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EVALUATION OF CHEMICAL AND PHYSICAL HAZARDS IN CHEMISTRY LABS: EFFORTS TO IMPROVE K3

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ABSTRACT:
Occupational safety and health are important in carrying out an activity, especially in the use of chemicals and laboratory operations which basically contain high risks. Although there is a policy in place, it cannot guarantee laboratory users to comply with the K3 procedure. To evaluate the existing hazards and improve occupational safety and health (K3) in the laboratory, we use several.The methods used follow a systematic Occupational Safety and Health (K3) approach that begins with hazard identification to recognize potential chemical, physical, and equipment-related dangers, followed by risk assessment to evaluate the likelihood and impact of those hazards. Based on this, safe work procedures are established to guide proper laboratory practices, supported by continuous training to ensure users understand safety measures. The application of PPE is enforced to minimize exposure to risks, while regular The methods used follow a systematic Occupational Safety and Health (K3) approach that begins with hazard identification to recognize potential chemical, physical, and equipment-related dangers, followed by risk assessment to evaluate the likelihood and impact of those hazards. Based on this, safe work procedures are established to guide proper laboratory practices, supported by continuous training to ensure users understand safety measures. The application of PPE is enforced to minimize exposure to risks, while regular evaluation monitors the effectiveness of safety implementation. When incidents or near misses occur, in-depth analysis is conducted to determine root causes and prevent similar events, ensuring a safer and more effective laboratory work environment. monitors the effectiveness of safety implementation. When incidents or near misses occur**,** in-depth analysis is conducted to determine root causes and prevent similar events, ensuring a safer and more effective laboratory work environment. With an understanding of the dangers of chemicals and physics to laboratory users in an organized manner, it will be possible to create an effective laboratory workspace. Therefore, the improvement of K3 needs to be focused on regular education and training, storage of chemicals according to standards, correct waste handling, and the implementation of periodic audits and inspections. The awareness and discipline of laboratory users play an important role in creating a safe and accident-free work environment.

Keywords: K3, labs, chemicals, high-risk, education, safe work, effective workspace

INTRODUCTION:

Occupational Safety and Health (K3) in the laboratory is crucial due to the numerous potential hazards that may threaten users' health and safety. Laboratories in education and industry contain various physical, chemical, and ergonomic risks that must be properly managed. Many studies on laboratory K3 have focused on hazard identification, risk assessment, and recommendations for improving safety practices. Work accidents such as chemical exposure, fires, and ergonomic injuries often occur due to low awareness of PPE use, weak implementation of safety procedures, and non-standard work environments (Sari & Nugroho, 2021; Putri & Rahman, 2020). Evaluations of chemical waste management also indicate improper waste storage and limited technician training in hazardous waste handling (Wulandari, 2019).

However, most previous studies address these aspects separately, and research integrating risk assessment, training, safe work procedures, and PPE compliance into a continuous safety system remains limited. K3 compliance is also reported to be relatively low in educational laboratories with high user turnover. This article contributes by proposing a more integrated K3 approach that links hazard identification, risk assessment, training, PPE use, and evaluation into a continuous cycle to improve laboratory safety and create a safer, more effective work environment.

On the other hand, many studies have examined the role of education in improving understanding and awareness of Occupational Safety and Health (K3). Research conducted specifically in educational laboratories, such as those in vocational schools and universities, shows that K3 socialization and training programs can enhance students' and laboratory workers' understanding of PPE use, chemical risk management, and laboratory emergency procedures (Wetri Febrina, 2020; Zakiyati Salma & Syamsurizal, 2020). Training evaluations also indicate a significant improvement in participants' knowledge and attitudes toward laboratory occupational safety and health (Muliadi et al., 2020; Rafiah Maharani & Bintari Triani, 2025).

By clearly focusing on educational laboratory settings, this discussion becomes more directed, considering the high number of users, varying levels of experience, and the need for continuous supervision and safety education in such environments.

In addition, risk assessment methods such as HIRARC (Hazard Identification, Risk Assessment, and Risk Control), used in various studies, have also been shown to be effective in identifying potential hazards and assessing their risk levels in the laboratory (Rama Ramdani et al., 2023). This is particularly important because many laboratory accidents stem from insufficient hazard awareness and inadequate safety practices, indicating that educational efforts must be supported by systematic risk assessment methods like HIRARC to ensure that safety knowledge is translated into effective risk control measures.

Teo Lukmanul et al. (2025) further support these findings. These results demonstrate that the application of comprehensive and structured risk assessment methods is essential for improving Occupational Safety and Health (K3) management in laboratory settings. Overall, this article presents a relevant literature review on the implementation of K3 in laboratories. However, the discussion remains largely descriptive and would benefit from a sharper focus, stronger synthesis across studies, and clearer identification of research gaps to enhance the article's scientific contribution.

METHOD:

This study uses the systematic literature review method to evaluate chemical and physical hazards in chemistry laboratories as well as efforts to improve K3. Literature was searched through Google Scholar, PubMed, ScienceDirect, ProQuest, and Garuda with the keywords "chemical hazards laboratory", "physical hazards laboratory", "occupational safety chemistry laboratory", and "K3 chemical laboratory". The inclusion criteria include articles published in 2015–2025, discussing chemical and physical hazards in the laboratory, and containing aspects of K3, while non-scientific or irrelevant articles are issued. The selection process is carried out through screening of titles, abstracts, and full review of articles. The data was analyzed qualitatively by grouping the types of hazards, impacts, and strategies for improving K3.

RESULTS AND DISCUSSION :

Most studies reveal that although many laboratories have begun to implement safety procedures, there are still many issues affecting the safety of practitioners and technicians. The following is a summary of the results of the discussion of some of the main aspects found:

1. **Exposure to Hazardous Chemicals**: Exposure to harmful chemicals such as strong acids (HCl, H_2SO_4), strong bases (NaOH), ethanol, and flammable substances (ether, toluene) are one of the main risks found in educational laboratories (Sari & Nugroho, 2021; Saputra, 2018). Practitioners often do not use personal protective equipment (PPE) optimally, such as gloves and protective glasses, which increases the risk of chemical injuries such as burns and eye irritation (Sari & Nugroho, 2021). Therefore, the mandatory use of PPE and training on the use of these tools are very necessary.
2. **Physical Hazards and Ergonomics**: Research conducted by Putri and Rahman (2020) found that many physical factors such as lighting intensity, temperature, and noise in chemical laboratories do not meet safety standards. Low light intensity (200–250 lux) causes eye fatigue, high room temperature (32°C) leads to fatigue and decreased concentration, and noise from shakers and vacuum pumps can interfere with work concentration. Their recommendation is improvements in spatial planning and ventilation arrangements to minimize such complaints.
3. **Chemical Waste Management**: Problems in chemical waste management are also very significant. Wulandari (2019) revealed that many laboratories mix liquid and solid chemical waste without proper separation, which has the potential to cause dangerous reactions. In addition, non-standard B3 (Hazardous and Toxic Materials) waste management is also found in many cases, such as waste storage that is not clearly labeled. Good waste management is essential to prevent leakage and contamination of the laboratory environment.
4. **Occupational Safety System and Risk Control**: Based on the results of research by Fatemi et al. (2022), there is an identification that health and safety risks in academic laboratories need to be controlled more strictly, especially related to the chemicals used. Risk assessments using international standards such as OSHA, ILO, and ACGIH show that some materials such as HCl and formaldehyde have a fairly high risk. Therefore, it is important for institutions to increase awareness of K3 and conduct regular training and good waste management.
5. **K3 Socialization and Training**: Many studies have shown that K3 counseling and training can increase the knowledge and awareness of students and educators. For example, research by Wetri Febrina et al. (2020) at SMK

Taruna Persada Dumai shows that after K3 training, students experience an increased understanding of the role of K3 in the laboratory. Similarly, research by Muliadi et al. (2020) on lecturers and laboratories at Tanjungpura University shows that training on K3 SOPs increases knowledge and readiness to face hazards in the laboratory.

