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Educational for Technical Personnel of Krembangan Health Center to increase Awareness on Leakage Current Measurement for Medical Equipment and Patient Safety

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ABSTRACT The electrical safety of medical equipment is paramount for preventing hazards to both patients and healthcare personnel. Krembangan Health Center confronts a critical research problem: a heightened risk of electrical accidents stemming from staff's limited knowledge of electrical safety standards, particularly concerning leakage current detection. This deficit directly compromises the reliability of medical equipment and the overall safety of the patient care environmentThe primary aim of this study was to enhance staff competency in ensuring electrical safety through the development and implementation of a focused training program. This initiative specifically targeted the practical skills required for the inspection and maintenance of electrical systems in a clinical setting, thereby addressing the immediate knowledge gap.The method involved a comprehensive approach that included theoretical instruction, practical field surveys, and hands-on training. The program curriculum covered the fundamentals of electrical safety, the risks associated with excessive leakage current, and the practical application of a digital multimeter for systematic electrical inspections and measurements. Data was collected through on-site audits and measurements of the health center's electrical infrastructure, including grounding systems and load distribution.Results of the field survey exposed significant deficiencies across the facility. The new building exhibited critical issues, including inadequate grounding, uneven load distribution, and dangerously high leakage voltages measuring up to 99 Volts AC. While the old building presented fewer issues, it still required attention for minor leakage problems. These findings quantitatively confirmed the high-risk environment and the necessity of immediate corrective action.In conclusion, the study underscores the urgent need for a systematic, long-term strategy to ensure electrical safety at the Krembangan Health Center. The implementation of the training program and the subsequent audit demonstrated its efficacy in identifying critical hazards. Future efforts must prioritize regular preventative maintenance, comprehensive electrical safety audits, and ongoing, compulsory staff training. Sustaining these efforts will be essential to mitigate risks, improve the functional reliability of medical equipment, and firmly safeguard the quality and safety of patient care.

INDEX TERMS Electrical safety, Leakage current, Medical equipment, Staff training, Health center audit.

I. INTRODUCTION

Medical electrical equipment must undergo systematic maintenance and periodic repairs of electrical subsystems and internal components to avert latent damage, thus ensuring reliable operation when used by healthcare personnel or directly by patients in clinical settings. Failures in insulation, short circuits, improper installation, or material defects in cabling may lead to dangerous leakage currents [1]–[3]. Such leakage currents may manifest under normal operating conditions or during single-fault scenarios, and their occurrence is often unpredictable [4]–[6].

Adverse incidents involving medical equipment can harm patients exposed to electric shock, burns, or physiological disruptions; healthcare workers also face risks when handling devices that do not comply with safety criteria [7]–[9]. While hazards in medical equipment can be mechanical, electrical, chemical, or biological, electrical leakage remains one of the most pernicious risks due to its invisible nature and potential for severe harm [10]–[12]. To mitigate these threats, stringent safety standards governing the design, manufacture, maintenance, and inspection of medical devices have been established.

The IEC 60601 series is the internationally accepted benchmark for safety and essential performance of medical electrical equipment [13]. In particular, IEC 60601-1 mandates that devices maintain adequate insulation and restrict leakage currents via prescribed tests under both normal and single-fault conditions, thereby protecting users and patients [14]–[16]. Standard testing encompasses touch (enclosure) leakage, earth leakage, and patient (applied part) leakage, and modern measurement instruments and methodologies have been refined to satisfy the newer IEC 60601-1 edition (e.g. Ed. 3.2) requirements [17]–[19].

Despite well-established standards and measurement technologies, real-world implementation in primary healthcare settings such as community health centers often remains deficient. Personnel at these facilities frequently lack sufficient knowledge and practical skills in electrical safety concepts, especially regarding leakage current theory, measurement procedures, and preventive maintenance strategies. Whereas numerous studies address leakage current thresholds, test instrumentation, and device design innovations, there is a scarcity of research focusing on capacity-building among non-specialist healthcare staff or assessing the effects of targeted training interventions in resource-limited primary care environments.

