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## Work-related electrical fatalities in Australia, 1982-1984

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HARVEY-SUTTON PL, DRISCOLL TR, FROMMER MS, HARRISON JE. Work-related electrical fatalities in Australia, 1982-1984. *Scand J Work Environ Health* 1992;18:293-7. Work-related electrical fatalities were studied as part of a larger investigation into all work-related fatalities in Australia in the period 1982-1984. The 95 electrical fatalities (all men) represented an incidence of 0.49 per 100 000 persons (0.79/100 000 men) in the employed civilian labor force during the study period. Electricity was the fifth highest cause of work-related fatalities in Australia and resulted in 10% of all workplace deaths. Ninety-four percent of the workers were performing their usual tasks at the time of their death, and 38% of them were doing work of an electrical nature at the time. The greatest number of deaths occurred on farms and nonconstruction industrial sites, with overhead powerlines as the main source of current. Better placement of overhead powerlines, improved worker awareness of electrical hazards, and the use of residual current devices would probably have prevented most of the deaths.

*Key terms:* electrocution, occupational, safety.

The first recorded work-related electrical fatality took place in 1879 when a stage carpenter was killed in Lyon, France, by an alternating current of 250 V from a Siemens dynamo (1). Electricity causes depolarization of cells, production of heat, or both (2). Death from electrical energy may result from one of the following four mechanisms: (i) gross destruction of tissue, (ii) ventricular fibrillation, (iii) mechanical asphyxia, or (iv) central respiratory arrest (3). Since there may be no characteristic changes evident at autopsy (2), investigation of the scene of the fatality and of the equipment in use is also usually necessary to attribute death to electricity. The magnitude of the current and its pathway in the body are the most important factors in determining whether exposure to electricity is fatal (4).

Only a limited number of studies of work-related electrical fatalities have been published worldwide. They comprise some studies within more comprehensive work-related fatality projects (5-11) and a few studies on specific series of electrocutions (12-15).

These studies indicate that despite the existence of a vast amount of experimental and technical knowledge concerning the hazardous nature of electricity and the knowledge of measures required for electrical safety, electrical fatalities still account for between 4 and 12% of fatalities in the workplace (9-11). There have

been no detailed studies of work-related electrical fatalities in Australia.

### Material and methods

Work-related electrical fatalities were studied as part of a larger investigation of work-related fatalities in Australia. Deaths attributable to work-related injury which occurred in Australia during the three calendar years 1982, 1983, and 1984 were studied. The study method has been described in detail elsewhere (5). An outline of the method follows.

A list was obtained of all deaths which occurred in the study period and which had been assigned International Classification of Diseases, revision 9 (ICD 9) codes corresponding to external causes of death, excluding only suicide and medical misadventure. The list contained 16 246 cases. Coroners' files were found for 15 462 (95.2%) of these cases. Research officers examined the files and assessed which of them met the study definitions of work-related fatalities. Data were extracted from coroners' files for these cases, recorded on data forms, and subsequently entered into computer files for analysis. One thousand seven hundred and thirty-eight cases were classed as work-related; of these 1544 were defined as coming from the employed civilian labor force. These deaths comprised 910 which occurred in the workplace, 368 which occurred on the road during work, and 266 which occurred on the road during journeys to or from work.

The employed civilian labor force included persons who worked for pay, profit, or payment-in-kind in a job or business or on a farm (including employees, employers, and self-employed persons) and persons who worked for 15 h or more without pay in a family business or on a farm. It was assembled, as far as possible, to correspond with the population that was cov-

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ered by the Australian Bureau of Statistics Labour Force Survey (16) and thus excluded persons who were less than 15 years of age or who were members of the armed forces. This definition is very similar to that used for the employed civilian labor force in the United States (17). Only electrical fatalities in the employed civilian labor force were included in the present analysis, as suitable denominators were not available for other population groups. The denominators used were the means of the 12 employed civilian labor force surveys undertaken during the three years of the study.

An electrical fatality was defined for this study as death due to the effects of electricity on the functions of the body. We extracted the electrical fatalities from the computerized Work-Related Fatality Study data set by identifying all cases in which the contact event was coded as "exposure to electricity" and the pathophysiological cause of death was coded as "effects of electricity." These cases were then cross-referenced with data compiled under the auspices of the Electrical Supply Association of Australia, which annually publishes information on each electrical fatality. Following this cross-referencing, three electrical fatalities were deleted and three further work-related fatalities were included, leaving 95 subjects in the final data set.

Occupations were coded according to *A Classification and Classified List of Occupations (CCLO)* (18). Several variables were constructed with the use of data from the Work-Related Fatality Study data collection

forms and information from the Electrical Supply Association of Australia.