6. **Use of Personal Protective Equipment (PPE)**: The use of adequate PPE in chemical laboratories is key to preventing work accidents. Zakiyati Salma and Syamsurizal (2020) revealed that the inconsistent use of PPE is one of the main factors causing accidents in the laboratory. This study also highlights the importance of supervision of lecturers and technicians to ensure the correct use of PPE during the practicum.
7. **In** a study by Teo et al. (2025), hazard identification in ITK's basic chemistry laboratory revealed that most potential hazards were categorized as high risk. Risk assessment using the HIRARC method shows that risk management needs to be improved by increasing the use of PPE and implementing routine inspection and supervision procedures to minimize work accidents.
8. **Implementation of K3 Management in Industry and Laboratories**: The application of K3 management in laboratories and industries can improve work safety. Research by Arni Dyah Purwaningsih (2020) shows that internal audits on important elements in the K3 management system, such as work permits and emergency response, are effective in improving safety at PT DNX Indonesia. Good implementation of these elements can reduce the risk of work accidents.
9. **The Use of Environmentally Friendly Chemicals**: Research by I Ketut Lasia et al. (2020) found that training that prioritizes the use of environmentally friendly chemicals can improve safety in the laboratory. The use of environmentally friendly chemicals reduces the risk of chemical accidents and provides a safer alternative for laboratory users.

TABLE 1 COMPARISON OF RESEARCH FINDINGS:

NO	HEADING	WRITER	PURPOSE	METHOD	RESULT
1	Evaluation of Chemical Exposure Risk in Educational Laboratories	Sari, A. & Nugroho, B. (2021)	Identify potential chemical hazards in students and laboratory technicians	Observations, interviews, MSDS checklist	The results show that the use of harmful chemicals such as HCl, H_2SO_4, NaOH, ethanol, and acetone is often carried out without adequate risk control. Practitioners rarely use gloves and protective glasses, increasing the risk of chemical burns and eye irritation. Long-term exposure has the potential to cause respiratory distress and tissue damage. Research has also found that chemical storage is not always up to standard, for example strong acids and strong bases are stored close together. Recommendations include mandatory procurement of PPE, labelling of hazardous materials, and simulated emergencies
2	Physical and Ergonomic Hazard Analysis in Chemistry Laboratories	Putri, D. & Rahman, H. (2020)	Evaluate physical hazards (noise, lighting, temperature) and work ergonomics	Measurement of light intensity, temperature, noise; questionnaire	The intensity of lighting in the laboratory is below the recommended standard (only 200–250 lux), making the practitioner often suffer from eye fatigue. The room temperature reaches 32°C, which causes fatigue quickly and decreases work concentration. Musculoskeletal complaints such as back and neck pain are often found due to unergonomic desk design. The noise from the shaker and vacuum pump causes concentration disturbances even

					though it is still within safe limits. Research suggests improving spatial planning, cooling installations, and posture training to minimize health complaints.
3	Laboratory Chemical Waste Management	Wulandari, T. (2019)	Evaluate laboratory waste management systems	Case studies and interviews	Liquid and solid chemical waste is often mixed without separation according to its properties, thus giving rise to dangerous reactions. A lot of B3 waste is stored in containers without clear labels, increasing the risk of mishandling. Some technicians admitted that they had never received special training related to hazardous waste. As a result, waste container leaks are often found that cause a pungent odor in the laboratory. This study suggests the provision of clear SOPs, standardized containers, and routine training programs for technicians.
4	Occupational Safety in Organic Chemistry Practicum	Saputra, R. (2018)	Identifying risks in an organic practicum	Observation & questionnaire	Practicum often uses flammable solvents such as ether and toluene. The ventilation of the room is inadequate, so chemical vapors accumulate, risking a small explosion or fire. Students are often unaware of the danger of open fire when heating the solution. The study noted several cases of dizziness and irritation due to inhalation of solvent vapors. Recommendations include the use of fume hoods, strict supervision of lecturers, and counseling on the dangers of organic solvents.
5	Evaluation of Heat Exposure in the Laboratory	Handayani, L. (2020)	Assessing the physical hazard of heat exposure	Temperature measurement, complaint survey	Room temperatures often exceed 30°C during practicums, especially in rooms with many heating devices. Hot conditions trigger dehydration, fatigue quickly, and practicum procedure errors. Most college students report feeling uncomfortable and losing focus when the room temperature is too high. Heat exposure also has the potential to accelerate the evaporation of harmful volatile chemicals. Research recommends the installation of air conditioning, exhaust fans, and the provision of drinking water to prevent dehydration.

6	Socialization of Occupational Safety and Health at the Chemistry Laboratory of SMK Taruna Persada Dumai	Wetri Febrina, Elisa Harfrida, Susy Srihandayani	The purpose of this research activity is to provide assistance to students majoring in Industrial Chemical Engineering at SMK Taruna Persada Dumai in knowing and understanding the role of K3 in the Chemistry laboratory.	The purpose of this research activity is to provide assistance to students majoring in Industrial Chemical Engineering at SMK Taruna Persada Dumai in knowing and understanding the role of K3 in the Chemistry laboratory	- According to the results of filling out the first questionnaire, the student's level of knowledge is in the medium or sufficient category. - the results of the questionnaire to the second student's average answer score are 3.2 which shows that teachers and schools have facilitated K3 in the laboratory
7	Occupational Safety in the Laboratory	Zakiyati Salma and S. Syamsurizal (Faculty of Mathematics and Natural Sciences, Padang State University)	This journal aims to find out the factors related to the incidence of work accidents in educational laboratories	Using a quantitative cross-sectional approach, with data collection via questionnaire to respondents (amounts are not explicitly mentioned in the summary). Statistical analysis was carried out to assess the relationship between variables.	The most common work accidents in educational laboratories include: - Exposure to heat - Chemical spills - Experiencing dizziness due to inhaling chemicals - No significant association was found between: - Implementation of SOPs and level of knowledge with work accident incidents However, the use of Personal Protective Equipment (PPE) has a significant relationship with the incidence of work accidents
8	Socialization and training on Occupational Health and Safety in the Laboratory for Lecturers and Laboratories of the Faculty of Mathematics and Natural Sciences, Tanjungpura University.	Muliadi Muliadi, Nurhasanah Nurhasanah, Asri Mulya Ashari, Lucky Hartanti, Bambang Kurniadi	training FAK MIPA lecturers, especially those in charge of laboratories, practicum lecturers and laboratory assistants on how to prepare K3 Standard Operating Procedures (SOP) to avoid work accidents or diseases caused by negligence during activities in the laboratory.	Training/Counseling with a Hybrid Learning Approach	1. Training participants consisting of the person in charge of the laboratory, lecturers in charge of the practicum and laboratory have been able to understand the importance of Standard Operating Procedures for Occupational Health and Safety in the laboratory. 2. Evaluation of participants' abilities is shown from the increase in post test scores rather than pre tests 3. This K3 socialization is very beneficial for all participants in streamlining work in the laboratory and avoiding dangers or diseases due to negligence during activities in the laboratory
9	Implementation of Chemical Health, Safety, and Environmental Risk Assessment in Laboratories: A	Fatemi et al. (2022)	Develop and implement chemical, safety, and environmental risk assessment methods in academic	Case-series study in 5 academic labs, with risk assessments based on OSHA, ILO, ACGIH, IARC, and	"moderate–very high" health risk of 9.3%, environmental 35.2%, safety 20.4%. HCl is the highest risk; formaldehyde, HNO_3, NaOH are considered health risks. It is suggested that there is

