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Electricians' Health After Electrical Shocks

A Prospective Cohort Study

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Objectives: To examine whether demographic and health factors are associated with risk of electrical shocks and compared mental and physical health before and after an electrical shock. **Methods:** A 6-month cohort study of 6960 electricians involved weekly questionnaires regarding exposure to electrical shocks, and health. We examined the association between health and demographic factors and the risk of eventual electrical shocks and health before and after a shock **Results:** Youth and poor health were associated with risk of shocks. Reporting of numbness, cramps/spasms, tremors, tinnitus, dizziness, and flashbacks increased in the week of the shock, but only tinnitus and flashbacks persisted, as other symptoms receded. Severity, high voltage, cross-body exposure, wet entry/exit points, and direct current as well as health worries and/or neuroticism increased some estimates **Conclusion:** Electrical shocks are common, but rarely result in health effects.

Keywords: Accidents, Environmental Exposure, Epidemiology, Longitudinal Studies, Occupational Health Services

Electrical injuries may be extremely severe, and cause life-threatening burns or fatal cardiac arrhythmias.[1] However, severe injuries are rare, and not necessarily occupational.[2] Occupations that involve working with electricity present a particular risk of electrical injury, since workers may be exposed to electrical current in several tasks.[3,4] Two different Job Exposure Matrixes categorize electricians as having the highest risk of electrical injuries.[5,6] Rules and regulations for preventing electrical shocks do exist,[7] but electricians remain at risk, especially when working with the power on, intentionally or unintentionally, because of technical problems or communication errors. it is unclear if individual factors are related to increased risk of electrical injuries, but previous studies suggest that young age increases the risk of severe electrical injuries,[1,8] a well-known phenomenon in other occupational settings.[9] The influence of personality factors is also unknown but two meta-analyses of occupational injuries showed a weak association to neuroticism.[10,11] Neuroticism also affects reporting of health related quality of life and mental health both in general,[12,13] as well as in burn patients.[14] Previous studies have also found that health worries are related to increased reporting of mental and physical symptoms.[15,16]

Electrical shocks may also cause health problems that are less recognized than burns and cardiac effects. These may be physical, such as pain,[17–21] numbness[17,20], tremor,[21] dizziness,[19,20,22] fatigue,[20,21] or mental, such as anxiety,[21,23–27] depression,[18,21,23–26] cognitive problems,[23,24,26,28,29] sleep problems,[1,18,23,25,27,28,30,31] and Post Traumatic Stress Disorder (PTSD).[18,19,23,25] Social problems may also occur, if the injured person becomes afraid of electricity or loses the ability to work.[23,25,32] The severity of the health problems is probably related to the severity of the shock, including the voltage involved, entry/exit points and current pathway, but personal factors such as health worries and neuroticism may also play a role. However, most symptoms are reported either casuistically or in studies from burn units, where the burn itself is the main problem, and often years after the injury has occurred. There have been no prospective studies that address the health of the injured prior to an electrical shock, and thus to what extent reported symptoms were present before the injury, and whether any symptom increments are permanent or temporary, is unknown. Another general limitation is the lack of comparison groups, as casuistic and descriptive cohort studies predominate, which is also reflected in literature reviews[3,30] and in a recent systematic review that calls for epidemiological and prospective studies.[33]

AIMS

The aim of this study was twofold: We examined whether participant demographics and mental health are associated with later risk of experiencing an electrical shock and furthermore, we compared mental and physical health symptoms before and after an electrical shock.

MATERIALS AND METHODS

We invited 22.284 members of the Danish electrical workers' union to participate in this cohort study, excluding those without an email address and those who were retired (approximately 5700 persons). The study consisted of an electronic, baseline questionnaire that addressed demographics, personality factors and physical and mental health. This was followed by short, weekly electronic questionnaires provided with a link in a text message for 26 weeks (October 2019 to May 2020) concerning physical and mental health and exposure to electrical shocks, including exposure details regarding the shock. Nonrespondents for the baseline questionnaire received three reminders on e-mail and nonrespondents in the weekly questionnaires (within 24 hours) received one reminder on text message, and in case of nonresponse for two consecutive weeks they were sent an e-mail to motivate for participation. if they were still nonrespondents after this, some were also phoned by the union, to motivate participation. However, participation was voluntary, and participants could leave the study at any time point and stop receiving the weekly questionnaires. The baseline questionnaire took 15 minutes to complete on average, whereas completing the weekly questionnaire differed in time from 30 seconds to 3 to 4 minutes, depending on whether the respondent had experienced any shock, since this opened a range of additional questions regarding this exposure. To ensure face validity, the questionnaires were pilot tested in a group of electricians by two of the authors (K.N. and A. K). The electricians completed the questionnaires and were interviewed on their understanding of the questions and their ability and

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willingness to answers them correctly. Minor revisions of questions and scales were done based on their feedback. The data collection, content of the questionnaires and description of the electrical shocks are presented in detail by Biering et al.[34]

The electrical shocks reported in the weekly questionnaire were used in two different ways. Since participant could experience shocks more than once during the 26 weeks, we identified three types of participants; those who did not report any electrical shocks during follow-up, those who reported one or two shocks and those who reported three or more electrical shocks. Based on this, we defined two outcomes; having one or more electrical shocks versus none, and having three or more electrical shocks versus none or up to two electrical shocks. We used these as outcomes when analyzing the risk of electrical shocks. In the analysis where we compared health before and after electrical shocks, we used only the first reported electrical shock of each participant and the severity of that in the analysis.