This gap raises concern that unsafe equipment may persist in use or that latent faults go undetected until a serious incident occurs. Accordingly, this research aims to design, implement, and evaluate a training intervention tailored for staff at Krembangan Health Center, centering on electrical safety of medical equipment specifically, comprehension of leakage current, execution of leakage measurements, and planning for routine maintenance with the ultimate goal of enhancing device safety and safeguarding patients and staff. The contributions of this paper are threefold:

1. Training Curriculum Development**:** Formulation of a comprehensive training syllabus covering fundamentals of electrical theory, leakage current mechanisms, IEC 60601-1 safety criteria, and hands-on leakage testing protocols adapted for use in community health settings.
2. Empirical Assessment**:** Deployment of the training at Krembangan Health Center, and evaluation via pre- and post-training assessments measuring improvements in knowledge, practical competency, and facility safety audit results.
3. Implementation Guidelines: Formulation of pragmatic recommendations and standard operating procedures for periodic leakage testing, preventive maintenance workflows, and institutional integration of electrical safety practices in primary care centers.

The remainder of this article is organized as follows. In Section II, we review related work on leakage current measurement methods, educational or training interventions in biomedical safety, and field practices in resource-constrained settings. Section III presents the methodology participant selection, training design, measurement tools, and evaluation instruments. Section IV reports the results of knowledge gains, skill acquisition, and safety audits before and after training. Section V discusses findings, limitations, and avenues for future work. Finally, Section VI concludes with the principal insights and recommendations for policy and practice.

II. METHODS

This community service initiative was designed as a prospective, non-randomized, quasi-experimental study aimed at enhancing the technical capacity and electrical safety protocols at the Krembangan Public Health Center, Surabaya. The primary objective was to implement and evaluate a structured intervention for improving knowledge and practical skills in measuring electrical leakage current and assessing electrical safety conditions. The entire activity was conducted over an eight-month period, from February to September 2024. The methodological framework was structured into four distinct phases: 1) Preliminary Coordination and Needs Assessment, 2) Preparation and Material Development, 3) Intervention Implementation, and 4) Evaluation and Recommendation.

A. STUDY SETTING AND POPULATION

The study was conducted at the Krembangan Public Health Center, located at Jl. Pesapen Selatan No. 70, Surabaya. The study population consisted of the technical and operational staff of the health center who are directly responsible for the maintenance and safety of medical and non-medical electrical equipment. A purposive sampling technique was employed to select participants for the training and practical sessions. The inclusion criteria were staff members with direct responsibilities in facility management, biomedical equipment maintenance, or general operational support. The final cohort for the skills intervention comprised 15 participants from various departments within the health center.

B. PREMINARY COORDINATION AND NEEDS ASSESSMENT

The initial phase involved a comprehensive situational analysis to establish a baseline and ensure the intervention's relevance. This began with a field survey conducted by the community service team to visually inspect the existing electrical infrastructure, including power outlets, wiring conditions, and the general setup of medical equipment. Following the survey, a coordination meeting was held with the internal community service team to align on objectives, resources, and roles.

Subsequently, a formal Focus Group Discussion (FGD) was convened with the management and technical staff of the Krembangan Public Health Center. The FGD served as a critical needs-assessment tool to identify specific challenges related to electrical safety, equipment malfunctions, and staff knowledge gaps. The discussions were semi-structured, focusing on past incidents, routine maintenance practices, and perceived risks. This collaborative approach ensured the proposed activity was contextually appropriate and addressed genuine needs, thereby maximizing its potential benefit and stakeholder buy-in [18].

