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Incidence and immediate consequences of electrical shocks among Danish electricians: a cohort study

Karin Biering , Anette Kærgaard, Ole Carstensen, Kent Jacob Nielsen

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Department of Occupational Medicine - University Research Clinic - Danish Ramazzini Centre, Herning Regional Hospital, Herning, Denmark

Correspondence to
Mrs Karin Biering; karbie@rm.dk

ABSTRACT

Objectives The health-related consequences of electrical shocks are mostly studied in patients from selected cohorts in hospital burn units, by making internal comparisons of subgroups, but without comparing them to unexposed individuals, or considering information regarding the preinjury health of the injured persons. Often, little is known about the details of the electrical shocks. Our purpose was to do a longitudinal study of Danish electrical workers, to monitor exposure to electrical shocks weekly over a 6-month period and to determine whether these shocks have short-term, health-related consequences.

Design Prospective cohort study with weekly measurements.

Setting Members of the Danish Union of Electricians.

Participants Of the 22 284 invited, 6960 electricians (31%) participated in the baseline data collection, and the participation rate in the weekly follow-up ranged from 61% to 81% during the 6 month follow-up.

Primary and secondary outcome measures The primary outcome measure was an electrical shock and secondary outcomes were the immediate health-related consequences of the shocks.

Results A total of 2356 electrical shocks were reported by 1612 (23%) of the participants during the 26-week follow-up. Alternating current and voltage below 1000 V were the most common forms of electricity. In most cases, the fingers/hands were the entry and exit points, but many were unable to specify the exit point. The participants categorised 73% of the electrical shocks as 'not at all severe', and most of the shocks did not cause any immediate physical damage. However, flashbacks were more common than physical consequences. Only a few of the participants contacted health services following an electrical shock, and even fewer were absent from work.

Conclusion Nearly one-fourth of Danish electricians experienced one or more electrical shocks during a 26-week period, but most of the shocks are not perceived as severe, and have only limited immediate consequences.

Strengths and limitations of this study

- ► First prospective cohort study for collecting information on electrical shocks among Danish electricians.
- ► The prospective design provides information about health before shocks in future studies.
- ► Low participation rate carries the risk of selection bias.
- ► Possibility of long-term follow-up in health registries.

INTRODUCTION

Electrical injuries occur in homes, in public and at all types of workplaces. Despite regulations and safety precautions, both children and adults are injured, although most injuries happen to young men.[1] Electrical workers, such as electricians and technicians working with electrical installations, are a professional group especially at risk of electrical injuries. When they are injured by electrical shocks, it is rarely a result of ignorance, but more often due to miscommunication, working without turning off the electrical current or simple sloppiness, perhaps because of time pressure.[2]

Existing knowledge about the frequency of electrical injuries is limited. In Denmark, as in most other countries, non-fatal electrical injuries are not systematically registered, and thus their incidence is unknown. For instance, electrical injuries in Denmark were registered with The Danish Safety Technology Authority until 2010, but only if the accident was caused by a technical fault in the equipment.[3] Hospitals are another source of information on electrical injuries, where electrical injuries have their own International Classification of Diseases 10th Revision code, which has been increasingly used in Danish hospitals over the last decade. Furthermore, work-related electrical injuries are registered by The Danish Working Environment Authorities (DWEA). All types of injuries may be registered, but registration is mandatory if the injury results in sick leave for at least the day following the day of the injury.[4] However, it is well-documented that only approximately 50% of occupational injuries are actually reported to DWEA.[5] Thus, under-reporting is likely, and less severe exposure to electrical current is not registered.[6] There is no comprehensive overview of the incidence of

electrical injuries' in Denmark, and this probably applies to other countries as well.