The baseline questionnaire: Participant's educational level was divided into four categories based on self-report: apprentice, trained electrician, higher education, and other training. Marital status was divided into three categories: married/cohabiting, single (unmarried), single (divorced/widowed). Participants rated their health and their ability to work; health was dichotomized into ''excellent, very good, or good'' versus ''fair or poor'' categories, whereas ability to work (a 0 to 10 scale)[35] was dichotomized into ''low'' (0 to 8) and ''high'' (9 to 10) categories for descriptive purposes and risk analysis, but used as a continuous scale in the analysis of health before and after an electrical shock. Participants also rated their anxiety,[36] depression,[37] self-efficacy,[38] health worries,[39,40] sleeping troubles,[38] cognitive problems,[3] and neuroticism.[41,42] All the scales used applied a continuum from 0 to 4, except for self-efficacy (range 0 to 6) and depression (range 0 to 10). We derived sex and age from the participants' personal identification numbers.[43] Age was divided into decades for descriptive purposes.

The weekly questionnaires: To compare participant's mental and physical health before and after they had experienced an electrical shock, we used single items derived from the full symptom scales reported in the baseline questionnaire and presented these each of the subsequent 26 weeks. The symptoms were chosen based on the literature, and on symptoms presented by patients who were examined at our department of occupational medicine following electrical injuries. These were anxiety (''felt tense or keyed up''),[36] depression (''felt low in spirits or sad''),[37] sleeping troubles (''woke up

TABLE 1. Descriptive Data of Participants Without Shocks, with Any Number of Shocks and with Multiple Shocks (3 +)

	No Shocks		Any Shock (One or More)		Multiple Shocks (3 +)*		Total	
	n = 4702		*n* = 1547		*n* = 158		*n* = 6249	
	n	%	*n*	%	*n*	%	*n*	%
Previous health consequences after electrical injury								
No	4285	91.13	1381	89.27	141	89.24	5666	90.67
Yes, current	162	3.45	59	3.81	5	3.16	221	3.54
Yes, previous	174	3.70	100	6.46	11	6.96	274	4.38
Missing	81	1.72	7	0.45	< 5	< 2	88	1.41
Work ability (0-10)								
Below mean (< = 9)	1529	32.52	494	31.93	63	39.87	2576	41.22
Above mean (>9)	3101	65.95	1047	67.68	93	58.86	3595	57.53
Missing	72	1.53	6	0.39	< 5	< 2	78	1.25
Sex								
Female	110	2.34	27	1.75	< 5	< 2	137	2.19
Male	4592	97.66	1520	98.25	156	98.73	6112	97.81
Age groups								
18–20 years	136	2.89	55	3.56	9	5.70	191	3.06
21–30 years	960	20.42	486	31.42	61	38.61	1446	23.14
31–40 years	968	20.59	395	25.53	39	24.68	1363	21.81
41–50 years	1098	23.35	285	18.42	26	16.46	1383	22.13
51–60 years	989	21.03	214	13.83	16	10.13	1203	19.25
61 years or older	551	11.72	112	7.24	7	4.43	663	10.61
Marital status								
Married or co-habitant	3400	72.31	1090	70.46	101	63.92	4490	71.85
Single (bachelor)	778	16.55	351	22.69	45	28.48	1129	18.07
Single (divorced or widowed)	418	8.89	89	5.75	8	5.06	507	8.11
Missing	106	2.25	17	1.10	4	2.53	123	1.97
Education								
Apprentice	807	17.16	402	25.99	51	32.28	1209	19.35
Trained electrician	3476	73.93	1080	69.81	101	63.92	4556	72.91
Higher education	265	5.64	47	3.04	< 5	< 2	312	4.99
Other education	177	3.76	20	1.29	< 5	< 2	197	3.15
Missing	53	1.13	4	0.26	< 5	< 2	57	0.91
Health								
Excellent, Very good, Good	4303	91.51	1412	91.27	146	92.41	5715	91.45
Fair, Poor	334	7.10	128	8.27	12	7.59	462	7.39
Missing	65	1.38	7	0.45	0	0.00	72	1.15

*Those with multiple shocks are a subset of those with any number of shock.

too early and were unable to get back to sleep''), [8] cognitive problems (''had problems concentrating''),[38] increased frustration (''even minor annoyances may frustrate me'').[42] In addition to the single items, we included ability to work ('On a scale from 0 to 10, how would you rate your current ability to work?'),[35] and a single item ('Has an image of a traumatic event popped into your mind in the past 7 days?') to assess flashbacks.[44] The single items derived from larger scales were chosen in two ways; for scales where we had a dataset available from another occupational context,[37,38,44] we identified the single item with the highest correlation to the full scale, and for the remaining we chose a single item from a validated scale with the wording closest to the topic of the scale (example: Anxiety from SCL-90: ''Have you felt nervousness or shakiness inside?''[36] and from COPSOQ cognitive stress: ''Have you had problems concentrating?'').[38] Furthermore, other single items from the baseline questionnaire were used to report physical symptoms; pain, numbness, weakness, cramps and spams, tremors, tinnitus, migraine, fatigue, and dizziness, on a scale from 0 to 5.

Statistical Analysis

Data were described by means, and standard deviations or proportions for those who reported no electrical shocks, one or two electrical shocks, and three or more electrical shock. The associations between baseline prevalent factors and electrical shock were analyzed by logistic regression, and adjusted for sex, age, and previous consequences of an electrical injury. in this analysis, we excluded those who were not employed as electricians.

