



ELECTRICAL INDUSTRY SAFETY: EXAMINING CONTROL STRATEGIES TO REDUCE ELECTRICAL RISKS BASED ON OSHA AND BLS (2011-2021) REPORTS

KESELAMATAN INDUSTRI KELISTRIKAN: MEMERIKSA STRATEGI PENGENDALIAN UNTUK MENGURANGI RISIKO LISTRIK BERDASARKAN LAPORAN OSHA DAN BLS (2011-2021)

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ABSTRACT

Background: One essential component of contemporary society is the use of electricity in a variety of industrial sectors. However, its vital role brings inherent risks that demand strict adherence to safety precautions. **Purpose:** This literature review investigates and evaluates control measures implemented in the electrical industry to reduce risks and lower the incidence of electrical fatalities. The analysis focuses on the effectiveness of these control strategies and their alignment with the hierarchy of control framework. **Review:** This literature review employs a descriptive quantitative analysis. This study analyzes data from 2011 to 2021. During this period, the Bureau of Labor Statistics (BLS) reported 1.653 work-related electrical fatalities, while the Occupational Safety and Health Administration (OSHA) reported 1.201. **Result:** 118 vocations were linked to electrical fatalities during this time. Of these, 31% of deaths occurred in electrical-related jobs, while 69% happened in non-electrical jobs. This finding highlights the urgent need for comprehensive safety measures and effective control strategies to mitigate electrical hazards. **Conclusion:** This literature review highlights the importance of applying the Hierarchy of Controls (HOC) in managing electrical risks in the workplace. It calls for proactive interventions and a cultural shift toward prioritizing safety, integrating human awareness with strict regulations to reduce electricity-related fatalities.

ABSTRAK

Latar belakang: Salah satu komponen penting dalam masyarakat kontemporer adalah penggunaan listrik di berbagai sektor industri. Namun, seiring dengan peran vitalnya, ada risiko yang melekat yang memerlukan perhatian khusus terhadap tindakan pencegahan keselamatan. **Tujuan:** Literatur ini menyelidiki dan mengevaluasi langkah-langkah pengendalian yang digunakan dalam industri listrik untuk mengurangi risiko dan menurunkan jumlah insiden kematian akibat listrik. Analisis dipusatkan pada efektivitas strategi kontrol bekerja dan keselarasannya dengan hierarki kerangka kerja kontrol. **Telaah pustaka:** Literatur ini menggunakan analisis kuantitatif deskriptif, menganalisis data laporan dari tahun 2011 hingga 2021. Selama periode ini, Biro Statistik Tenaga Kerja (BLS) melaporkan sebanyak 1.653 insiden kematian akibat listrik terkait pekerjaan, dan Administrasi Keselamatan dan Kesehatan Kerja (OSHA) melaporkan sebanyak 1.201. **Hasil:** Sebanyak 118 pekerjaan dikaitkan dengan kematian akibat listrik selama periode ini. 31% insiden kematian terjadi pada pekerjaan kelistrikan dan 69% terjadi pada pekerjaan non-kelistrikan. Hasil ini menunjukkan pentingnya penerapan langkah-langkah keselamatan dan strategi pengendalian yang diperlukan untuk mengurangi risiko dan kematian akibat listrik. **Kesimpulan:** Literatur ini mengkaji pentingnya penerapan Hierarki Kontrol (HOC) dalam menilai manajemen bahaya listrik di tempat kerja, menekankan perlunya tindakan proaktif dan perubahan budaya untuk memprioritaskan keselamatan, menggabungkan kesadaran manusia dengan hukum yang ketat untuk mengurangi kematian yang terkait dengan listrik.

Literature Review

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INTRODUCTION

The widespread use of electricity in workplaces necessitates strict and vigilant safety measures. Safeguarding against electrical hazards is crucial to preventing accidents, injuries, and fatalities. This study examines the various aspects of electrical safety with a particular focus on the controls used by the electrical industry. The study aims to assess the effectiveness of these measures in mitigating electrical risks by analyzing them through the lens of the hierarchy of controls framework.

