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BIOSAFETY TRAINING AND SAFE WORK PRACTICES AMONG LABORATORY PERSONNEL: A SYSTEMATIC REVIEW OF TRAINING AND ORGANIZATIONAL INTERVENTIONS

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Abstract

Background. Laboratory personnel are exposed to biological hazards every working day, and training is the most common control used to reduce that risk. It is less clear which training or organizational interventions improve both biosafety knowledge and actual adherence.

Objective. To identify which training or organizational interventions improve biosafety knowledge and adherence among laboratory technicians, and to compare the Saudi and regional picture with international evidence.

Methods. Systematic review reported against PRISMA 2020. PubMed and Consensus were searched on 21 November 2026. Studies were eligible if they evaluated a training, programme or organizational intervention in laboratory personnel and reported knowledge, attitude, practice or compliance outcomes. Screening and extraction were done at title and abstract level by a single AI-assisted reviewer. Findings were synthesized narratively (SWiM) because designs and outcomes were too varied to pool.

Results. Of 107 unique records, 8 studies met the criteria (7 training or programme evaluations and 1 inspection-design experiment). All eight were uncontrolled or hypothetical designs. In five pre–post studies totalling 221 participants, knowledge rose after instructor-led or active-learning training; in Liberia, mean test scores rose from 41% to 75.5%. Programme-level evaluations reported more positive safety-practice responses (50% to 84%) and, in Kenya, uptake in 41% of facilities visited after a trainer-cascade model. A discrete choice experiment predicted compliance could rise from 25.9% to 74.5% with well-designed inspections. No controlled, observed-adherence or Saudi biosafety intervention study could be verified. Certainty was low for knowledge and very low for practice.

Conclusions. Training reliably improves short-term knowledge. Evidence that it changes behaviour is thin, and the best-supported route to adherence appears to combine active training with management support, clear procedures and feedback. Controlled studies with observed practice in Saudi laboratories are needed.

Keywords: biosafety; laboratory personnel; training; compliance; occupational health; systematic review; Saudi Arabia

1. Introduction

Laboratory biosafety is the set of containment principles, safety equipment and operating practices that protect laboratory workers, the community and the environment from accidental exposure to

pathogens and toxins, and from their release. In routine clinical laboratories this means everyday tasks such as correct personal protective equipment use, safe handling of sharps, spill management and waste segregation.

A recent mixed-methods systematic review of 34 studies found that laboratory staff generally had good knowledge and attitudes towards infection prevention and control, yet practice remained poor and training was often inadequate (Aldhamy et al., 2023). That pattern, a gap between knowing and doing, is the central problem for any biosafety training programme.

The regional picture shows the same weakness in training and systems. In Al-Madinah, about two-thirds of surveyed laboratory workers had received safety training, and several unsafe behaviours, including needle recapping, were linked to the absence of training (Khabour et al., 2018). Among hospital staff in Dammam and Jeddah, laboratory personnel had the highest sharp-injury prevalence (Al-Zahrani et al., 2024). Surveys from Morocco and Sudan describe low rates of formal training and basic biosafety infrastructure (Bajjou et al., 2019; Elduma, 2012). Internationally, interventions range from single-day workshops to national trainer-cascade programmes and inspection regimes, but their effects on behaviour have not been brought together for technicians.

This review therefore asks: **which training or organizational interventions improve biosafety knowledge and adherence among laboratory technicians?** A secondary aim was to benchmark the Saudi and wider regional evidence against international studies.

2. Methods

2.1 Design and review question

This is a systematic review reported according to PRISMA 2020. No protocol was registered. The question was framed as follows. *Population*: laboratory technicians and other laboratory personnel handling biological material. *Intervention*: any biosafety training (lecture, workshop, active-learning, virtual, trainer-cascade) or organizational measure (programme, inspection, supervision). *Comparator*: pre-intervention status, no intervention or alternative design. *Outcomes*: knowledge, attitudes, self-reported or observed practice, and compliance or implementation of safety measures.

2.2 Eligibility criteria

Included studies evaluated an intervention in laboratory personnel and reported at least one quantitative outcome. Excluded were cross-sectional surveys with no intervention, studies of students or non-laboratory staff, reviews and commentaries (used only for background), and records whose bibliographic details could not be verified in PubMed.

