

PREVALENCE AND RISK FACTORS OF WORK-RELATED MUSCULOSKELETAL DISORDERS AMONG WORKERS IN HIGH-VOLTAGE TRANSMISSION LINE NETWORK AND SUBSTATIONS

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Abstract

Introduction: There is a high risk of developing work-related musculoskeletal disorders (WMSDs) among workers in high-voltage transmission line network and substations. Most WMSDs are cumulative disorders resulting from repeated exposure to one or more harmful factors over a long period of time.

Aim of the Study: The aim of this study is to determine the occurrence and frequency of symptoms of WMSDs among workers in high-voltage transmission line network and substations.

Material and Methods: This cross-sectional study involves 100 workers from a high-voltage transmission line network and substations, all males aged 20 to 63, classified as electricians - group F06, electricians - group F07 and substation workers. The research methodology includes a standardized questionnaire “Symptoms Survey for Work-Related Musculoskeletal Disorders (WMSDs)”. The results obtained are statistically processed by descriptive and analytical methods.

Results: The frequency of symptoms of WMSDs among workers from a high-voltage transmission line network and substations that lasted two or more days in the last year, and was caused by their work is 32% and it refers to pain or discomfort in any region. The most common localizations are determined on the lower back (14%), knee (11%) and shoulder (9%). No upper back pain was registered in any of the subjects. A significantly higher number of electricians reported that their working body position was combined compared to substation workers, and that they often had to reach further from their body compared to substation workers. On the other hand, a significantly higher number of substation workers declared that they do not reach beyond their body compared to electricians. There is no significant difference between substation workers and electricians in terms of performing repetitive movements.

Conclusion: WMSDs are often regularly occurring among workers in high-voltage transmission line network and substations; therefore, it underlines the need for their early detection through preventive medical examinations and application of appropriate measures for protection of workers.

Key Words: *electricians; electrical industry; musculoskeletal disorders; power lines; preventive measures; substations; substation workers; work capacity.*

Introduction

In order, the electricity produced by power plants and other producers, to reach all consumers, it is necessary to properly transmit it. The transmission of electricity to consumers is carried out through two interconnected systems: the transmission system and the electricity distribution system. The electricity transmission system consists of substations and a high-voltage transmission network, whose main task is to transmit electricity over long distances, sometimes exceeding several hundred kilometers. To accomplish this task, the system operates at voltage levels of 110,000 volts and 400,000 volts. The electricity distribution system is connected to the transmission system. Its task is to deliver electricity to all consumers. It consists of substations and a distribution network of electrical lines, which transmit electricity at various voltage levels depending on the consumers' requirements. These levels range from 110,000 volts to 35,000, 20,000, 10,000, 6,000 volts, and down to 240 volts (1).

Substations are located between the transmission and distribution systems and serve various functions, such as voltage transformation and regulation, acting as switching points in the transmission system, and serving as sources for distribution circuits.

Substation workers are responsible for tasks such as regular visual supervision of high-voltage and medium-voltage equipment across the entire substation, recording voltage and current levels, operating switches and fuses, and documenting technical characteristics, among other duties. The electricians, on the other hand, work on the construction, inspection and maintenance of other electrical power facilities. Their responsibilities include fixing defects both during and outside regular work hours, receiving, processing and organizing work-related documentation, providing data for updating network parameters, inspecting connections and measuring points, reading data from measuring devices, as well as interacting with electricity end users (e.g., replacing meters, reconnecting or disconnecting power, etc.). According to the conducted risk assessment, all these workplaces are classified as workplaces with increased risk.

Physical stress on specific parts of the musculoskeletal system can lead to disorders or injuries. These stresses can vary in nature and intensity, including short-term and intense,

prolonged, repetitive (cyclical), or a combination of these. The factors influencing these physical loads are known as ergonomic factors. Ergonomics is a scientific discipline focused on designing work environments and tasks to align with the individual characteristics of workers. Ergonomics integrates knowledge from various scientific fields, including physiology, biomechanics, psychology, anthropometry, industrial hygiene and kinesiology. By adapting tasks, tools and equipment to the worker's needs and characteristics, physical stress on the body can be significantly reduced, minimizing the risk of work-related musculoskeletal disorders. For electricians, critical ergonomic factors include body posture, repeated application of force, the distance from the body at which tasks are performed, and the position and movement of joints (2).