The most significant energy source utilized in workplaces is electricity, and there is a clear correlation between economic growth and electricity use (Falahati *et al.*, 2019). Despite being an essential human need, electricity poses a risk to the safety of users, employees, and technologists. As technological development continues, the hazards associated with electrical contact have also increased. In the growing construction sector, electrical installation has become a critical component of project operations and functionality (Cui and Shan, 2021). Electrical accidents are a major problem for the construction industry because they are nearly five times more likely to result in serious or fatal outcomes compared to other types of incidents (Suárez-Cebador *et al.*, 2014). In the United States alone, the construction industry reports over 5,000 electric shock deaths annually, or roughly 20% of all work-related deaths. Moreover, electrical accidents occur 25 times more frequently than fall-related accidents (Falahati *et al.*, 2019). This highlights the pressing need for increased awareness and proactive prevention of electric shock hazards (Gambhir *et al.*, 2022). Hazard identification is always the first step towards putting a safer design into practice and preventing major accidents. It is essential for figuring out the causes and effects of potential hazards inherent in processes (Qi *et al.*, 2021; Sadeghi-Yarandi *et al.*, 2023). Incidents are attributed to a lack of awareness of the importance of electrical hazards and workplace safety and health (Salvaraji *et al.*, 2022). Accident statistics continue to reflect the consequences of improper energy control, with numerous worker fatalities on construction sites each year (Burllet-Vienney *et al.*, 2021). The advancement and development of the building itself, as well as the industry, will be aided by relevant units and personnel paying closer attention to and using grounding and lightning protection technology during actual construction to reduce the risk of lightning disasters affecting the building's personnel and internal electrical equipment safety (Cui and Shan, 2021). Qu *et al.* (2022) address the challenge faced by maintenance personnel in identifying and resolving complex electrical hazards by proposing a

knowledge-driven recognition methodology. Any workplace handling or regularly using electricity should place a high priority on the safety of its employees and visitors. A study by Baby *et al.* (2021) revealed a significant correlation between worker health, climate aspects related to safety, personal characteristics, and occupational accidents. Individual factors like age, expertise, level of education, and positional role greatly influence how electrical workers act in a safe manner. Electrical safety regulations mandate that organizations implement safety measures and follow best practices. These regulations are crucial in establishing the benchmarks for a safe and secure work environment. Global workplace safety laws include the Australian Model Code of Practice for Managing Electrical Risks, the UK HSE, the US OSHA, and the EU Directive. This literature review evaluates the effectiveness of control measures in the electrical industry and examines how well they align with the hierarchy of controls framework to reduce electrical hazards and fatalities.

LITERATURE STUDY

Descriptive quantitative analysis method

This study employs a descriptive quantitative analysis based on secondary data obtained from the Electrical Safety Foundation's Workplace Injury and Fatality Statistics report (Injury and Statistics, 2018) as presented in Figure 1. The report furnishes statistical information pertaining to electrical fatalities that occurred in the US workplaces between 2011 and 2021. According to the Occupational Safety and Health Administration (OSHA) reports that 1,201 deaths during this period were linked to electrical incidents. Meanwhile, the Bureau of Labor Statistics (BLS) reported a total of 1,653 electrical fatalities during the same time frame. It's interesting to note that 69% of these fatal electrical incidents happened in professions not normally connected to electricity use. In total, electrical fatalities were recorded across 118 different job categories. Of these, 31% occurred in the electrical industry, while the remaining 69% involved non-electrical industries. Over the eleven years analyzed (2011 - 2021), both non-electrical and electrical occupation fatalities decreased by an average of 1.2% and 0.89%, respectively. This suggests a gradual reduction in the number of fatalities across both occupational groups. It is important to note that BLS reports total workplace fatalities, but the Occupational Safety and Health Administration (OSHA) only records cases with completed accident reports. As a result, BLS data provides a more comprehensive account of electrical fatalities, while OSHA data reflects only those incidents that have undergone formal investigation.