2.3 Information sources and search

PubMed was searched with six queries and Consensus with one natural-language query on 21 November 2026 (Table 1). Queries combined biosafety, training, laboratory personnel and, for regional coverage, Saudi Arabia and Middle East terms. PubMed was also used to verify the citation details of every included study. Reference lists were not hand-searched, and Embase, Scopus and Web of Science were not available.

Table 1. Search strategy and records retrieved (searched 21 November 2026).

Source	Query as run	Records
PubMed	biosafety training laboratory personnel knowledge practice intervention	10
PubMed	biosafety laboratory Saudi Arabia knowledge practices	4
PubMed	laboratory biosafety training effectiveness systematic review	8

Source	Query as run	Records
PubMed	laboratory workers biosafety compliance intervention Middle East OR Gulf OR Egypt OR Iran	30*
PubMed	biosafety biosecurity training laboratory technicians competency assessment	2
PubMed	laboratory safety training Saudi Arabia laboratory personnel occupational exposure	6
Consensus	training interventions to improve biosafety knowledge and adherence among laboratory technicians	50
Total	PubMed 60 + Consensus 50	**110**

*PubMed's automatic term mapping matched 575,087 records for this query; the 30 most relevant-ranked records were screened. All 30 were off-topic. Duplicates removed: 3.

2.4 Selection, extraction and appraisal

One AI-assisted reviewer screened titles and abstracts, then assessed 22 records in more detail at abstract level. Full texts were not retrieved, and there was no second reviewer. For each included study the following were extracted: country, design, sample, intervention, outcomes and key numerical results, and each was tagged Saudi, GCC–MENA or International. No formal risk-of-bias instrument was applied. Instead, each study was appraised descriptively (control group, follow-up length, outcome type, response rate), and certainty for each outcome domain was rated informally in the spirit of GRADE as low or very low.

2.5 Synthesis

Meta-analysis was not attempted because outcomes were measured on different scales, designs were uncontrolled and several papers did not report scores. Results are presented as a structured narrative synthesis (SWiM) by intervention type and outcome domain, with a descriptive before–after chart for the three studies that reported comparable percentages.

3. Results

3.1 Study selection

The searches returned 110 records; after removing 3 duplicates, 107 were screened (Figure 1). Of these, 85 were excluded at screening (45 off-topic, 40 descriptive surveys with no intervention). Twenty-two records were assessed in more detail and 14 excluded: 3 involved students or non-laboratory staff, 4 were reviews or commentaries, 2 lacked intervention outcome data, and 5 pre–post or follow-up reports could not be verified in PubMed. Eight studies were included.

