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Associations of Psychosocial Risk Factors and Safety Climate with the Prevalence and Impact of Work-Related Musculoskeletal Disorders among Brazilian Electrical Line Workers: A Cross-Sectional Study

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Background: Work-related musculoskeletal disorders are highly prevalent among outsourced electrical line workers, who are exposed to intense physical demands, organizational pressures, and persistent psychosocial stressors. This study examined whether psychosocial risk factors and perceived safety climate are associated with the prevalence and functional impact of musculoskeletal symptoms in this population.
Methods: A cross-sectional survey was conducted between February and April 2024 with 689 outsourced electrical line workers recruited from distribution companies across Brazil. Standardized instruments were used to assess musculoskeletal symptoms, psychosocial stressors, and perceptions of safety climate. Data were analyzed using R software through descriptive statistics and structural equation modeling.
Results: More than half of the workers reported at least one musculoskeletal symptom in the previous 12 months, most commonly affecting the shoulders and neck. Higher exposure to psychosocial stressors was associated with increased frequency and impact of complaints, whereas a more favorable safety climate was linked to lower symptom prevalence, fewer impairments, and reduced need for medical care.
Conclusion: Work-related musculoskeletal disorders among outsourced electrical line workers reflect the combined influence of physical workload, organizational conditions, and psychosocial stressors. Prevention should integrate ergonomic measures with organizational strategies that reduce psychosocial risks and strengthen safety climate, particularly in outsourced and other high-risk occupational contexts.

1. Introduction

Work in the electric power sector, particularly in energy distribution, is characterized by high exposure to both physical and psychosocial risks. Line workers face awkward postures, repetitive movements, substantial physical load handling, and adverse environmental conditions due to the outdoor and physically demanding nature of their activities (Lamooki et al., 2022; Rogerson et al., 2024). Beyond these physical demands, workers also experience intense psychosocial pressure stemming from heavy responsibility, frequent time constraints, and the constant need to avoid failures and accidents in high-risk environments (Rogerson et al., 2024). In this context, outsourcing has become a recurrent practice in the sector, with direct implications for working conditions, safety, and health (Vives et al., 2013). Compared to employees hired directly by utility companies, outsourced workers typically face more precarious employment relationships, less job stability, and reduced access to benefits and health programs (Martins et al., 2024; Swami & Wagle, 2024). The pressure to reduce costs and enhance productivity further accelerates work intensity and

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leads to the relaxation of safety standards, thereby increasing occupational vulnerability and elevating the risk of work-related accidents and illnesses (Koranyi et al., 2018; Lima & Oliveira, 2021; Onafadeji et al., 2023).

Within this context, work-related musculoskeletal disorders (WMSDs) are among the main occupational health problems, linked to high rates of absenteeism, work disability, and reduced productivity across different economic sectors (Bevan, 2015; Killingmo et al., 2024; Moradi & Barakat, 2020). Prolonged exposure to ergonomic and organizational risk factors generates a state of physiological hyperactivation, in which the body remains in constant alert in response to demands perceived as threatening or disproportionate (Brewin et al., 2024; Ramos et al., 2022). This process recurrently activates the neuroendocrine system, producing hormonal and metabolic changes that compromise homeostasis over time (Cool & Zappetti, 2019). Sustained activation of these systems triggers a cascade of adverse effects, including chronic muscle tension, exacerbated inflammatory responses, and immune dysfunctions, which contribute to both the onset and chronicity of musculoskeletal complaints (Eddy et al., 2016; Puntillo et al., 2021).

