative support.

Results: The findings indicate robust compliance with foundational hygiene protocols, specifically hand hygiene (76%) and standard glove usage (88%). Conversely, a critical vulnerability was identified regarding comprehensive protective measures, with only 29% of personnel consistently utilizing advanced personal protective equipment, such as respiratory masks and ocular protection. Systemic deficiencies in continuous education were prominent, as 57% of respondents reported a lack of periodic training updates. Consequently, only 35% of the workforce perceived their working environment as fully secure.

Conclusion: While baseline hygiene practices are commendably maintained, the transition to a comprehensive safety culture is impeded by selective PPE compliance and inconsistent administrative support. Bridging this gap requires the institutionalization of mandatory, continuous biosafety training and the standardization of protective resource allocation across both public and private sectors.

Keywords: *Infection, Biosafety, Laboratories, Occupational, Training*.

1. Introduction

Background

The fundamental architecture of modern healthcare relies heavily on the diagnostic and analytical output of medical laboratories [1]. These environments are at the forefront of epidemiological surveillance, clinical diagnosis, and therapeutic monitoring [2]. However, the intrinsic nature of laboratory work demands the daily handling of virulent biological specimens, thereby creating an occupational landscape fraught with severe biological hazards [3]. Personnel working in these settings face continuous exposure to bloodborne pathogens, aerosolized infectious agents, and various microbiological threats [4].

Effective infection control and biosafety compliance in medical laboratories are critical to mitigating occupational hazards and preventing the transmission of pathogenic agents within healthcare settings. Previous local studies emphasize that awareness levels regarding infection control directly influence safety behaviors and the mitigation of microbial contamination risks in medical environments. Building upon this evidence, it is essential to systematically evaluate how biosafety compliance is maintained among laboratory professionals across different healthcare environments. This study aims to bridge the gap between standard safety protocols and daily laboratory practices by comparing

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compliance levels between public and private sectors, thereby identifying institutional factors that influence occupational safety performance [5].

The World Health Organization (WHO) and the Centers for Disease Control and Prevention (CDC) systematically classify clinical laboratories as high-risk environments [6]. Historically, the transmission of pathogens within these confines has occurred via percutaneous inoculations (such as needle stick injuries), direct mucocutaneous contact with contaminated surfaces, and the inhalation of bio-aerosols generated during routine procedures like centrifugation or pipetting [7]. To combat these vectors of transmission, regulatory bodies such as the Occupational Safety and Health Administration (OSHA) have developed stringent Bloodborne Pathogens Standards, emphasizing that rigorous adherence to physical and procedural barriers can nearly eliminate the incidence of laboratory-acquired infections (LAIs) [8].

Despite the existence of universally accepted guidelines, translating these theoretical frameworks into daily operational compliance remains a persistent challenge in many healthcare systems, particularly in developing regions [9]. Ineffective sterilization techniques and unintentional exposure through microscopic skin abrasions remain primary causes of occupational illness [10]. The implementation of robust infection control relies on a multi-tiered approach: meticulous hand hygiene, regular environmental sanitation, the consistent application of appropriate chemical disinfectants, and the unfailing use of Personal Protective Equipment (PPE) [11].

Furthermore, the lifecycle of a biological specimen does not end at analysis; safe disposal of biological waste via incineration or high-pressure steam sterilization is an equally critical component of the biosafety chain [12]. Yet, physical resources alone are insufficient. Human behaviour is the ultimate determinant of safety [13]. Evidence heavily suggests that the frequency and quality of professional training are directly proportional to the risk awareness and compliance levels of the staff [14].

In the context of the Libyan healthcare system, specifically within the two municipalities of Msallata and Al-Khums, preliminary field observations have suggested notable variances in the implementation of these global standards [15]. These disparities are often influenced by the institutional setting—specifically, the operational and financial differences between public (government-funded) and private laboratories [16]. The core problem this research addresses is identifying the exact extent to which international protocols are effectively applied locally, isolating the socio-environmental factors influencing human adherence, and comparing the operational efficacy of safety climates across the public and private sectors [17].

Foundational Principles of Laboratory Biosafety

The discipline of infection control within biological laboratories is an extensive matrix of engineering controls, administrative policies, and individual work practices [1]. Its primary objective is the containment of biohazards to prevent cross-contamination of specimens and, more critically, to protect personnel from exposure to infectious agents [3]. Pathogenic transmission in these settings is insidious, often occurring through micro-droplets or fomites that are invisible to the naked eye [7].

Standard precautions, as delineated by the WHO and CDC, assert that all biological samples must be treated as potentially highly infectious [2]. This principle mandates a foundational suite of practices. Foremost is sterilization, which requires that all reusable instruments undergo rigorous chemical or thermal eradication of microbial life [4]. Alongside sterilization is the critical requirement for Personal Protective Equipment (PPE), serving as the primary barrier between the host and the pathogen [8]. Finally, the handling of post-analytical materials requires strict biological waste management protocols to ensure environmental safety beyond the laboratory walls [5].

The Impact of Continuous Professional Education

The academic consensus strongly indicates that the provision of physical safety equipment is futile without the behavioural modification achieved through continuous training [13]. Robinson et al. provided a comprehensive comparative analysis of personnel subjected to intensive, recurring safety education versus those receiving only onboarding orientation [14]. Their data unequivocally demonstrated that recurring training cycles result in significantly higher compliance rates and lower incidences of accidental exposure [14].