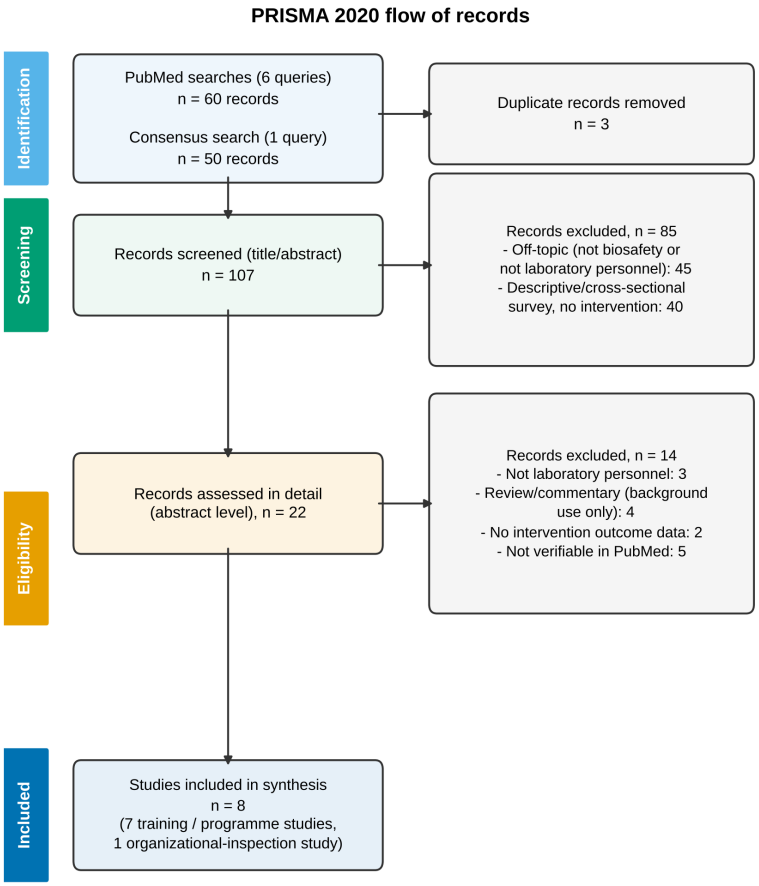

Figure 1. PRISMA 2020 flow diagram of the review. Counts are the actual numbers from the searches described in Table 1.

3.2 Characteristics of included studies

The included studies (Table 2) came from India, Egypt, Pakistan, Liberia, Kenya, China and a 22-country training network. Two (both from Egypt) were tagged GCC–MENA and six International. None was conducted in Saudi Arabia. Seven evaluated education or programmes before and after delivery and one modelled worker preferences for inspection design. Sample sizes were small to moderate (20 to 402 trained participants, 188 for the inspection study), and no study had a concurrent control group.

Table 2. Characteristics and main results of the eight included studies.

Study (setting tag)	Design and sample	Intervention	Outcomes	Main result	Appraisal notes
Mehta & Diwakar (2021) India (International)	Single-group pre–post; 40 technicians, tertiary hospital	Training on universal work precautions	Knowledge, attitude, practice (questionnaire)	Significant improvement in all three domains (paired t-test, chi-square); scores not given in abstract	No control; immediate post-test; self-report

Study (setting tag)	Design and sample	Intervention	Outcomes	Main result	Appraisal notes
El-Gilany et al. (2017) Egypt (GCC–MENA)	Quasi-experimental pre–post; 20 technicians	Programme on laboratory safety and medical waste	KAP scores at baseline and 2 months	Significant increase in KAP scores at 2 months	Very small; only study with a follow-up interval
Elhadidy et al. (2019) Egypt (GCC–MENA)	Pre–post; 42 faculty handling biological material	Two active-learning biorisk workshops	Knowledge test; course evaluation	Knowledge gain, $p < .001$; most felt practice would change	Faculty not technicians; intent not behaviour
Qasmi et al. (2022) Pakistan (International)	Pre–post; 52 participants	Interactive virtual biorisk training	Knowledge and awareness; speaker feedback	Significant gain, $p < .001$	Voluntary participation; short term
Malik et al. (2022) Liberia (International)	Pre–post; 67 participants (64 human health)	Three one-day active-learning workshops	Knowledge test	Mean score 41% to 75.5%, $p < .001$; gaps in PPE and hand hygiene	No control; immediate post-test
Shrivastava et al. (2023) 22 countries (International)	Retrospective evaluation; 402 trained, 81 (20%) responded	20 biosafety courses (14 core safety elements)	Positive implementation responses, 6 months before vs after	50% to 84%; Safety Policies 67% to 94%	20% response; recall bias
Bota et al. (2021) Kenya (International)	Programme description; 264 managers, 48 trainers, 1,044 workers, 216 facilities; 51 visited	Sensitization, training of trainers, cascade training, mentorship	Biosafety measures in place at site visit	Gains in 21 of 51 visited facilities (41%), e.g., spill kits (81%), eye-wash stations (76%)	No baseline comparison; management buy-in noted

Study (setting tag)	Design and sample	Intervention	Outcomes	Main result	Appraisal notes
Qin et al. (2023) China (International)	Discrete choice experiment; 188 workers, 35 laboratories	Inspection design (inspector, frequency, timing, feedback, reward or sanction)	Stated willingness to comply	Predicted compliance 25.86% to 74.54% with best-practice inspections	Hypothetical choices, not observed behaviour

KAP, knowledge, attitude and practice; PPE, personal protective equipment. Tags: GCC–MENA = Gulf Cooperation Council and wider Middle East and North Africa.