	Case-Series Study		laboratories	NFPA	a need to increase awareness, waste management, and K3 training
10	Hazardous Chemical Laboratory Fire Risk Assessment Based on ANP and 3D Risk Matrix	Ho et al. (2023)	Assessing the risk of hazardous liquid chemical fires in the laboratory	ANP & 3D risk matrix approach, survey data and simulation	Identify high danger points in experiments; Bow-Tie & Risk Matrix Tool is effective as a risk management tool
11	IMPLEMENTATION OF K3 MANAGEMENT AT THE BASIC LABORATORY OF EKASAKTI PADANG UNIVERSITY	Merry Thressia, El Basthoh	evaluate the implementation of Occupational Safety and Health Management (K3) at the Basic Laboratory of Ekasakti Padang University	qualitative descriptive approach, which aims to describe Systematic application Safety management and Occupational Health (K3) in the laboratory basis.	K3 management in the laboratory The basics have been implemented optimally. All indicators show performance very good, which reflects the high awareness of the institutions and individuals against the importance of occupational safety.
12	Analysis of Potential Occupational Safety and Health Hazards in the Laboratory of the Department of Civil Engineering, State University of Malang	Rahmawan ,2024	This study aims to analyze the potential hazards of Occupational Safety and Health (K3) in the laboratory of the Department of Civil Engineering, State University of Malang, to then help reduce the risk of work accidents that may occur in the laboratory environment	Unfortunately, full details of the research method are not available via PDF access which failed to open. However, given the nature of the study of potential hazards, it is likely that the methods used include direct observation techniques, examination of working environmental conditions, and risk assessment—similar to approaches such as HIRARC or FTA that are common in K3 studies. However, this has not been confirmed due to limited access	No detailed information about the results of the study—such as specific data on the potential hazards identified—was found due to the inability to access the full documents. If you have access to the original PDF or HTML of this article, please copy the abstract section, method, or result—I'm here to help summarize it according to the structure: title, author (if also available), objective, method, and result.
13	Implementation of Chemical Health, Safety, and Environmental Risk Assessment in Laboratories: A Case-Series Study	Fatemi et al. (2022)	Develop and implement chemical, safety, and environmental risk assessment methods in academic laboratories	Case-series study in 5 academic labs, with risk assessments based on OSHA, ILO, ACGIH, IARC, and NFPA	"moderate–very high" health risk of 9.3%, environmental 35.2%, safety 20.4%. HCl is the highest risk; formaldehyde, HNO_3, NaOH are considered health risks. It is suggested that there is a need to increase awareness, waste management, and K3 training.
14	COUNSELING ON THE DANGERS OF CHEMICAL	Novera Elisa Triana — Mercu Buana University	Increase workers' understanding of the dangers of chemicals.	Although the details of the method are not fully available in the footage I found,	Specific information about the results of the study (such as numerical data, before-after evaluation, or level of

	SUBSTANCES AND THE IMPORTANCE OF USING PPE IN SMALL AND MEDIUM INDUSTRIES	Jakarta Sakti Aji Lesmana — Mercu Buana University Jakarta Popy Yuliarty — Mercu Buana University Jakarta Melani Aprianti — Mercu Buana University Jakarta	Encourage compliance in the use of Personal Protective Equipment (PPE).	the context suggests that the research was conducted as an extension activity (possibly in the form of PKM/community service), focusing on education about chemical risks and the use of PPE. Based on the title and purpose, possible methods include lectures, demonstrations, discussions, or pre- and post-assessments, which are commonly used in similar activities.	compliance improvement) was not available in the snippets I found. However, it is mentioned that there is an increase in understanding and awareness, as well as active participation, which reflects the effectiveness of the extension
15	Counseling on Laundry Chemicals Risks and the Implementation of Occupational Safety and Health (K3) in the Laundry Industry	Indah Permata Sari — Trisakti University Dian Mardi Safitri — Department of Industrial Engineering, Faculty of Industrial Technology, Trisakti University Winnie Septiani — Department of Industrial Engineering, Faculty of Industrial Technology, Trisakti University Bambang Cholis Su'udi — Department of Industrial Engineering, Faculty of Industrial Technology, Trisakti University	Providing counseling to laundry workers about the risk of exposure to chemicals used in the laundry industry and the importance of implementing occupational safety and health (K3), especially the use of personal protective equipment (PPE)	The form of activity: direct counseling to laundry workers in one of the laundry industries in Tangerang City.	The evaluation of activities showed an increase in the knowledge of laundry workers about the risks of chemicals as well as how to prevent and handle exposure. The benefits of counseling and delivering the material were also considered positive—all workers agreed that this activity was very useful and that the material was delivered very clearly
16	Hazard Communication and K3 Cultural Education for	Fitriyani Ftr (Andalas University)	Detect and communicate various hazards and risks of Occupational Safety	It is implemented in three stages: Initial survey for risk	There was a significant increase in the knowledge of workers — from an average of 57 pre-tests to 79.25 post-tests, or a

