

## Original Article

# Descriptive Study of Occupational Accidents and their Causes among Electricity Distribution Company Workers at an Eight-year Period in Iran



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## ABSTRACT

**Background:** Occupational accidents are unplanned events that cause damage. The socio-economic impacts and human costs of accidents are tremendous around the world. Many fatalities happen every year in workplaces such as electricity distribution companies. Some electrical injuries are electrocution, electric shock, and burns. This study was conducted in an electricity distribution company (with rotational 12-hour shift work) in Iran during an 8-year period to survey descriptive factors of injuries.

**Methods:** Variables collected included accident time, age of injured worker, employment type, work experience, injury cause, educational background, and other information about accidents.

**Results:** Results indicated that most of the accidents occurred in summer, and 51.3% were during shift work. Worker negligence (malpractice) was the cause of 75% of deaths. Type of employment had a significant relationship with type of injuries ( $p < 0.05$ ). Most injuries were electrical burns.

**Conclusion:** High rate of accidents in summer may be due to the warm weather or insufficient professional skills in seasonal workers. Shift workers are at risk of sleep complaints leading to a high rate of work injuries. Acquiring knowledge about safety was related to job experiences. Temporary workers have no chance to work all year like permanent workers, therefore impressive experiences may be less in them. Because the lack of protective equipment and negligence are main causes of accidents, periodical inspections in workshops are necessary.

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## 1. Introduction

The World Health Organization describes an accident as “an unplanned and unanticipated event”. The International Labor Organization also defines occupational accidents as unanticipated and unplanned events that cause a certain damage or injury [1]. Despite implementing the safety strategies in workplaces, occupational accidents and incidents have been increasing in parallel to developing industries and consequently their consequences can be unpleasant [2]. The socio-economic impacts and human costs of

occupational and industrial accidents are tremendous around the world. Often there is not enough or accessible information about these events from all countries in the world. Globally, over 264 million industrial accidents happen every year, with over 350,000 mortalities [3]. Although more than half of these mortalities occur in developing countries, the estimation of accident costs is especially difficult there [4]. Generally, according to the Iranian Ministry of Labor, 43% of all occupational injuries annually occur for workers who are under the supervision of this Ministry. Occupational injuries are mainly caused by work conditions as well as some

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personal characteristics [5]. In our country, a lot of money is annually devoted to compensate workplace disabilities and payments of diseases for workers when they are not working [6]. Main causes of occupational accidents are untidiness, noise, too hot or cold environments, old or poorly maintained machines, and lack of training or carelessness of employees [7].

Many workers are exposed to electrical energy during their tasks. There are four main types of electrical injuries: electrocution (fatal), electric shock, burns, and falls caused by contact with electrical energy [8]. In Taiwan, electrical mortalities involve 14.6% of all fatal accidents in construction industries and they are the second cause of occupational mortalities after falling accidents (30%) [9]. Electricity is the fifth reason for occupational injuries leading to death (accounting for 7% of all workplace fatalities) in the USA, and it can create a specific hazard to workers who work routinely in proximity to electrical sources [10]. According to the Occupational Safety and Health Administration (OSHA), an average of 12,976 lost-workday injuries and 86 fatalities related to electric power generation, transmission, and distribution employees occur annually [11]. OSHA's Integrated Management Information System identified that out of 944 work-related electrocutions for 1984–1986, 61% of fatalities were caused by contact with high-voltage powerlines [8]. Based on a review article, electricity is the greatest killer among electric utility workers. A total of 66 employees were killed in 1975, 36 from electric shocks and burns [12]. Some studies have demonstrated the highest ratio of electrocution deaths happen among electricians and electrical helpers, and among utility workers and those who have been hired in the construction and manufacturing industries [13–15]. Causes of accidents are not easily clarified, especially in fatal accidents. Based on the scenario analysis of OSHA, there are three major reasons for electrical accidents: unsafe equipment or installation, environment, and work practices [9]. After studying the 244 cases leading to death, the National Institute for Occupational Safety and Health (NIOSH) introduced five case scenarios that describe the incidents resulting in those fatalities: (1) direct worker contact with an energized powerline (28%); (2) direct worker contact with energized equipment (21%); (3) boomed vehicle contact with an energized powerline (18%); (4) incorrectly installed or damaged equipment (17%); and (5) conductive equipment contact with an energized powerline (16%) [8]. There are few reports on mortalities caused by electricity and limited studies on analyzing occupational electrocutions and all accidental deaths caused by electricity.