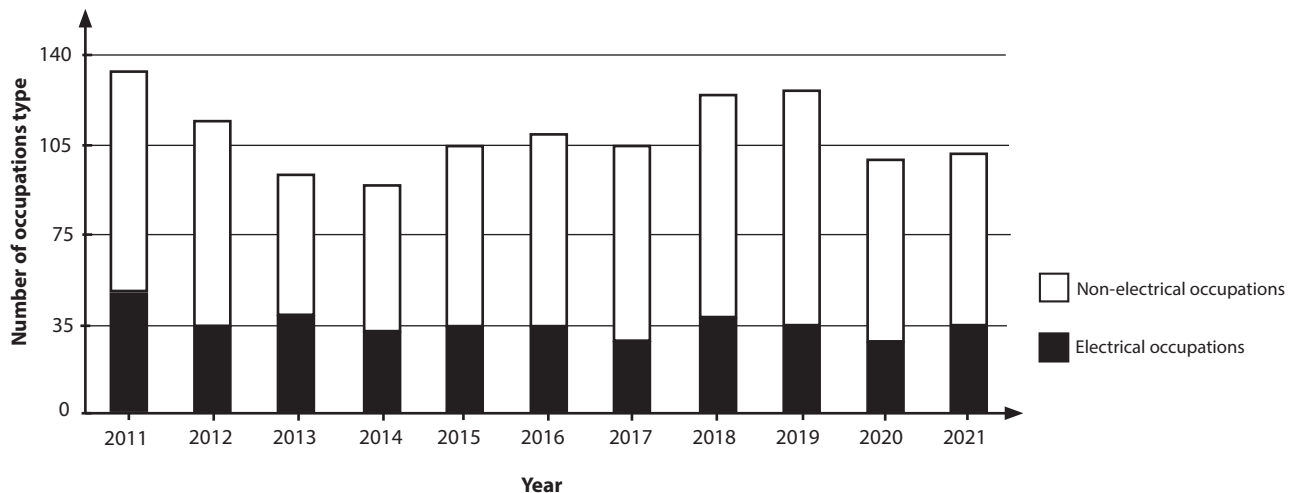


Figure 1. Electrical deaths according to type of occupation (Injury and Statistics, 2018)

Guidelines for managing safety and health programs are outlined by the Occupational Safety and Health Administration (OSHA, 2015), which highlights the value of employer and employee cooperation in identifying and putting control measures in place for workplace hazards. A systematic framework for minimizing or eliminating workplace risks, the Hierarchy of Controls (HOC) is regarded as the gold standard in occupational safety management (Figure 2). It consists of five levels of intervention, arranged in descending order of effectiveness. Personal Protective Equipment (PPE), administration controls, engineering, substitution, and elimination.

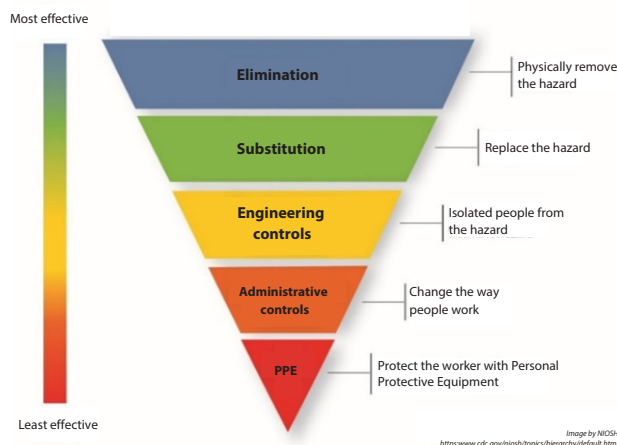


Figure 2. Control hierarchy (CDC, 2023)

The first and the most effective level, elimination, involves techniques to completely remove a hazard from the work environment. One method of elimination is to modify the work process using tools or equipment that aren't electrical. The second level, substitution, entails replacing a hazardous element with a less dangerous alternative, such as switching from high-voltage to low-voltage equipment engineering. The third level

of engineering control, involves utilizing protective technology to keep people away from danger. One way to protect workers from electrical shock is to use gloves or insulated equipment. The fourth level, administration controls, seeks to lessen exposure to hazards by modifying how people operate. Examples include doing regular safety audits, providing training, and implementing safe work procedures and practices. Finally, PPE, the fifth level of hazard control consists of instruments that lessen exposure to hazards. Employers are required to ensure that workers are protected from electrical hazards by PPE, like gloves, safety glasses, and hard hats (OSHA, 2015).