	Wood Furniture Industry Workers in Payakumbuh City	A Girl Who Is A Princess Maya Khairunisa Wafiq Ainul Fiqran Michelle Angela Marianda Diamond	and Health (K3) in the wooden furniture industry, as well as improve workers' understanding of the handling and prevention of exposure to hazards such as wood dust and chemicals (paints, solvents, glues)	identification. Counseling/education includes hazard recognition, reading of the Material Safety Data Sheet (LDKB), and the use of PPE. Evaluation of the implementation two months later. The implementation involves pre-test and post-test to measure participants' understanding	difference of +22.25 points (28%) However, a two-month evaluation after counseling showed that the use of PPE by workers was still minimal; the need to provide comfortable PPE and make its use mandatory is put forward as a recommendation
17	K3 Risk Analysis in WWTP Areas in Textile Factories using HIRARC	Rama Ramdani; Jefferson Siahaan; Tini Setiawati	Hazard identification, risk assessment, and risk control at WWTP	Qualitative approach: interviews, observations; HIRARC framework	24 hazards found; 5 low risk, 15 moderate, 4 high; Comprehensive Control Recommendations
18	Promotion of Occupational Safety and Health (K3) towards Increasing Knowledge and Attitudes about the Use of Personal Protective Equipment (PPE) in Laboratories in Students at SMK Kimia Tunas Harapan, East Jakarta	Rafiah Maharani Pulungan Bintari Triani Both are affiliated with SMK Kimia Tunas Harapan in East Jakarta	Investigate the relationship between K3 (Occupational Safety and Health) promotion and students' knowledge and attitudes regarding the use of Personal Protective Equipment (PPE) in chemistry laboratories.	Research design: Quantitative, using purposive sampling technique. Population: 203 students. Sample: 100 students from grades 10 and 11 who were willing to be respondents. K3 Promotion Intervention: Conducted in two meetings through the lecture method, with visual media (poster) and audiovisual (video). Data analysis: Paired Sample t-test to see the difference before and after K3 promotion	Knowledge: Before K3 promotion, only 25% of students had good knowledge. After the promotion, the percentage increases to 95%. Attitude: The percentage of students with a positive attitude increased from 40% to 56% after K3 promotion. Conclusion: There is a significant relationship between K3 promotion and students' knowledge and attitudes towards the use of PPE. Recommendation: Schools need to provide adequate PPE to students before practicum in the laboratory
19	Hazard Identification and Risk Assessment to Control Potential Work Accidents at the Basic Chemistry Laboratory of the Kalimantan Institute of	Teo Lukmanul Hakim, Made Yuri Suriyani, Adhe Paramita, Wahyuni Harliyanti (2025)	Observational research with hazard identification in the laboratory, then risk assessment was carried out using the HIRARC (Hazard Identification, Risk Assessment and Risk Control) method.	To identify potential hazards and assess the level of risk in ITK's basic chemistry laboratory, as well as provide risk control recommendations to improve occupational safety.	There are physical, chemical, biological, and ergonomic hazards in the laboratory. Most hazards are in the high risk category. Control recommendations: the use of PPE, the rearrangement of work areas, and the

	Technology (ITK)				implementation of routine inspection and supervision procedures. The implementation of control is expected to be able to reduce the potential for work accidents in the laboratory.
20	Implementation of Internal Audit of the Work Permit and Emergency Response Element Management System as an Effort to Improve K3 Performance at PT DNX Indonesia Site Adaro South Kalimantan	Arni Dyah Purwaningsih, Student of the D-3 Hiperkes program, Faculty of Medicine, Sebelas Maret University	The research aims to examine the effectiveness of the implementation of internal audits on two important elements in the K3 management system, namely work permits and emergency response, in order to improve occupational safety and health performance at PT DNX Indonesia, Adaro site, South Kalimantan	The research method is descriptive, with data collection carried out through: Direct observation in the field, interviews with related parties, and Literature study (analysis of laws and regulations related to work permits and emergency response). The data is then analyzed to assess the implementation of internal audits within the framework of applicable regulations.	Research shows that: PT DNX Indonesia site Adaro has carried out an internal audit of the management system on the elements of work permits and emergency response on a continuous basis. Work permit elements have been applied to a variety of risky work conditions, such as: work at height, hot work, excavation high voltage, and other routine jobs. Emergency response elements have also been well prepared, including: preparation of emergency response procedures, Setting an emergency meeting point, the formation of an emergency response team, provision of P3K facilities, as well as adequate fire protection systems such as fire extinguishers (Light Fire Extinguishers) and hydrants. The implementation of this internal audit is in accordance with the provisions of the Indonesian Ministerial Regulation No. Per.05/MEN/1996
21	Introduction to Occupational Safety and Health Culture in Senior High School Laboratories through Education	Deviyanti, Cici Chairunisa Mas' um, Hardianty Hardianty, Siti Nurmanis Sari	to increase students' understanding of the importance of K3 culture in the laboratory	Filling out an initial questionnaire to measure the level of students' initial understanding, delivering material through lectures and live demonstrations, and interactive Q&A sessions to deepen participants' understanding.	- Significant increase in student awareness and level of insight related to laboratory K3. - Understand the objectives, causes and risks that arise if you do not apply the principles of K3 in the laboratory.
22	Implementation of the HIRAC (Hazard Identification, Risk Assessment, And Control) Method to	M Ansyar Bora, Subakti Eko Pratama, Ririt Dwiputri Permatasari, I	to explore the implementation of the HIRAC method in the laboratory of PT. XYZ and evaluate its impact	Hazard Identification, Risk Assessment, and Control (HIRAC), this method has been widely recognized as	1) There are three main rooms with the highest risk findings. 2) Many rooms do not provide clear information about the use of personal protective equipment (PPE).

	Improve K3 in the Laboratory of PT. XYZ	Made Sondra Wijaya	on improving occupational safety.	an effective approach to managing risks in a variety of industries, including laboratories	3) Recommended Solutions offered
23	Improving Occupational Safety in the Laboratory through Training on the Use of Environmentally Friendly Materials	I Want to Be With You, By Stephanie (2020)	Laboratory training that combines discussion and practice (hands-on practicum) regarding the use of environmentally friendly materials as an alternative to conventional chemicals.	To improve work safety in the laboratory through training on the safe and environmentally sound use of practicum materials.	The training includes pretests and postes, as well as the use of environment-based materials and modification of practicum procedures. There was an increase in the average score from the pretest 57.4% to the post 81.25%, indicating an increase in participants' understanding as a result of the training. Participants became better able to identify safe ingredients, understand the properties of chemicals, and develop environmentally friendly chemistry practicums. Overall, training is said to be effective in improving work safety in the laboratory through an environmentally friendly materials approach
24	Analysis of Good Manufacturing Practice and Good Hygiene Practice with Hazard Analysis and Critical Control Point (HACCP): Food Safety Study of MSME Products of Tofu Factory ABC	Fadli Choironi	This research aims to: 1. Identify the implementation of Good Manufacturing Practice (GMP) and Good Hygiene Practice (GHP) at the ABC Tofu Factory. 2. Analyze potential hazards at each stage of production that could cause food safety risks based on the HACCP system. 3. Provide recommendations for improvements to improve the	This study uses a descriptive approach with a case study at the ABC Tofu Factory which was selected purposively. Data was collected through direct observation, interviews with production owners and employees, and documentation. The analysis was carried out by evaluating the suitability of the implementation of GMP and GHP and identifying critical points (CCPs) in the production process using HACCP principles.	The implementation of GMP at the ABC Tofu Factory has a score of 31.72%, which is classified as very under-meets the requirements. Aspects that need to be improved include buildings, laboratories, labeling, and maintenance. The implementation of GHP obtained a score of 43.84%, classified as less than meets the requirements. Aspects that need to be improved include equipment, pest control, waste management, and employee training. The HACCP analysis identifies several critical points (CCPs) in the tofu production process, namely: o Soybean acceptance process: chemical hazards

			food safety of ABC Tofu Factory products.		(pesticide residues). o Boiling process: physical hazard (cigarette dust). o The process of making vinegar: biological hazards (bacterial contamination). o Tofu printing process: biological hazard (bacterial contamination). o Delivery process: physical hazard (contamination from the road)
25	Risk analysis of hazardous chemicals in organic chemistry laboratories	I Dewa Putu Subamia (Undiksha), 2019.	Descriptive-qualitative analytics; observation, analysis of chemical labels and MSDS, as well as documentation of use.	Describe the characteristics of hazardous chemicals, the types of risks, and the level of risk to users of organic chemistry laboratories.	Hazardous chemicals are categorized as irritant, toxic, corrosive, flammable, explosive, etc. Identified risks include poisoning, irritation, explosion, fire, and tissue damage. The level of risk is quite high, so it demands increased awareness of lab users.