This study was conducted in an electricity distribution company in Iran during an 8-year period to survey descriptive factors of injuries. Also the distribution of accidents, as effective factors to prevent accidents in future, were determined. Finally, some recommendations for developing effective safety programs to decrease the risk of electrocution are provided.

## 2. Materials and methods

This descriptive study was performed in western regions of Tehran and Alborz province in 2013. An occupational injury surveillance study was conducted for workers of nine regions covered by an electricity distribution company in Alborz and events recorded in the central buildings and central warehouses in 2005–2012 were evaluated. Also reports of the safety committee meetings related to the study of extreme accidents were studied to determine the causes of accidents. Variables collected include accident time, age of injured worker, type of employment (permanent, temporary), work experience, type of injury, cause of injury, affected parts of the body, action after the accident (hospitalization, nonhospitalization, or death), educational background, marital status (single, married), job title (electrical work, others), rest days

(yes, no), work shift (yes, no), and other information related to accidents. Work shift in this study was a rotational 12-hour work. Working hours are fixed, more than 8 hours in duration, which results in a working week of <5 full days of work/week. In the studied company, workers work 12 hours in a shift (from 08:00 to 20:00) and after that they have a rest equal to the duration of two shifts (24 hours). For the 8-year period, accident registers and payrolls were examined to collect data on the number of workers involved in activity, nature of employment, nature of activity, and the number of accidents. Data related to no time loss injury (the affected person resumes work within 24 hours of injury and there is no leave) as well as time loss injury (the affected person does not resume work within 24 hours of injury and leave is taken until the person becomes fit to resume duty) were taken into consideration for analysis of occupational injury data.

Also, there are three shifts in the shift work schedule of company: morning, afternoon, and night. This schedule determines the time of work beginning for each worker. For instance, a worker begins to work in the morning shift for 12 hours and rests for the next two shifts. Another worker begins his work in the afternoon shift and rests for 24 hours. This schedule continues at all times.

When an occupational accident occurs, initial therapy is done in the company's center of occupational health and safety and details of the injury are reported to the concerned inspectorate and social security system. Afterwards, all related records are documented in the center of occupational health and safety.

### 2.1. Statistical analysis

The statistical calculations and analysis were performed using SPSS version 18 (SPSS Inc., Chicago, IL, USA). Tests such as Chi-square and univariate analysis of variance were used for data analysis. The level of significance was taken as  $p < 0.05$ .

## 3. Results

The information of 119 injured workers due to accidents during an 8-year period were collected in an electricity distribution company. The results of descriptive analyses are in Tables 1 and 2. The average age at injury was 36 years (range, 21–72 years). Most workers were married (63%). About 44.6% of workers had a high school degree, 46.2% had a diploma, and only 9.2% were college educated. Most injured workers had temporary employment (63%), 29.4% of them had 1–5 years of work experience, and 73% had an electrical job. The bar chart plot in Fig. 1 indicates that the maximum of accidents occurred in 2011 (21%). Based on results (Fig. 2), the number of accidents in the first days of the week had increased and there was a peak in the middle of the week (21%). A working week in Iran begins from Saturday. Fatigue can be a reason for declining efficiency and increasing error rates in the middle part of the working week among workers. Fig. 3 indicates that the most accidents occurred in summer (31.1%) and in June (14.3%); therefore the highest rate of accidents was in the first half of the each year. Fig. 4 shows that 50% of accidents occurred prior to 12.00 noon. It was found that 17.6% and 51.3% of accidents were on rest days and during the shift work, respectively (Table 2). There were seven deaths (5.8%) during 8 years in this company; the cause of four deaths was found and worker negligence was determined as the cause of 75% of them. It was found that 54.5% of hospitalizations were due to a lack of protective equipment. Some managers do not allocate a sufficient budget to buy proper protective equipment and sometimes such equipment is provided but not used by workers. Results showed that hands (37.8%), head (27.8%), feet (23.1%), and back (11.3%) were the most affected parts in accidents.

