

Musculoskeletal symptoms among energy distribution network linemen

Sintomas musculoesqueléticos em eletricitistas de rede de distribuição de energia

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Abstract

Background: Linemen should be evaluated regarding the presence of musculoskeletal symptoms to guide the identification of risk factors for development of work-related musculoskeletal disorders (WMSD) and to allow the implementation of preventive measures. **Objectives:** To assess the occurrence of WMSD symptoms among linemen working at a regional branch of an electricity distribution company, to investigate whether there were differences in the proportions of symptomatic workers among the functions performed, and to perform a preliminary survey of the main risk factors present. **Methods:** Thirty male linemen (mean age 38.1±5.5 years) were evaluated, divided into three teams according to their job function (Live Line Linemen, LLL; Maintenance/Emergency Linemen, MEL; Commercial Linemen, CL). Musculoskeletal symptoms were identified on a body map, qualified using the McGill questionnaire and quantified using a numerical scale. The DASH questionnaire was also applied to evaluate the impact of the shoulder symptoms on the workers' performance. **Results:** Seventy percent of the linemen presented at least one musculoskeletal symptom in the shoulders, back or knees. All of the LLL team presented musculoskeletal symptoms and these workers had the highest scores in the DASH questionnaire (28±15). Sixty-seven percent of the MEL team presented symptoms, and their DASH score was 8±11. Fifty percent of the CL team presented symptoms, but none of them had shoulder symptoms. The proportion of workers with shoulder symptoms was related to their job function (p=0.02). **Conclusions:** A high proportion of the linemen presented symptoms which varied according to the occupational activity. Interventions are needed to reduce the risk of WMSD among the linemen evaluated.

Key words: musculoskeletal symptoms; risk factors; WMSD; distribution linemen.

Resumo

Contextualização: A presença de sintomas musculoesqueléticos em eletricitistas deve ser caracterizada para auxiliar na identificação de fatores de riscos para os distúrbios osteomusculares relacionados ao trabalho (DORT) e para possibilitar implementação de medidas preventivas. **Objetivos:** Avaliar a ocorrência de sintomas de DORT em eletricitistas de uma regional de uma empresa de distribuição de energia elétrica, verificar se existiam diferenças entre as funções exercidas quanto à proporção de trabalhadores sintomáticos, e realizar um levantamento preliminar dos principais fatores de riscos presentes. **Métodos:** Foram avaliados 30 eletricitistas do sexo masculino (38,1±5,5 anos), divididos em três equipes conforme a função exercida (ELV=Eletricitistas Linha Viva; EEM=Eletricitistas Emergência/Manutenção; EC=Eletricitistas Comerciais). Sintomas musculoesqueléticos foram identificados em mapa corporal, qualificados pelo Questionário McGill e quantificados por escala numérica. O questionário DASH também foi aplicado para avaliar impacto dos sintomas nos ombros na performance dos trabalhadores. **Resultados:** 70% dos eletricitistas apresentaram ao menos um sintoma musculoesquelético nos ombros, coluna ou joelhos. A equipe ELV apresentou sintomas musculoesqueléticos em 100% dos trabalhadores e maior pontuação no questionário DASH (28±15). A equipe EEM apresentou sintomas em 67% dos trabalhadores e pontuação DASH de 8±11, e a equipe EC apresentou sintomas em 50%, mas sem sintomas nos ombros. A proporção de trabalhadores sintomáticos nos ombros estava associada à função exercida (p=0.02). **Conclusões:** Eletricitistas avaliados apresentaram alta proporção de trabalhadores sintomáticos, que variou conforme a atividade ocupacional. Intervenções são necessárias para reduzir os riscos de DORT dentre os eletricitistas avaliados.

Palavras-chave: sintomas musculoesqueléticos; fatores de risco; DORT; eletricitistas de distribuição.

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Introduction ...