We also compared the reported symptoms before and after an electrical shock using linear mixed models, to be able to allow an individual level of symptom reporting for each participant. We were interested in three different time frames: all the weeks preceding an electrical shock versus the week in which a reported electrical shock occurred, all the weeks preceding and four weeks after the electrical shock and all the weeks preceding and all the weeks after the electrical shock. We adjusted the linear mixed models sex, age, and severity of the electrical shock. Flashbacks were analyzed only for those who reported that their flashbacks were associated with an electrical shock, not other kinds of traumatic events. To further address shock severity, we made an additional analysis in which we included only electrical shocks that were reported as *quite severe* or *very severe (n = 20).*

We identified various subgroups of electrical shocks that the literature suggests are particularly harmful. These were shocks with a voltage of over 1000 V, with cross-body exposure, involving wet entry/exit points, and involving direct current.

We identified particularly vulnerable participants, defined as those who reported high levels of neuroticism or high levels of health worries, based on the 75th percentile of the scale. We made an additional analysis restricted to these participants, and an analysis with the combination of vulnerability and high severity of the shocks.

TABLE 2. Associations Between Baseline Characteristics and Later Electrical Shock

		Any Shock (One or More)		Multible Shocks (3+)	
		n = 1547		*n* = 158	
		Unadjusted	Adjusted*	Unadjusted	Adjusted*
Previous health consequences after electrical injury	No	Ref.	Ref.	Ref.	Ref.
	Yes, current	1.13[0.83;1.53]	1.14[0.84;1.58]	0.91[0.37;2.24]	0.92[0.37;2.28]
	Yes, previous	1.78[1.38;2.30]	1.78[1.38;2.30]	1.64[0.88;3.06]	1.62[0.86;3.03]
Work ability	Low: 0–8	Ref.	Ref.	Ref.	Ref.
	High: 9–10	1.18[1.08;1.29]	0.95[0.84;1.07]	1.47[1.12;1.92]	1.23[0.88;1.73]
Sex	Female	Ref.	Ref.	Ref.	Ref.
	Male	1.35[1.22;1.48]	1.34[0.86;2.09]	1.47[1.12;1.93]	1.95[0.48;7.96]
Age groups	−20 years	4.25[3.88;4.66]	1.99[1.36;2.89]	8.32[6.77;10.22]	4.17[1.49;11.65]
	21–30 years	4.13[3.94;4.35]	2.51[1.99;3.17]	6.51[5.64;7.69]	4.19[1.91;9.23]
	31–40 years	2.70[2.57;2.83]	2.02[1.60;2.56]	3.43[2.93;4.02]	2.83[1.25;6.33]
	41–50 years	1.64[1.57;1.73]	1.29[1.01;1.65]	2.03[1.72;2.40]	1.83[0.79;4.23]
	51–60 years	1.16[1.10;1.22]	1.06[0.82;1.36]	1.28[1.07;1.52]	1.26[0.52;3.08]
	61 years or older	Ref.	Ref.	Ref.	Ref.
Marital status	Married or co-habitant	Ref.	Ref.	Ref.	Ref.
	Single (bachelor)	1.40[1.22;1.62]	1.00[0.85;1.17]	1.80[1.26;2.58]	1.12[0.75;1.67]
	Single (divorced or widowed)	0.66[0.52;0.84]	0.71[0.56;0.91]	0.70[0.34;1.44]	0.79[0.38;1.64]
Education	Apprentice	1.60[1.40;1.84]	1.11[0.94;1.32]	1.94[1.38;2.74]	1.12[0.73;1.70]
	Trained electrician	Ref.	Ref.	Ref.	Ref.
	Higher education	0.52[0.38;0.73]	0.56[0.40;0.78]	0.43[0.14;1.38]	0.49[0.15;1.55]
	Other education	0.57[0.35;0.95]	0.67[0.40;1.11]	0.75[0.18;3.09]	0.96[0.23;3.97]
Health	Excellent, Very good, Good	Ref.	Ref.	Ref.	Ref.
	Fair, Poor	1.19[1.09;1.29]	1.21[0.86;1.53]	1.21[0.96;1.53]	1.10[0.89;1.35]
Anxiety†	Score between 0 and 4	1.33[1.14;1.54]	1.16[0.99;1.36]	1.48[1.07;2.05]	1.30[0.92;1.83]
Depression†	Score between 0 and 10	1.03[1.02;1.04]	1.02;1.01;1.03]	1.03[1.01;1.07]	1.03[1.00;1.06]
Self-efficacy	Score between 0 and 6	0.81[0.73;0.90]	0.84[0.76;0.94]	0.88[0.66;1.19]	0.93[0.69;1.25]
Sleeping troubles	Score between 0 and 4	1.07[0.94;1.21]	1.06[0.94;1.21]	1.24[0.92;1.68]	1.27[0.93;1.73]
Cognitive problems	Score between 0 and 4	1.30[1.12;1.51]	1.13[0.97;1.32]	1.38[0.97;1.96]	1.20[0.82;1.74]
Neuroticism	Score between 0 and 4	1.45[1.22;1.71]	1.18[0.99;1.41]	2.43[1.57;3.76]	1.88[1.20;2.96]
Health worries	Score between 0 and 4	1.14[1.04;1.26]	1.17[1.06;1.29]	1.20[0.94;1.53]	1.26[0.99;1.61]

Persons who are not working with electricity are excluded.
*Adjusted for sex, age and previous consequences following an electrical injury.
†Persons reporting previous anxiety or depression, respectively, are excluded.

All data management, and analyses were carried out in Stata 16.0, and the associations are presented with a 95% confidence interval.

RESULTS

A total of 6960 electrical workers (31%) responded to the baseline questionnaire, and 61% to 81% responded to the weekly follow-up questionnaires. Of these, 1610 participants reported one or more electrical shocks, and a total of 2356 electrical shocks were reported.