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Furthermore, as the nature of biological threats evolves—evidenced by recent global pandemics—safety protocols must adapt [11]. Regular updates and seminars not only reinforce routine implementation but drastically enhance emergency response capabilities [14]. Educational strategies are thus not an administrative luxury but a core operational requirement necessary to maintain high biosafety standards [18]. Jones et al. (2020) further corroborated this, emphasizing that biosafety training positively influences behavioral improvements across all hierarchies of laboratory staff, mitigating human error [19].

Sectoral Disparities: Public vs. Private Environments

Institutional frameworks heavily influence the degree to which safety protocols are realized in practice [16]. A critical study by Robinson et al. examined 200 medical laboratories, focusing on PPE compliance and resource availability across different healthcare sectors [16]. The findings highlighted that private laboratories consistently exhibit higher compliance metrics [16]. This is generally attributed to more agile management structures, better funding allocation for continuous equipment procurement, and stricter internal auditing [16].

Conversely, public sector laboratories frequently grapple with bureaucratic delays, resource scarcity, and insufficient funding for continuous educational programs [16]. This structural disparity results in observable deficits in PPE adherence and protocol execution [15]. Researchers argue that to standardize occupational health, there is an urgent imperative to restructure resource allocation and institutionalize training within public healthcare facilities [17].

Variability in the Implementation of Preventive Measures

While knowledge of basic hygiene is generally widespread, practical execution remains paradoxically inconsistent. Martinez et al.explored the variability in compliance regarding fundamental practices such as hand sanitization and surface disinfection [11]. While hand hygiene is universally acknowledged as the cornerstone of infection prevention, their research indicated that the utilization of secondary and tertiary barriers—such as ocular protection and particulate respirators—is frequently neglected due to discomfort or perceived inconvenience [11].

Moreover, it was identified that shortages of high-grade chemical disinfectants and a general failure [4, 17]. To counter this, literature strongly advocates for a multi-dimensional approach integrating systemic education, reliable resource supply chains, and active supervisory monitoring to foster a resilient culture of safety [9, 18].

Research Questions and Hypotheses

The investigation is driven by the fundamental question of whether the current educational and administrative frameworks are sufficient to cultivate a proactive safety culture. To operationalize this inquiry, the research tests two primary hypotheses:

Hypothesis I: There is a noticeable positive relationship between the frequency of a laboratory worker's participation in updated infection control training and their adherence to comprehensive preventive measures.

Hypothesis II: There are observable differences in the perceived effectiveness and execution of infection control protocols based on the organizational framework of the workplace, specifically between public and private sectors.

By testing these hypotheses, the study aims to provide local health authorities with the empirical backing necessary to overhaul and standardize training programs, thereby complying with international benchmarks.

Aims of the Study

To thoroughly dissect the occupational safety climate, this study pursues the following specific objectives:

To quantitatively assess the baseline awareness and practical commitment to infection control measures among active laboratory personnel.

To identify operational gaps and inconsistencies in routine procedures, particularly concerning hand hygiene, surface sterilization, and comprehensive PPE utilization.

To synthesize the empirical data into actionable, evidence-based recommendations to assist healthcare administrators in fortifying institutional safety protocols.

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2. Methodology

Study Design and Methodology

To comprehensively address the research objectives, a cross-sectional, descriptive-analytical research design was adopted. This methodological approach is highly effective in the occupational health sciences for capturing the prevalence of specific behaviours and attitudes within a defined professional cohort at a specific point in time. It allows for the precise quantification of compliance rates and facilitates the comparison of variables across different demographic and institutional subsets.

Study Setting and Target Population

The geographical scope of the investigation encompassed the two municipalities Msallata and Al-Khums in Libya. Data collection was systematically executed over a four-week period, from November 1 to December 1, 2024. The target population included clinical laboratory specialists, medical technologists, phlebotomists, and laboratory supervisors. This demographic was intentionally selected as they constitute the frontline workforce, experiencing the highest daily frequency of direct exposure to potentially infectious clinical specimens.

Sampling Strategy and Participant Profile

A purposive, randomized sampling technique was employed to recruit 100 participants. To ensure the findings accurately reflected the broader occupational landscape, the sample was stratified to include representatives from purely government-run facilities, purely private institutions, and individuals operating in mixed capacities (working in both sectors). The inclusion criteria required participants to have minimum duration of one year of active laboratory experience minimum duration of active laboratory experience to ensure they had sufficient exposure to the facility's operational culture.

Research Instrumentation

The primary instrument for data acquisition was a structured, electronic 24-item questionnaire. Recognizing the importance of instrument reliability, the questionnaire was subjected to peer review by a a panel of infection control experts and senior epidemiologistsat Elmergib Universty panel of infection control experts and senior epidemiologists to establish content and face validity. The survey was divided into distinct thematic axes: Demographic and professional variables (age, gender, experience, sector). Adherence to personal hygiene and PPE protocols. Execution of environmental sterilization and bio-waste management. Accessibility to institutional training and perception of administrative support. Subjective evaluation of the workplace safety climate. Responses were captured using a combination of binary responses and standard Liker scales (e.g., Always, Sometimes, Rarely, Never) to gauge the frequency of behaviors.