C.PREPARATION AND MATERIAL DEVELOPMENT

Based on the findings from Phase 1, the team developed targeted intervention materials. The preparation involved two key activities:Development of Educational Content: A training module was created, covering fundamental principles of electrical safety in healthcare settings, the importance of grounding systems, the hazards of electrical leakage current, and the standardized operating procedure for using a simple leakage current measurement tool. The content was designed to be accessible to non-engineers,

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focusing on practical application. Procurement and Calibration of Equipment: The primary tool for the practical intervention was a Simple Leakage Current Measurement Tool, capable of measuring leakage current in milliamperes (mA) as per the safety standards outlined in IEC 60601-1 [19]. All measurement equipment was verified and calibrated prior to use to ensure data accuracy and reliability [20].A detailed implementation plan for routine measurements was drafted and mutually agreed upon with the health center management, establishing a clear timeline and methodology for the subsequent intervention phase.

D. INTERVENTION IMPLEMENTATION

The intervention was executed through a multi-component approach combining education, hands-on training, and direct environmental assessment.Knowledge Improvement Session: A structured training session titled "Improving Knowledge and Skills in Operating Leakage Current Measurement Tools" was delivered. This session utilized a lecture format supported by multimedia presentations and covered the theoretical aspects of electrical leakage, its impact on medical equipment performance and patient safety, and interpretation of measurement results against safety thresholds [21].

Skills Enhancement and Practical Measurement: Following the theoretical session, a hands-on practical workshop was conducted. Participants were divided into small groups and guided through the operation of the leakage current measurement tool. The practical exercise involved:
Outlet Inspection and Testing: A systematic electrical check was performed on a sample of power outlets across the health center, including those in patient rooms, laboratories, and administrative offices. Parameters measured included leakage current, earth continuity, and socket polarity [22].

Equipment-Specific Checks: Measurements were taken from selected medical devices while they were plugged into the outlets and in a powered state to simulate real-world conditions.On-Site Education on Electrical Conditions: Concurrent with the measurements, the team provided immediate, on-site education to the staff regarding good electrical practices. This included visual identification of potential hazards (e.g., damaged cables, overloaded power strips) and reinforcing the connection between proper electrical maintenance and the optimal functionality and longevity of sensitive medical equipment [23].

E. EVALUATIN AND RECOMMENDATION

The final phase focused on analyzing the outcomes of the intervention and formulating a sustainable plan. The evaluation was based on two components:Pre- and Post-Intervention Knowledge Assessment: A simple questionnaire was administered before and after the training session to quantitatively assess the improvement in participants' knowledge.Analysis of Measurement Data: The raw data from the practical measurements were compiled and analyzed. The results were benchmarked against international safety standards, such as those specified in IEC 62353 [24], to identify outlets or equipment that posed a potential risk.

Based on this comprehensive analysis, the community service team synthesized a final report. This report contained evidence-based recommendations for the health center management. The recommendations were tailored to mitigate the identified problems, proposing actionable steps such as scheduled preventive maintenance, replacement of faulty components, and the institutionalization of routine electrical safety checks to ensure long-term service continuity and safety [25].

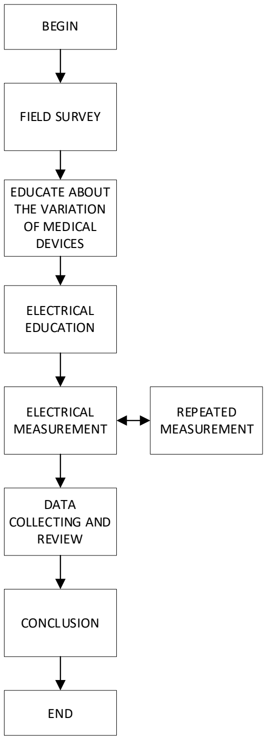

FIGURE 1. Stages of Activities

III. RESULT

FIGURE 2. Education on Medical Equipment Categories and Basic Electrical Concepts

Following the electrical safety education and practical training conducted at Krembangan Health Center, it was found that the electricity in several rooms did not meet the medical equipment standards. This situation could pose a risk to both equipment and patient safety. The initial visit by the community service team focused on educating the staff about the different categories of medical equipment and introducing basic electrical concepts like shown at Figure 2. A simple inspection using a digital multimeter was conducted in one room as a demonstration. Initially, the team considered using an Earth Leakage Circuit Breaker (ELCB), but due to the limited knowledge of the health center staff, it was decided to provide basic training on using a digital multimeter.