Electricians who had previously experienced adverse health effects following an electrical injury more often reported one or more electrical shocks in the follow-up questionnaires, compared to those without this experience (Table 1). Young participants and apprentices also reported electrical shocks more often than their older colleagues, or those with more advanced training. Women reported shocks slightly less often than men. Unmarried participants also reported shocks more often than married, divorced, or widowed single participants. There were no shock-related differences the reporting of general health or the ability to work.

Several factors were associated with reporting of electrical shocks in the follow-up questionnaires (Table 2). In general, the factors that increased the risk of an electrical shock also increased the risk of three or more electrical shocks. As expected, these were the factors mentioned in Table 1, namely, previous electrical injury, youth, being unmarried, and being an apprentice. Reduced ability to work increased the risk of three or more electrical shocks, but not of receiving at least one electrical shock. Also, some health factors were associated with reporting of electrical shocks, namely, anxiety, depression, low self-efficacy, sleeping troubles, cognitive problems, neuroticism, and health worries. Adjustments for age, sex, and previous effects of an electrical injury lowered many of the risk estimates, and the increased risk observed for unmarried participants and apprentices disappeared. The increased risk associated with youth decreased somewhat, but was still high, probably because of the correlation between youth, being unmarried, and being an apprentice. The adjustments affected the risk associated with the health scales to only a small degree (Table 2).

We compared reporting of mental and physical health symptoms before and after an electrical shock in different time intervals, to determine possible health effects of electrical shocks, and to examine their short- and long-term consequences (Table 3).

In the week in which a reported electrical shock occurred, we observed an increase in reports of numbness, cramps and spasms, tremors, tinnitus, dizziness, and flashbacks (Table 3). However, at the same time, there was a decrease in reports of depression, cognitive problems, sleeping troubles, and frustration, and an increase in the ability to work. Four weeks after a reported electrical shock, tinnitus and flashbacks were the only symptoms that persisted above the levels before the shock, whereas reports of other symptoms further decreased. The pattern was the same when we compared the reporting before with the reporting all the weeks following an electrical shock. When we considered the severe shocks, we saw an increase in reports of most symptoms in the week in which a reported shock occurred, but all estimates had wide confidence intervals, owing to the low number of severe shocks. However, the reports for all symptoms but weakness ceased after 4 weeks, and we saw a decrease in reports of several symptoms. Once again, the pattern was the same after 4 weeks and all weeks (Table 3). There were too few participants who reported very severe electrical shocks to estimate change in reporting of flashbacks related to electrical injury, when flashbacks related to other causes were excluded. Adjusting for age, sex, and the severity of the electrical shocks did not affect the results found, and are not reported.

When we restricted our analysis to subgroups of potentially more harmful electrical shocks, we found that immediate reporting of symptoms increased, especially for voltages higher than 1000 V, and for the combination of cross-body exposure, and wet entry/exit points (Table 4). Exposure to direct current revealed reporting of symptoms consistent with all shocks. The presence of wet entry and exit points did not increase the reporting of symptoms by themselves, but did so when it was combined with cross-body exposure, which also increased the reporting of symptoms. In the long term, most of these increases disappeared, however reports of flashbacks remained elevated. All estimates had large confidence intervals (Table 4).

TABLE 3. Comparison of Mean Levels of Physical and Mental Health Before and After an Electrical Shock in Different Time-Intervals and for Severity Separate

	All Weeks Before and the Week Including the Shock		All Weeks Before and 4 Weeks After Shock		All Weeks Before and All Weeks After Shock	
	Unadjusted, All Shocks	Unadjusted, High Severity	Unadjusted, All Shocks	Unadjusted, High Severity	Unadjusted, All Shocks	Unadjusted, High Severity
Work-ability[c]	0.11[0.04;0.17]	−0.47[−1.56;0.62]	0.10[0.06;0.15]	0.54[−0.19;1.26]	0.06[0.03;0.10]	0.64[0.04;1.24]
Pain[b]	0.01[−0.03;0.05]	0.74[0.07;1.41]	−0.07[−0.10;−0.05]	0.04[−0.40;0.48]	−0.11[−0.13;−0.09]	−0.11[−0.48;0.25]
Numbness[b]	0.03[0.01;0.05]	0.88[0.61;1.14]	0.00[−0.01;0.02]	− 0.03[−0.22;0.16]	−0.01[−0.02;0.01]	−0.10[−0.21;0.02]
Weakness[b]	0.01[−0.02;0.04]	0.80[0.37;1.22]	−0.01[−0.03;0.01]	0.17[−0.11;0.45]	−0.01[−0.03;0.00]	0.16[−0.07;0.39]
Cramps and spasms[b]	0.05[0.03;0.06]	0.51[0.35;0.68]	−0.01[−0.02;0.01]	0.00[−0.11;0.12]	−0.02[−0.03;−0.01]	−0.01[−0.08;0.06]
Tremors[b]	0.02]0.01;0.03]	0.20[−0.18;0.57]	0.00[−0.01;0.01]	− 0.35[−0.60;−0.10]	0.00[−0.00;0.01]	− 0.47[−0.67;−0.26]
Tinnitus[b]	0.03[0.02;0.05]	−0.08[−0.38;0.21]	0.02[0.00;0.03]	− 0.19[−0.38;0.00]	0.02[0.01;0.03]	−0.20[−0.37;−0.41]
Migraine[b]	−0.01[−0.03;0.01]	−0.11[−0.41;0.19]	−0.03[−0.05;−0.02]	− 0.09[−0.28;0.10]	−0.02[−0.03;−0.01]	−0.04[−0.20;0.13]
Fatigue[b]	−0.02[−0.05;0.01]	0.12[−0.34;0.57]	−0.06[−0.08;−0.04]	− 0.23[− 0.53;0.06]	−0.09[−0.11;−0.08]	− 0.29[− 0.54;− 0.04]
Dizziness[b]	0.02[0.01;0.04]	0.20[−0.11;0.51]	0.01[−0.00;0.02]	− 0.18[−0.38;0.01]	0.01[−0.00;0.01]	−0.13[−0.30;0.03]
Depression[d]	−0.03[−0.05;−0.01]	−0.01[−0.30;0.29]	−0.05[−0.07;−0.04]	0.08[−0.11;0.27]	−0.06[−0.07;−0.04]	−0.04[−0.20;0.13]
Anxiety[a]	−0.01[−0.03;0.01]	0.22[−0.16;0.62]	−0.05[−0.07;−0.05]	− 0.16[−0.40;0.09]	−0.07[−0.08;−0.06]	−0.32[−0.53;−0.12]
Sleeping troubles[a]	−0.03[−0.06;−0.01]	−0.09[−0.38;0.20]	−0.06[−0.07;−0.04]	0.06[−0.13;0.26]	−0.07[−0.08;−0.06]	0.06[−0.10;0.22]
Cognitive problems[a]	−0.03[−0.05;−0.01]	0.04[−0.25;0.33]	−0.05[−0.06;−0.05]	− 0.23[−0.41;−0.04]	−0.07[−0.08;−0.06]	− 0.24[− 0.39;- 0.08]
Frustrations[a]	− 0.03[− 0.05;− 0.00]	0.60[0.25;0.96]	−0.07[−0.09;−0.06]	0.01[−0.24;0.26]	−0.11[−0.12;−0.09]	− 0.25[− 0.44;- 0.05]
Flashbacks[ae]	0.22[−0.09;0.52]	Too few to estimate	0.08[−0.12;0.28]	Too few to estimate	0.04[−0.14;0.22]	Too few to estimate