According to the fundamental principles of the HOC, higher-level control measures—particularly those involving technological interventions that modify the physical work environment—are generally more protective and effective than behavioral controls that target people's behaviors at work. However, these higher-level measures also take more work to implement (Zhao *et al.*, 2015). To ensure worker health and safety, control measures should follow the prescribed hierarchy. Engineering solutions like replacement or elimination should be given top priority, then safe work procedures, administrative controls, and PPE. This strategy complies with the OSHA program management guidelines for safety and health (OSHA, 2015). However, in order to guarantee the effectiveness of chosen controls, employers must regularly assess how well they are lowering worker exposures and identifying areas for improvement, in addition to providing supervisors and employees with the necessary training on how to apply controls correctly (Baby *et al.*, 2021; CDC, 2023). Babalola *et al.* (2023) highlight the use of Immersive Technologies (ImT) for training, education, and occupational safety and health as a means of preventing or minimizing illnesses, injuries, and deaths. It also showed that, among other OSH risks, ImT-based training and instruction address the risks of fire, falls, electricity, and chemicals.

The best approach to improve safety performance, based on analytical results from a study by Chan *et al.* (2020), involves a collaborative effort to manage procedural elements, conduct regular safety inspections, and influence human behaviors—particularly those involving risk-prone habits such as smoking and alcohol consumption. Employers, employees, and their representatives must all closely follow safety rules and regulations when handling health and safety issues in diverse workplaces. Furthermore, as stated by OSHA (2015), its Core Elements of the Safety and Health Program Management Guidelines emphasize several key components: worker participation, coordination and communication on multiemployer worksites, education and training, program evaluation and improvement, hazard identification and assessment, hazard prevention and control, and management leadership. By prioritizing electrical safety and adhering to these safety principles, organizations protect not only their workforce but also their operational assets and corporate reputation.

RESULT

The report on Workplace Injury and Fatality Statistics (Injury and Statistics, 2018) by the Electrical Safety Foundation presents data on workplace electrical fatalities in the United States from 2011 to 2021. The findings reveal that the majority of electrical-related deaths occurred in non-electrical occupations with 69% of fatalities reported in roles not typically associated with handling electricity. In total, electrical fatalities were reported in 118 different types of jobs. Of these, 31% of deaths happened in jobs involving electricity,

and 69% happened in jobs involving non-electricity. The number of fatalities from non-electrical occupations decreased by 1.2% on average, while the number from electrical occupations decreased by 0.89% on average. Table 1 presents the top ten professions where electrical deaths occur (2011 – 2021) according to the Electrical Safety Foundation International (ESFI) statistical report.

The sources of electrical fatalities identified in the data include a wide range of hazardous exposure encountered by workers. The most common cause was contact with overhead powerlines (582), unexpected contact with energy (385), working on energized parts (55), ground fault (46), damaged wiring or equipment (41), troubleshooting or testing (29), worker errors (21), underground powerlines (11), arc-flash (10), lockout/tagout (9), improper installation (4), back-feed (2), defective equipment or equipment failure (1), and a combination of two or more sources in certain cases.

It is evident from the data (Figure 3) that collision with overhead power lines, which accounts for 45.70% of electrical fatalities, is the primary cause of these incidents. 44.90% of electrical fatalities are caused by working on or close to energized conductors or parts, making this the second most common cause. Of all electrical fatalities, 8.40% are related to lockout/tagout procedures gone wrong or the removal of safety controls; the remaining 1% of cases are attributed to other miscellaneous sources. It is crucial to implement control measures to reduce the risk of electrical fatalities because the majority of electrical fatalities that occurred in non-electrical occupations may have been caused by a lack of awareness of electrical safety and control measures.