**Table 1**  
Demographic and working information for injured workers in an electricity distribution company (2005–2012) (n = 119)

Variables	Descriptive statistics
Age (y)	
Mean	36.00
Mode	36.00
Standard deviation	10.32
Minimum	21.00
Maximum	72.00
Marital status	
Married	75 (63)
Single	44 (37)
Education background	
Collegiate	11 (9.2)
Diploma	55 (46.2)
High school	53 (44.6)
Type of employment	
Permanent	44 (37.0)
Temporary	75 (63)
Work experience (y)	
<1	16 (13.4)
1–5	35 (29.4)
6–10	26 (21.8)
11–15	14 (11.8)
16–20	9 (7.6)
21–25	11 (9.2)
> 25	8 (6.7)
Type of job	
Electrical work	87 (73.1)
Others	32 (26.9)

**Table 2**  
Parameters affecting on accidents in workers of an electricity distribution company (2005–2012) (n = 119)

Variables	Descriptive statistics n (%)
Rest days	
Yes	21 (17.6)
No	98 (82.4)
Shift work	
Yes	61 (51.3)
No	58 (48.7)
Action after accident	
Hospitalization	56 (47.1)
Nonhospitalization	56 (47.1)
Death	7 (5.8)
Cause of accident	
Lack of protective equipment	30 (25.2)
Negligence	21 (17.6)
Tools and unsafe environment	8 (6.7)
Other	60 (50.5)
Injury type	
Electrical burns	57 (47.9)
Fracture	30 (25.2)
Others	32 (26.9)

1998, showed that 46 electrocution deaths occurred in Jefferson, Alabama; 27(58.7%) of them were related to work. Based on the National Traumatic Occupational Fatality surveillance system, data for 1980–1992 indicated contact with electrical energy caused 5348 deaths in workers (in average, 411 deaths/year) [8]. From 1982 to 1994, NIOSH investigated 224 electrocution incidents resulted in 244 workers fatalities [8]. In Denmark, 29% of indoor electrical accidents occurred in electricity distribution sector and production and in production of heat. In the Nordic countries, the most common location for outdoor electrical accidents was electricity and production sector, and in production of heat and more than 40% of the outdoor electrical accidents occurred in this location [16].

Because of a positive skewness in age distribution in this study (median, 34; mode, 23 years), it can be concluded that accidents are more common in the younger age groups. These findings are consistent with studies by Saha et al [17], Colao et al [18], Candela et al [19], Wadsworth et al [20], Ghods et al [21], Macedoet and Silva [22]. In our survey, the highest rate of death was seen at mean

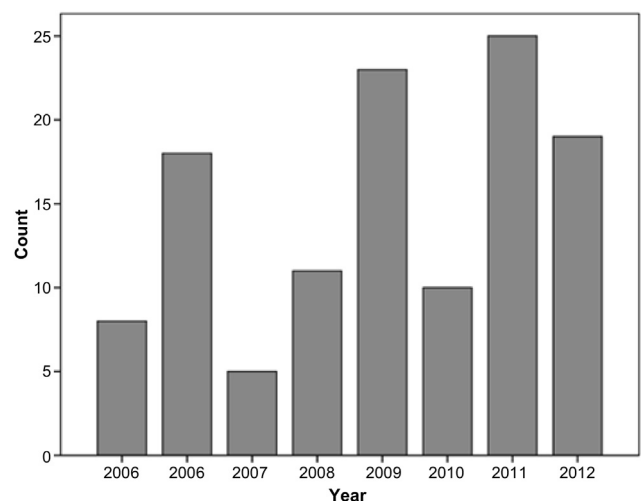
According to the Chi-square test (Table 3) the type of employment had a statistically significant relationship with the type of injury and educational background ( $p < 0.05$ ). Furthermore, analyzing accidents based on the type of injuries indicated that the highest number of injuries in temporary and permanent employment was electrical burns (Table 3). Most temporary employees had a diploma degree and the most common educational level of permanent employees was high school.

To compare the mean of age in some groups, data were initially normalized by logarithm transformation. The Kolmogorov–Smirnov test confirmed normality ( $p = 0.114$ ). Furthermore the Leven test for homogeneity indicated that variances were equal for groups ( $p > 0.05$ ). Then the univariate analysis of variance was used. Mean age in temporary workers (30.34 years) was less than permanent workers (43.93 years) and there was a statistically significant difference between them ( $p < 0.001$ ). Mean ages for hospitalized and nonhospitalized groups and for workers who had died were 34.64 years, 36.86 years, and 27.83 years respectively; however, as can be seen in Table 4, there were no significant differences between them ( $p > 0.05$ ).

#### 4. Discussion

Globally, there are few documented studies to determine the prevalence rate and pattern of accidents in electricity distribution companies, and in Iran there is no study on those parameters in such companies. The aim of this study was to describe the occupational accidents to find the effective causes of their occurrence.