Data Collection, Ethics, and Statistical Analysis

The distribution of the electronic surveys occurred directly at the respective clinical sites to maximize the response rate. Strict ethical protocols were adhered to in accordance with standard epidemiological research guidelines. Informed consent was obtained from all respondents, with explicit assurances regarding the anonymity and confidentiality of their data, emphasizing that the findings would be utilized exclusively for academic and safety improvement purposes.

Data processing and statistical evaluation were conducted utilizing descriptive statistical methods. The raw data were transformed into frequencies and valid percentages, subsequently modelled into graphical representations (bar charts and pie charts) to visually map the distribution of compliance metrics and identify statistically notable trends.

3. Results

The results of the questioners were represented graphically in 24 charts; where the empirical data extracted from the 100 respondents yield a highly detailed operational profile of current biosafety practices. The findings are categorized chronologically from demographic distributions to specific technical competencies.

Demographic and Professional Profile

The demographic and the professional profile of the participants were presented in figures (1- 4) four figures (1, 2, 3 and 4) as follow; where the socio-demographic variables of the cohort indicate a highly balanced and relatively young workforce. Analysis of gender distribution (As

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exposed in Figure 1) reveals near parity, with females comprising 51% of the sample and males 49%. The age distribution (Figure 2) illustrates a workforce dominated by early-career professionals; the vast majority (59%) falls within the 20–30 year age bracket, whereas senior personnel over the age of 50 represent a marginal 3% of the cohort. This demographic reality is mirrored in the professional experience data (As revealed in Figure 3), which shows that 60% of the respondents possess 10 years of experience or less. Regarding the structural distribution of the workforce across the healthcare sectors (As shown in Figure 4), 40% of the personnel operate exclusively within private laboratories; another 40% split their professional time between public and private sectors, while a smaller subset of 20% is employed solely within public government facilities.

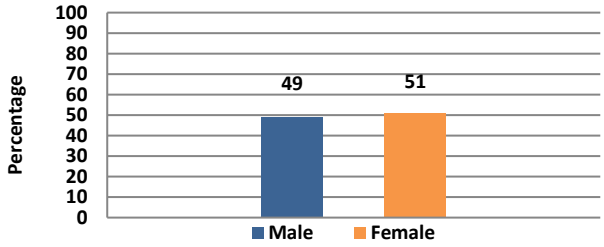


Figure 1.Distribution of sample according to gender

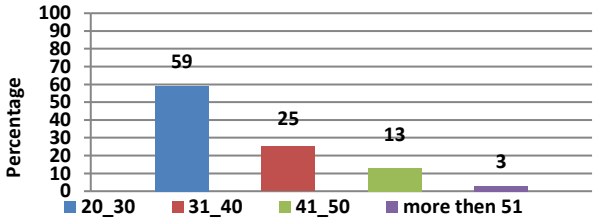


Figure 2. Distribution of sample according to age

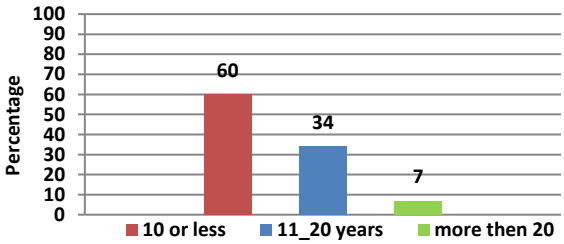


Figure 3. Distribution of sample according to years of work

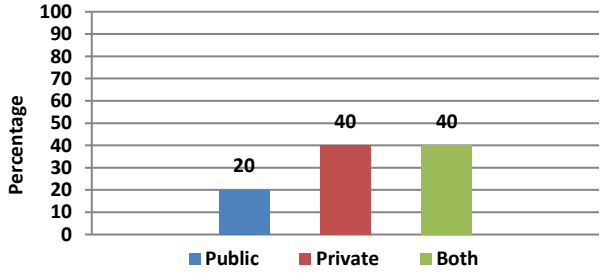


Figure 4. Distribution of sample according to workplaces

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Adherence to Personal Protective Practices and Hygiene

The adherence to personal protective practices and the hygiene were showed in in five figures (5- 9) five figures (5, 6, 7, 8 and 9) as follow; where the data reflects an encouragingly high baseline of individual discipline regarding fundamental hygiene. As illustrated in Figure 5, a significant majority of the workforce (76%) report that they "always" execute standard hand washing and sanitization protocols both prior to and immediately following the handling of clinical samples. Similarly, compliance regarding the primary physical barrier—glove usage—is remarkably high. Figure 6 demonstrates that 88% of personnel consistently wear gloves during laboratory operations. Furthermore, an overwhelming 98% of respondents exhibit an acute awareness of barrier integrity, stating they immediately replace their gloves upon detecting any tears or punctures (As exposed in Figure 7).