Table 1. Top 10 occupations with electrical fatalities (2011-2021) according to the Electrical Safety Foundation International (ESFI) statistical report

Occupation	Electrical / Non-electrical	Rate (%)
Electricians	Job related to electricity	15.15
Installers and repairers of electrical power	Job related to electricity	8.49
Apprentices of electricians	Job related to electricity	3.25
Laborers, excluding construction	Job unrelated to electricity	10.07
Laborers in construction	Job unrelated to electricity	8.99
Jobs related to pruning trees	Job unrelated to electricity	5.33
Mechanics of refrigeration, heating, and air conditioning	Job unrelated to electricity	2.83
Construction, maintenance and painters	Job unrelated to electricity	2.75
Roofers	Job unrelated to electricity	2.16
Heavy-duty truck drivers	Job unrelated to electricity	1.92

Source: Injury and statistics (2018)

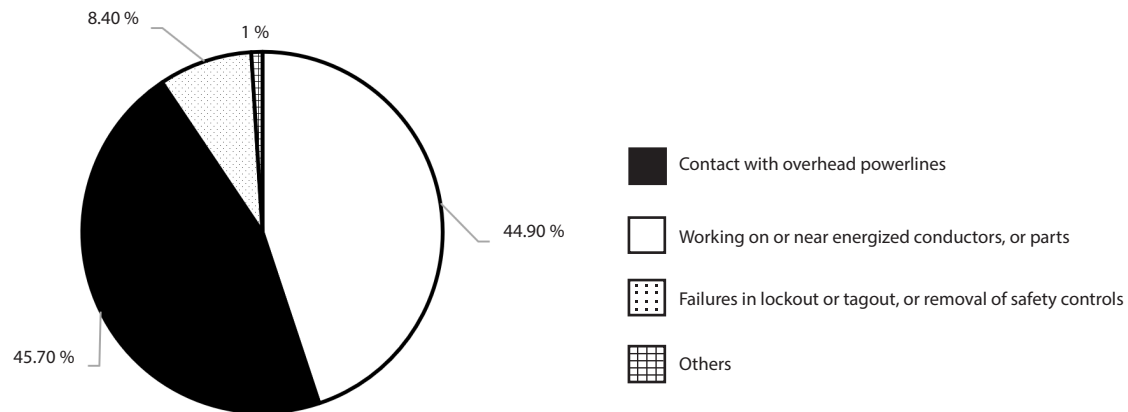


Figure 3. Source of electrical fatality

DISCUSSION

The non-profit ESFI was founded in 1994, with the goal of advancing electrical safety in both residential and workplace environment). The U.S. Consumer Product Safety Commission (CPSC), Underwriters Laboratories (UL), and the National Electrical Manufacturers Association (NEMA) collaborated to create the organization. Electrical manufacturers, distributors, independent testing labs, retailers, insurers, utilities, safety organizations, trade and labor associations, and others voluntarily contribute to ESFI's funding. A census of actual fatal injuries, the Census of Fatal Occupational Injuries (CFOI) is conducted annually by the BLS. Two or more independent sources of information such as death certificates, news articles, police reports, OSHA reports and other official documents verify each case. Comparably, to determine the quantity of nonfatal injuries and illnesses, the BLS performs its Survey of Occupational Injuries and Illnesses. Due to their sheer volume, nonfatal injuries are calculated statistically using information from a substantial yearly survey of injuries that employers submit (Injury and Statistics, 2018).

Electrical fatalities analysis

Important patterns and trends can be found by looking at reported data on electrical fatalities over a sizable period of time. The BLS and the OSHA provide valuable insights into the frequency and distribution of electrical fatalities across a wide range of occupations. These statistics' distribution is clarified by a critical analysis, which highlights the need for specialized control measures in a range of industry sectors.