This study indicates that many accidents have occurred in the company. A survey conducted by Taylor et al [10] between 1981 and



**Fig. 1.** Bar chart plot for number of accidents in an electricity distribution company (2005–2012).

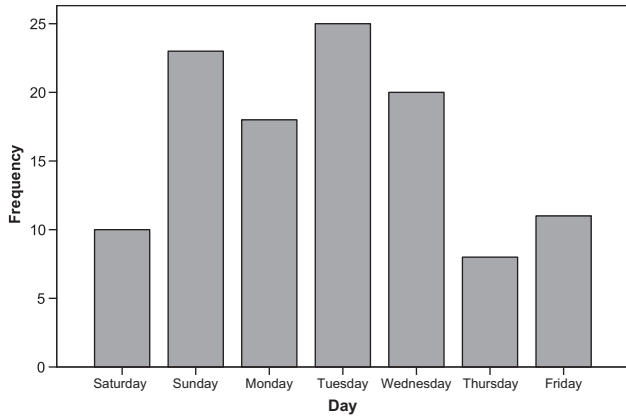


Fig. 2. Frequency of accidents on different days of the week.

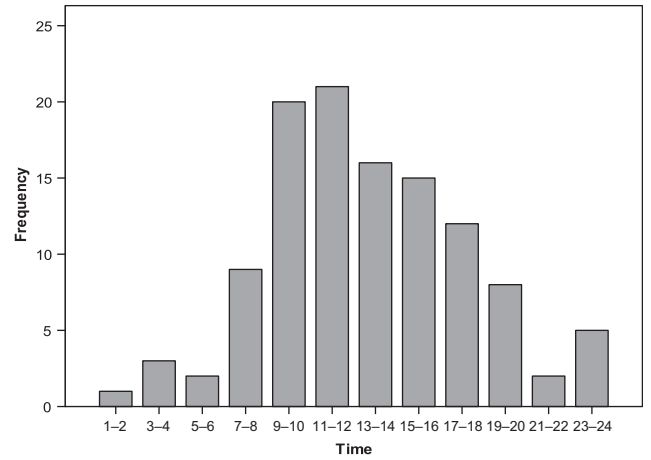


Fig. 4. Number of accidents at different times of the day.

age 36 years but in the USA this rate happened at age 45 years and over [23]. Likewise, according to some studies, fatalities due to electrocution take place at a younger age than other occupational mortalities generally [13,15]. Also, based on the Fatality Assessment and Control Evaluation surveillance data, the victims (243 men and 1 woman) ranged in age from 17 years to 70 years, mean 34 years [8]. However, high intensity of accidents and high quantities of them in younger workers can be attributed to working in high-risk occupations, activities, and industries.

Results showed that the highest rate of accidents have occurred for workers with experience of 1–5 years. Also, the lowest rate of accidents was found in workers with 16–20 years' and more than 25 years' experience. In the Halvani et al [24] study, the highest and lowest rates of accidents were seen for job experience of <1 year (34.8%) and >20 years (12.5%), respectively. This is not completely consistent with our findings but may be due to differences in the studied population.

In Iran there is a considerable climatic diversity leading to several seasons in various parts, so that in some zones the cold of the winter and the heat of the summer can be seen simultaneously [25]. The average annual ambient temperature in Alborz and west of Tehran is 27–30 °C in January, July, and August. As the results indicate, the maximum and minimum number of work accidents happened in summer and autumn, respectively; therefore it seems that the growth of economic activities especially in the electricity sector in summer and the recession of them in autumn explain the

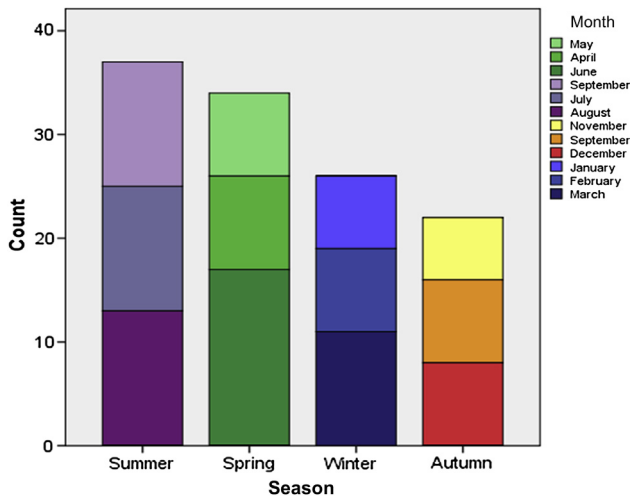


Fig. 3. Frequency distribution of accident based on season and month.