However, the empirical data reveals a sharp decline in compliance when progressing from basic to comprehensive Personal Protective Equipment. Figure 8 exposes a critical vulnerability: merely 29% of the cohorts “always” don the complete mandated protective ensemble (which includes laboratory coats, respiratory masks, and protective eyewear). The majority of participants The majority (64%) admit to utilizing the full kit only "sometimes." Despite this selective compliance with advanced PPE, the response to acute contamination remains highly professional; 100% of the prticaipants 100% of the staff reported that they immediately change their laboratory coat if it becomes visibly contaminated with biological fluids (As shown in Figure 9).

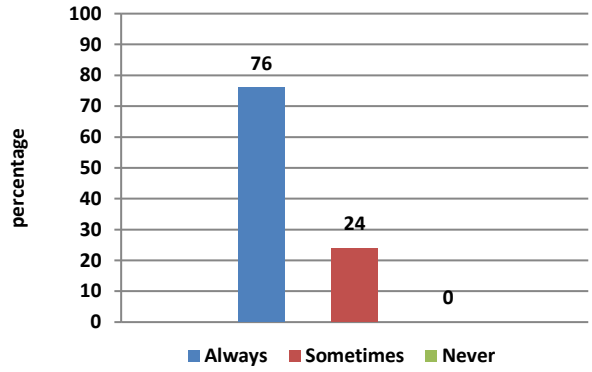


Figure 5. Distribution of participants based on their commitment to hand washing and using sanitizers before and after handling laboratory samples.

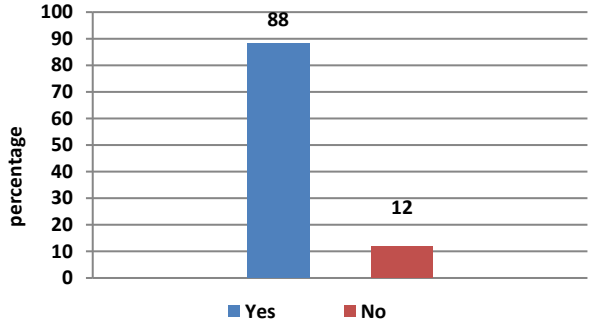


Figure 6. Distribution of responses regarding gloves usage during work.

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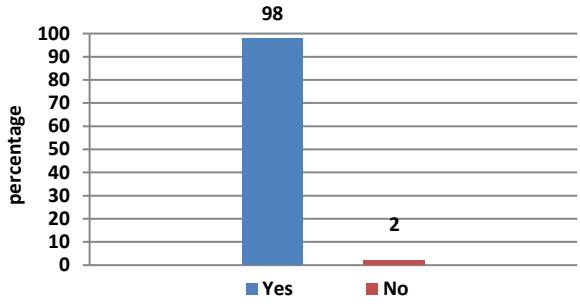


Figure 7. Distribution of responses regarding changing torn gloves

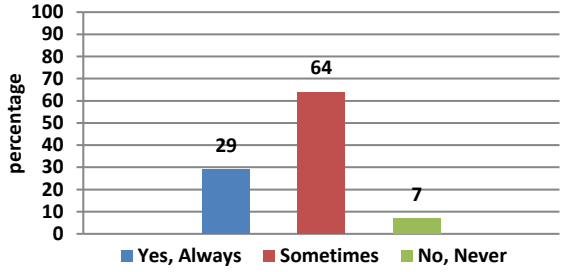


Figure 8. Frequency of wearing protective cloths among participants.

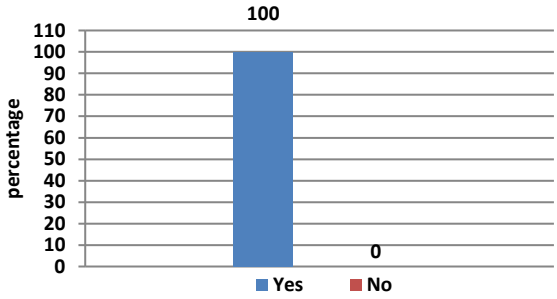


Figure 9. Distribution of participants regarding changing lab coats when visibly contaminated.Environmental Disinfection and Biological Waste Management

Figures 10-14 illustrated the environmental disinfection and the biological waste management of the participants in this study as follow; maintaining the sterility of the analytical environment is clearly prioritized by the workforce. The survey data (As presented in Figure 10) confirms that 96% of participants routinely clean and chemically disinfect their work surfaces before commencing and after concluding their shifts.

The management of hazardous outputs also shows strong compliance metrics. About 85% of respondents assert that biological and infectious waste is "always" disposed of through safe, standardized protocols, See Figure 11. According to Figure 11, 85% of respondents assert that biological and infectious waste is "always" disposed of through safe, standardized protocols. Accessibility to basic sanitation infrastructure is nearly universal, with 99% of workers confirming that hand-washing sinks and chemical sanitizer stations are easily accessible within their immediate work areas (As appeared in Figure 12). Despite these positive indicators, there is notable inconsistency regarding the maintenance of analytical machinery. While 62% of the staff confirm that laboratory equipment is sterilized on a strict, scheduled basis, a concerning 38%

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noted that such rigorous equipment maintenance only occurs "sometimes" (As shown in Figure 13), pointing toward potential systemic lapses in operational oversight.