DISCUSSION

Studies related to occupational safety and health (K3) in the laboratory show various risks that must be watched out for, both in terms of chemicals, physical conditions, and ergonomics. Various studies, such as those conducted by Sari & Nugroho (2021), Putri & Rahman (2020), and Wulandari (2019), identify potential hazards in the laboratory that are often not balanced by adequate risk control, such as the use of personal protective equipment (PPE), non-standard chemical storage, and lack of good ventilation. Other research, such as by Zakiyati Salma & Syamsurizal (2020) and Handayani (2020), also highlights the importance of increasing knowledge about K3 and the use of PPE in the laboratory. Some studies suggest the application of risk assessment methods such as HIRAC to assess hazards and design comprehensive risk control measures. In general, the results of the study emphasize the need for education, routine training, and the preparation of standard operating procedures (SOPs) to reduce accidents and improve work safety in laboratories.

CONCLUSION

Evaluation of chemical and physical hazards in chemical laboratories shows that there are still significant potential risks to occupational safety and health. Chemical hazards that are often found include toxic, corrosive, flammable, and reactive materials, while physical hazards include the risk of fire, explosion, and injury due to the use of unsafe laboratory equipment. The application of K3 principles in the laboratory is still not optimal, as can be seen from the lack of use of personal protective equipment, lack of safety training, and inconsistent implementation of standard work procedures. Therefore, efforts to improve K3 need to be focused on regular education and training, storage of chemicals according to standards, correct waste handling, and the implementation of periodic audits and inspections. The awareness and discipline of laboratory users play

an important role in creating a safe and accident-free work environment.

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The sample of this meta-analysis comprised eligible primary studies selected based on predefined inclusion and exclusion criteria. No direct sampling of participants was conducted, as the unit of analysis was published research articles rather than individual respondents.

Data Sources and Data Collection

Primary studies were identified through electronic database searches, including PubMed and Google Scholar. The search strategy combined keywords and Boolean operators as follows: ("Readiness" OR "Utilization") AND ("electronic medical record" OR EMR OR "electronic health record" OR EHR) AND ("health worker" OR "health professionals") AND ("computer skill" OR "literacy" OR "training") AND ("cross sectional" OR "aOR" OR "adjusted odds ratio").

All retrieved articles were screened in several stages. First, titles and abstracts were reviewed to remove duplicates and irrelevant studies. Second, full-text articles were assessed for eligibility based on the inclusion and exclusion criteria. The screening and selection process was documented using a PRISMA flow diagram.

Inclusion and Exclusion Criteria

The inclusion criteria were full-text cross-sectional studies published in English between 2015 and 2025, involving health workers as study subjects, reporting multivariable analysis with adjusted odds ratios (aOR), examining computer skills or computer/EMR-related training as exposures, and readiness to use EMR as the outcome.

Studies were excluded if they were published before 2015, written in languages other than English, or had incomplete outcome or effect size data.

Operational Definitions

Electronic medical records (EMR): a digital-based medical recording system used to record, store, and manage patient health information electronically in a healthcare facility.

Computer skill: the ability of a health worker to operate computer hardware and software.

Computer training: participation in a formal or non-formal training program designed to improve competency in general computer use or specific EMR software.

Quality Assessment

The methodological quality of the included studies was assessed using the Critical Appraisal Skills Programme (CASP) checklist for cross-sectional studies. Each study was evaluated for clarity of objectives, appropriateness of methodology, measurement validity, and control of confounding factors.

Data Analysis

Data were extracted from eligible studies using a standardized extraction form, including author, year of publication, study setting, sample size, exposure variables, and adjusted odds ratios with 95% confidence intervals. Effect estimates from individual studies were entered into Review Manager software (RevMan version 5.3).

Pooled adjusted odds ratios and 95% confidence intervals were calculated using a fixed-effect model. Statistical heterogeneity was assessed using the I^2 statistic and corresponding p-values. Publication bias was evaluated visually using funnel plots.

Results

The meta-analysis process began with defining the research question. The question in this study was whether

computer skills and training influence readiness to use an EMR. The PICO formulation was intended to be used as a reference in searching for relevant articles. The article search was conducted comprehensively through several online databases such as Google Scholar and PubMed.

The article selection process is shown by the prism flow chart which can be seen in Figure 1. The initial search yielded 11 studies that met the inclusion criteria. All studies were conducted in Ethiopia and Kenya and published between 2015 and 2025. The total sample size across studies was 2,809 health workers for the computer skills analysis and 3,161 for the training analysis.

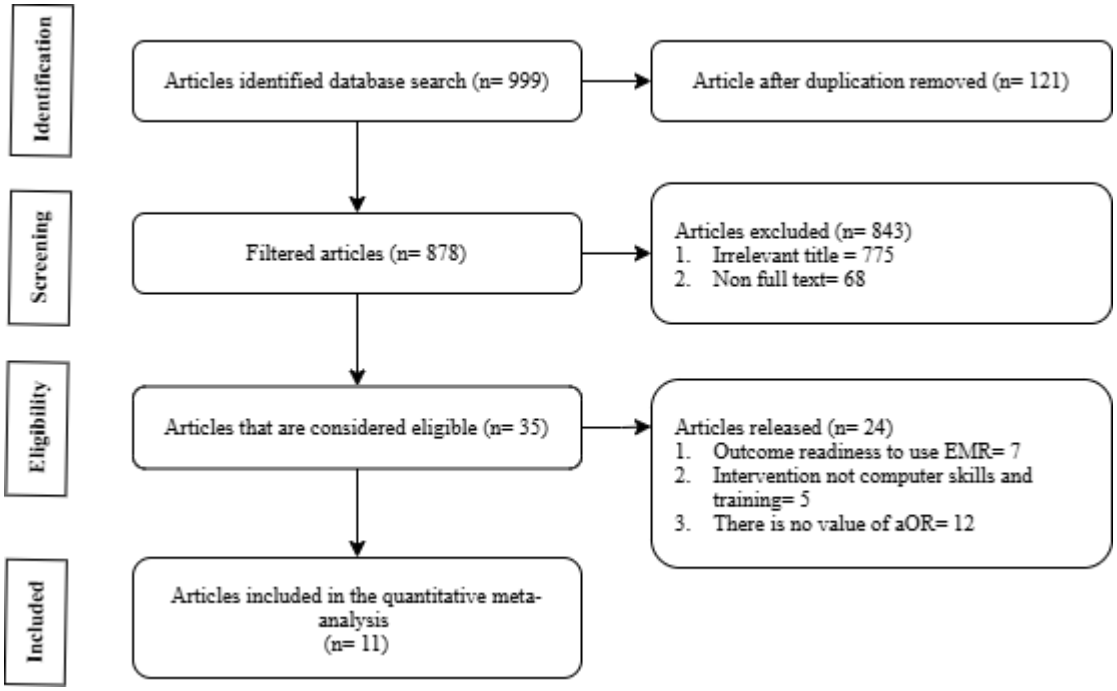

Figure 1. PRISMA Flow Diagram

Table 1. Critical appraisal of cross-sectional studies of the influence of computer skills and training on the readiness to use EMR