3.3 Synthesis by intervention type

Instructor-led and active-learning training. Five studies with 221 participants in total (Mehta & Diwakar, 2021; El-Gilany et al., 2017; Elhadidy et al., 2019; Qasmi et al., 2022; Malik et al., 2022) measured knowledge before and after training, and all found improvement (Table 3). The only study with numeric scores in the abstract showed a rise from 41% to 75.5% (Malik et al., 2022). The formats were varied, including lectures, one-day workshops, hands-on and case-based sessions, and live virtual training, and the evidence does not allow one format to be ranked above another. Two studies also measured attitudes and self-reported practice, and both reported gains, but only El-Gilany et al. (2017) looked beyond the immediate post-test, at two months.

Table 3. Narrative synthesis by outcome domain, with informal certainty rating.

Domain	Studies	Direction of effect	Certainty	Main reasons for rating
Knowledge after training	5 (n = 221)	Improved in all five	Low	Uncontrolled; immediate post-test; small samples
Attitudes and self-reported practice	2 (Mehta; El-Gilany)	Improved in both	Very low	Self-report; one follow-up at 2 months
Programme-level implementation of safety measures	2 (Shrivastava; Bota)	More safety practices in place after programme	Very low	Retrospective; 20% response; 41% of visited sites
Organizational enforcement (inspection)	1 (Qin)	Higher predicted compliance	Very low	Stated, hypothetical behaviour

Certainty ratings are the reviewers' informal judgements, not formal GRADE assessments.

Programme and system-level interventions. The two large programmes combined training with the workplace. The multi-country course evaluation reported that positive responses on implemented safety practices rose from 50% to 84% in the six months after the course, with the largest gain in safety policies (Shrivastava et al., 2023). Kenya's trainer-cascade model reached 1,044 workers in 216 facilities. At 51 site visits, measurable improvements, such as spill kits, eye-wash stations and incident documentation, were found in 21 facilities (41%), and the authors attributed progress to manager buy-in that released resources (Bota et al., 2021).

Organizational enforcement. The single inspection study found that five design features (who inspects, how often, when, how results are communicated, and whether follow-up involves a reward or sanction) strongly influenced willingness to comply, with predicted compliance rising from 25.86% to 74.54% under the best combination (Qin et al., 2023). Because respondents chose between hypothetical scenarios, this shows what workers say would motivate them, not what happens on the bench.

Figure 2 sets the three studies reporting comparable before–after percentages side by side. The outcomes differ (a knowledge test, implementation responses and modelled compliance), so the chart is descriptive and the values should not be pooled.

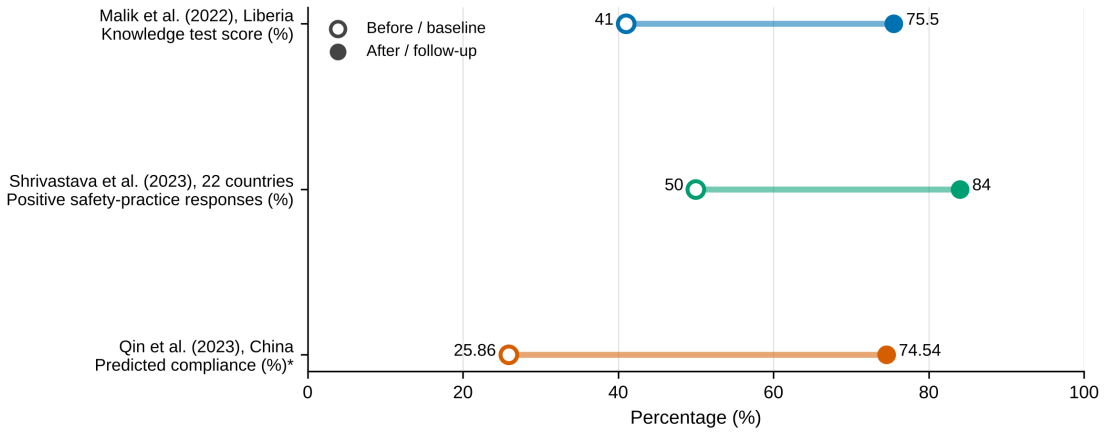

Figure 2. Before and after values in the three studies reporting percentages (Malik et al., 2022; Shrivastava et al., 2023; Qin et al., 2023). The measures differ and are not pooled. *Qin et al. values are modelled from a discrete choice experiment (hypothetical scenarios), not observed behaviour.