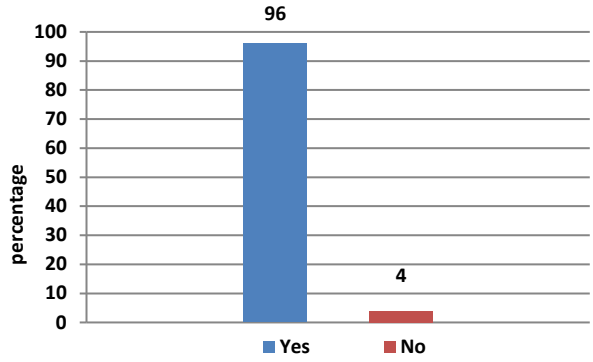


Figure 10. Distribution of participants based on their cleaning and disinfecting of surfaces before and after laboratory work.

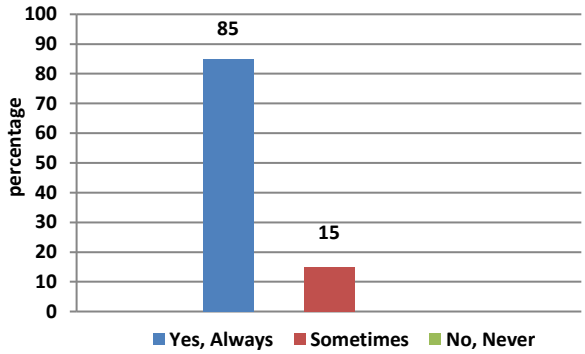


Figure 11. Distribution of participants according to the proper and safe disposal of biological waste.

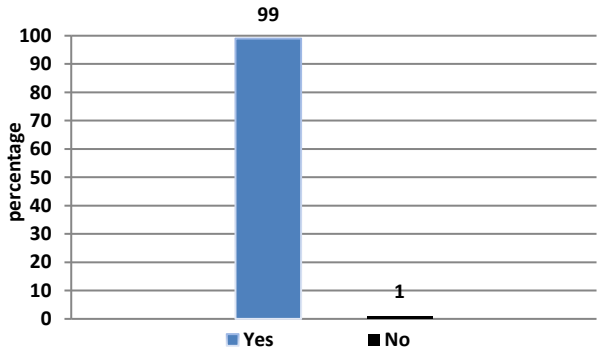


Figure 12. Distribution of participants based on the availability of hand washing and disinfectant stations in accessible locations.

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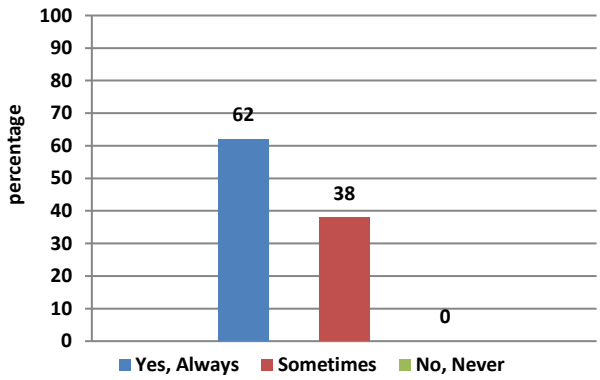


Figure 13. Distribution of participants according to regular cleaning and sterilization of equipment and tools based on scheduled times.

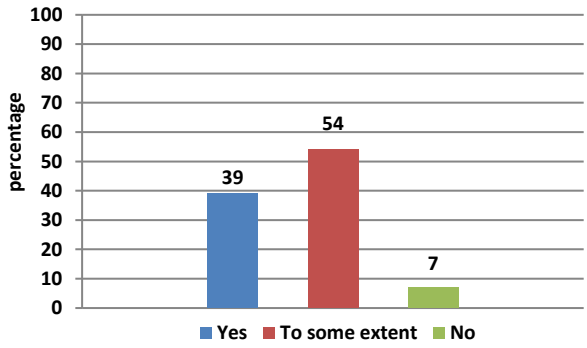


Figure 14. Distribution of participants' perception of laboratory safety in terms of infection control.

Perception of the Safety Climate and Management Support

The perception of the safety climate and the management Support are shown in in eleven figures 14-24 11 figures 14- as follow; A central component of occupational health is the psychological safety and confidence of the staff. The findings here reveal a moderate-to-low level of institutional confidence. As depicted in Figure 14, only 35% of the laboratory professionals perceive their working environment as completely "safe," with the majority (54%) classifying it merely as "somewhat safe." This subjective assessment aligns precisely with overall satisfaction metrics (As presented in Figure 23), where 70% of respondents expressed being only "somewhat" satisfied with the prevailing infection control standards.

When evaluating administrative frameworks, the existence of protocols is clear, but trust in management execution is fragmented. An encouraging 91% of workers acknowledge the existence of clear, documented procedures for managing accidental exposure to infectious agents (As shown in Figure 17). Yet, a disparity arises in post-incident expectations; only 71% of personnel anticipate receiving full institutional and management support following a biological accident (As appeared in Figure 18). Communication pathways also exhibit slight fractures: while 52% feel they can easily communicate safety concerns to their superiors, 13% report a complete absence of effective channels for safety feedback (As exposed in Figure 22).