Electrical fatalities source

According to White *et al.* (2016), the leading cause of death in the workplace is overhead power line contact, followed by electrocution, which makes up

12% of all work-related deaths. Given the possibility of catastrophic events resulting from electrical equipment failures, it is imperative that protection mechanisms and electrical power systems be carefully planned, installed, operated, and maintained (Kallambettu and Viswanathan, 2018). Thus OSHA (2015) suggested that in order to prevent incidents, employees get training on recognizing, containing, and actively participating in hazards as a key strategy in preventing workplace incidents.

Electrical safety and control measures

A multi-layered strategy incorporating different control measures is required for the thorough management of electrical hazards. These controls include PPE, engineering controls, substitution, elimination, and administrative controls, spanning the entire hierarchy of controls. Whereas engineering controls concentrate on reducing risks through technical methods, elimination and substitution strategies seek to remove or replace potentially dangerous components. Procedures and guidelines are part of administrative controls, and PPE acts as the last line of defense.

Significance of hierarchy of control

The HOC provides an offers a structured framework for evaluating the effectiveness of safety measures implemented in the workplace. It helps evaluate the advantages and disadvantages of current safety procedures in the electrical industry by ranking the most to least effective strategies. This model also clarifies the distinction between preventive approaches, such as elimination and engineering controls, and reactive measures, such as administrative controls and PPE. Elimination involves the complete removal of a potential hazard. Substitution may require replacing a potential hazardous substance (threat) with a less hazardous one. Engineering control requires putting a barrier to shield workers from the potential hazard. Administrative

control may require introducing a work routine to reduce work stress or long-term exposure to a potential hazard. While still important, PPE is considered the least effective in the hierarchy of controls. It may reduce the impact of the damage, but does not remove the cause of the hazard.

The study highlights how control mechanisms and electrical safety interact in this particular industry. A comprehensive approach to hazard management is important, as demonstrated by the analysis of electrical fatalities and the HOC framework. It is possible to greatly reduce the risks connected with electrical hazards by stressing preventative measures and giving higher-order control strategies priority, for the electrical industry to promote a safer working environment, a coordinated effort to implement and enforce these measures is essential.

Research-based control measure for other industries

Research by Kartika *et al.* (2020) highlights the importance of effective control measures in industries beyond the electrical sector. In the paint manufacturing industry, for example, the evaluation of safe benzene exposure levels for workers reveals that even minimal concentrations can exceed recommended limits for both acute and chronic health effects. The suggested values on a daily basis, for both chronic and acute effects are exceeded by a safe concentration of 0.028 ppm. This emphasizes how important it is to have strong controls in place in order to reduce risks. Control recommendations like putting in place a functional exhaust ventilation system prove crucial in lowering hazardous exposures, as shown in the paint manufacturing setting (Kartika *et al.*, 2020).

Risk assessment plays a critical role in occupational health and safety, especially in high-risk sectors such as the garment and textile manufacturing industry. When hazards were identified using techniques such as Job Safety Analysis (JSA), it was discovered that more than half of the job descriptions in this sector presented high risks related to fire, physical, chemical, and ergonomic hazards. This emphasizes how important it is to have strong control mechanisms. This study serves as an example of how extra precautions, like specific protective gear and reaction to emergency protocols, are necessary to guarantee employee safety in situations involving high risk (Rahman *et al.*, 2020).

The study by Ayu *et al.* (2018) underscores the critical role of knowledge and supervision in shaping weld workers' compliance with PPE usage. Results showed a relationship between knowledge, supervision, and adherence to safety procedures, with those with insufficient knowledge and supervision being more likely to ignore safety procedures. In the electrical industry, a similar focus on supervision and knowledge

can go a long way toward guaranteeing adherence to safety procedures and reducing potential risks.