According to Seeley and Marklin¹, few linemen have the physical capacity required to perform their job function until retirement because many of them sustain musculoskeletal injuries over years of exposure to high force demand tasks. This line of work also has risks associated with the development of work-related musculoskeletal disorders (WMSD) due to heavy tasks, inadequate posture, handling of materials and to changing weather during field work^{2,3}.

According to the Brazilian Ministry of Social Security⁴, the risk for developing occupational injuries while working in the area of electricity production and distribution is very high and corresponds to the maximum score on a three-point scale. In spite of this, there are few published studies on Brazilian linemen. Recent studies found in the available literature focused only on the impact of the privatization of the energy sector⁵ and on evaluations of the health and capacity of workers⁶. No studies were found on the prevalence of musculoskeletal symptoms in Brazilian linemen that aim to identify the risk factors. Awareness of the risks imposed by the job can reduce the rate of work-related accidents because, according to a study on nurses, ergonomic interventions also improve work safety and reduce absentee rates⁷. In addition, studies on the presence of risk factors can be complemented by functional evaluations of workers. Thus, the impact of disorders on worker performance can be verified, which provides an indication of the need of ergonomic intervention to control these risk factors^{8,9}. As a result, specific preventive measures can be implemented to decrease or eliminate the main risk factors and, therefore, improve the quality of life of workers¹⁰.

After a preliminary evaluation of the tasks performed by electricity distribution linemen, it was hypothesized that the proportion of linemen with musculoskeletal symptoms is high and that the affected body region varies according to the job function.

Therefore, the aims of the present study were to assess the occurrence of WMSD symptoms among linemen working at a regional branch of an electricity distribution company, to investigate whether there were differences in the proportions of symptomatic workers according to the functions performed, and to conduct a preliminary survey of the main risk factors.

Methods ...

Subjects

The study included thirty male linemen (mean age 38.1±5.5 years old) employed exclusively by an electricity distribution

company, who performed various field tasks in a country area of São Paulo State. These linemen comprised 84% of the linemen working at the evaluated regional branch and they were part of a group of 1233 linemen with similar functions in the company. Only one worker was excluded from the sample (Total N=31) due to musculoskeletal symptoms resulting from neurocysticercosis. The project was approved by the Research Ethics Committee of Universidade Federal de São Carlos (protocol 0032.0.135.000-07).

The distribution linemen were divided into three groups according to the type of tasks they performed (Figure 1):

1) Live Line Linemen (LLL) (6 linemen): linemen who service the live high- and low-voltage distribution network. This group uses bucket trucks with aerial baskets to elevate the linemen (Figure 1A).

2) Maintenance/Emergency Linemen (MEL) (18 linemen): linemen who act in emergency situations and in pre-programmed services. They are responsible for inspecting and servicing the medium- and low-voltage network and for maintaining street lights. The MEL group uses ladders to perform tasks, and the linemen are tied to the pole or ladder by belts. Three ladder sizes are used: a central ladder (10.2m) connected to the vehicle which is not carried by the linemen; a portable ladder (7.8m, 31kg) which must be carried by two people; and another portable ladder (6.6m, 26kg) carried by a single lineman (Figure 1B).

3) Commercial Linemen (CL) (6 linemen): inspection linemen who are responsible for cutting/restoring the energy supply and for the maintenance/removal of energy consumption meters. These tasks require little use of ladders and less exertion, with occasional use of tools (Figure 1C).

Procedures

The data was collected with the use of questionnaires between April 25th and July 3rd, 2007. The questionnaires were applied in groups of no more than five people in private locations, before the start of the work shift. The subjects were informed about the general procedures of the study and signed a consent form that guaranteed data confidentiality.

The questionnaire was refined in two pilot studies to obtain the final version. The first pilot study was conducted with the head engineer of the company who suggested some changes to improve the clarity of the questions for the employees. The second pilot study was conducted with four linemen who evaluated the clarity of the questions. Those which were not understood correctly were reformulated.