Primary Study	Criteria													Total
	1a	1b	1c	1d	2a	2b	3a	3b	4	5	6a	6b	7	
Akeyo *et al*., 2025	2	2	2	2	1	2	1	1	2	2	2	2	2	23
Awol *et al*., 2020	2	2	2	2	1	2	2	2	2	2	2	2	2	25
Gelchu *et al*., 2025	2	2	2	2	1	2	1	1	2	2	2	2	2	23
Hailegebreal *et al*., 2023	2	2	2	2	2	2	1	1	2	2	2	2	2	24
Mekonin *et al*., 2023	2	2	2	2	1	2	2	2	2	2	2	2	2	25
Mulugeta *et al*., 2024	2	2	2	2	2	2	1	1	2	2	2	2	2	24
Oumer *et al*., 2021	2	2	2	1	2	2	2	2	2	2	2	2	2	25
Tesfa *et al*., 2021	2	2	2	2	2	2	1	1	2	2	2	2	2	24
Tolera *et al*., 2022	2	2	2	2	2	2	1	1	2	2	2	2	2	24
Yehualashet *et al*., 2015	2	2	2	2	1	2	2	2	2	2	2	2	2	25
Yilma *et al*., 2023	2	2	2	2	2	2	2	2	2	2	2	2	2	26

Description: 2= Yes; 1= Uncertain; 0= No

Question criteria descriptions:

The quality appraisal of the primary studies was guided by several key criteria. First, the formulation of research

questions was assessed using the PICO framework to determine whether the population examined in each primary study was consistent with the population defined in the meta-analysis. This assessment also examined whether the operational definition of the intervention or exposure in the primary study matched the definition intended in the meta-analysis, whether the comparison or unexposed group was defined consistently, and whether the outcome variables measured in the primary study corresponded to the outcome defined for the meta-analysis.

Second, the methods used to select research subjects were evaluated. In analytical cross-sectional studies, this included assessing whether samples were selected randomly from the target population. When random sampling was not applied, the appraisal considered whether participants were selected based on outcome status or exposure status, and whether such selection methods were appropriate for the study design.

Third, the methods for measuring exposure and outcome variables were reviewed. This involved examining whether similar measurement instruments were used across the primary studies and, when variables were measured on a categorical scale, whether comparable cutoffs or category definitions were applied. Consistency in measurement was considered important for ensuring comparability across studies.

Fourth, potential design-related bias was assessed. For studies in which samples were not selected randomly, attention was given to whether investigators had taken steps to minimize selection bias. This included evaluating whether the selection of participants based on outcome status was independent of exposure status, or whether selection based on exposure status was independent of outcome status.

Fifth, the appraisal examined how primary studies controlled for confounding factors. This involved determining whether investigators conducted multivariate analyses or other appropriate statistical techniques to account for the influence of potential confounders on the association between exposure and outcome.

Sixth, the statistical analysis methods used in each primary study were assessed. This included verifying whether multivariate analytical models, such as multiple logistic regression or multiple linear regression, were applied and whether effect estimates derived from these analyses, such as adjusted odds ratios or adjusted regression coefficients, were reported.

Finally, the possibility of conflicts of interest was considered by reviewing whether the primary studies disclosed funding sources or sponsorship that could have influenced the interpretation or reporting of results. Studies with no apparent conflict of interest were considered to have a lower risk of bias in their conclusions.

The Effect of Computer Skills on EMR Readiness

Table 2 presents description of 7 primary articles with cross-sectional included in the meta-analysis of the influence of computer skills on readiness to use EMR among health workers with a total sample of 2,809.

Table 2. Description of primary studies on the effect of computer skills in readiness to use EMR

Author	Country	Sample	P	I	C	O
Awol *et al*., 2020	Ethiopia	414	Health professionals	Good skill	Poor skill	EMR readiness
Gelchu *et al*., 2025	Ethiopia	384	Health professionals	Good skill	Poor skill	EMR readiness

Author	Country	Sample	P	I	C	O
Hailegebreal *et al*., 2023	Ethiopia	416	Health professionals	Good skill	Poor skill	EMR readiness
Mulugeta *et al*., 2024	Ethiopia	382	Health professionals	Good skill	Poor skill	EMR Implementation
Tesfa *et al*., 2021	Ethiopia	383	Health professionals	Good skill	Poor skill	EMR readiness
Tolera *et al*., 2022	Ethiopia	402	Healthcare professionals	Good skill	Poor skill	The use of EMR
Yehualashet *et al*., 2015	Ethiopia	428	Health professionals	Good Skill	Poor skill	The use of EMR

Table 3. Adjusted Odds Ratio (aOR) of the effect of computer skills on the readiness to use EMR among health workers

Author (Year)	aOR	CI 95%	
		Lower Limit	Upper Limit
Awol *et al*., 2020	3.30	1.05	5.31
Gelchu *et al*., 2025	2.49	1.41	4.39
Hailegebreal *et al*., 2023	3.06	1.49	6.29
Mulugeta *et al*., 2024	2.66	1.16	6.09
Tesfa *et al*., 2021	3.12	1.68	5.76
Tolera *et al*., 2022	1.32	0.68	2.56
Yehualashet *et al*., 2015	1.74	1.16	2.85

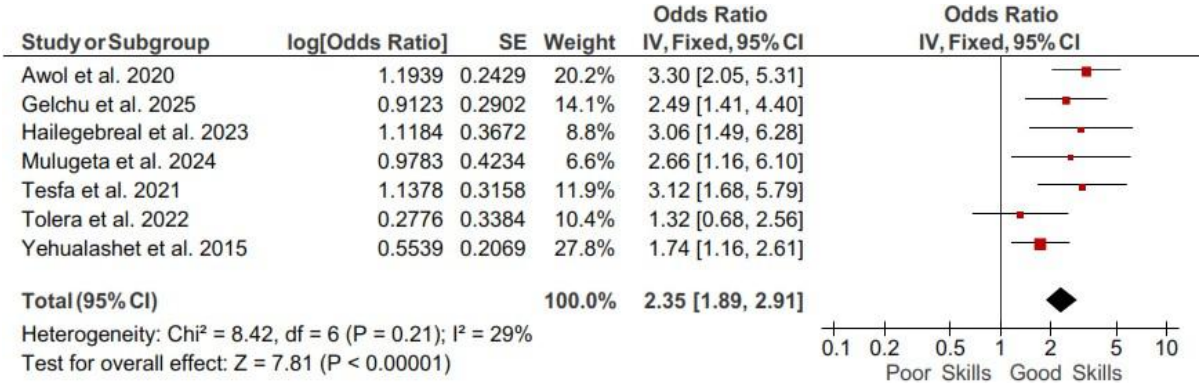

Figure 2. Forest plot of the effect of computer skills on the readiness to use EMR

The forest plot in Figure 2 presented seven studies that reported the association between computer skills and readiness to use EMR. The pooled analysis showed an adjusted odds ratio of 2.35 (95% CI = 1.89 to 2.91; $p < 0.001$). Statistical heterogeneity among the included studies was low ($I^2 = 29\%$, $p = 0.21$).