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Educational Deficits and Efficacy of Protocols

The most profound systemic weakness identified in the study pertains to the continuity of professional education. The data establishes a clear "training paradox." While a majority (66%) felt that the initial safety training provided upon their employment was adequate (As appeared in Figure 15), the system fails in continuous professional development. Figure 21 highlights a major operational deficit: 57% of laboratory workers do not receive any regular, periodic training updates regarding evolving biological risks or new safety techniques. This educational stagnation directly impacts the staff's self-assessed competency. Only 51% are fully confident that they possess sufficient knowledge of modern infection risks, whereas 47% concede they comprehend these risks only "to a certain extent" (As shown in Figure 16).

Consequently, the workforce views the current institutional measures with a degree of skepticism. Only 46% evaluate their laboratory's current infection control procedures as "very effective" (As exposed in Figure 19). There is a resounding consensus on the necessity for systemic evolution; 40% perceive a "great need" to overhaul and improve current safety protocols, and another 47% see a need for improvement "to a certain extent" (As appeared in Figure 20). Notably, an overwhelming 94% of the cohort strongly agree that any financial expenditures directed toward upgrading infection control and biosafety are completely justified investments (As shown in Figure 24).

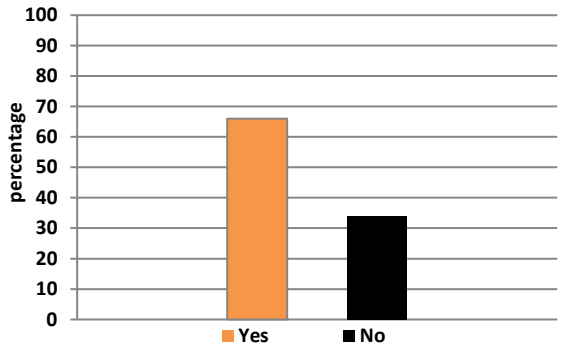


Figure 15. Distribution of participants regarding whether they received adequate training on infection control procedures.

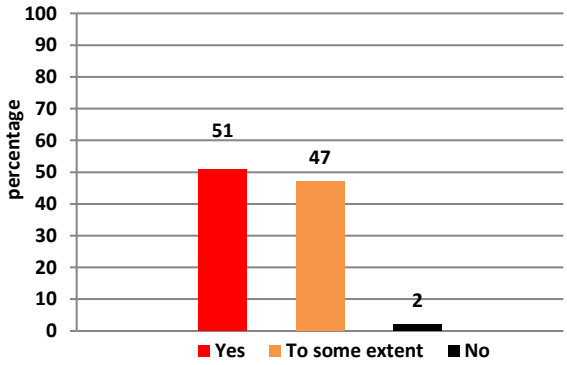


Figure 16. Distribution of participants based on their knowledge of infection risks in the laboratory.

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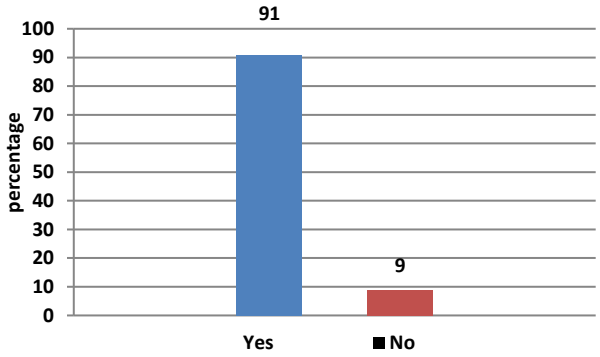


Figure 17. Distribution of participants according to the clarity of procedures in case of exposure to infectious samples.

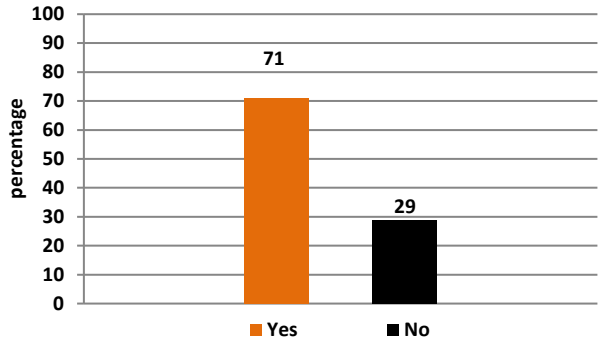


Figure 18. Distribution of participants regarding expectations of receiving management support in the event of an incident.

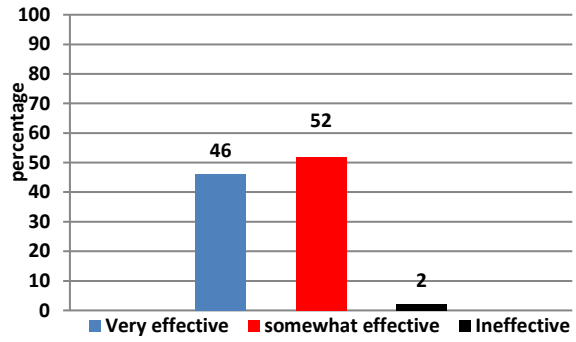


Figure 19. Distribution of participants' evaluation of the effectiveness of infection control procedures in the laboratory.