The first part of the questionnaire included general questions on demographic data (age, gender, height, weight) and occupational data (time of employment in the company,

description of previous and current tasks, time in the same job function, exposure to and duration of certain tasks in relation to the work week, such as: travel, walking, preparation of job site and observation). The questionnaire also included questions on work leave, general health, fitness level and housework.

In the second part of the questionnaire, the worker was shown a body map adapted from Corlett and Bishop¹¹ and asked to identify any regions of discomfort that occurred more than three times in the last year or that lasted more than three consecutive days. This discomfort should not be related to a traumatic injury. The workers were then asked to characterize the symptoms according to the McGill pain questionnaire already translated and validated into Portuguese¹². The last part of the questionnaire contained numerical pain scales¹³ ranging from 0 to 10 to rate the intensity of discomfort in each region of the body at the time of the evaluation.

Based on the previous analysis of the questionnaire results, the shoulder region was the most affected by musculoskeletal symptoms. To evaluate the impact of the musculoskeletal symptoms on the worker's performance, a new data collection was arranged which used the Portuguese version of the optional work module of the DASH questionnaire¹⁴. According to the analysis procedure of this questionnaire, the score was calculated for a descriptive comparison between the symptomatic groups due to the small number of subjects in each group.

Data referring to work leave and absences were obtained from the company's human resource department to verify how much the musculoskeletal symptoms were affecting the workers. To identify the main tasks of each group, the linemen were asked to complete activity control spreadsheets. The linemen recorded the activities performed during the day on a spreadsheet that had already been adopted by the company and was used with relative frequency, therefore no training was required.

The workplace was also systematically observed by two trained examiners in order to identify the risk factors in the more frequent tasks performed by each group. The occupational activities evaluated by these examiners were also recorded on video to complement the evaluation. The WMSD risk factors present during the activities were identified by the examiners. After reaching a consent on the risk descriptions, the examiners interpreted the risk factors using the methodology by Wells¹⁵ and pertinent studies available in the literature¹⁶⁻¹⁹.

Data analysis

Descriptive data analysis was performed using means and standard deviation. The non-parametric Kruskal-Wallis test was used to compare groups as to age, BMI, time as linemen and exposure. The Mann-Whitney test was used for multiple

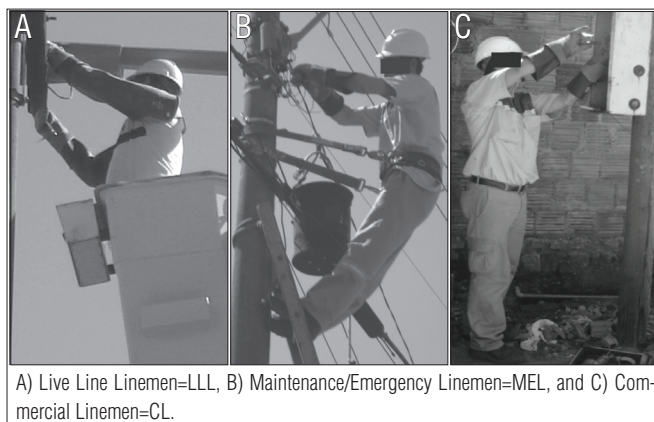


Figure 1. Linemen divided into groups according to tasks.

comparisons with Bonferroni correction. The χ^2 test was used to verify the association between aspects of daily life (housework and physical activity) and the incidence of symptoms. The χ^2 test was also used to verify the association between groups and the rate of symptomatic and asymptomatic linemen. Contingency tables were made for each symptomatic body region. The data were analyzed in the software Statistica, and the level of significance was set at $\alpha=0.05$.

Results ...