Data were analyzed with the SAS (statistical analysis system) (19). Confidence intervals were calculated with the use of the Poisson distribution, but they do not take into account the sample variance associated with the 12 surveys of the employed civilian labor force. The resultant intervals were therefore narrower than the true confidence intervals.

## Results

Between 1 January 1982 and 31 December 1984, 95 deaths were identified in the employed civilian labor force that could be attributed to contact with electricity. All of the decedents were men. This figure represents an average annual incidence of 0.49 electrical fatalities per 100 000 persons, or 0.79 per 100 000 men, in the employed civilian labor force. All 95 deaths took place in the workplace (as opposed to occurring on roads). They represented 6.2% of all 1544 deaths in the Work-Related Fatalities Study and 10.4% of the 910 workplace deaths in the Work-Related Fatalities Study.

The mean age of the 95 persons killed was 33.1 (SD 10.6, range 16–68) years. The annual incidence showed a peak incidence in the 25- to 34-year age range, with a suggestion of a smaller peak in the 55- to 59-year age range. Eighty of the deaths (84%) occurred among those less than 45 years of age (table 1).

The largest number of electrical fatalities (N=67, 71%) occurred in the group tradesman, production-process workers and laborers not otherwise classified (CCLO 600–747). This is the group which contains electricians and linesmen. The rural workers group, containing farmers, fisherman, and timber getters, had the second highest number of electrical fatalities (N=16, 17%). The highest annual incidence of electrical fatalities occurred in the group miners, quarrymen and related workers (8.5/100 000 men). However, the three workers involved were working with above-ground drilling equipment, rather than in mining or quarrying, at the time of their deaths. Rural workers had the second highest annual incidence (4.5/100 000 men).

Thirty-four of the 95 electrical fatalities (38%) involved persons whose occupations were electrical in nature, and in four other cases the victims were doing work of an electrical nature at the time of the electrocution. Ninety-four percent of the workers were performing their usual job at the time of the fatal event.

The greatest number of electrical fatalities (N=21, 22%) took place on farms and in places of primary production. The next highest took place at other industrial sites, followed by residential sites and construction sites (table 2).

A significantly greater number of electrical fatalities occurred in the hotter months of the year (Octo-

**Table 1.** Work-related electrical fatalities in Australia by age of decedent, 1982–1984. (95% CI = 95% confidence interval)

Age (years)	Deaths (N)	Incidence <sup>a</sup>	95% CI
15–19	7	0.73	0.29–1.50
20–24	16	1.04	0.59–1.68
25–34	37	1.12	0.79–1.54
35–44	20	0.72	0.44–1.11
45–54	5	0.25	0.08–0.58
55–59	7	0.83	0.33–1.72
≥60	3	0.52	0.10–1.51
Total	95	0.79	0.64–0.97

<sup>a</sup> Average annual incidence per 100 000 men in each age stratum of the employed civilian labor force.

**Table 2.** Work-related electrical fatalities by location of occurrence.

Type of place	Number	Percent
Farm, primary production	21	22.1
Other industrial site	19	20.0
Residential	15	15.8
Construction site	14	14.7
Factory, warehouse	10	10.5
Private enterprise <sup>a</sup>	7	7.4
Other	9	9.5
Total	95	100.0

<sup>a</sup> Private enterprise engaged in commercial activity.

ber—March,  $X^2_1 = 17.5$ ,  $P < 0.0001$ ). This was true for both indoor ( $X^2_1 = 10.6$ ,  $P < 0.01$ ) and outdoor ( $X^2_1 = 7.1$ ,  $P < 0.01$ ) fatalities.

Ninety-two of the electrical fatalities resulted from exposure to alternating current, the other three resulting from exposure to direct current. Fifty-nine deaths resulted from exposure to low voltage current, mostly at around 240 V, but three deaths occurred at voltages of less than 90 V.

Moisture was definitely a contributory factor to the fatal outcome in 31 (44%) of the 71 cases in which the role of moisture could be ascertained. Lack of adequate clothing was felt to have contributed to the fatality in half of the 32 cases in which clothing was detailed.

The majority of the 95 electrical fatalities resulted from exposure to electricity from aerial powerlines ( $N = 40$ , 42%) or from fixed wiring ( $N = 27$ , 28%). Other sources included flexible cords and accessories ( $N = 13$ , 14%) and appliances and equipment ( $N = 14$ , 15%). In most of the cases involving powerlines, the mode of contact was via another conductor, such as a crane (table 3).