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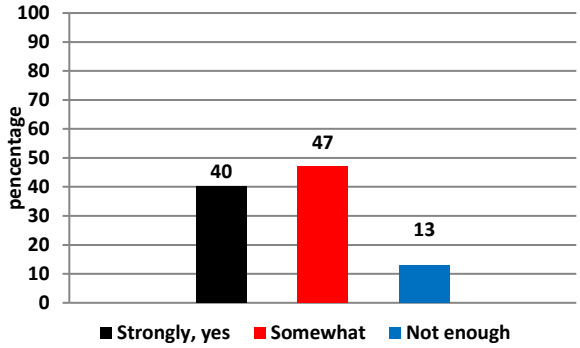


Figure 20. Distribution of participants' opinions on the need to improve infection control procedures.

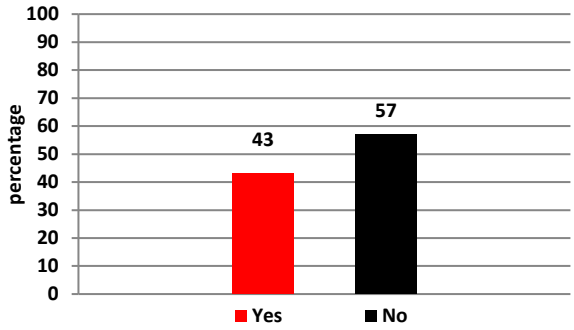


Figure 21. Distribution of participants according to the availability of regular training on infection control procedures.

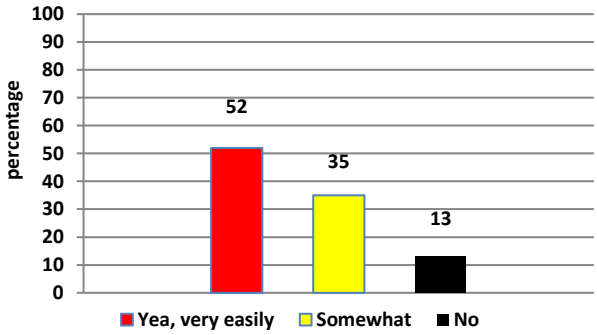


Figure 22. Distribution of participants based on their ability to reach management to provide feedback on safety improvements.

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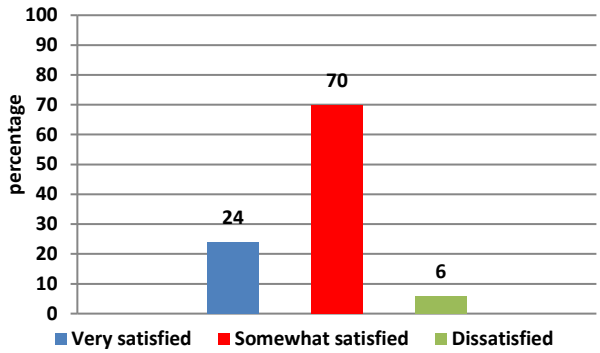


Figure 23. Distribution of participants regarding their satisfaction with the safety level in terms of infection control.

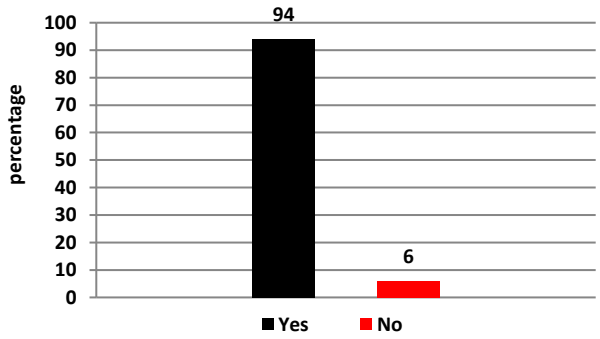


Figure 24. Distribution of participants' opinions on whether the expenses incurred for infection control are justifieDiscussion

The analytical synthesis of the empirical data generated from medical laboratories in the two municipalities Msallata and Al-Khums provides a nuanced understanding of the occupational safety climate. By cross-referencing these findings with the broader epidemiological literature, this section interprets the core strengths, the paradoxes of compliance, and the systemic vulnerabilities inherent in the current healthcare framework.

4. Discussion

The Paradox of Compliance: Foundational vs. Comprehensive Protection

The data demonstrates highly commendable levels of individual adherence to basic hygiene. The fact that 76% of personnel strictly adhere to hand sanitization and 88% consistently utilize gloves aligns seamlessly with the epidemiological consensus established by Martinez et al. which identifies hand hygiene as the most statistically significant variable in interrupting pathogen transmission [17]. The 98% immediate replacement rate for damaged gloves further indicates a workforce that is acutely aware of direct tactile biological threats.

However, a critical "compliance paradox" emerges when evaluating comprehensive protective behavior. The severe drop in compliance, where only 29% consistently utilize full PPE, including ocular and respiratory protection exposes a profound vulnerability. This specific gap corroborates the concerns articulated by Johnson and Patel who argued that the hyper-focus on manual hygiene often breeds a false sense of security, leading to the dangerous neglect of bio-aerosol risks [7]. This selective compliance suggests that workers psychologically prioritize immediate, visible risks (blood on hands) over invisible, airborne hazards (aerosolized viral particles). Overcoming this requires transitioning the institutional culture from viewing comprehensive PPE as an "optional discomfort" to an absolute, non-negotiable operational standard.