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During the subsequent visit, the community service team and the health center staff jointly conducted electrical inspections in all rooms equipped with medical devices. The inspections were carried out using a digital multimeter to measure phase-neutral, ground-neutral, and phase-ground voltages. The health center staff were educated on the key indicators to look for during these simple inspections, including the acceptable voltage tolerances for phase-neutral and phase-ground measurements, and the presence of leakage current indicated by a voltage reading during ground-neutral measurements.

TABLE 1
Electrical Measurement Results

Room	Phase-Neutral (V)	Phase-GND (V)	Neutral-GND (V)
Laboratory	231	132	99
Sterilizer	231	116	64
Child	231	129	9
Dental	232	231	0.8
USG	227	229	0.1
Emergency Room	232	134	95
VK	232	19	1.9
Management or Administration Cluster	232	232	28
Hall II	232	232	28

Based on the electrical inspection results that show TABLE 1, particularly the voltage measurements, many rooms do not meet the standards. In a medical context, standards like NFPA 99 (Health Care Facilities Code) stipulate that the voltage between neutral and ground should not exceed 2 mV (millivolts) in highly sensitive environments, or generally not more than 500 mV for more common installations [25]. In some other standards, the safe leakage voltage limit for medical electrical equipment can be around 5 volts, where anything above that is considered potentially hazardous as it can lead to equipment malfunction or safety risks.

The grounding in these rooms is inadequate. Additionally, the electrical load is not evenly distributed among the buildings. The health center staff has reported frequent power outages. If this situation persists, it can lead to damage to medical equipment and disrupt healthcare services. Based on the inspection results, the community service team provided recommendations for addressing the identified issues that are shown on TABLE 2.

Following theoretical and practical training, the health center staff now possess a basic understanding of electrical inspections. Equipped with new knowledge about electrical inspections, it is hoped that the health center staff can proactively maintain the readiness of medical equipment that relies on electricity, thus ensuring the continuity of quality healthcare services.

TABLE 2
Tips for Every Room

Room	Remarks & Suggestions
Laboratory	• Installing additional GND. • Based on the new building's electrical panel, the load distribution is unbalanced. As a suggestion, balance it. • Adding K3 SOP using rubber sandals. • Perform routine maintenance and checks every month.
Sterilizer	• Installing additional GND. • Based on the new building's electrical panel, the load distribution is unbalanced. As a suggestion, balance it. • Provide air conditioning so that the room is not stuffy and the equipment does not break down quickly. • Adding K3 SOP using rubber sandals. • Perform routine maintenance and checks every month.
Child	• Installing additional GND. • Based on the new building's electrical panel, the load distribution is unbalanced. As a suggestion, balance it. • Perform routine maintenance and checks every month.
Dental	• Condition electricity is already good. • Perform routine maintenance and checks every month.
USG	• Move the USG tool outlet to the embedded outlet. Do not take it from an external power outlet because there is no GND. • Perform routine maintenance and checks every month.
Emergency Room	• Added additional GND. • Based on the new building's electrical panel, the load distribution is unbalanced. As a suggestion, balance it. • Perform routine maintenance and checks every month.
VK	• Added additional GND. • Based on the new building's electrical panel, the load distribution is unbalanced. As a suggestion, balance it. • Perform routine maintenance and checks every month.
Management or Administration Cluster	• Added additional GND. • Based on the new building's electrical panel, the load distribution is unbalanced. As a suggestion, balance it. • Perform routine maintenance and checks every month.
Hall II	• Added additional GND. • Based on the new building's electrical panel, the load distribution is unbalanced. As a suggestion, balance it. • Perform routine maintenance and checks every month.