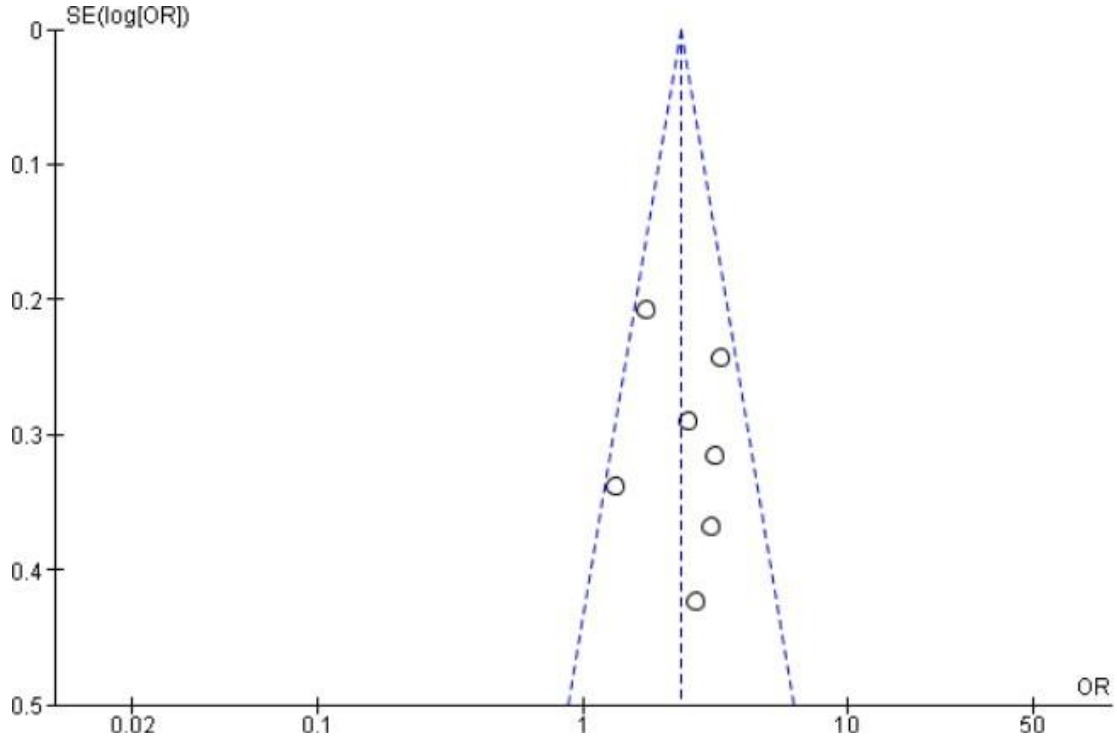

Figure 3. Funnel plot of the effect of computer skills on the readiness to use EMR

The funnel plot in Figure 3 showed a symmetrical distribution of studies on both sides of the pooled effect size. The distribution of studies followed an inverted funnel pattern across different levels of precision.

The Effect of Training on EMR Readiness

Table 4 presents description of 8 primary articles with cross-sectional included in the meta-analysis of the influence of computer or EMR-specific training on readiness to use EMR among health workers with a total sample of 3,181.

Table 4. Description of primary studies on the effect of computer skills in readiness to use EMR

Author	Country	Sample	P	I	C	O
Akeyo *et al*., 2025	Kenya	220	Health workers	Training	No training	EHR sustainability
Awol *et al*., 2020	Ethiopia	414	Health professionals	Training	No training	EMR readiness
Hailegebreal *et al*., 2023	Ethiopia	416	Health professionals	Training	No training	EMR readiness
Mekonin *et al*., 2023	Ethiopia	498	Health professionals	Training	No training	EMR utilization
Mulugeta *et al*., 2024	Ethiopia	382	Health professionals	Training	No training	EMR Implementation
Oumer *et al*., 2021	Ethiopia	412	Health professionals	Training	No training	EMR utilization

Author	Country	Sample	P	I	C	O
Yehualashet *et al*., 2015	Ethiopia	428	Health professionals	Training	No training	The use of EMR
Yilma *et al*., 2023	Ethiopia	411	Health professionals	Training	No training	EMR readiness

Table 5. Adjusted Odds Ratio (aOR) of the effect of computer training on the readiness to use EMR among health workers

Author (Year)	aOR	CI 95%	
		Lower Limit	Upper Limit
Akeyo *et al*., 2025	2.53	1.57	5.12
Awol *et al*., 2020	3.63	1.69	5.80
Hailegebreal *et al*., 2023	2.00	1.06	3.67
Mekonin *et al*., 2023	4.45	2.17	9.10
Mulugeta *et al*., 2024	2.87	1.80	4.56
Oumer *et al*., 2021	5.88	2.93	11.88
Yehualashet *et al*., 2015	1.98	1.65	3.02
Yilma *et al*., 2023	1.59	1.02	2.46

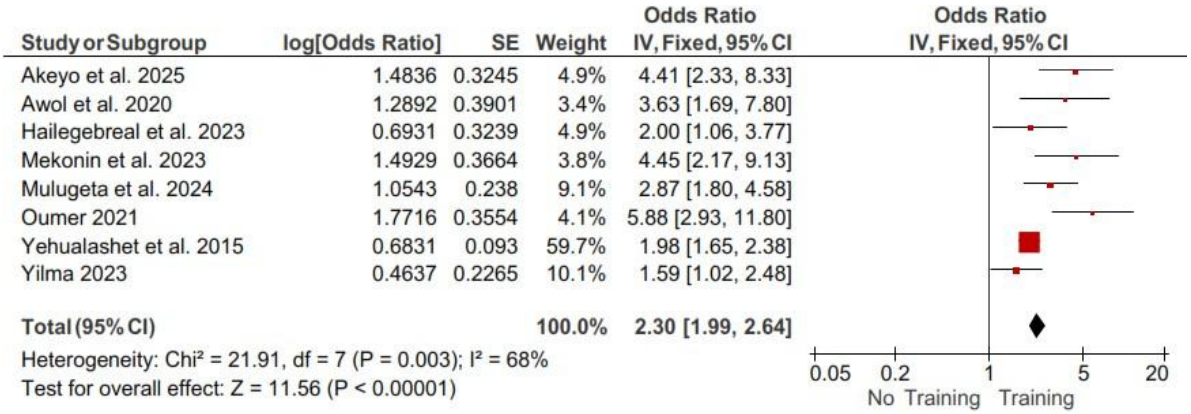

Figure 4. Forest plot of the effect of training on the readiness to use EMR

The forest plot in Figure 4 presented the association between computer or EMR-specific training and readiness to use EMR. The pooled analysis showed an adjusted odds ratio of 2.30 (95% CI = 1.99 to 2.64; $p < 0.001$). Moderate heterogeneity was observed among the included studies ($I^2 = 68\%$, $p = 0.003$).