The consequences of exposure to electrical current range from a momentary scare and temporary pain, to severe burns and tissue damage, to death, although fatal electrical injuries are rare in Denmark, with an average of fewer than two per year in a population of 5.8 million.[3] A range of case studies and studies of groups of patients who have suffered an electrical injury suggest a variety of mental and physical symptoms. Some of these are common physical symptoms, such as headaches, muscle pain, sensory disturbances, but mental symptoms, such as cognitive problems, anxiety and depression are also reported.[7–9]

The purpose of this project was to collect data regarding participants' health previous to their reported electrical shocks, to facilitate unbiased comparisons within and between participants' health and to establish a basis for long-term follow-up in future studies.

The aim of this study was to prospectively monitor and describe electrical shocks and their immediate health-related consequences in a cohort of Danish electricians.

MATERIALS AND METHODS

This was a 6-month prospective cohort study of Danish electricians, with weekly questionnaires.

Setting and data collection

The Danish Union of Electricians has approximately 28 000 members, and organises electricians, technicians, apprentices and others electrical workers in Denmark. It is estimated that 67% of all Danish electricians are members. The data collection was conducted from October 2019 to May 2020 and had two parts: a baseline survey and 26 weeks of short, weekly, follow-up questionnaires. The survey content is described later in detail.

Before inviting union members to participate in the cohort, an information campaign about the project was presented to the members through the union's print magazine, webpage, Facebook pages, newsletters, and at member meetings and meetings of work environment representatives. This was done to ensure a high participation rate. To motivate participation, during the enrolment phase and each week of follow-up, we held a lottery for cinema-ticket vouchers for respondents, and three of the eleven local union branches held a lottery for a hotel stay for those who participated in the entire follow-up period.

Invitations to participate in the cohort were emailed to all members of the union who had registered an email address. The information campaign continued in the weeks after the invitations were sent, and along with updates on the project throughout the follow-up period, to motivate the members to respond and to continue responding during the follow-up period. After the initial invitation email, we emailed up to three reminders to the members, approximately 1 week apart. Furthermore, the union phoned a large number of non-responders, to motivate them to participate.

Procedures

Inclusion in the cohort required agreement to participate in the follow-up period, during which participants received a text message with a link to a short, web-based questionnaire each Wednesday, for 26 consecutive weeks. A small group of participants received the weekly link by email instead of text message, primarily persons working offshore, where phone connections were not stable. The links to the weekly questionnaires remained open to responses throughout the data collection period, but responses were placed according to their actual response date, and shocks reported more than 14 days after the incident were excluded (primarily during the first week of the data collection, some reported shocks from several years before). If a participant did not respond to text message within 24 hours, they received a reminder. If a participant did not respond for two consecutive weeks, the researchers sent an email with a request to respond and continue participating in the study. If the participants did not respond after this, their contact information was given to their local union branch, where local representatives tried to phone them and motivate them to continue participating. Not all non-responders were phoned, owning to capacity of personnel in the union branches, and some were phoned in vain, or a message was left on their answering service. This telephone reminder procedure was unsystematic, because of variations in the resources of the union branches, and over time.

Data were collected and managed using REDCap electronic data capture tools, hosted by Aarhus University.[10]

Content of the baseline and weekly follow-up web-based surveys

The baseline survey consisted of questions about the participants, their health and their perception of their health. This included questions about symptoms and recent exposure to electrical shocks, as in the weekly questionnaire (online supplemental file 1). Questions about recent exposure to electrical shock were designed so the participants were only presented with questions that were relevant to them, based on the answers they gave. Most notably, the participants responded to a range of detailed questions about the characteristics and consequences of a shock only if they reported having experienced an electrical shock.

The weekly follow-up questionnaires included questions on electrical shock exposure, and posed questions on absenteeism, ability to work and single-item versions of the symptom scales used in the baseline survey (online supplemental file 1), regardless of the participant's exposure to electrical shock, to prospectively monitor the participant's health prior to any electrical injury that might eventually occur.