high rate of accidents in summer. These results somewhat conform to the findings of past research [26]. High rate of accidents in summer may be due to the warm weather in Alborz province and west of Tehran, or insufficient professional skills and experience in seasonal workers including high school and university students. This is consistent with Halvani et al's study on construction accidents [27]. Frequencies of electrocution incidents based on months in 1982–1994 [identified by Fatality Assessment and Control Evaluation (FACE)], showed high rate of accidents in August ( $n = 35$ ), January ( $n = 29$ ), and July ( $n = 27$ ), respectively [8]. A lack of training may have contributed to this. Also, workers are more susceptible to electrocution during the summer, because during hot, humid weather the skin has less resistance to electric current. A possible explanation for the drop in electrocution accidents during the winter months is that there is use of heavier clothing, gloves, and boots.

Results showed the high accident rates among married workers. Sometimes married persons have some problems that can lead to accidents. Identifying these problems may decrease the influence of them on occurring accidents. Also, the higher rate of accidents among married people might be attributed to mental and family problems. According to Niles [28], the main cause of human errors are complexity, stress, work environment, fatigue, education, and experiences. Stress and fatigue can be higher among married workers than single ones because of higher responsibilities in the life. It may be led to more unsafe acts resulting in accident. This result conforms to the findings of researches in Iran and other countries [29].

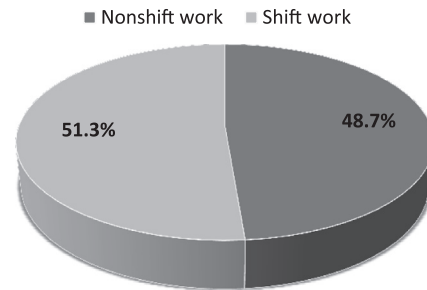
Table 3 Relationship between types of employment, type of injuries and level of education

Variables	Type of employment n (%)		p
	Permanent	Temporary	
Type of injury			0.011
Electrical burns	14 (31.8)	43 (57.3)	
Fracture	12 (27.3)	18 (24.0)	
Others	18 (40.9)	14 (18.7)	
Total	44 (100)	75 (100)	
Level of education			0.029
College degree	6 (13.7)	5 (6.7)	
Diploma	13 (29.5)	42 (56.0)	
High school	25 (56.8)	28 (37.3)	
Total	44 (100)	75 (100)	

**Table 4**  
Comparing of age mean based on type of employment, action after accident, and accident cause

Variables	Mean of age (y)	<i>p</i> (Leven test)	<i>p</i>
Type of employment		0.072	<0.001
Permanent	43.93		
Temporary	30.34		
Action after accident		0.053	0.179
Hospitalization	34.64		
Nonhospitalization	36.86		
Death	27.83		
Cause of accident		0.659	0.491
Lack of protective equipment	32.59		
Negligence	33.56		
Tools and unsafe environment	39.67		
Kolmogorov–Smirnov test to assess normality			0.114

The highest rate of accidents (45%) occurred during shift work. Results indicate that shift work considerably increased the risk of occupational injuries in the company. There are some arguments against 12-hour shifts, for instance they promote fatigue and compromise alertness and performance, thereby reducing operational efficiency or safety. Despite the increased opportunities for leisure time on 12-hour shifts, the longer working day has the potential to contribute to human error and accidents at work in the studied company. As Fig. 4 indicates, in comparison with early hours of shift work, a lot of accidents have occurred near the end of shift work (for morning shift; hours 1–12 in Fig. 3) and it may be related to reducing the workers efficiencies at the end hours of long shifts. There is a decline in alertness and performance during the last few hours of a 12-hour shift. However, as can be seen, hours near the end of shift work take place at nighttime, when increasing melatonin hormone concentration can lead to worker fatigue, resulting in the occurrence of an accident. Based on studies, afternoon and night increased the risk of occupational injury compared to morning shift in industrialized countries (Fig. 5). A recent review demonstrated that the risk of occupational injuries during evening shifts increased by 18.3% and in night shifts by 30.4% in comparison with morning shifts. This review is based on five studies published between 1972 and 1995 [30,31]. The authors [32–34] later added two studies to their review, and concluded that the risk of occupational injuries were 15% higher during evening shifts and 28% higher during night shifts in comparison with morning shifts. This is consistent with Fransen et al's [35] finding that even after accounting for decreased working hours relative to nonshift workers, there was a markedly increased risk of work injuries for rotating shift work. In an American paint company, workers had a greater injury rate (25%) during night shifts than morning shifts, and the injury risk was highest in the last 3 hours of the night shift [36]. Shift workers are at particular risk of sleep complaints [37,38], and it can be a factor contributing to the relatively high rate of fatal and nonfatal work injuries in this group of workers [39,40]. In this study, however, there was a slight disruption to sleep across the working week for the 12-hour shifts. The sleep quality problems can be attributed to the quick returns in the shift change and the direction of rotation of the schedule. Regardless of whether the workers are on a delaying or an advancing work rotation schedule, circadian rhythms may be disrupted in a similar manner. It is worth mentioning, 12-hour shift workers significantly have lower problems with sleep in comparison with 8-hour shifts.