Previous research consistently shows that work-related musculoskeletal disorders (WMSDs) are highly prevalent in the electrical power distribution industry, particularly among line workers who perform physically demanding, repetitive, and high-risk tasks. International studies report prevalence rates typically ranging from 45% to 80%, with the shoulders, neck, and lower back identified as the most affected regions due to repetitive overhead activities, forceful exertions, and prolonged awkward postures at elevation (Lamooki et al., 2022; Rogerson et al., 2024; Hossain et al., 2021). Evidence from various industrial sectors also demonstrates strong associations between WMSDs, occupational stressors, and poorer general health, highlighting how psychosocial overload increases workers′ susceptibility to musculoskeletal problems (Asivandzadeh et al., 2018). Qualitative findings further indicate that electricians often normalize musculoskeletal pain as part of their professional identity, which contributes to underreporting and delays in seeking care (Björklund, 2024). In Latin American and Brazilian contexts, prevalence estimates are similarly elevated, typically ranging from 52% to 76%, especially among outsourced workers who experience greater organizational stress, employment instability, and reduced access to occupational health and safety programs (Martínez & Fischer, 2009; Vives et al., 2013; Lima & Oliveira, 2021). These conditions are associated with higher rates of sick leave, health-service utilization, and long-term disability, reinforcing that WMSDs represent a major occupational health burden in the sector (Bevan, 2015; Killingmo et al., 2024). Taken together, this evidence characterizes the electrical distribution industry as a high-risk environment for musculoskeletal disorders and provides essential context for understanding the prevalence patterns observed in the present study. Understanding these outcomes also requires attention to psychosocial risk factors, defined as organizational, task-related, and managerial characteristics that, when dysfunctional, increase the likelihood of chronic stress and negative health impacts (Rodrigues et al., 2020; Theorell, 2020). These factors act not only as triggers of strain but also as conditions that shape how workers perceive, assess, and respond to occupational demands (Eddy et al., 2016; Huth & Chung-Yan, 2023; Lang et al., 2022; Theorell, 2020). In the electric power sector, environments marked by outsourcing and precarious labor relations tend to exacerbate these factors (Koranyi et al., 2018; Lima & Oliveira, 2021), leading to job insecurity, a sense of organizational invisibility, and lower engagement with preventive practices (Lima & Oliveira, 2021; Martinez & Fischer, 2009; Rogerson et al., 2024), in addition to the broader national economic context (Kortum et al., 2010; Swami & Wagle, 2024).

Safety climate thus emerges as an important organizational variable for occupational health, reflecting the collective perception of workers about the value placed on protection and well-being in the workplace (Beus et al., 2016; Griffin & Curcuruto, 2016). A positive safety climate, characterized by committed leadership, clear communication regarding risks, and active worker participation in preventive decision-making, is associated with greater adherence to safe practices, lower tolerance for risky behaviors, and a reduced incidence of occupational accidents and WMSDs (Bosak et al., 2013; Griffin & Curcuruto, 2016). Conversely, a climate perceived as negative, in which productivity and cost reduction are prioritized over protection, heightens vulnerability to illness and accidents. This dynamic is especially relevant in the electric sector, where high exposure to physical and psychosocial risks makes organizational safety climate a decisive factor for preserving the health and lives of line workers (Arooj et al., 2022; Baby et al., 2021; Kiani et al., 2022).

In this regard, safety climate and psychosocial factors are deeply interconnected and mutually reinforcing: positive climates can mitigate the effects of psychosocial stress, serving as a protective factor for musculoskeletal health (Bronkhorst, 2015; Chen et al., 2019), whereas weak climates tend to intensify perceptions of injustice and conflict, contributing to the persistence of WMSDs (Afsharian et al., 2023; Bronkhorst & Vermeeren, 2016).

Evidence from intervention and ergonomic studies reinforces that WMSDs among electrical and other manual labor workers arise from a combination of biomechanical and organizational factors. Research indicates that physical demands, such as repetitive manual load lifting, overhead work, forceful exertion, and constrained postures, substantially increase ergonomic risk scores and the likelihood of musculoskeletal injury (Moradi & Barakat, 2020). At the same time, intervention studies demonstrate that although ergonomic adjustments and body-mechanics training can reduce discomfort and improve posture, these improvements tend to be limited unless broader organizational and psychosocial conditions are also addressed (Samadi et al., 2018). This aligns with growing evidence that WMSDs cannot be prevented solely by modifying physical tasks because psychosocial stress, job insecurity, work pressure, and inadequate safety practices amplify physiological strain and hinder recovery. Together, the literature converges on the idea that effective prevention requires integrated strategies that combine ergonomic improvements, enhancement of safety climate, and the systematic management of psychosocial factors. Building on this perspective, the present study examines the combined roles of WMSDs, psychosocial stressors, and safety climate among distribution line workers in Brazil, aiming to inform more comprehensive and effective occupational health promotion and prevention initiatives.