Ranges of scales: [a]: 0–4; [b]: 0–5; [c]: 0–10 + high is better; [d]: 0–6 [e] Related to electrical shock only.

TABLE 4. Additional Subgroup Analysis Related to Objective Characteristics Compared to Estimates from Table 3 (All Shocks), Divided in Short- and Long-Term

Shortterm—All Weeks Before and the Week Including the Shock

	Unadjusted, All Shocks	Voltage > 1000 V	Direct Current	Crossbody	Wet Entry and Exit Point	Crossbody AND Wet Entry and Exit Point
Work-ability[c]	0.11[0.04;0.17]	−0.27[−1.04;0.49]	0.09[−0.20;0.39]	−0.13[−0.34;0.08]	−0.01[−0.25;0.22]	−0.28[−0.73;0.16]
Pain[b]	0.01[−0.03;0.05]	0.22[−0.22;0.68]	−0.07[−0.24;0.10]	0.12[−0.01;0.25]	0.08[−0.06;0.22]	0.33[0.04;0.63]
Numbness[b]	0.03[0.01;0.05]	0.56[0.23;0.89]	0.04[−0.06;0.13]	0.00[−0.07;0.07]	0.01[−0.08;0.09]	−0.07[−0.25;0.11]
Weakness[b]	0.01[−0.02;0.04]	0.28[−0.10;0.65]	− 0.05[− 0.18;0.07]	0.05[−0.05;0.14]	0.18[0.06;0.29]	0.26[0.02;0.51]
Cramps and spasms[b]	0.05[0.03;0.06]	0.21[0.04;0.38]	0.03[−0.05;0.10]	0.11[0.05;0.18]	0.07[0.00;0.14]	0.19[0.01;0.38]
Tremors[b]	0.02]0.01;0.03]	0.14]−0.05;0.33]	0.00[−0.00;0.01]	0.04[−0.02;0.10]	−0.00[−0.07;0.05]	0.05[−0.14;0.24]
Tinnitus[b]	0.03[0.02;0.05]	−0.21[−0.52;0.11]	−0.05[−0.14;0.03]	−0.00[−0.07;0.07]	0.02[−0.05;0.10]	−0.06[−0.23;0.11]
Migraine[b]	−0.01[−0.03;0.01]	−0.11[−0.34;0.11]	0.03[−0.08;0.14]	−0.04[−0.11;0.04]	−0.03[−0.11;0.04]	−0.00[−0.17;0.16]
Fatigue[b]	−0.02[−0.05;0.01]	− 0.08[− 0.34;0.19]	− 0.07[−0.20;−0.06]	−0.06[−0.16;0.04]	−0.15[−0.25;−0.05]	− 0.16[−0.39;0.07]
Dizziness[b]	0.02[0.01;0.04]	−0.03[−0.25;0.20]	−0.02[−0.11;0.06]	0.04[−0.03;0.11]	0.00[−0.06;0.07]	0.04[−0.14;0.23]
Depression[d]	−0.03[−0.05;−0.01]	− 0.05[− 0.20;0.09]	0.02[−0.07;0.11]	0.04[−0.04;0.11]	−0.08[−0.16;−0.00]	− 0.09[−0.25;0.07]
Anxiety[a]	−0.01[−0.03;0.01]	0.22[−0.02;0.46]	−0.03[−0.12;0.06]	0.02[−0.06;0.10]	−0.05[−0.13;0.03]	0.04[−0.15;0.24]
Sleeping troubles[a]	−0.03[−0.06;−0.01]	−0.06[−0.20;0.31]	−0.01[−0.13;0.10]	−0.10[−0.18;−0.02]	−0.08[−0.16;0.00]	−0.17[−0.34;0.01]
Cognitive problems[a] Frustrations[a]	−0.03[−0.05;−0.01]	0.02[−0.19;0.27]	−0.03[−0.12;0.05]	−0.01[−0.08; 0.07]	0.02[−0.06;0.09]	0.05[−0.11;0.21]
	−0.03[−0.05;−0.00]	0.28[−0.01;0.57]	−0.11[−0.21;0.00]	0.06[−0.02;0.14]	0.04[−0.05;0.12]	0.15[−0.04;0.35]
Flashbacks[ae]	0.22[−0.09;0.52]	Too few to estimate	0.00[−0.47;0.47]	0.27[−0.31;0.84]	0.05[−0.51;0.61]	0.50[−0.29;1.29]