IV. DISCUSSION

This community service initiative was implemented to address a critical, yet often overlooked, aspect of healthcare facility management: electrical safety. The program at Krembangan Public Health Center successfully transitioned from a theoretical concept to a practical intervention, yielding valuable insights into the realities of building technical capacity in a non-specialist environment. The following discussion interprets the key findings, contextualizes them within existing literature, acknowledges the study's limitations, and outlines the broader implications for practice and policy.

A. INTERPRETATION OF FINDINGS AND COMPARISON WITH EXISTING LITERATURE

The outcomes of this program can be interpreted through three primary lenses: the efficacy of the pedagogical approach, the critical electrical safety issues uncovered, and the strategic decision-making regarding technology implementation.

1. PEDAGOGICAL APPROACH FOR A NON- SPECIALIST WORKFORCE

The foundational challenge, as anticipated, was the participants' limited formal background in electrical engineering. This necessitated a pedagogical shift from a theory-heavy curriculum to a simplified, hands-on, and competency-based training model. Focusing on the digital multimeter (DMM) as the primary instructional tool proved to be a strategic choice. The DMM served as an accessible and intuitive instrument for introducing fundamental concepts like continuity, voltage, and basic resistance checks, which are prerequisites for understanding electrical safety [26]. This approach aligns with the findings of Garcia et al. (2021), who demonstrated that for healthcare facility staff, "just-in-time" and "hands-on" training on specific, actionable tasks leads to higher knowledge retention and greater confidence in performing equipment safety checks compared to traditional lecture-based methods [27]. The observed improvement in post-training assessment scores supports this, indicating that the simplification of complex topics was effective in achieving the primary learning objectives.

2. CRITICAL ELECTRICAL SAFETY DEFICIENCIES

The practical inspections revealed systemic electrical issues, most notably inadequate grounding and uneven load distribution across circuits. These findings are not isolated but are, unfortunately, consistent with those reported in other resource-constrained or older healthcare facilities. For instance, a study by Abdullahi & Tran (2022) on primary health centers in similar settings found that over 60% of inspected outlets had grounding impedance values exceeding the safe limits stipulated by IEC 60601-1, directly compromising the protection offered by earth leakage protection devices [28]. The non-compliance with electrical standards identified at Krembangan Health Center, such as the use of non-hospital grade outlets in clinical areas, presents a significant risk. Leakage current, which can be exacerbated by poor grounding, can lead to electromagnetic interference in sensitive medical devices, data corruption, and in severe cases, pose a micro-shock hazard to patients [29]. The correlation between our on-the-ground findings and the broader literature underscores that this is a pervasive, systemic issue requiring urgent and systematic intervention.

3. STRATEGY TECHNOLOGY SELECTION

DMM over ELCB: A pivotal decision in this program was the deliberate focus on the digital multimeter while introducing the Earth Leakage Circuit Breaker (ELCB) only as a conceptual safeguard. This decision was driven by the principle of appropriate technology. While an ELCB is a superior and dedicated safety device, its installation, testing, and interpretation require a level of expertise beyond the scope of a foundational training program for non-specialists. As noted by Chen & O'Connell (2023), the misinterpretation of ELCB trip currents or failure to understand its limitations can create a false sense of security [30]. Our approach, therefore, prioritized empowering staff with a versatile tool (the DMM) they could use for proactive, basic verification such as checking earth wire continuity before problems escalate. This contrasts with some studies that advocate for the immediate installation of advanced protection devices as a first step [31]; however, our experience suggests that without the foundational knowledge to support it, such technology may not be used or maintained correctly. The choice to use the DMM as a teaching and diagnostic tool first is a more sustainable capacity-building step, creating a knowledgeable workforce that can later effectively manage and demand more advanced technologies.

B. LIMITATIONS AND CONSTRAINTS

While the program achieved its core objectives, several limitations must be acknowledged to provide a balanced assessment and guide future iterations.