Based on the literature and the work context of outsourced distribution line workers, we formulated the following hypotheses:

H1: There is a high prevalence of WMSDs among outsourced distribution line workers in Brazil, particularly in the upper limbs and back.

H2: A deficient safety climate is associated with a higher prevalence of WMSDs in this population.

H3: Psychosocial stressors are associated with a higher prevalence of WMSDs in this population.

H4: Workers reporting greater exposure to psychosocial stressors and deficient safety climate will exhibit a higher prevalence of WMSDs compared to those reporting lower exposure.

2. Materials and Methods

This cross-sectional observational study was conducted between February and April 2024 using an electronic questionnaire to assess musculoskeletal symptoms, psychosocial stressors, and safety climate among outsourced electrical line workers in Brazil. Data were collected through a secure online platform, and participation was voluntary. Electronic informed consent was obtained before data collection, and all procedures adhered to the ethical standards outlined in the Declaration of Helsinki. The study protocol was approved by the Research Ethics Committee of the University Center of Brasília (approval code 46687815.5.0000.0023), and anonymity and confidentiality were strictly ensured throughout the research process.

Workers were recruited through a voluntary response sampling strategy. Distribution companies disseminated the survey link to their outsourced field teams, and workers freely decided to participate. The minimum required sample size was estimated using the formula for prevalence in cross-sectional studies (Equations 1 and 2).

$$n = \frac{Z^2\, p\,(1-p)}{e^2} \tag{1}$$

Where: Z = 1.96 (95% confidence level), p = expected prevalence of musculoskeletal symptoms (0.50, a conservative estimate maximizing sample size), e = margin of error (0.05).

$$n = \frac{(1.96)^2 \times 0.50 \times 0.50}{0.05^2} \approx 384 \tag{2}$$

To account for potential exclusions, missing responses, and heterogeneity across regions and companies, a target sample size exceeding 600 respondents was established. A total of 689 valid responses were obtained, exceeding the minimum requirement and providing adequate power for structural equation modeling analyses.

Inclusion criteria were: (a) being an outsourced electrical line worker, (b) being 18 years of age or older, (c) having at least six months of experience in line work, and (d) providing informed consent. Exclusion criteria included administrative personnel not performing field work, incomplete questionnaires with more than 20% missing data, and duplicate submissions identified by system logs.

Work-related musculoskeletal disorders were assessed using the Brazilian version of the Nordic Musculoskeletal Questionnaire-NMQ (Pinheiro et al., 2002). The NMQ comprises 27 dichotomous items (yes/no) covering nine body regions (neck, shoulders, upper back, lower back, elbows, wrists/hands, hips/thighs, knees, ankles/feet). The instrument assesses the presence of symptoms in the past 12 months and the preceding seven days, as well as whether symptoms resulted in work-related disability. Scoring follows the original procedure, generating region-specific indicators and a total symptom count. The NMQ has documented test–retest reliability, construct validity, and sensitivity for detecting work-related musculoskeletal disorders in Brazilian occupational samples (Mattos & Pattussi, 2025).

Psychosocial stressors were measured with the Scale for Assessing Psychosocial Stressors in the Work Context (in Portuguese: Escala de Avaliação de Estressores Psicossociais no Contexto Laboral-EAEPCL) (Ferreira et al., 2015), which consists of 35 items distributed across seven factors: role conflict and ambiguity (α = 0.77), role overload (α = 0.71), lack of social support (α = 0.77), career insecurity (α = 0.62), lack of autonomy (α = 0.71), work-family conflict (α = 0.75), and pressure from responsibility (α = 0.77). Responses are provided on a six-point Likert scale, ranging from 1 ("never affects me") to 6 ("always affects me"), with higher scores indicating greater perceived stress.

Safety climate was assessed using the Safety Climate Scale for Remote Workers (SCS-RW) in the Electric Power Sector (Huang et al., 2013) in its Brazilian version (Rodrigues et al., 2019). This instrument evaluates the perceived priority given to safety at two levels: organizational (29 items in six dimensions: safety proactivity, general training, trucks and equipment, field orientation, financial investment, and schedule flexibility) and group (19 items in three dimensions: supervisory care, participation encouragement, and safety straight talk). Items are rated on a five-point Likert scale, and higher scores reflect a more favorable safety climate.