**Fig. 5.** Accident percentages in shift work and nonshift work.

Based on our findings, the type of employment was related to type of injuries. The number of permanent workers was lower in comparison with temporary workers. Furthermore, most temporary and permanent workers were burned because of electricity. Other injuries such as falls from height were more common in permanent workers. The safety training system of the company was relatively poor and acquiring knowledge about the safety was only related to the job experience. Permanent workers may be in a superior situation in the company than temporary workers although they have the same work experience in the same company. This is because temporary workers do not get a chance to work for a whole year like the permanent workers, and so acquisition of experience may be less in temporary workers. There are similar findings about higher accidents for temporary workers in other studies [41,42]. As a result, some parameters such as temporary status of the working group and lack of job security can play an important role in occurring accidents for such workers [17].

Statistical analysis based on the cause of the accidents showed that lack of protective equipment, workers negligence, and unsafe work environment were main cause for 30%, 21%, and 8% of accidents, respectively. Because the lack of protective equipment and negligence are main causes of accidents in western regions of the Tehran and Alborz Electricity Distribution Company it is necessary that the province's labor inspection unit do periodical inspections in workshops and industries. These inspections can lead to decreasing the rate of accidents considerably by emphasizing safety standards and improving conditions for workers.

Moreover, it should be noted that in this study the number of accidents increased with decreasing education level. Most accidents occurred among the permanent workers having a high school education and temporary workers having a diploma. More workers are without a college degree than with one, so a higher number of accidents in the group with a lower education level is predictable. In order to determine the effect of education level on accident rates, balanced groups with similar number of workers are required. Therefore, more research on this variable is recommended. Other studies have observed that training cannot reduce accidents when the level of hazards is high and there are few or no reliable techniques and safe working practises in organizations [43]. These findings suggest that further research should be carried out on the appropriateness of safety training programs.

Preventing occupational accidents is an important task of human resource management. Multifactorial interventions can be effective in decreasing occupational accidents. Workplace visits, risk assessment activities, and attitude surveys among the general public need to be combined in order to influence claim incidence and fundamental occupational morbidity. Occupational health engineering and design solutions should be developed to reduce the foregoing problems. The choice of applicable development activities should be preferably made to decrease the injury severity. A



reduction in nonfatal injuries may reflect changes in work organization and improved safety standards [44].

Lockout/tagout is an essential safety procedure to protect workers from injury due to working on or near electrical circuits and equipment. This can prevent contact with operating equipment parts [45].

These data suggest that the following recommendations (based on NIOSH) can be effective to reduce occupational electrocution.

- (1) Carry out and develop a comprehensive safety plan and revise existing plans to thoroughly address electrical safety in the workplace.
- (2) Teach safe and correct ways of working to the workers.
- (3) Provide training for those workers who work directly with electrical energy to test equipment in order to ensure their safety during performance of their assigned tasks.
- (4) Implement safety meetings at regular intervals.
- (5) Implement scheduled and unscheduled safety inspections at work sites.
- (6) Persuade all workers to take part in workplace safety.
- (7) Ensure that proper personal protective equipment is available and worn by workers where required.
- (8) Conduct job hazard analyses of all tasks that might expose workers to the hazards related with electrical energy and carry out control measures that will adequately insulate and isolate workers from electrical energy [8].

### Conflict of interest

There is no conflict of interest to be declared.

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