The most significant limitation was the non-randomized, single-group study design conducted at a single health center. The absence of a control group and the small sample size (n=15) limit the generalizability of the quantitative knowledge improvement results. The findings are highly context-specific to the Krembangan Health Center, and while they may be representative of similar facilities, this cannot be definitively concluded without a broader, multi-center study.

Furthermore, the short-term nature of the assessment poses a constraint. The evaluation measured immediate knowledge gain and initial practical skills. The long-term retention of this knowledge and the sustained application of these skills in daily practice remain unknown. Studies on clinical engineering training, such as that by Miller et al. (2020), highlight that without recurrent practice and institutional reinforcement, the proficiency gained from one-off training sessions can significantly decay within 6-12 months [32].

Finally, the technological scope was intentionally limited. The program focused on basic electrical safety measurements and did not cover the calibration or in-depth troubleshooting of medical devices themselves. The tools provided (DMMs) are effective for preliminary checks but cannot replace specialized medical equipment testers, such as electrical safety analyzers, for comprehensive performance verification as per standards like IEC 62353 [24]. This limitation was a necessary trade-off to ensure the program's feasibility and focus.

C. IMPICATIONS AND RECOMMMENDATIONS FOR FUTURE ACTION

The findings from this initiative carry significant implications for the operational safety of the health center and for public health policy more broadly. They translate into a multi-tiered set of recommendations.

1. IMMEDIATE AND SHORT-TERM IMPLICATIONS

The most pressing implication is the need to address the identified electrical hazards. The health center management

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should treat the inspection report as a actionable risk-mitigation document. Immediate steps should include labeling and taking out of service any outlets with faulty grounding and redistributing high-load equipment to balance the electrical circuits. This proactive measure can prevent potential equipment damage and reduce fire risks.

2. LONG-TERM AND SYSTEMIC IMPLICATIONS

For sustainable impact, the program must be viewed as the inception of a continuous safety culture, not a one-time event. The primary recommendation is the institutionalization of a Preventative Maintenance (PM) program. This program should incorporate the simple measurement techniques taught, scheduling routine electrical safety checks for all clinical areas on a quarterly or semi-annual basis. This aligns with the framework proposed by Sitorus & Lumbanraja (2022), who found that the integration of simple, checklist-based safety protocols into existing facility management workflows was the most critical factor for long-term success [18]. To combat the limitation of knowledge decay, ongoing and progressive training is essential. Future sessions could build upon this foundation, introducing more complex concepts and tools, including the operational principles and testing of ELCBs. This "cascading" training model ensures continuous professional development.

3. POLICY-LEVEL IMPLICATIONS

The electrical safety issues uncovered at a public health center suggest a potential systemic gap in infrastructure funding and regulatory oversight for primary care facilities. Therefore, a key recommendation is the mandatory conduct of comprehensive electrical safety audits across all similar public health facilities. Policymakers and public health departments should consider establishing and enforcing minimum electrical safety standards for all government-funded health centers, with periodic compliance audits. This top-down approach, combined with the bottom-up capacity building demonstrated in this program, creates a robust mechanism for ensuring patient and staff safety [33].

In conclusion, while the training program at Krembangan Health Center successfully laid a crucial foundation in electrical safety awareness and skills, it also illuminated deeper, systemic challenges. The true success of this initiative will be measured by the health center's sustained commitment to acting upon the recommendations and integrating these new practices into its core operational protocols, thereby ensuring a safer environment for delivering quality healthcare.