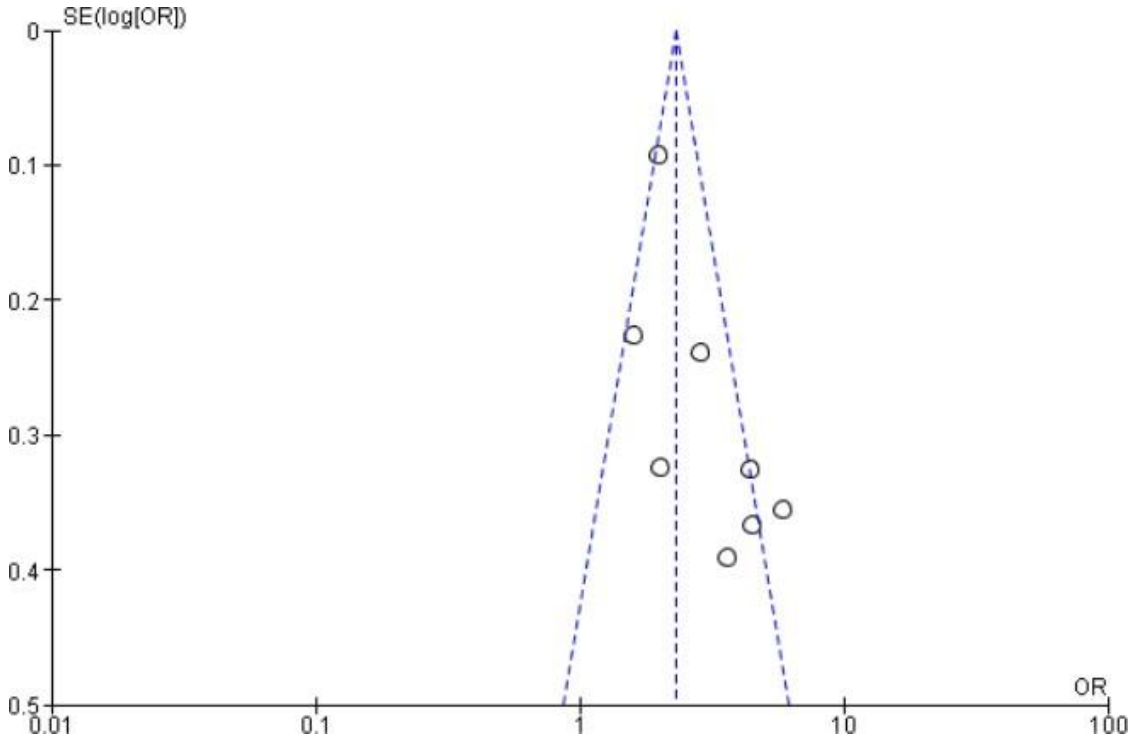

Figure 5. Funnel plot of the effect of training on the readiness to use EMR

The funnel plot in Figure 5 showed a slightly asymmetrical distribution of studies, particularly in the lower precision area, while the overall distribution remained relatively balanced.

Discussion

The Effect of Computer Skills on EMR Readiness

The pooled analysis demonstrated a strong association between computer skills and readiness to use EMR, with health workers who had good computer skills showing higher readiness (aOR = 2.35; 95% CI = 1.89–2.91). The low level of heterogeneity (I^2 = 29%) indicated that this relationship was consistent across the included studies, suggesting that computer skills played a similar role in different healthcare settings.

The symmetrical funnel plot further supported the robustness of this finding, as no clear visual indication of publication bias was observed. The balanced distribution of studies across different levels of precision suggested that the pooled estimate was unlikely to be substantially influenced by selective reporting or small-study effects.

These findings are in line with previous studies conducted in Ethiopia, which consistently reported computer skills as a key determinant of EMR readiness (Tesfa et al., 2021). Similar evidence was also reported by Hailegebreal et al., (2023) who found that computer-literate health workers experienced lower anxiety and greater confidence when using EMR systems. Evidence from other countries, including Myanmar (Oo et al., 2021), and a systematic review by Yehualashet et al., (2021), also identified computer literacy as a major factor influencing EMR adoption.

From a theoretical perspective, this association can be explained using the Technology Acceptance Model. Health workers with better computer skills are more likely to perceive EMR systems as easy to use and useful, which increases their readiness to engage with the technology. Adequate computer skills may also reduce fear of technology and enhance confidence in managing digital tasks, thereby facilitating smoother integration of EMR into daily clinical practice.

Practically, these results highlight the need for health systems to strengthen basic computer literacy as part of EMR implementation strategies. Improving foundational digital skills among health workers may serve as an effective and sustainable approach to enhancing EMR readiness, particularly in low-resource settings.

The Effect of Training on EMR Readiness

The pooled results indicated that computer or EMR-specific training was significantly associated with readiness to use EMR (aOR = 2.30; 95% CI = 1.99–2.64). Although moderate heterogeneity was observed ($I^2 = 68\%$), the direction of effect was consistent across studies, indicating that training contributed positively to EMR readiness despite variations in study characteristics.

The slight asymmetry observed in the funnel plot suggested some variability in study precision; however, the overall distribution remained relatively balanced, indicating no substantial publication bias. The observed heterogeneity may be attributable to differences in training duration, content, delivery methods, and the availability of post-training support across settings.

These findings are consistent with earlier studies from Ethiopia and Kenya. Gelchu et al., (2025) and Mulugeta et al., (2024) reported that hands-on and practice-oriented training improved health workers' competence and confidence in using EMR systems. Tolera et al., (2022) further showed that training programs incorporating scenario-based learning and continuous technical support resulted in sustained readiness and lower resistance to system adoption. Similar conclusions were drawn in a systematic review by Derecho et al., (2024) and a study by (Samadbeik et al., 2020), both of which emphasized the importance of structured EMR training.

The effect of training on readiness can be explained through social cognitive theory, where training provides mastery experiences that enhance self-efficacy. As health workers gain practical exposure and repeated practice, their confidence and perceived ability to use EMR systems increase, which in turn strengthens their readiness to adopt the technology.

In practice, these findings suggest that EMR implementation should be accompanied by comprehensive and continuous training programs rather than one-time sessions. From a scientific perspective, the results reinforce training as a core determinant of EMR readiness and highlight the need for future research to examine which training components are most effective in different healthcare contexts.

Conclusion

This research shows that computer skills and training are highly effective in increasing health workers' readiness to use Electronic Medical Records. The impact is substantial, health workers with computer skills or training are about twice as likely to be prepared to use digital systems. These findings are consistent across various study locations in East Africa, showing that improving digital literacy is a key success factor for digital transformation in healthcare.

Based on these findings, hospitals and health centers should regularly assess their staff's computer skills and provide appropriate training. This training should be designed based on the specific jobs of health workers to make it more effective. For future research, studies should examine the long-term impact of training on the actual use of electronic medical records.

This study has some limitations. The results may not work the same way in other countries because of different

local situations. Also, all the data came from cross-sectional studies, which cannot directly prove cause and effect. Variations in the quality and methods of training across different study locations may have also influenced the results.

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Author Contribution

Naim Khoirul Ummah conceived the study, conducted the data extraction, analysis, and drafted the manuscript. Bhisma Murti supervised the study, provided methodological guidance, and critically revised the manuscript. All authors approved the final version.

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