There was no statistical difference between groups with regard to the anthropometric characteristics of age ($p=0.364$) and BMI ($p=0.2362$). The groups' mean age and BMI were: LLL 41.6 ± 6.4 years and 25.9 ± 2.8 kg/m²; MEL 37 ± 5.1 years and 27.5 ± 2.5 kg/m²; CL 38 ± 4.6 years and 25.8 ± 2.3 kg/m². There was also no significant difference with regard to the time in the job function ($p=0.3528$) or to time spent on trips ($p=0.0647$), walking ($p=0.33$), time preparing the job site ($p=0.65$) or in observation ($p=0.31$) during one work week, however there was a difference as to the use of the aerial basket and ladder. Only the MEL and CL groups use ladders, and the MEL group makes the most use of that tool ($p=0.003$).

The χ^2 test results showed that there was no association between the incidence of discomfort and non-occupational factors: housework ($p=0.14$) and physical activity ($p=0.42$). The presence of chronic disease was not considered in the test because only two subjects had chronic health problems. The χ^2 test of observed frequency versus expected frequency only showed a significant difference for the shoulder region in the symptom reports according to body regions ($p=0.02$).

The proportion of symptomatic linemen who reported at least one region of discomfort among the 30 evaluated employees was 87% (26 in 30). The most frequent regions of discomfort were: shoulder, spine and knee. Table 1 shows the proportion

of symptomatic workers and the mean intensity of discomfort in the most frequent body regions in each group. The reports of spinal discomfort (13 linemen) were mainly in the lumbar region (62%), followed by the thoracic (31%), neck and coccyx (15% each) regions. If the reported symptoms for these spine regions were considered separately, the proportion of symptomatic linemen for each spinal region would be comparatively lower to the proportion of symptomatic linemen for the shoulder region. Therefore, the shoulder region was the single most affected region in these linemen. Other body regions with fewer reports of discomfort were forearms (13%), elbows (10%), arms, buttocks and thigh (7% each). Thus, the proportion of discomfort in the upper limbs was 57%.

The presence of symptoms varied from group to group even though the mean pain intensity was similar. Table 1 shows a higher number of symptomatic linemen in the LLL group, and the shoulder was the main discomfort region among the linemen of this group.

The McGill Questionnaire symptoms reported by the linemen in the shoulder region were: aching, heavy, boring, drilling, triggering, tingling and tiring. In the spinal region, the symptoms reported by the linemen only referred to aches and stabbing pain. In the knees, the subjects only reported aches.

Eleven of the 13 symptomatic shoulder employees answered the DASH questionnaire (five LLL linemen and six MEL linemen). The questions about the impact of the symptoms on work showed that the LLL group had moderate to no difficulty performing usual tasks, with a mean score of 28 ± 15 . The MEL group had little to no difficulty with a mean score of 8 ± 11 . Only one lineman from the LLL group did not answer all the questions of the DASH optional work module.

Table 1. Proportion of symptomatic workers (%) and intensity (mean \pm standard deviation) of symptoms in the most frequent body regions according to groups (LLL=Live Line Linemen, MEL=Maintenance/Emergency Linemen, CL=Commercial Linemen).

Body region	LLL (n=6)	MEL (n=18)	CL (n=6)	Total (n=30)
Shoulder				
Proportion of symptomatic linemen (%)	100	39	0	43
Pain intensity (Mean \pm SD)	3 \pm 2	4 \pm 1	0	
Spine				
Proportion of symptomatic linemen (%)	17	56	33	43
Pain intensity (Mean \pm SD)	4 \pm 0	4 \pm 2	5 \pm 1	
Knee				
Proportion of symptomatic linemen (%)	33	33	17	30
Pain intensity (Mean \pm SD)	4 \pm 1	4 \pm 2	4 \pm 0	
Total proportion of symptomatic linemen (%)	100	67	50	70

Table 2 lists the most frequent tasks by groups and describes the main risks of WMSD of the shoulder, spine and knee as identified by the examiners. Some tasks are common to more than one group.

In spite of the high rate of musculoskeletal symptoms, there was no record of work-related accidents in 2006. Absences for various reasons reached a total of 297 days (18.5 days/year per employee). Sports injuries and knee surgery accounted for 59 days of medical leave for four linemen. Back pain and spinal surgery accounted for 17 days of leave for other linemen. Thus, spine and knee accounted for 25.5% of work absences.