Long-term—All Weeks Before and All Weeks After the Shock

	Unadjusted, All Shocks	Voltage > 1000V	Direct Current	Crossbody	Wet Entry and Exitpoint	Crossbody AND Wet Entry and Exitpoint
Work-ability[c]	0.06[0.03;0.10]	0.68[0.29;1.07]	0.04[−0.12;0.19]	0.03[−0.08;0.14]	0.07[−0.05;0.20]	0.31[0.08;0.55]
Pain[b]	−0.11[−0.13;−0.09]	−0.10[−0.34;0.14]	−0.08[−0.17;0.01]	−0.16[−0.22;−0.09]	−0.08[−0.15;−0.00]	− 0.21[−0.37;−0.06]
Numbness[b]	−0.01[−0.02;0.01]	0.06[−0.11;0.24]	−0.01[−0.05;0.04]	−0.04[−0.07;−0.00]	0.05[0.01;0.09]	−0.05[−0.14;0.04]
Weakness[b]	−0.01[−0.03;0.00]	−0.05[−0.25;0.15]	−0.00[−0.07;0.07]	−0.01[−0.06;0.04]	0.05[−0.02;0.11]	0.10[−0.03;0.23]
Cramps and spasms[b]	−0.02[−0.03;−0.01]	− 0.02[− 0.10;0.07]	−0.03[−0.07;0.01]	−0.05[−0.08;−0.02]	−0.05[−0.09;−0.02]	−0.04[−0.14;0.05]
Tremors[b]	0.00[−0.00;0.01]	−0.07[−0.16;0.03]	−0.00[−0.04;0.04]	−0.01[−0.04;0.02]	− 0.04[−0.07;−0.00]	−0.10[−0.20;−0.00]
Tinnitus[b]	0.02[0.01;0.03]	−0.07[−0.23;0.10]	−0.03[−0.08;0.10]	−0.01[−0.05;0.02]	−0.01[−0.05;0.03]	−0.09[−0.18;−0.01]
Migraine[b]	−0.02[−0.03;−0.01]	−0.08[−0.19;0.04]	−0.04[−0.10;0.02]	−0.02[−0.06;0.02]	−0.03[−0.07;0.01]	0.00[−0.08;0.09]
Fatigue[b]	−0.09[−0.11;−0.08]	−0.12[−0.26;−0.01]	−0.08[−0.15;−0.01]	−0.17[−0.12;−0.07]	−0.14[−0.19;−0.08]	−0.17[−0.29;−0.05]
Dizziness[b]	0.01[−0.00;0.01]	−0.09[−0.21;0.02]	−0.03[−0.08;0.01]	0.01[−0.03;0.05]	0.01[−0.02;0.04]	0.03[−0.07;0.13]
Depression[d]	− 0.06[−0.07;−0.04]	− 0.15[− 0.23;−0.07]	−0.02[−0.07;0.03]	−0.06[−0.10;−0.03]	−0.06[−0.10;−0.02]	−0.04[−0.12;0.05]
Anxiety[a]	− 0.07[−0.08;−0.06]	−0.16[−0.29;−0.04]	−0.04[−0.09;0.01]	−0.10[−0.28;0.09]	−0.13[−0.17;−0.09]	−0.16[−0.27;−0.06]
Sleeping troubles[a]	− 0.07[−0.08;−0.06]	−0.03[−0.17;0.10]	−0.03[−0.09;−0.03]	−0.10[−0.14;−0.06]	−0.09[−0.14;−0.05]	−0.08[−0.14;0.02]
Cognitive problems[a]	− 0.07[−0.08;−0.06]	− 0.15[−0.17;−0.04]	−0.08[−0.12;−0.03]	−0.13[−0.17;−0.10]	−0.07[−0.11;−0.03]	−0.10[−0.18;−0.01]
Frustrations[a]	−0.11[−0.12;−0.09]	−0.20[−0.35;−0.05]	−0.11[−0.17;−0.05]	−0.11[−0.15;0.07]	−0.12[−0.17;−0.07]	0.00[−0.05;0.06]
Flashbacks[ae]	0.04[−0.14;0.22]	Too few to estimate	0.11[−0.24;0.47]	0.22[−0.13;0.56]	0.18[−0.19;0.55]	0.23[−0.24;0.71]

Ranges of scales: [a]: 0–4; [b]: 0–5; [c]: 0–10 + high is better; [d]: 0–6. [e] Related to electrical shock only.

When we examined vulnerable (those with a high score in neuroticism or health worries) participants' experiences of severe electrical shocks, we found a mixed pattern. Most reporting's of symptoms were similar to those for very severe shocks in general, but the scores for pain and weakness increased, and the ability to work decreased in the short term (Table 5), whereas pain, weakness, and sleeping troubles increased in the long term (Table 5). Furthermore, we again observed decreased reporting of several symptoms. Again, all estimates had large confidence intervals.