Table 1 Demographic characteristics of participants (N=6960) and non-participants (n=15 324)

	Participants	%	Non-participants	%
Sex				
Women	150	2.2	192	1.2
Men	6810	97.8	15 132	98.8
Age				
<30 years	1690	24.3	4744	31.0
≥30 years	5270	75.7	10 580	69.0
Education				
Apprentice	1209	17.4		
Trained electrician	5100	73.3		
Higher education	391	5.6		
Other education	203	2.9		
Missing	57	0.8		
Seniority				
Mean number of years working with electricity (SD)	19	(13.9)		
Marital status				
Married or cohabiting	5059	72.7		
Single (bachelor)	1189	17.1		
Single (divorced or widowed)	585	8.4		
Missing	127	1.8		
Current work situation				
Working with electricity	5952	85.5		
Working with something other than electricity	659	9.5		
Not working (on leave, unemployed, sick leave, other)	245	3.5		
Missing	104	1.5		
Self-reported health (general health item from SF-36)				
Excellent, very good, good	6363	91.5		
Fair, poor	525	7.5		
Missing	72	1.0		
Smoking				
Yes, currently a smoker	1222	17.5		
No, but previously smoked	1856	26.7		
No, never smoked	3806	54.7		
Missing	76	1.1		
Alcohol use				
0 units/week	1935	27.8		
1–14 units/week	4636	66.6		
15 or more units/week	318	4.6		
Missing	71	1.0		
Body mass index				
<18.5 underweight	51	0.7		
18.5–<25 normal weight	2322	33.4		
25–<30 overweight	2895	41.6		
30+ obese	1527	21.9		
Missing	165	2.4		

Patient and public involvement statement

When we designed and planned the project, we involved a steering group of members from the electricians' union and other organisations that addressed electricity and technical safety, to ensure that the participants would be able to understand questionnaires, and that they covered relevant aspects of electrical injuries. We also tested the questionnaire on a small group of electricians before the final version was launched.[11–18]

Linkage of data

Every person working and living in Denmark has a unique personal identification number, called the CPR number.[19] The participants consented to the use of their CPR numbers for later follow-up in registries. Each Danish citizen as well as registered migrant workers holds this unique CPR number that provide the possibility to link each person across different registries. This makes it possible to study outcomes after the relatively short follow-up survey. In this study, the CPR number was used to determine participant sex and age.

Analysis

Data were presented as counts and percentages, including information about missing data. Participants were compared with non-participants with regard to age and sex. Details regarding exposure to electrical shocks and their immediate consequences were described, and participation and proportions of electrical shocks over time were presented graphically. All data management and analysis were conducted in Stata V.16.1

RESULTS

Participation

We invited 22 284 members of the Danish Union of Electricians to participate, excluding members without an email address, and retired members. Of these, 6960 agreed to participate, but 50 did not complete the baseline questionnaire. Table 1 provides demographic information for respondents compared with non-respondents, and other baseline characteristics. The proportion of women and of persons over 30 was larger among respondents than non-respondents, in line with other population-based studies. Most of the participants were trained electricians, and apprentices were the second largest group. They reported slightly better health than the Danish population in general, and reported lower alcohol use, whereas the smoking habits and body mass index were in line with the Danish male population.[20]

Participation during follow-up

The weekly response rate declined from 81% to 62% during the first 11 weeks of follow-up. After that, the response rate stabilised at approximately 63% for the rest of the data collection period (figure 1).

Electrical shocks

During the 26 weeks of follow-up, 2356 electrical shocks were reported with 1133 persons (16.3%) reporting one shock, 319 persons (4.6%) reporting two shocks, 97 persons (1.4%) reporting three shocks and 63 persons (0.9%) reporting four to nine shocks. This indicates that 1612 (23%) of the participants had experienced at least one electrical shock during these 26 weeks.

The shocks (not persons) are presented in detail in the following tables. The vast majority of the shocks were classified as 'not at all severe' by the participants. The type of electricity was most often alternating current and voltage under 1000 V (table 2A).