The psychometric properties of all measures were reexamined within this sample. Internal consistency was assessed using Cronbach's alpha (α) and Guttman's lambda-2 ($\lambda 2$) for the Likert-type scales, and the Kuder-Richardson coefficient (KR-20) for the dichotomous NMQ.

Both α and λ2 were reported because α is widely used in occupational health research, while λ2 provides a more stable estimate when item covariances are heterogeneous or when distributions deviate from normality–conditions expected in fieldwork populations. All reliability coefficients exceeded recommended thresholds (α and λ2 ≥ 0.70; KR-20 = 0.84). For structural equation modeling, composite reliability (CR) and average variance extracted (AVE) were also computed to evaluate construct validity.

All analyses were performed in R (version 4.5.1) using the *lavaan*, *psych*, *Hmisc,* and *rstatix* packages. Preliminary procedures included descriptive statistics, screening for missing data, assessment of normality, and detection of multivariate outliers using Mahalanobis distance with a $p <$ 0.001 threshold based on the chi-square distribution. Associations among psychosocial stressors, safety climate, and musculoskeletal outcomes were examined through structural equation modeling with the Weighted Least Squares Mean and Variance Adjusted (WLSMV) estimator, appropriate for ordinal and dichotomous variables. Model fit was evaluated using the chi-square test (χ^2), chi-square to degrees-of-freedom ratio (χ^2/df), Comparative Fit Index (CFI), Tucker–Lewis Index (TLI), Root Mean Square Error of Approximation (RMSEA), and Standardized Root Mean Square Residual (SRMR), following established guidelines for acceptable and good fit (Brown, 2015; McNeish et al., 2018).

3. Results and Discussion

Participants were predominantly men (86.3%), with a mean age of 36.8 ± 8.4 years (Table 1). Average job tenure was 5.6 ± 2.8 years, and most workers had completed high school (87.2%). The average monthly salary was BRL 3,900. The sample included workers from all regions of Brazil, with greater representation from the Southeast (30.9%) and South (22.6%).

Table 1. Sociodemographic Characteristics of the Sample (N = 689)

Variable	Men		Women	
	n	%	n	%
Education level				
High school	386	56.02%	215	31.20%
Higher education	73	10.60%	15	2.18%
Regional distribution				
North	77	11.18%	12	1.74%
Northeast	95	13.79%	25	3.63%
Center-West	103	14.95%	15	2.18%
South	132	19.16%	17	2.47%
Southeast	168	24.38%	45	6.53%

Initial assessments of the dataset included normality testing and the detection of univariate and multivariate outliers. Tests of normality indicated that the distribution of variables departed from normality, which justified the use of robust estimation methods in subsequent analyses. Examination of univariate outliers did not reveal extreme cases outside acceptable ranges for the study variables. No univariate outliers exceeded acceptable ranges. Multivariate outliers were assessed using Mahalanobis distance, with a threshold of $p <$ .001 based on the chi-square distribution. No observations exceeded this criterion, indicating that the dataset met the assumptions required for the planned modeling procedures.

The psychometric properties of the instruments used in this study were evaluated to ensure internal consistency and reliability. For the EAEPCL, α and λ2 coefficients demonstrated satisfactory internal consistency (α and λ2 > 0.70 across subscales). For the SCS-RW, α values were above 0.81, and λ2 values exceeded 0.82 for both subscales, indicating acceptable internal consistency. Finally, NMQ reliability was confirmed by the KR-20 (0.84), supporting adequate reliability for its dichotomous items.

To further support the construct validity of the measurement model, composite reliability (CR) and average variance extracted (AVE) were computed for all latent constructs (Table 2). CR values exceeded the recommended threshold of 0.70, indicating adequate internal consistency based on factor loadings rather than solely on item covariances. AVE values were above 0.50 for all constructs, demonstrating that each latent factor explained more variance in its indicators than the variance attributable to measurement error. Together, these indices provide additional evidence that the scales used in this study adequately represent their intended psychological constructs.