Discussion

In the present study, the main body regions affected by musculoskeletal symptoms in the distribution linemen (Table 1) are in agreement with Graves et al.². However, these authors observed a higher prevalence of lumbar spine symptoms (64%). Another difference between Grave et al.² and the present study is the identification of different tasks among the linemen.

The division into groups allowed the identification of different risk factors according to the performed task. There was no difference between groups with regard to anthropometric data; time performing the job function; time spent on travel, walking, site preparation and observation. Therefore, the proportion of symptomatic workers in each group can be attributed to the specific occupational factors of that group, such as: type of the tasks and use of ladder/aerial basket.

The difference between groups was expected because the job functions vary in terms of exposure to risk factors, even though they have some similar tasks. However, the high rate of shoulder discomfort in the LLL group was not expected because the versatility of the mechanical arm of the aerial basket allows greater proximity to the work station and better worker positioning. Furthermore, the linemen do not have to handle ladders, which are a risk factor for shoulder and spine injuries. Ladder handling poses risks both during removal from the vehicle (because the ladder is attached to stiff supports at a height of 1.7m) and during transport due to its weight and form of handling¹⁶.

The observation of the LLL group by the examiners indicated an inadequate positioning of the aerial basket, therefore the linemen performed the task at a distance from the body and with upper limbs above the shoulder line, as observed in Figure 1A. This could be one of the justifications for the high incidence of shoulder discomfort in this group. According to a review study on the causes of musculoskeletal injuries, tasks which are performed above the shoulder line are associated with the presence of musculoskeletal symptoms in that region²⁰.

Table 2. Most frequent tasks performed by each group (LLL=Live Line Linemen, MEL=Maintenance/Emergency Linemen, CL=Commercial Linemen) and associated risks factors of WMSD of the shoulder, spine and knee.

Group	Tasks	Specific risk factors	General risk factors of each group	General risk factors of all groups
LLL	Cross-arm maintenance	Exertion	Static cervical extension, upper limb elevation above shoulder level, static standing posture for prolonged periods.	Whole-body vibration, during travel, prolonged sitting postures, frequent tool handling, hand grip exertion, material handling in awkward posture, stress.
	Suspension insulator exchange	Exertion		
	Pruning (chain-saws)	Hand/arm vibration, exertion		
MEL	Transformer repair	Exertion	Static neck extension, static shoulder posture, upper limb elevation above shoulder level, frequent ladder handling, hyperlordosis caused by security belt, frequent ladder climbing.	
	Various emergency services	Various		
	Wire reconnection			
	Street light maintenance	Overstretching, extreme upper limb and spine posture		
	Pruning (saw/machete)	Impact, exertion, repetition		
	Instructions to consumers	No risks	No risks	
CL	Meter inspection	Awkward back posture	Occasional upper arm elevation above shoulder level, occasional ladder handling, occasional ladder climbing.	
	Meter exchange/removal	Exertion		
	Cutting/restoring energy supply	Stress		
	Instructions to consumers	No risks	No risks	

In addition to the biomechanical aspects, another possible explanation for the high incidence of shoulder symptoms is occupational stress²¹. The LLL group has a higher risk of electrical shock, resulting in a greater demand for concentration and, consequently, greater psychogenic tension, which is also a potential risk factor for the development of WMSD in the shoulder and neck regions²².

Although there was no association between the spinal symptoms and the groups, some risk factors can be pointed out for the MEL group as it demonstrated a higher incidence of symptoms in that body region. The frequent ladder handling is one of these factors because the weight of the ladder (26Kg) is over the limit recommended by the literature to avoid spinal musculoskeletal injuries (23Kg in ideal conditions)²³. The MEL group is also exposed to other risk factors for spinal symptoms, i.e. the use of the safety belt (Table 2). This belt ties the lineman to the pole or ladder and accentuates lumbar lordosis when used to hold the weight of the body (Figure 1B). The increased lordosis leads to higher tension in the facet joints, posterior disc protrusion and ultimately lumbar pain, joint degenerations and spondylolysis²⁴. Contrary to expectations, the MEL group did not report discomfort in the foot and ankle region as a result of frequent ladder use, but there were reports of knee discomfort.