During the follow-up period, there was a small decline over time in the reports of the incidence of shocks, and a dip in reporting over Christmas and the new year (around weeks 12–13 of the data collection), because of the holidays (figure 2). In the baseline questionnaire,

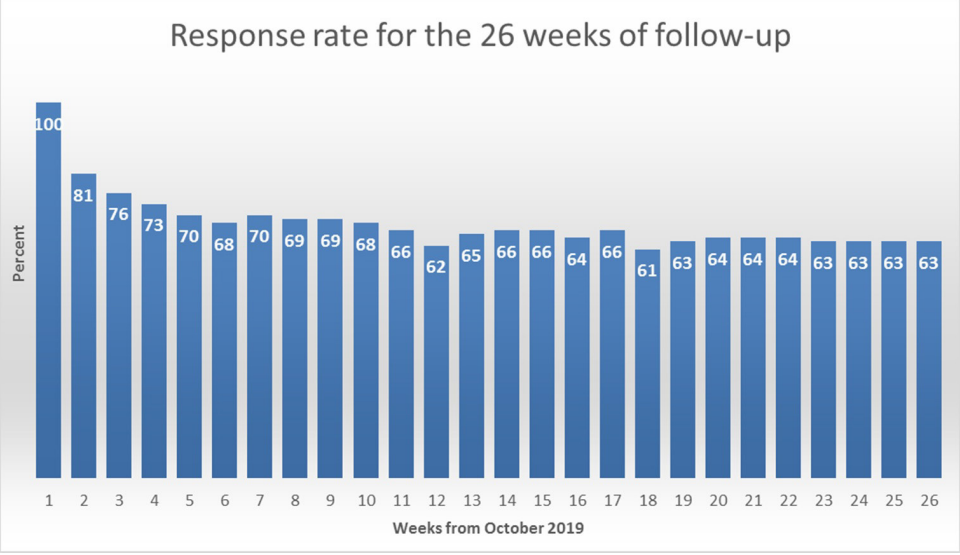

Figure 1 Response rate during the 26 weeks of follow-up.

Table 2A Description of electrical shocks reported (N=2356) over 26 weeks by Danish electricians

	n	%
Number of shocks/person		
1	1133	48.1
2	638	27.1
3	291	12.3
4–9	294	12.5
Type of electricity		
Alternating current	2006	85.1
Direct current	142	6.0
Electrical arc	8	0.3
Induction	27	1.2
Static electricity	102	4.3
Unknown	65	2.8
Missing	6	0.3
Voltage		
Under 230 V	340	14.4
230 V	1455	61.8
400 V	62	2.6
400–1000 V	16	0.7
Over 1000 V	22	0.9
Unknown	78	3.3
Missing	383	16.3
Self-reported severity		
Not at all severe	1725	73.2
Slightly severe	534	22.7
Somewhat severe	66	2.8
Quite severe	15	0.6
Very severe	6	0.3
Missing	10	0.4

several of the participants reported shocks going back some time, but these were omitted from the data if they happened more than 14 days before the questionnaire was completed.

Immediate consequences

Most of the shocks had an entry point in a finger, hand or arm. In most cases, the exit point was also a finger, hand or arm, but many reported that the exit point was unknown. Current passing across the body (in most cases, upper extremity to upper extremity) was less frequent than same side exposure, but again, many did not know, equivalent to reporting of the unknown exit points. Exposure on dry skin was more common than on wet/damp skin (table 2B).

Most of the shocks did not cause any immediate injury, direct or indirect. Table 2C shows consequences reported in the same week as the shock. Only 13 shocks were followed by unconsciousness, whereas 49 shocks led to memory loss; these numbers may be a bit higher than reported, as seven and nine persons, respectively, answered 'do not know' to these questions. In 177 cases those who experienced electrical shocks contacted their doctor/went to hospital, and 68 led to an injury-related absence from work. In 252 cases, shocks caused flashbacks; this exceeds the number of shocks that resulted in physical injury (table 2C).