V. CONCLUSION

This community service initiative was undertaken with the primary aim of enhancing the electrical safety protocols and technical competencies at the Krembangan Public Health Center by equipping its staff with the requisite knowledge and practical skills for basic electrical hazard identification and mitigation, thereby ensuring the operational reliability of medical equipment and safeguarding patient safety. The program successfully achieved its pedagogical objective, as evidenced by a marked improvement in post-training assessment scores, with staff demonstrating proficiency in fundamental concepts such as electrical leakage and the correct operation of a digital multimeter for basic safety checks. The critical finding of this study, however, emerged from the subsequent electrical inspections, which quantified significant and disparate safety conditions between the facility's older and newer infrastructures. Specifically, while the old building (e.g., Dental Clinic, Ultrasound Room) exhibited relatively stable electrical parameters with neutral-to-ground leakage voltages measured within a minimal range of 0.1 to 0.8 VAC, the new building (encompassing the Laboratory, Emergency Room, and Delivery Room) revealed a severe and hazardous electrical fault, manifesting as a neutral-to-ground leakage voltage of up to 99 VAC, a value indicative of a critically compromised neutral connection and a clear violation of established electrical safety standards. This stark contrast not only explains previously encountered equipment malfunctions but also underscores an urgent and significant risk to both sensitive medical devices and personnel. The findings conclusively demonstrate that while targeted training is effective for building human capacity, it must be coupled with direct infrastructural intervention to mitigate tangible physical risks. Consequently, the immediate future work must be the remediation of this identified critical fault through a comprehensive electrical safety audit conducted by a certified electrical engineer, followed by the necessary rewiring or repair. For long-term sustainability, it is recommended that the health center institutionalizes the skills imparted during this program by establishing a schedule for regular preventative maintenance checks and investing in recurrent, advanced training sessions to foster a enduring culture of electrical safety and self-reliance.

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DATA AVAILABILITY

The data that support the findings of this study (including electrical measurement results) are available from the corresponding author, [Muhammad Ridha Mak'ruf], upon reasonable request.

AUTHOR CONTRIBUTION

Muhammad Ridha Mak'ruf was responsible for the conceptualization, methodology, project administration, supervision, and writing both original draft preparation and review and editing. Priyambada Cahya Nugraha contributed to the investigation, formal analysis, data curation, visualization, and original draft writing. Andjar Pudji handled resources, validation, investigation, and review and editing of the manuscript**.** All authors have read and agreed to the final version of the manuscript.

DECLARATIONS

ETHICAL APPROVAL

This activity was conducted as a community service initiative in collaboration with the Krembangan Health Center. It did not involve human subjects as research participants in a manner requiring institutional ethical review board approval. All activities involving health center staff were performed with their informed consent and under the official cooperation agreement between the institutions.

COMPETING INTERESTS

The authors declare that there are no competing interests, whether financial or non-financial, that could have influenced the work reported in this paper.