3.4 Saudi and regional context

No verified biosafety intervention study from Saudi Arabia was found. The Saudi and regional evidence therefore consists of descriptive surveys that show where the need lies (Table 4; Figure 3). In Al-Madinah, 68% of 208 laboratory workers had safety training, yet 67% reported recapping needles, and unsafe behaviours were associated with a lack of training ($p < 0.05$) and short experience (Khabour et al., 2018). In Taif, hospital laboratory workers were more aware of safety than students, but both groups showed gaps (Abu-Siniyeh & Al-Shehri, 2021). In Dammam and Jeddah, laboratory personnel had the highest sharp-injury prevalence (29.2%) of the hospital workers studied (Al-Zahrani et al., 2024). Only 17.4% of Moroccan laboratory staff had prior formal biosafety training (Bajjou et al., 2019), and only 16.8% of Khartoum laboratories had a biosafety officer (Elduma, 2012).

Table 4. Saudi and regional descriptive studies that provide context for the intervention evidence (not included in the synthesis).

Study	Setting tag	Design and sample	Key finding
Khabour et al. (2018)	Saudi (Al-Madinah)	Cross-sectional; 208 laboratory workers	About 68% trained; unsafe behaviours (e.g., needle recapping 67%) linked to no training
Abu-Siniyeh & Al-Shehri (2021)	Saudi (Taif)	Cross-sectional; 185 students and workers	Workers more aware than students; gaps in emergency equipment use

Study	Setting tag	Design and sample	Key finding
Al-Zahrani et al. (2024)	Saudi (Dammam, Jeddah)	Cross-sectional; hospital workers	Sharp-injury prevalence 8.4% overall; 29.2% among laboratory personnel
Bajjou et al. (2019)	GCC–MENA (Morocco)	Cross-sectional; 235 staff (19% response)	Only 17.4% had formal training; low knowledge of aerosol-generating tasks (30.2%)
Elduma (2012)	GCC–MENA (Sudan)	Facility survey; 190 laboratories	16.8% had a biosafety officer; 23.7% written SOPs; 5.8% a biosafety cabinet
Shakoor et al. (2016)	International (Pakistan)	Barrier survey; 64 workshop attendees	Barriers were mostly workplace-level: lack of time, authority and incentives

SOP, standard operating procedure.

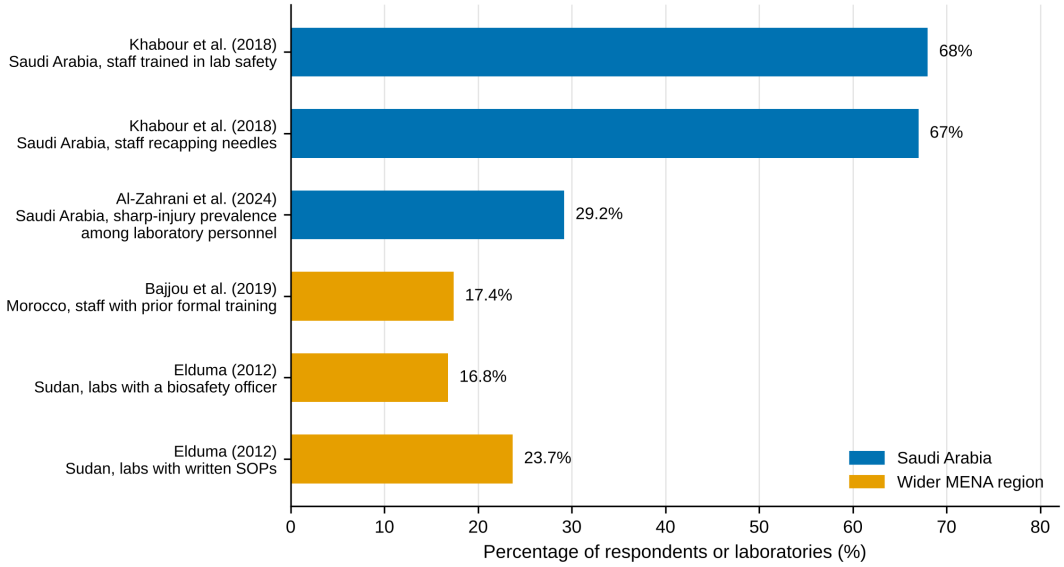

Figure 3. Selected baseline indicators from Saudi and wider MENA descriptive studies. Denominators differ (staff or laboratories) and the Al-Zahrani value is an injury prevalence; bars are for context, not for ranking.