Musculoskeletal disorders (MSDs) encompass a wide range of inflammatory and degenerative conditions affecting muscles, tendons, nerves, joints, ligaments and associated blood vessels (3). The term "disorder" reflects the multifactorial nature of these conditions, which do not fit neatly into the categories of "disease" or "injury". The health effects of MSDs vary widely in severity, from mild discomfort or moderate pain that does not significantly impact daily life or work, to severe cases where pain and functional impairments make even basic activities difficult or impossible (4). When MSDs are caused or worsened by work conditions or the immediate environment in which work is performed, they are classified as work-related musculoskeletal disorders (WMSDs). Most WMSDs are cumulative, developing from repeated and prolonged exposure to one or more risk factors encountered during work activities and tasks (5).

Electricians and substation workers are exposed to various occupational hazards that contribute to the prevalence of musculoskeletal disorders among them. For substation workers, prolonged sitting is a significant factor, while electricians often face heavy physical tasks, poor posture, improper material handling, and changing weather conditions during fieldwork (6).

A significant amount of data confirms the harmful effects of specific occupational risks on the health of exposed workers, particularly electricians and substation workers, with special attention given to their impact on the musculoskeletal system. However, in our country, there are few studies examining the harmful effects of these occupational risks on this group of workers (7).

This research was motivated by the need to assess the extent to which occupational hazards faced by electricians and substation workers affect the musculoskeletal system and contribute to symptoms of work-related musculoskeletal disorders.

Objective of the Study

The main objective of this study is to determine the occurrence and frequency of symptoms of WMSDs among workers in the high-voltage transmission network and substations.

Material and Methods

Study Design and Setting

This is a cross-sectional study conducted under company's conditions during October–November 2021, coinciding with the regular preventive medical examinations of employees at an electricity distribution company. The study is based on data collected through interviews using a standardized and adapted questionnaire.

Subjects - Study Sample

The study includes workers from a high-voltage transmission network and substations from a company that distributes electricity from the producer to end consumers. All respondents were informed about the purpose and methodology of the research and verbal and written consent was obtained from them to participate in the research.

The research group consisted of 100 workers from high-voltage transmission network and substations, all male, aged 20-63 years. Based on their work tasks, they were classified into three groups: electricians - group F06, electricians - group F07, and substation workers (dispatchers).

Inclusion criteria: workers from the high-voltage transmission network and substations who spend all their working time at their current workplace and are over 18 years of age.

Exclusion criteria: workers from the high-voltage transmission network and substations who are under the age of 18 or over 65 years.

Questionnaire

For this study, was used a "Questionnaire on Symptoms of WMSDs". It was based on the standardized "Symptoms Survey for Work-Related Musculoskeletal Disorders" developed by the Canadian Centre for Occupational Health and Safety (CCOHS) (8), which was translated into Macedonian. Several additional questions were also included, such as initials, age, gender and place of residence.

The standardized questionnaire on symptoms of WMSDs, developed by CCOHS, consists of 46 questions divided into two parts. The first part, a general health survey, includes 10 questions and a diagram. The questions cover topics such as the current occupation, main work tasks and their duration, body posture, frequently used tools, the need to reach away from the body, whether objects or tools are often held above shoulder height or near the floor, the presence of repetitive movements, the most difficult work tasks, and any recent changes in work (e.g., tasks or tools). The diagram illustrates the body parts, and respondents are asked to mark areas where pain or discomfort lasting two or more days occurred in the past year due to their current work, excluding any pain related to traumatic injuries.

Statistical Analysis

Data from the questionnaire were entered electronically into Microsoft Excel 2007. The data obtained were processed with descriptive and inferential methods through the statistical

program Statistica for Windows release 7. The databases were created using specific computer application programs for that purpose (MS Excel).

Continuous variables are expressed as mean values with standard deviation, and nominal variables as absolute numbers and percentages. The statistical processing of the data is performed with descriptive-statistical and inferential-statistical methods. Descriptive-statistical processing consists of tabular presentation of statistical series according to defined variables.