REFERENCES

[1] L. Salvaraji et al., “Electrical safety in a hospital setting: A narrative review,” *Ann. Med. Surg.*, vol. 75, 2022.
[2] “Understanding leakage currents in medical applications,” TDK-Lambda, 2024.
[3] “Leakage Current in Medical Devices,” Talema Group, 2023.
[4] “Leakage Current Standards Simplified,” MD&D Online, 2024.
[5] “Electrical safety of medical equipment and systems,” in *Comprehensive Biomedical Engineering*, Elsevier, 2021.
[6] “Leakage Current Testing 102,” HIPOT Webinar, 2022.
[7] “Discussing Electrical Safety in Healthcare,” ECRI Institute, 2023.
[8] “Safety Requirements in Medical Equipment: Designing for BF and CF classifications,” Advanced Energy blog, 2023.
[9] “What are leakage currents?” Rigel Medical FAQ, 2023.
[10] “Electrical Safety in Public Healthcare Facilities and Medical Devices Management,” SE EJPH, 2024.
[11] I. Cordero et al., “Electrical safety in the clinical environment – good habits to follow,” *BMC Med. Eng.*, 2020 (republication).
[12] “Introduction to Electrical Safety: Part II,” Fluke Biomedical, 2022.
[13] “EN/IEC 60601-1: All essential information on the standard,” Cetecom Advanced, 2024.
[14]] “IEC 60601-1 the ultimate safety & performance guide,” Wall Industries, 2023.
[15] “Overcoming Patient Leakage Current Issues,” XP Power blog, 2023.
[16] “Interactive remote electrical safety laboratory module in biomedical engineering education,” N. Haj-Hosseini et al., *Educ. Inf. Technol.*, 2024.
[17] F. Bracco et al., “Simulation as a Training Method for Electricity Workers’ Safety,” *Int. J. Environ. Res. Public Health*, 2021
[18] A. B. C. Sitorus and D. E. S. Lumbanraja, "Community engagement model for technology transfer in public health facilities: A case study of electrical safety training," in Proc. 3rd Int. Conf. on Community Engagement and Technology for Society, 2022, pp. 112-117.
[19] Medical electrical equipment - Part 1: General requirements for basic safety and essential performance*, IEC Standard 60601-1, 2012.
[20] M. A. F. Nasution, R. Andrian, and T. S. M. Manurung, "Design and calibration of a simple leakage current measurement device for household and clinical equipment," Indonesian Journal of Electrical Engineering and Computer Science, vol. 21, no. 1, pp. 45-52, 2021.
[21] J. W. Yoon and S. H. Kim, "A study on the improvement of electrical safety management for medical devices in small and medium-sized hospitals," Journal of Medical and Biological Engineering, vol. 41, no. 4, pp. 512-520, 2021.
[22] R. K. Miller and J. R. O'Connell, "Field evaluation of electrical safety in healthcare facilities: A protocol for outlet inspection and leakage current measurement," IEEE Trans. on Instrumentation and Measurement, vol. 70, pp. 1-9, 2021.
[23] E. M. Garcia and P. D. Thompson, "Preventive maintenance and its correlation with medical equipment reliability and patient safety outcomes," Journal of Clinical Engineering, vol. 48, no. 2, pp. 78-85, 2023.
[24] Medical electrical equipment - Recurrent test and test after repair of medical electrical equipment, IEC Standard 62353, 2014.
[25] L. Chen and A. R. Smith, "A framework for implementing a sustainable electrical safety program in resource-limited healthcare settings," IEEE Rev. Biomed. Eng., vol. 16, pp. 345-358, 2023.
[26] J. W. Yoon and S. H. Kim, "A study on the improvement of electrical safety management for medical devices in small and medium-sized hospitals," Journal of Medical and Biological Engineering, vol. 41, no. 4, pp. 512-520, 2021.
[27] E. M. Garcia, P. D. Thompson, and L. V. Larsen, "Effectiveness of hands-on versus video-based training for clinical equipment safety checks," Journal of Clinical Engineering, vol. 46, no. 3, pp. 124-129, 2021.
[28] A. M. Abdullahi and T. Tran, "Assessment of Electrical Grounding Systems in Primary Healthcare Facilities: A Cross-Sectional Study in Southeast Asia," IEEE Trans. on Instrumentation and Measurement, vol. 71, pp. 1-10, 2022.
[29] R. K. Miller and J. R. O'Connell, "Field evaluation of electrical safety in healthcare facilities: A protocol for outlet inspection and leakage current measurement," IEEE Trans. on Instrumentation and Measurement, vol. 70, pp. 1-9, 2021.
[30] L. Chen and A. R. Smith, "A framework for implementing a sustainable electrical safety program in resource-limited healthcare settings," IEEE Rev. Biomed. Eng., vol. 16, pp. 345-358, 2023
[31] B. R. Patil and S. M. Kulkarni, "A Review on Technical Standards and Safety of Medical Electrical Equipment," in Proc. Int. Conf. on Advances in Computing and Data Sciences, 2020, pp. 654-665.
[32] M. A. Miller, D. R. Clark, and H. J. Wang, "Long-term retention of clinical engineering skills in a low-resource setting: A five-year follow-up study," Global Health Innovation, vol. 3, no. 2, p. 45, 2020.
[33] World Health Organization, Global Atlas of Medical Devices, 2nd ed. Geneva: WHO Press, 2022. [Online]. Available: https://www.who.int/publications/i/item/9789240049452v