Thirteen of the aerial powerline-related deaths occurred on farms, and nine involved the deaths of linemen associated with the maintenance of powerlines for electrical utilities and railways. Aerial powerlines accounted for all of the electrical fatalities among the miners and quarrymen (drilling-rig operators) and for all of the electrical fatalities among construction workers (due to cranes contacting the powerlines).

The mode of contact for the 27 electrical fatalities resulting from exposure to energized fixed wiring is shown in table 4. Almost half of the electrical fatalities associated with fixed wiring occurred in domestic residences, and more than half of the workers were electricians by trade.

Eleven fatalities involved welding machines and their cords and accessories. This figure represented 12% of electrical fatalities overall and 20% of the nonaerial powerline electrical fatalities. About half were due to defective cords and accessories, and in almost half the cases the welding machine was in good condition.

Of the 55 electrical fatalities not due to contact with aerial powerlines, it was determined from a review of the circuitry involved that 36 (65%) could have been prevented by the use of residual current devices. In nine cases it was unclear whether a residual current device could have prevented the electrical fatality, and in the remaining 10 cases (18%) a residual current device would not have been appropriate.

## Discussion

One in ten workplace deaths was related to exposure to electricity. Exposure to electricity as the precipitating cause of death in the workplace ranks fourth in Australia, and fifth among all the deaths identified in the

**Table 3.** Work-related electrical fatalities caused by contact with a powerline according to agent which contacted the powerline.

Agent of contact	Number	Percent
Human body	14	35.0
Crane boom	7	17.5
Material being manually moved (other than irrigation pipes)	6	15.0
Trucks	4	10.0
Irrigation pipes	4	10.0
Drilling rigs	3	7.5
Other	2	5.0
Total	40	100.0

**Table 4.** Work-related electrical fatalities caused by contact with fixed wiring according to source of contact.

Source of contact	Number	Percent
Switchboards and control panels	9	33.3
Perished insulation around wires	5	18.5
Handtools contacted wires	4	14.8
Defect in conduit	3	11.1
Live power points and switches	3	11.1
Other	3	11.1
Total	27	100.0

Work-Related Fatalities Study overall (including traffic-related fatalities). Exposure to electricity was similarly ranked in national work fatality surveillance data in the United States (20).

It has been claimed that international figures for fatal electrical accidents are relatively reliable and comparable (21). However, there is considerable variation between the reported incidences of electrical fatalities in various countries, and these differences cannot be explained on the basis of power consumption (22). Possibly, differences in the definition of electrical fatality, reporting practices, or the selection of denominators may at least partly explain the variation. It is also possible that electrical safety standards or exposure to electrical hazards varies significantly between countries. Australia has a detailed standard for all electrical wiring and insulation (23), but, apart from direct comparisons between the standards of various countries, no quantifiable data are available that would allow comparisons between the standards of countries with differing incidences of electrical fatalities (21).

There were no electrical fatalities among women in the employed civilian labor force. In comparison, of 1544 fatalities in the employed civilian labor force in the Work-Related Fatalities Study, 96 were deaths of women (5). This phenomenon probably reflects the nature of the work women have traditionally performed in Australia rather than differing work practices between the genders. There was one death of a woman

among the 944 electrical fatalities in a study in the United States (13).

The age distribution of electrical fatality incidence, with the peak in the 25- to 34-year age group and the suggestion of a smaller peak above 55 years, is consistent with data from the United States (24, 25). However, it is distinctly different from the age-incidence pattern for all work-related fatalities recorded in the Work-Related Fatalities Study, which showed a rising incidence with increasing age, peaking in the  $\geq 60$ -year age range.

The distribution of electrical fatalities in relation to occupational groups was consistent with that of other studies (12). A New Zealand study (15) drew attention to the number of electrical workers and farmers or farmworkers electrocuted. The differing frequencies and incidences of electrical fatalities among occupational groups probably reflect the type of training and the varying awareness of, and exposure to, the hazards of electricity. For example, the rural community may not perceive the relatively high risk of electrocution on farms, and farmers may not be adequately trained to perform work in which electricity is a hazard. Although miners and quarrymen had the highest incidence of electrical fatalities, there were only three fatalities in this occupational group, all of which were of drilling-rig operators whose rigs contacted aerial powerlines while they worked on farms. It has been suggested that further engineering devices, such as insulation or electronic aids which would prevent contact with dangerous electric fields, should be on all booms and extensions of drilling rigs (13, 24).

Forty percent of the workers were performing work of an electrical nature at the time of death; this finding is consistent with those of other studies (13). The remaining 60% of the workers were not performing work of an electrical nature, a finding which emphasizes the fact that many workers are exposed to electricity in the course of their work even when their work does not appear to be primarily electrical. Conversely, since the 34 electrical workers among the electrical fatalities represented only 52% of the 66 electrical workers in the Work-Related Fatalities Study data set, it should be noted that electricity is not the only work-related hazard facing electrical workers.