4. Discussion

Across eight studies from six countries and a multinational network, biosafety training consistently raised test scores, but the evidence that it changes what technicians do is much weaker. This matches the knowing–doing gap described in the wider laboratory literature, where knowledge and attitudes are good and practice still lags (Aldhamy et al., 2023). Most included studies measured knowledge immediately after the session, used no control group and relied on self-report, so improvements may be partly due to test familiarity or short-lived.

The more convincing signals for behaviour come from programmes that did more than teach. The Kenyan model paired trainers, mentorship and manager sensitization, and visible improvements followed where management supplied resources (Bota et al., 2021). The multi-country evaluation found its largest gains in written safety policies (Shrivastava et al., 2023), which suggests that training works best when it is anchored to procedures the laboratory can actually follow. A Pakistani barrier survey points the same way: technicians cited lack of time, authority and

incentives, not lack of awareness, as the main obstacles (Shakoor et al., 2016). The inspection experiment adds that how oversight is delivered, including who inspects and how feedback is given, may matter as much as the training itself (Qin et al., 2023), although this rests on stated choices.

For Saudi laboratories, the regional surveys show a training gap and its consequences rather than a tested remedy. Training was linked to safer behaviour in Al-Madinah (Khabour et al., 2018), and laboratory personnel carried the highest sharp-injury burden in the Dammam and Jeddah sample (Al-Zahrani et al., 2024). These findings are broadly concordant with Morocco and Sudan, where formal training and basic infrastructure were scarce (Bajjou et al., 2019; Elduma, 2012). What is distinct for Saudi Arabia is the absence of a verified interventional study with biosafety outcomes. One Saudi pre–post educational study among technicians (n = 30) that included biosafety items within an HIV-screening curriculum was seen in the Consensus results but could not be verified in PubMed, so it was not synthesized.

Practical implications follow with caution. Laboratories planning training can reasonably combine active, role-specific sessions with written procedures, supervisor support and feedback, and should measure practice by observation or incident data as well as by questionnaires. These are hypotheses from low-certainty evidence, not proven recommendations. Future studies should use controlled or stepped designs, report observed adherence and exposure incidents, follow technicians for at least several months, and be run in Saudi laboratories.

5. Strengths and limitations

Strengths include a prespecified question, two complementary search sources, bibliographic verification of every included study in PubMed, and explicit comparison of Saudi and international evidence. Important limitations apply. Screening and extraction were done by a single AI-assisted reviewer at abstract level without full texts; only PubMed and Consensus were searched and no protocol was registered; no formal risk-of-bias tool was used; and five potentially relevant intervention reports were excluded because they could not be verified in PubMed, which may bias the picture. Findings are limited to English-language records, and the heterogeneity of designs and outcomes prevented pooling. Several studies were small, had low response rates or measured immediate outcomes only.

6. Conclusion

Training and organizational interventions improve biosafety knowledge among laboratory technicians in the short term, with low-certainty evidence. Evidence for improved adherence is limited to self-report, programme audits and hypothetical choices. Interventions that link training with management support, clear procedures and feedback look the most promising, and well-designed controlled studies with observed practice, ideally in Saudi laboratories, are the priority.

Declarations

Ethics approval and consent. Not applicable; this review used published data only.

Registration. The review was not registered.

Funding. Not applicable

Conflicts of interest. Not applicable

Data availability. All data were extracted from the published studies listed in the references.

Use of AI. Literature searching, screening, data extraction, figure preparation and a first draft were produced with an AI system (Claude, Anthropic). The authors are responsible for verifying the content before submission.

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