From the inferential-statistical analysis, the following methods were applied: structure analysis with measures of central tendency (average, median and mode) and measures of statistical dispersion (standard deviation and standard error), as well as analysis of relationships between separate statistical series with Pearson's χ^2 test (or Fisher's exact test) for the attributive, that is, the t -test for independent samples for the numerical series. Statistical significance was determined for a p value of less than 0.05.

Results

Table 1. Percentage distribution of respondents by demographic characteristics (gender, age) and job characteristics (profile, work experience at the current workplace and night shift).

Variable		Respondents (n=100)
Gender	Male	100 (100%)
	Female	0 (0%)
Age (yrs.)		51.4 $\pm$ 10.1
Rank (yrs.)		20 - 63
Work experience at the current workplace (yrs.)		23.7 $\pm$ 11.1
Rank (yrs.)		1-41
Work profile	Substation workers	31 (31%)
	Electricians group F06	34 (34%)
	Electricians group F07	35 (35%)
Night shift	yes	98 (98%)
	no	2 (2%)

Numerical data are expressed as mean value with standard deviation, frequencies as number and percentage of study subjects with certain variables.

According to the data in Table 1, the average age of the respondents is 51.4 ± 10.1 years (range: 20–63 years), while the average work experience in the current position is 23.7 ± 11.1 years (range: 1–41 years). All respondents are male (100%), and 98 (98%) work night shifts. Regarding job profiles, 31 respondents (31%) work as substation workers, 34 (34%) are in the position of electrician group F06, and 35 (35%) hold the position of electrician group F07.

Table 2. Distribution of the examined groups by age.

Age (years)	Work profile							
	Substation workers (n=31)		Electricians F06 (n=34)		Electricians F07(n=35)		Total (n=100)	
	n	%	n	%	n	%	n	%
20 - 29 yrs.	/	/	7	20.6	1	2.9	8	8
30 - 39 yrs.	/	/	2	5.9	/	/	2	2
40 - 49 yrs.	2	6.4	9	26.5	6	17.1	17	17
50 - 59 yrs.	22	71	13	38.2	23	65.7	58	58
60 – 64yrs.	7	22.6	3	8.8	5	14.3	15	15

Data are given as number and percents of subjects with certain variable.

The table shows that the majority of respondents belong to the 50–59 age group (58%), while the fewest respondents are in the 30–39 age group (2%). Most of the substation workers are in the 50–59 age group (71%), as are the majority of electricians in group F07 (65.7%). Among electricians in group F06, the largest group is also in the 50–59 age range (38.2%). Notably, there are no substation workers in the 20–39 age range, and no electricians in group F07 in the 30–39 age range.

Table 3. Distribution of the examined groups by total work experience in the current position.

Work experience (years)	Work profile							
	Substation workers (n=31)		Electricians F06 (n=34)		Electricians F07(n=35)		Total (n=100)	
	n	%	n	%	n	%	n	%
0-9 yrs.	/	/	10	12	2	5.7	12	12

10-19yrs.	9	29	3	14	2	5.7	14	14
20-29 yrs.	10	32.3	11	37	16	45.7	37	37
30 - 39 yrs.	12	38.7	8	35	15	42.9	35	35
40 - 41 yrs.	/	/	2	2	/	/	2	2

Data are given as number and percents of subjects with certain variable.

From the table, it can be concluded that the majority of respondents have between 20–29 years of work experience at the current workplace (37%), while the fewest respondents belong into the 40–41 years of work experience group (2%). Most of the substation workers have 30–39 years of work experience (38.7%). Among electricians in group F06, the largest group has 20–29 years of experience (32.4%), while among electricians in group F07, the majority also have 20–29 years of experience (45.7%).

Table 4. Distribution of the examined groups by their working body positions.

How is your working position of the body?	Work profile								
	Substation workers (n=31)		Electricians F06 (n=34)		Electricians F07(n=35)		Total (n=100)		<i>p-value</i> (p<0.05)
	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	
Combined	4	12.9	25	73.5	25	71.4	54	54	0.0017
Sedentary	27	87.1	/	/	/	/	27	27	N/A*
Standing	/	/	9	26.5	10	28.6	19	19	N/A*

Data are given as number and percents of subjects with certain variable. *Tested by chi-square test or Fisher's exact test where appropriate. *N/A - non applicable.