DISCUSSION

Key results

Of the 22 284 eligible members of the Danish Union of Electricians, 6960 (31%) participated in our cohort study, and of these, 61%–81% participated in the 26-week follow-up. During the data collection period, 2356 electrical shocks were experienced by 23.1% of the participants. Of the participants, 1133 (16.3% of participants) experienced one shock and 1223 (6.9% of participants) experienced two to nine shocks. The reporting of shocks declined slightly over time. Most of the shocks were reported as 'not severe'. The most frequent type of electricity was alternating current and a voltage below 1000 V. The most common entry and exit points were fingers, hands and arms, predominantly dry skin. Surprisingly, many electricians could not determine whether they had current passing across the body, 66% of these because they could not determine the exit point of a shock.

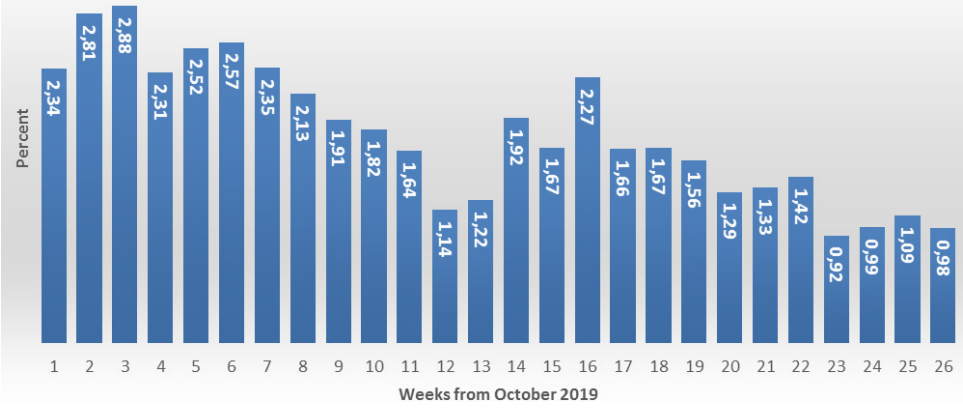

Figure 2 Proportion of participants reporting electrical shocks during the 26 weeks of follow-up.

Table 2B Description of reported electrical shocks by entry and exit point (N=2356)

	n	%
Entry point		
Hand/finger	2116	89.8
Arm	67	2.8
Other	24	1.0
Missing*	149	
Moistness of entry point		
Dry	1771	75.2
Wet/damp	428	18.2
Missing*	157	6.7
Exit point		
Hand/finger	1077	45.7
Arm	171	7.3
Other	270	11.5
Unknown	689	29.2
Missing*	149	6.3
Moistness of exit point		
Dry	1218	51.7
Wet/damp	281	11.9
Missing*	857	36.4
Current passing across the body		
Yes	249	10.6
No	1106	46.9
Unknown	842	35.7
Missing*	159	6.7

*Those who reported electrical arc, induction or static electricity were not asked these questions, and included in the missing group.

Table 2C Immediate consequences of electrical shock (reported in same week as shock) (N=2356)

	n	%
Physical injury caused by the shock		
Yes: red marks on skin	110	4.7
Yes: burn	45	1.9
Yes: other	29	1.2
No	2164	91.9
Missing	8	0.3
Other physical injury related to the shock (eg, from falling)		
Yes	34	1.4
No	2315	98.3
Missing	7	0.3
Unconsciousness		
Yes	13	0.5
No	2322	98.6
Unknown	7	0.3
Missing	14	0.6
Memory loss		
Yes	49	2.1
No	2292	97.3
Unknown	9	0.4
Missing	6	0.3
Contacted health services		
Yes: outpatient visit	150	6.4
Yes: admitted	27	1.1
No	2166	91.9
Missing	13	0.6
Absent from work		
Yes: the same day	57	2.4
Yes: more than 1 day	11	0.5
No	2278	96.7
Missing	10	0.4
Self-reported ability to work		
Very good	2167	92.0
Good	151	6.4
Average to very poor	8	0.3
Missing	30	1.3
Flashbacks		
Not at all	2094	88.9
To a minor extent	208	8.8
To some extent	31	1.3
In high/very high extent	13	0.6
Missing	10	0.4

The immediate consequences reported the same week as an electrical shock were also rare. However, 4.7% resulted in red skin marks, 2.1% resulted in memory loss and 10.7% caused flashbacks to various extents. In 7.5% of cases, healthcare services were contacted, but few shocks resulted in absence from work for more than the same day, and in parallel with this, only a few reported reduced ability to work following a shock.