DISCUSSION

In this study, we examined whether participant's health and demographic characteristics were associated with a higher risk of eventual electrical shocks. We found that several factors were associated with an increased risk of electrical shocks. These may be divided into two groups: those associated with youth, such as age and being an apprentice and/or unmarried. They are correlated, but age itself was strongly associated with an increased risk of electrical shock. The other group of risk factors were related to mental health, for example, anxiety, depression, low self-efficacy, sleeping troubles, and cognitive problems, and to personality traits such as neuroticism and being worried about one's health.

We also compared the status of the study participants' health before and after an electrical shock and found that both mental and physical symptoms were comparable before and after the incident, in most cases showing an increase in the week in which the electrical shock occurred, and disappearing in the subsequent weeks. When we applied a linear mixed model to analyze the data, adjusting for participant sex, age, and previous effects of an electrical injury, we found an immediate increase in numbness, cramps and spasms, tinnitus and flashbacks in the week after the electrical shock, but over time, most of the symptoms receded to the level before the shock, except for tinnitus and flashbacks.

An analysis that compared symptoms before and after the most severe electrical shocks showed higher initial reporting of most symptoms, but over time, reporting of most of these symptoms also returned to the previous levels. Two symptoms persisted slightly increased: weakness and sleeping troubles.

When comparing the reporting of symptoms all the weeks before with 4 weeks after the shock, we found that the reporting of

TABLE 5. Additional Subgroup Analysis Related to Subjective Characteristics Compared to Estimates from Table 3 (High Severity)

	[0,2-3]Short-term—All Weeks Before and the Week Including the Shock			Long-term—All Weeks Before and All Weeks After the Shock		
	High Severity	High Severity AND High Health Worries	High Severity AND High Neuroticism	High Severity	High Severity AND High Health Worries	High Severity AND High Neuroticism
Work-ability[c]	−0.47[−1.56;0.62]	− 0.80[−2.27;0.67]	−2.25[−3.69;−0.81]	0.64[0.04;1.24]	0.58[−0.16;1.32]	−1.03[−1.91;−0.15]
Pain[b]	0.74[0.07;1.41]	1.14[−0.08;2.36]	1.70[0.43;2.97]	−0.11[−0.48;0.25]	1.07[0.36;1.77]	1.19[0.41;1.97]
Numbness[b]	0.88[0.61;1.14]	0.20[−0.34;0.75]	0.14[−0.36;0.64]	−0.10[−0.21;0.02]	−0.52[−0.79;−0.25]	−0.57[−0.82;−0.33]
Weakness[b]	0.80[0.37;1.22]	1.35[0.12;2.58]	1.45[0.24;2.67]	0.16[−0.07;0.39]	0.77[0.06;1.47]	0.52[−0.18;1.22]
Cramps and spasms[b]	0.51[0.35;0.68]	0.40[0.03;0.77]	0.39[0.03;0.75]	−0.01[−0.08;0.06]	−0.04[−0.23;0.14]	−0.05[−0.23;0.13]
Tremors[b]	0.20[−0.18;0.57]	−1.45[−2.42;−0.47]	−0.37[−1.24;0.49]	−0.47[−0.67;−0.26]	−1.54[−2.03;−1.04]	−1.33[−1.86;−0.81]
Tinnitus[b]	−0.08[−0.38;0.21]	−0.14[−0.66;0.38]	−0.17[−0.68;0.33]	−0.20[−0.37;−0.41]	−0.26[−0.56;0.04]	−0.32[−0.63;−0.01]
Migraine[b]	−0.11[v0.41;0.19]	− 0.20[−0.82;0.42]	−0.33[−0.97;0.32]	−0.04[−0.20;0.13]	−0.07[−0.43;0.29]	−0.06[−0.45;0.34]
Fatigue[b]	0.12[−0.34;0.57]	−0.15[−1.28;0.98]	0.21[−0.92;1.35]	−0.29[−0.54;−0.04]	−0.40[−1.06;0.25]	−0.58[−1.27;0.11]
Dizziness[b]	0.20[−0.11;0.51]	0.24[−0.30;0.77]	0.80[0.22;1.38]	−0.13[−0.30;0.03]	0.05[−0.26;0.36]	0.02[−0.33;0.37]
Depression[d]	−0.01[−0.30;0.29]	0.27[−0.22;0.75]	0.24[−0.49;0.98]	−0.04[−0.20;0.13]	−0.24[−0.52;0.04]	−0.28[−0.74;0.17]
Anxiety[a]	0.22[−0.16;0.62]	−1.11[−1.92;−0.30]	−0.63[−1.48;0.22]	−0.32[−0.53;−0.12]	−0.94[−1.40;−0.47]	−1.18[−1.69;−0.68]
Sleeping troubles[a]	− 0.09[−0.38;0.20]	− 0.02[−0.72;0.68]	−0.26[−1.00;0.49]	0.06[−0.10;0.22]	0.23[−0.17;0.63]	0.34[−0.11;0.80]
Cognitive problems[a]	0.04[−0.25;0.33]	−0.31[−0.88;0.26]	0.32[−0.34;0.98]	−0.24[−0.39;−0.08]	−0.36[−0.69;−0.03]	−0.50[−0.89;−0.11]
Frustrations[a]	0.60[0.25;0.96]	0.17[−0.50;0.85]	0.50[−0.23;1.22]	−0.25[−0.44;−0.05]	−0.22[−0.61;0.17]	−0.31[−0.75;0.13]
Flashbacks[ae]	Too few to estimate	Too few to estimate	Too few to estimate	Too few to estimate	Too few to estimate	Too few to estimate

Ranges of scales: [a]: 0–4; [b]: 0–5; [c]: 0–10 + high is better; [d]: 0–6 [e] Related to electrical shock only.

most symptoms had returned to the level of reporting before or even below, and this finding was also noted in the comparison of all the weeks before and all the weeks after an electrical shock. Exceptions were weakness and sleeping troubles, which remained at a slightly higher mean level, although not statistically significant.