The three groups reported musculoskeletal symptoms in the knees. Although the present study did not identify the affected part of the knee, the symptoms may be associated with some factors such as standing for long periods of time with little room for leg movement¹⁸ due to the limited size of the

aerial basket or because of safety reasons on the ladder. The MEL linemen also have to climb and descend ladders regularly which can lead to patellar compression against the femoral trochlea due to the high level of quadriceps contraction and subsequent anterior knee pain²⁵.

Based on the questions of the DASH optional work module, higher limitations were identified in the LLL group with a mean score of 28.1±14.8. Jester, Hart and Germann⁹ found a lower score in workers who perform mostly manual tasks (16.7±23.2). In contrast, the mean MEL group score (8.3±10.9) is closer to the score of workers who do not perform manual tasks (7.8±14.5)⁹. In this sense, the LLL linemen showed functional limitations in the upper limbs, especially the shoulders, compared to the other groups.

Even though the shoulder region was the most affected, there was no record of absences or work leave due to that reason. In contrast, the spine and knee accounted for 25.5% of the work absences. Some of the knee problems were a result of sports injuries, however the cumulative aspect of these injuries cannot be dismissed. The preponderant influence of the knee and spine regions on absence rates has already been demonstrated by Kelsh and Sahl²⁶ in studies on injury rates of all kinds of workers in the electricity sector, including administrative workers.

The lack of work leave due to shoulder injury suggests that the symptoms in that region may not have reached the most critical stage at the time of the evaluation. Although the evaluated linemen performed different tasks, the present results are in agreement with those observed by Grave et al.², who found

a higher impact of spinal and knee discomfort on the linemen due to the higher incidence of these symptoms and to the fact that they seem more debilitating than shoulder discomfort. In spite of that, shoulder symptoms should also be taken into account because they can be predictors of WMSD occurrence²⁷, especially considering the tasks performed by the linemen of the present study.

Based on the identified risks, intervention measures should be proposed to reduce musculoskeletal overload. Workers should be made aware of the risk factors for musculoskeletal injuries, and improvements should be made to tools, safety belts, and ladder handling. Changes to the weight of the ladder and the height at which the ladder is tied up to the vehicle should also be proposed. Yet, interventions in work organization such as task rotation, reduction in overtime and recruitment of more linemen during peak periods should also be analyzed. In spite of these possible ergonomic changes, more studies should be conducted so that the intervention process can be more effective. In addition to other biomechanical factors not fully investigated in the present study, the complexity of WMSDs also involves psychosocial factors.

The restricted sample size is a limitation of the present study. However, the present results show tendencies in the characterization of the risk factors for electricity distribution linemen. Another aspect worth mentioning is that these professionals are exposed to a variety of risk factors,

including organizational and individual aspects, which were not investigated because they went beyond the objectives of the present study. Thus, future studies should be carried out on a wider sample for an epidemiological assessment of that population, as well as biomechanical evaluations of its occupational hazards.

Conclusions

The present results showed a high incidence of musculoskeletal symptoms in electricity distribution linemen working in São Paulo State. The proportion of symptomatic linemen varied according to task with regard to shoulder symptoms which confirms the initial hypothesis of the present study. Specific ergonomic intervention measures for each group are necessary to control the current risks and, thus, reduce the incidence of symptoms and prevent the aggravation of existing disorders. Ergonomic risk control measures for the LLL group should focus, mainly, on the shoulder and knee region, while for the MEL group, the shoulder and spine should be focused. For the CL group, risk control measures should focus on the spine and knee. To develop an effective ergonomic intervention in risk control, more studies need to use direct measures to assess the ergonomic hazards of the tasks performed by distribution linemen.

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