Limitations

To the best of our knowledge, the cohort of electrical workers we studied is the first to be monitored for electrical injuries through a prospective design. Despite an intensive campaign to motivate participation, this survey had a relatively low participation rate. This is a possible limitation of the study, especially because the distribution of ages was different among participants and non-participants. Attrition during the follow-up phase may also present a problem, as 19% did not respond to any of the follow-up messages, and up to 40% of those who responded to the baseline questions stopped answering during the follow-up phase. However, some participants who stopped answering during the data collection returned later. This intermittent pattern of answering

is not as prone to bias as attrition is, if the respondents provided answers both before and after an electrical shock. The decline in the number of shocks over time was greater than the attrition, and we could not find an explanation for this. We examined the response pattern for changes related to reporting a shock, but that was not the case. Participation in the study may have increased awareness of the risk of electrical shock, and this may have led to the decrease.

Participation in the study, especially the baseline survey, which included many questions with various types of response categories, required fundamental reading skills. This may have caused persons who had reading difficulties to be under-represented in the cohort as they might give up on answering. On the other hand, all members of the Danish Union for Electricians are trained electricians, technicians or apprentices who should have sufficient reading skills to participate in this sort of study.

Interpretation

Only a small proportion of the electrical-shock-related injuries prompted participants to contact a healthcare professional. Most previous studies of electrical injuries are based on hospitalised patients, unusually those in specialised burn units. This study describes a heterogeneous group of electrical shocks, and thus the low proportion of extremely severe shocks reported means that it is not comparable to previous studies in other settings. Since, as far as we know, this study is the first to monitor electrical injuries among electricians through a prospective design with repeated measurements, it is not possible to compare this study with previous work. However, a Norwegian retrospective study of electricians estimated an incidence of 7.6 serious electrical injuries per 100 person-years,[6] which, translated to our design, would result in over 200 serious injuries over 6 months of follow-up. This was not reflected in our findings, in which only 31 shocks were reported as 'quite severe' or 'very severe'. We cannot know whether or not this discrepancy is related to recall bias in the Norwegian study, a different study population, or changes in incidence over time. A retrospective Swedish study of electricians who had experienced at least one electrical shock showed that half of the respondents had experienced an electrical injury at some point in their working life.[21]

Generalisability

This study may be generalised to other populations of electricians, where the regulations and safety guidelines are in line with the Danish ones. If the participants' risk of electrical shock is consistent with those who did not participate, the incidence and the characteristics of the shocks may be extrapolated to the entire population of Danish electricians. The opportunity to examine the cohort's participants' health before and after an electrical shock may provide results that are generalisable to other contexts, as the participants are compared with themselves before and after an electrical shock, rather than to other populations.

Contributors KB, AK, OC and KJN designed the study, discussed its results, strengths and limitations, and approved the final version of the manuscript. KJN programmed the REDCap data collection; KB carried out the initial data management and analysis, wrote the first draft of the manuscript and is responsible for the overall content.

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Competing interests None declared.

Patient consent for publication Obtained.

Ethics approval The data collection was approved by Central Region on behalf of the Danish Data Protection Agency #1-16-02-139-19. Approval from the Ethics Committee is exempted in Denmark for questionnaire-based data collection.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available upon reasonable request.

ORCID iDs

Karin Biering http://orcid.org/0000-0001-7038-9566
Kent Jacob Nielsen http://orcid.org/0000-0002-4643-5697

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