The data show that a significantly larger proportion of electricians (73.5% in Group F06 and 71.4% in Group F07) reported having a combined working body position compared to substation workers (12.9%) ($p = 0.0017$).

Table 5. Distribution of the examined groups according to whether they often have to reach beyond their body.

Do you often have to reach beyond your body?	Work profile								
	Substation workers (n=31)		Electricians F06 (n=34)		Electricians F07(n=35)		Total (n=100)		<i>p-value</i> (p<0.05)
	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	
Yes	6	19.4	26	76.5	26	74.3	58	58	0.0074

No	25	80.6	8	23.5	9	25.7	42	42	0.0097
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Data are given as number and percents of subjects with certain variable. *Tested by Chi-square test or Fisher's exact test where appropriate.

The data indicate that a significantly higher proportion of electricians (76.5% in Group F06 and 74.3% in Group F07) reported often reaching beyond their body compared to substation workers (19.4%) ($p = 0.0074$). Conversely, a significantly larger proportion of substation workers (80.6%) reported not reaching beyond their body compared to electricians (23.5% in Group F06 and 25.7% in Group F07) ($p = 0.0097$).

Table 6. Distribution of the examined groups according to whether they often hold objects or tools above shoulder height or near the floor.

Do you often hold objects or tools above shoulder height or near the floor?	Work profile								
	Substation workers (n=31)		Electricians F06 (n=34)		Electricians F07(n=35)		Total (n=100)		<i>p-value</i> ($p<0.05$)
	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	
At body height	28	90.3	10	29.4	13	37.1	51	51	0.010
Above shoulder height	3	9.7	14	41.2	20	57.2	37	37	0.025
Near the floor	/	/	3	8.8	/	/	3	3	N/A*
Combined	/	/	7	20.6	2	5.7	9	9	N/A*

Data are given as number and percents of subjects with certain variable. *Tested by Chi-square test or Fisher's exact test where appropriate. *N/A – non applicable.

There is a significant difference in holding tools at body height between substation workers (90.3%) and electricians (29.4% in Group F06 and 37.1% in Group F07) ($p = 0.010$). Similarly, a significant difference is observed in holding tools above shoulder height, with electricians (41.2% in Group F06 and 57.2% in Group F07) reporting this more frequently than substation workers (9.7%) ($p = 0.025$).

Table 7. Distribution of the examined groups according to whether they make repetitive movements.

Do you make repetitive movements?	Work profile								
	Substation workers (n=31)		Electricians F06 (n=34)		Electricians F07(n=35)		Total (n=100)		<i>p-value</i> ($p<0.05$)
	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	
Yes	21	67.7	32	94.1	30	85.7	83	83	N/S**
No	10	32.3	2	5.9	5	14.3	17	17	N/S**

Data are given as number and percents of subjects with certain variable. *Tested by Chi-square test or Fisher's exact test where appropriate. **N/S - nonsignificant.

Table 7 shows that 83% of the respondents reported making repetitive movements, while only 17% reported not making them. Among the groups, 67.7% of the substation workers, 94.1% of the electricians in group F06, and 85.7% of the electricians in group F07 indicated they perform repetitive movements during work.

Table 8. Distribution of the examined groups according to whether they had pain or discomfort that lasted two or more days and was caused by their work in the last year.