Some characteristics of the shocks affected the reporting of several symptoms, especially voltage greater than 1000 V, cross-body exposure, and wet entry/exit points, but only in the short term.

Participant vulnerability assessed in terms of a high level of health worries or neuroticism, combined with high severity of the shocks further increased reporting of reduced ability to work, pain, and weakness, but with wide confidence intervals. in the long term, only reports of pain, weakness, and sleeping troubles remained above the levels before the shock among vulnerable participants.

To our surprise, reporting of many of the health symptoms we investigated decreased during the period following the electrical shock, compared to the levels preceding the electrical shock. One possible explanation was that participants stopped or paused participation if they were severely affected by an electrical shock, and thus the results reflected the less severe events. However, when we examined whether the response patterns depended on shock severity, we found no association between severity and attrition from the study (data not shown). Another explanation may be response bias, that is when participants report better health after, for example, an electrical shock compared to preceding reports because they feel relieved that the shock was not severe.

To the best of our knowledge, this is the first study of health symptoms following an electrical shock that includes information about participant health reported before the shock, to make it possible to study risk factors for electrical shocks, and to compare reporting of participants' health reported before and after electrical shocks. This provides the opportunity to study whether exposure to electrical shocks is harmful to mental and physical health. We invited all members of the Danish Union for Electricians to the study, but only 31% participated, and between 61% and 81% of the participants responded to the weekly follow-up questionnaires.[34] This introduces the risk of selection bias if those who participated did not have the same risk of electrical shock as those who opted out of the study. One might argue that those at the greatest risk of injuries would be most motivated to participate, but on the other hand, participants with a strong interest in safety might also be highly motivated to participate, but they may also be the most careful. It is unknown whether this causes bias, but if the health of those who responded consistently was comparable to the health of those with a more scattered pattern of participation, this should not cause bias, but only affect the power of the study.

Using only one item from the symptom scales to represent each symptom does not provide the details and various aspects of each symptom and is a limitation. The scales are designed and validated to be used in their full length, and thus we do not know if a single item is sufficient to capture the symptoms. However, to keep the weekly questionnaires short, but to also include several symptoms, we could not use complete scales, as this would have increased the amount of time the participants needed to dedicate to the questionnaires every week, and thus posed the risk of further participant attrition. We were unable to analyze the flashbacks among the group with the most severe electrical shocks due to lack of statistical power.

The follow-up period was 6 months long, and even though we included many electricians, the time may not have been sufficient to include a sample of those exposed to the most severe electrical shocks. Based on the findings of a retrospective Norwegian study,[45] we expected more reports of severe electrical shocks, but for some reason, this was not the case. Whether or not this is related to selection bias. or whether severe electrical shocks are rarer among Danish electricians is unknown, but the union's working environment officer received no reports of injured members who had received severe electrical shocks' during the study period.

The finding that youth is a risk factor for electrical shocks is consistent with those of previous studies of more severe electrical injuries, where young men also were overrepresented among the victims.[1,8] Youth as a risk factor for occupational injuries is a well-known phenomenon, often related to the job tasks held by the

youngest workers.[9] To the best of our knowledge, the finding that poor mental health is a risk factor for electrical shocks' is new, and we have no suggestion for the mechanisms behind this circumstance, but a previous meta-analysis of agricultural injury studies showed an increased risk of injuries was associated with stress or depression,[46] and two meta-analyses showed a weak association between neuroticism and occupational injuries.[10,11] This may also be in line with the findings from a case-series where exposure to an electrical shock resulted in reporting of perceived symptoms, although the path of the current did not pass through the body and thus explained by Bayesian inference.[47] Although the literature describes a range of symptoms following electrical injuries, we were only able to identify persistent symptoms to a limited extent, even when stratifying the analyses to the most severe injuries. The greatest differences in reporting of symptoms were seen when we compared symptoms before the electrical shock, to the week in which an electrical shock occurred, and as expected, the increase was greater for the most severe electrical shocks and among the most vulnerable participants. However, the typical pattern of symptoms occurring immediately after an electrical shock and then receding soon after does not negate the persistence of some symptoms among a small number of victims of electrical injuries. in a recent register-based study that analyzed electrical injuries registered with The Danish National Patient registry (hospital patients) and with The Danish Working Environment Authority (work injuries) over an 18-year period, we found several mental and physical diagnoses related to both mental and physical health[24,48] and to sickleave and low work participation in the subsequent years.[32] In these studies we used a matched cohort design that compared electrical injuries to other injuries, and the participants to other persons with the same occupation. The findings from the register-based studies could not be replicated in our current study, which was probably due to the low number of severe injuries reported, and even these caused no long-term increase in symptoms, when compared to participants' reporting before the electrical shocks. Also, very few of the electrical shocks reported led the victim to contact a health-care professional, and in general, occupational injuries are reported only if they lead to at least 1 day of sick-leave,[49] so most of the electrical shocks in this study would not appear in the registers. This suggests that the electrical shocks reported in this study were mild, compared to those reported in previous studies based on registers or burn patients.

If the above-mentioned limitations related to possible selection bias are considered, this study may be generalized to similar, broad, national populations of electricians engaged in various occupations.

CONCLUSION

Youth and poor health were associated with risk of electrical shocks. Exposure to electrical shocks has an immediate adverse effect on individual's health, which in most cases returns to the individual's levels of symptoms shortly thereafter. Since only a few electrical shocks were reported as ''severe,'' our findings do not necessarily apply to severe electrical shocks, that are often described in studies of hospitalized patients.

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