Rafi'ah *et al.* (2018) study examined the elements influencing safety behavior among plate-cutting workers by utilizing the Theory of Planned Behavior to assess behaviors, attitudes, and arbitrary standards at PT. PAL in Indonesia. The results highlight the importance of behavioral control and show a correlation between it and workers' intentions to engage in a safe manner. Although there was no significant relationship between attitudes and subjective norms and safety behavior intentions, there was a clear correlation with behavioral control. In the electrical industry, a similar focus on encouraging behavioral control can significantly improve safety procedures and reduce risks.

Sandianto *et al.* (2018) study revealed a strong correlation between job stress and workload by examining the frequency of work-related stress experienced by nurses on the outpatient unit. The research discovered a noteworthy correlation between increased job stress among nurses and their mental workload, but no significant relationship between age, gender, or physical workload and stress at work. A logistic regression analysis showed that there was a significant 39.539 times higher chance for nurses to endure a significant psychological burden. It also showed that mental workload was the main factor causing elevated job stress. This emphasizes how crucial it is to treat mental workload in order to lessen nurses' occupational stress. Stress management and general safety precautions can be greatly impacted by the electrical industry's similar focus on workload considerations, particularly mental workload.

Nugroho *et al.* (2023) study highlights the importance of occupational health and safety skills by looking at the relationship amid close call incidents and safety and occupational health factors for nurses. The study found a noteworthy correlation between near-miss occurrences and work equipment, despite the fact that knowledge of near-misses revealed a poor correlation and both showed a feeble inverse relationship. The skills related to occupational health and safety demonstrated a significant inverse relationship with near-miss incidents, suggesting their critical function in mitigating these incidents. This highlights how important it is to develop strong occupational safety and health competencies to reduce incidents involving nurses at work. When comparing this to the electrical industry, a similar emphasis on enhancing occupational safety and health competencies could significantly reduce incidents and ensure safety procedures.

Rachman *et al.* (2022) study illustrates the complexity of exposure-related health risks by examining the connection between health markers and benzene exposure among shoe industry employees at home

industry. Despite workplace benzene levels exceeding recommended safety thresholds, the study revealed significant variation in workers' spmA concentrations. The inverse relationship between airborne benzene concentrations and spmA concentrations highlights the complex range of health consequences that can arise from exposure. These findings highlight the significance of thorough evaluations and comprehending complex connections between exposure and results in terms of health, highlighting the need for careful safety measures to lower risks. In contrast, understanding how exposure affects health outcomes is crucial for developing effective safety procedures in the electrical industry.

CONCLUSION

This study evaluates the effectiveness of electrical hazard management techniques using the ESFI reports from 2011 to 2021. The study underscores the need for proactive measures to mitigate electrical hazards, with a significant number of fatalities linked to electricity. The study also highlights the disparity in fatalities among different occupations, emphasizing the importance of human behavior and adherence to established protocols. The effectiveness of these policies depends on their implementation and upholding in practical contexts.

In summary, maintaining electrical safety requires more than just technical fixes. It also requires a comprehensive strategy that combines strong legal frameworks with thorough instruction, training, and established safety procedures. This research calls for an urgent cultural shift that places electrical safety at the forefront—merging awareness, supervision, and regulatory enforcement to minimize risks. Neglecting these evaluations may endanger workers' health, compromise performance quality, and increase the likelihood of illness, disability, and even death.

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AUTHOR CONTRIBUTION

The contributions of each author include ideas, data generation, data analysis, and manuscript preparation. A. O. O. conceived the study and manuscript preparation. A. R. T., I. P., S. Z., and J. J. contributed to supervision, reviewing and validation. All authors discussed the results and contributed to the final manuscript.

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Not applicable.

DATA AVAILABILITY

The data used in this research was obtained from The Electrical Safety Foundation, based on OSHA and BLS (2011-2021) Reports. The datasets generated and/or analysed during the current study are available in the link <https://www.esfi.org/electrical-fatalities-in-the-workplace-2011-2021/>

CONFLICT OF INTEREST

The authors declare that, "no conflicts of interest exist among the participants involved in this research".

ETHICAL APPROVAL

This study does not require ethical approval because it does not use experimental animals and/or humans in this section.

INFORMED CONSENT

Not applicable.

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