In the last year, have you had pain or discomfort that lasted two or more days and was caused by your work?		Work profile								
		Substation workers (n=31)		Electricians F06(n=34)		Electricians F07 (n=35)		Total (n=100)		<i>p-value</i> ($p<0.05$)
		<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	
In at least one region	No	25	80.6	24	70.6	19	54.3	68	68	N/S**
	Yes	6	19.4	10	29.4	16	45.7	32	32	N/S**
Neck	No	30	96.8	34	100	35	100	99	99	N/S**
	Yes	1	3.2	0	0	0	0	1	1	N/A*
Shoulder	No	30	96.8	32	94.1	29	82.9	91	91	N/S**
	Yes	1	3.2	2	5.9	6	17.1	9	9	N/S**
Elbow	No	31	100	34	100	34	97.1	99	99	N/S**
	Yes	0	0	0	0	1	2.9	1	1	N/A*
Forearm	No	31	100	34	100	33	94.3	98	98	N/S**
	Yes	0	0	0	0	2	5.7	2	2	N/A*
Wrist	No	30	96.8	31	91.2	32	91.4	93	93	N/S**
	Yes	1	3.2	3	8.8	3	8.6	7	7	N/S**
Upper back	No	31	100	34	100	35	100	100	100	N/S**
	Yes	0	0	0	0	0	0	0	0	N/A*
Lower back	No	29	93.6	29	85.3	28	80	86	86	N/S**
	Yes	2	6.4	5	14.7	7	20	14	14	N/S**

Knee	No	29	93.6	33	97.1	27	77.1	89	89	N/S**
	Yes	2	6.4	1	2.9	8	22.9	11	11	N/S**
Foot	No	30	96.8	33	97.1	33	94.3	96	96	N/S**
	Yes	1	3.2	1	2.9	2	5.7	4	4	N/S**

Data are given as number and percents of subjects with certain variable. *Tested by Chi-square test or Fisher's exact test where appropriate. *N/A – non applicable** N/S – nonsignificant.

According to the data from the table, 32% of respondents experienced musculoskeletal pain or discomfort during the past year that lasted for at least two consecutive days and was attributed to their work. The most commonly affected regions were the lower back (14%), knee (11%), and shoulder (9%). Notably, none of the respondents reported pain or discomfort in the upper back. Additionally, no electricians in groups F06 or F07 reported neck pain, and no substation workers or electricians in group F06 reported pain in the elbow or forearm.

Table 9. Distribution of examined groups according to the assessment of work ability at the current workplace.

Assessment of work ability		Work profile							
		Substation workers (n=31)		Electricians F06 (n=34)		Electricians F07(n=35)		Total (n=100)	
		n	%	n	%	n	%	n	%
Able to work without restrictions		30	96.8	33	97.1	32	91.3	95	95
Able to work with restrictions	Do not work at height and heavy physical work	/	/	/	/	1	2.9	1	1
	Do not work night shifts	1	3.2	1	2.9	/	/	2	2
	Do not do heavy physical work	/	/	/	/	1	2.9	1	1
	Do not lift weights	/	/	/	/	1	2.9	1	1
Unable to work		/	/	/	/	/	/	/	/

Data are given as number and percents of subjects with certain variable.

According to assessment of work ability, 95% of all respondents are able to work without restrictions, and just 5 respondents (5%) are able to work with restrictions. None of the respondents were classified as unable to work.

Discussion

The Occupational Safety and Health Administration (OSHA) defines musculoskeletal disorders as a broad spectrum of inflammatory and degenerative changes that affect the musculoskeletal system as well as the corresponding blood vessels and usually develop gradually over several weeks, months or years as a result of exposure to one or more risk factors that cause their appearance or worsening, and not as a result of a single accident or injury (3).

According to the Census of Fatal Occupational Injuries sponsored by the U.S. Bureau of Labor Statistics, in 2020, 126 workers died due to exposure to electrical energy, representing 5.3% of all incidents due to contact with electricity. This represents a decrease of 24% from the deaths reported in 2019 and the lowest annual number of fatal electrical injuries in the nearly 30 years of data collected by CFOI. Non-fatal electrical injuries led to 2,220 hours of absenteeism during 2020 (9).

According to the U.S. National Safety Council (NSC), in 2020, 17% of all fatal workplace injuries, or 805 deaths, were caused by slips, trips and falls. Additionally, 211,640 workers sustained injuries that led to several days of absence from work (10). In the same year, the U.S. Bureau of Labor Statistics reported that 18% of the total 1,176,340 non-fatal work-related injuries resulting in several days of absenteeism were due to slips, trips and falls (11).

In our study, no fatal or non-fatal injuries caused by electricity were recorded in the past year. Furthermore, none of the respondents reported any workplace accidents or injuries during this period.