Ninety-four percent of the deceased workers were performing duties that they normally undertook in the course of their jobs. Consequently, they should have been aware of the hazards of electricity in the job they were performing at the time of the fatal event. Therefore questions arise regarding the adequacy of the training and experience of these workers.

Farms and places of primary production constituted the single location with the greatest number of fatal events. Aerial powerlines were the source of exposure in over half of the fatal events occurring on farms. Of the electrical fatalities that were associated with exposure to electricity from flexible cords and accessories, nearly half occurred on farms. Other studies have

also noted that the death rate from electrical current was significantly higher in rural areas than in large cities (13, 24). These findings may reflect the outdoor nature of much of the work and the need to transport the source of electrical power to various different sites. Furthermore, they reflect inadequate repairs being performed by farmers and farmworkers without formal training.

Seventy-three of the electrical fatalities occurred in the period October—March inclusive, the hotter months in Australia. This seasonal distribution of electrical fatalities was also found in the United States (24) and was suggested to be related to the seasonal patterns in construction and farm work. However, in this study both more indoor and outdoor electrical fatalities occurred in the summer months. The role of perspiration (which markedly lowers the skin's resistance to electric current), rainfall, and humidity in the seasonal variation is unclear.

High-voltage powerlines are traditionally regarded as hazardous. However, the high proportion of all electrical fatalities involving domestic voltages is consistent with British findings (26) and with the fact that most appliances and pieces of equipment in the workplace use domestic voltages.

Moisture was a contributing factor in a high proportion of deaths, a finding which highlights the need to be especially careful with electricity whenever moisture is nearby. The following sources of moisture were identified: perspiration, damp ground under houses, and water that was an integral part of a process such as irrigation, concreting, and slaughtering. The 17% of electrical fatalities in which it appeared that clothing was inadequate represented half the cases in which clothing was detailed and so is probably an underestimate of the true proportion. Most clothing does not provide true insulation from electricity, but inadequate clothing exposes bare skin to the energized source. Clothing may exert its protective effect by preventing perspiring skin from contacting sources of electric current. Therefore it is probably a wise precaution for most workers to wear long-sleeved shirts, long trousers, and boots if exposure to electricity is possible.

The high proportion of electrical fatalities involving aerial powerlines (40%) can be compared with the result of a recent New Zealand study of all electrical fatalities (15) and two American studies of work-related fatalities (12, 13), which reported proportions of 40, 12, and 60%, respectively. The number of deaths among farmers in relation to aerial powerlines was almost the same as among linesmen. Aerial powerlines are a well-known hazard in the vicinity of irrigation pipes. However irrigation pipes represented only about one-third of the fatalities associated with aerial powerlines on farms, and the results from this study suggest that special attention should also be directed towards the location of aerial powerlines near grain and goods delivery areas and stock yards. Apart from six cases involving railways, it was determined that all electri-

cal fatalities associated with aerial powerlines could feasibly have been prevented by the placement of powerlines underground. Alternatively, some fatalities may have been preventable by the better placement of aerial powerlines.

Contact was made with earth either directly or indirectly in most of the electrical fatalities involving fixed wiring in premises, flexible cords, accessories, appliances, or equipment. This contact is essential for residual current devices to prevent a fatality. The use of residual current devices at switchboards would probably have prevented 36 of the electrical fatalities; a further eight of the electrical fatalities may possibly have been prevented. Thus 44 of the 55 electrical fatalities not involving powerlines might have been prevented by residual current devices. This finding is consistent with those of other studies (13).

The major strengths of this study were that it was population-based and probably included all work-related electrical fatalities that occurred in the specified population during 1982—1984. Well-defined criteria were used for the identification of the cases, and information on the cases came from coroner's files. In Australia this is a reliable and permanent source of data (27). Rates were presented only in relation to occupational groups because reliable numerator and denominator data were not available for other groups.

The main limitations of the study were that the data were not assembled primarily for the study of electrical fatalities, nor specifically for the investigation of factors associated with the fatal outcome of exposure to electricity and the factors that would have prevented the fatal outcome. There was a lack of detail on exposure to electricity, and we have had to interpolate using other data sources (eg, Electrical Supply Association of Australia). It would have been useful to have more information about the voltages involved, the anthropometric data of the workers, and the circumstances surrounding the failure to disconnect or isolate the electrical sources.

In conclusion, this study established that electricity is a significant cause of workplace fatalities. Many of the electrical deaths might have been prevented by adequate training of the workers involved, the use of residual current devices, or safer placement of overhead powerlines (either overhead or underground).

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