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The Systemic Failure of Continuous Education

Perhaps the most consequential finding of this research is the pronounced deficit in on-going professional education. While the majority of staff enters the workforce with adequate initial orientation (66%), the institutional failure to provide continuous training (reported by 57% of workers) creates a stagnant safety culture.

This educational void directly validates the study's first hypothesis regarding the relationship between training and compliance. As previously highlighted by Martinez et al and Jones et al initial training decays over time; without periodic reinforcement, behavioural drift occurs, leading to the procedural shortcuts observed in the PPE data [18, 19]. Because medical science and biological threats evolve rapidly, the lack of updated training leaves almost half the workforce (47%) feeling only partially knowledgeable about the risks they face daily. This lack of confidence directly undermines the overall safety climate of the laboratory.

Workplace Disparities and the Perception of Safety

The structural dynamics of the workforce, evenly split between private and mixed-sector employment, highlight subtle but impactful systemic disparities. Basic infrastructure, such as access to sanitation stations (99%) and surface disinfectants (96%), appears resilient across the board. This supports the observation by Al-Mogbel that modern laboratories are generally successful in procuring basic physical supplies [11].

Yet, physical supplies do not equate to psychological security. The finding that a mere 35% of professionals feel unequivocally "safe" in their environment is a severe indictment of the broader safety management system. This aligns with the findings of Robinson et al. which indicate that public and mixed-sector laboratories often lack the rigorous, standardized auditing processes present in strictly private institutions [16]. When 38% of staff report that equipment sterilization is only conducted "sometimes," it indicates a failure in administrative oversight rather than a lack of physical resources.

Administrative Support and Safety Culture

A robust safety culture relies not just on protocols, but on trust between the scientific staff and hospital administration. The data reveals a concerning fracture in this relationship. With 29% of the workforce doubting they would receive full management backing in the event of an accidental exposure, there is a high risk of underreporting. When incidents are not reported due to fear of punitive action or administrative apathy, the institution loses vital epidemiological data necessary to prevent future accidents. As Robinson et al. (2023) emphasized, an environment where employees cannot easily provide safety feedback (as noted by 13% of the cohort) is an environment fundamentally unequipped to improve [10].

4. Conclusions and Recommendations

Conclusions

This comprehensive analytical study has successfully mapped the biosafety landscape among clinical laboratory professionals in the Msallata and Al-Khums municipalities. The empirical evidence paints a dual picture: a workforce that exhibits strong individual competence and discipline regarding baseline hygiene (specifically hand washing and standard glove usage), yet operates within an institutional framework that lacks rigorous continuous support.

The core vulnerabilities identified do not stem from an absence of initial knowledge or physical resources, but from a systemic breakdown in continuous professional education and comprehensive PPE enforcement. With over half the workforce lacking periodic training updates, a dangerous environment of selective compliance has emerged, particularly regarding respiratory and ocular protection. Consequently, the overarching perception of workplace safety remains moderately low. Ultimately, while the foundational architecture for infection control exists in these laboratories, it requires urgent, standardized administrative intervention to evolve into a proactive, resilient, and fully effective culture of occupational safety.

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Recommendations

Derived directly from the data analysis and aligned with global best practices, the following strategic recommendations are proposed to healthcare policymakers and laboratory directors:

1. **Institutionalization of Continuous Education:** Healthcare administration must transition from a model of one-time orientation to mandatory, continuous professional development. Implementing quarterly or bi-annual interactive biosafety workshops is crucial to update staff on evolving pathogens and to correct procedural drift.
2. **Strict Enforcement of Comprehensive PPE Protocols:** Laboratory management must enforce a zero-tolerance policy regarding the neglect of advanced PPE. The consistent use of laboratory coats, protective eyewear, and particulate masks must be mandated, particularly during processes known to generate bio-aerosols, aligning local practices with rigid OSHA standards.
3. **Cultivation of a Non-Punitive Reporting Culture:** To bridge the trust gap between staff and management, laboratories should establish transparent, non-punitive incident reporting systems. Ensuring that workers feel unconditionally supported post-exposure will drastically improve incident tracking and subsequent risk mitigation.
4. **Standardization of Auditing Across Sectors:** Health ministries must implement standardized, unannounced biosafety audits that apply equally to public and private sector laboratories. This will address the operational disparities and ensure that equipment calibration and deep sterilization are conducted on strict schedules rather than "sometimes."
5. **Appointment of Dedicated Biosafety Officers:** Each diagnostic facility must appoint a certified Biosafety Officer whose sole responsibility is to monitor procedural compliance, manage bio-waste supply chains, and act as the direct communicative liaison between frontline staff and hospital administration.
6. **Implementation of Visual and Cognitive Reminders:** Strategic placement of high-visibility, standardized biological hazard protocols and step-by-step emergency response infographics at every analytical workstation will serve to minimize cognitive load and reduce human error during high-stress operational hours.

ETHICAL STATEMNET

Not appicable.

CONFLICT OF INTEREST

The author declares that they have no competing interests.

AUTHORS' CONTRIBUTIONS

The author, FS is solely responsible for the conception, design, experimental work, data analysis, and the writing this manuscript.

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