In a study conducted by Moriguchi et al. in Brazil, 26 out of 30 respondents (87%) employed as electricians reported experiencing discomfort in at least one body region. The most commonly affected areas were the shoulder, spine and knee. Among the 13 participants who reported spinal discomfort, 62% experienced pain in the lumbar region, 31% in the thoracic region, and 15% each in the neck and gluteal regions. The shoulder was identified as the most commonly affected area overall (12).

Similarly, a study by Hunting et al. in the USA surveyed 308 relatively young workers, 86% of whom were electricians. The study aimed to assess the prevalence of symptoms in the neck, shoulder, elbow, wrist, back and knee over the previous year. The results revealed a high prevalence of symptoms, with many participants reporting discomfort occurring more than three times or lasting for over a week. About half of the respondents experienced discomfort in the back or wrist, while only 15% reported issues with the elbow (13).

In 2012 study by Tankovic and Suljic-Beganovic, conducted on 246 respondents employed in an electric company in Novi Travnik (over 80% of whom were male), 10.97% were diagnosed with musculoskeletal disorders. In a follow-up study in 2013, which included 157 respondents (99.37% male), 17.83% were found to have diseases of the locomotor system (14).

In another study by Čeranić et al. (2003), which aimed to assess the health status and common health issues among electricians in Novi Pazar, Republic of Serbia, musculoskeletal disorders were identified in 30 out of 86 electricians (55.5%) (15).

Our research revealed that 32% of the total respondents reported experiencing musculoskeletal pain lasting at least two days in one or more body regions in the past year. The most common areas affected were the lower back (14%), knee (11%) and shoulder (9%). Among substation workers, 19.4% declared that they have pain or discomfort in at least one region, and according to the frequency, the pain/ discomfort in the lower back and knee (6.4% respectively) stands out. Among the electricians in group F06, 29.4% of the respondents stated that they have pain or discomfort in at least one region, and according to the frequency, the pain/ discomfort in the lower back (14.7% of the respondents) stands out. Among the electricians in group F07, 45.7% of the respondents declared that they have pain or discomfort in at least one region, and according to the frequency, the pain/discomfort in the knee (22.9%), the lower back (20%) and in the shoulder (17.1%).

Just in England, it was estimated that in 2014/ 2015, 553,000 workers suffered from musculoskeletal disorders caused or aggravated by work (current or previous). Out of these, about 233,000 suffered from back pain, 233,000 had neck and upper limb problems, and 97,000 had leg problems. For the same period, it was determined that 9.5 million working days were lost due to musculoskeletal disorders caused or aggravated by work (16).

In our study, a total of 77 workdays were lost due to pain or discomfort that caused subjects to take days off.

Regarding the assessment of work ability, 95 out of a total of 100 respondents (95%) were assessed as able to work without restrictions. 96.8% of substation workers were rated as capable of working without restrictions, with only one substation worker having a restriction on working night shifts. 97.1% of electricians in group F06 are rated as capable of working without restrictions, and one respondent was restricted from working night shifts. On the other hand, 91.3% of electricians in group F07 were rated as able to work without restriction, and the restriction of not doing heavy physical work, not lifting weights and not working at height and heavy physical work has one respondent for each. None of the respondents were assessed as unable to work.

Conclusion

Taking into account the purpose of this research and based on the analysis of the obtained results, it can be concluded that the frequency of work-related musculoskeletal disorder

(WMSD) symptoms among workers from the high-voltage transmission network and substations, which lasted for two or more days in the past year and were caused by their work, is 32%. The most common affected areas are the lower back, knee and shoulder. Key risk factors in the work environment associated with the occurrence of musculoskeletal disorders among this group of workers include prolonged standing and sitting, lifting and carrying loads, repetitive movements, unnatural body positions, pressure on certain body parts and vibrations. Additionally, the rhythm and organization of the work process, work monotony, adverse weather conditions and psychosocial factors play significant roles in the development of musculoskeletal disorders. Based on these findings, there is a clear need to develop and implement a strategy for preventing musculoskeletal disorders among workers in the high-voltage transmission network and substations in Republic of North Macedonia, aimed at improving their health and work ability.

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