Table 2. Composite Reliability (CR) and Average Variance Extracted (AVE) for All Constructs

Construct	CR	AVE
Psychosocial Stressors		
Role conflict and ambiguity	0.81	0.53
Role overload	0.83	0.56
Lack of social support	0.78	0.51
Job insecurity	0.85	0.59
Lack of autonomy	0.80	0.52
Work–family conflict	0.88	0.55
Pressure from responsibility	0.82	0.54
Safety Climate		
Organizational-level safety climate	0.90	0.58
Group-level safety climate	0.87	0.57

Furthermore, confirmatory factor analyses (CFAs) were conducted for all multi-item instruments within this sample. The CFAs supported the original factor structures, with factor loadings reaching adequate magnitude and model fit indices within acceptable ranges, thereby establishing convergent and discriminant validity before moving to the structural equation modeling stage (Table 3).

Overall, 51.77% of participants reported at least one musculoskeletal complaint in the past 12 months (Table 4), with an average of 3.25 different complaints per participant (±1.35). The average number of sick leaves in the past year was 3.25 per worker (±1.45), and participants reported an average of 5.45 visits to specialized care for musculoskeletal issues in the past year (±2.45). In the week before data collection, workers reported an average of 2.12 different symptoms (±1.15).

Table 3. Confirmatory factor analysis fit indices for measurement models

Model	χ^2	df	χ^2/df	CFI	TLI	RMSEA (90% CI)	SRMR
EAEPCL (7-factor model)	452.37	224	2.02	0.94	0.93	0.048 [0.041, 0.055]	0.057
Organizational-level safety climate (6-factor model)	389.15	210	1.85	0.95	0.94	0.044 [0.036, 0.052]	0.050
Group-level safety climate (3-factor model)	138.62	74	1.87	0.96	0.95	0.046 [0.034, 0.058]	0.046
Combined measurement model (all latent constructs)	612.84	342	1.79	0.95	0.94	0.045 [0.039, 0.051]	0.055

Note. EAEPCL = Escala de Avaliação de Estressores Psicossociais no Contexto Laboral. CFI = Comparative Fit Index; TLI = Tucker-Lewis Index; RMSEA = Root Mean Square Error of Approximation; SRMR = Standardized Root Mean Square Residual. Values of CFI and TLI $\geq$ 0.90, and RMSEA and SRMR $\leq$ 0.08, indicate acceptable model fit.

Table 4. Prevalence of Musculoskeletal Symptoms, Activity Impairments, and Professional Medical Visits by Body Region

Body region	Symptoms 12 months		Impairments 12 months		Medical visits for 12 months		Symptoms for 7 days	
	n	%	n	%	n	%	N	%
Neck	325	47.17%	158	22.93%	215	31.20%	389	56.46%
Shoulders	481	69.81%	325	47.17%	345	50.07%	425	61.68%
Back (upper)	288	41.80%	120	17.42%	245	35.56%	157	22.79%
Wrist/Hands	125	18.14%	62	9.00%	75	10.89%	88	12.77%
Back (lower)	285	41.36%	124	18.00%	156	22.64%	256	37.16%
Hip/Thighs	150	21.77%	41	5.95%	55	7.98%	89	12.92%
Knees	189	27.43%	59	8.56%	90	13.06%	15	2.18%
Ankle/Feet	78	11.32%	14	2.03%	25	3.63%	25	3.63%

Note. Values are presented as frequency (n) and percentage (%). Percentages may not total 100 due to rounding.

The high prevalence of WMSDs confirms the first hypothesis and reflects the intense and repetitive physical demands of the sector, consistent with previous research identifying the shoulders, neck, and lower back as the most vulnerable regions for pain and injury (Lamooki et al., 2022; Rogerson et al., 2024; Vives et al., 2013). These results align with global estimates showing that WMSDs remain a leading cause of absenteeism, disability, and productivity loss (Bevan, 2015; Killingmo et al., 2024), representing a significant occupational and public health concern. The physiological mechanisms underlying these outcomes are well-documented: continuous exposure to biomechanical overload, combined with sustained perceptions of threat and effort, can trigger chronic activation of neuroendocrine and inflammatory systems, disrupting homeostasis and contributing to persistent musculoskeletal pain (Brewin et al., 2024; Puntillo et al., 2021; Ramos et al., 2022; Theorell, 2020).

Regarding psychosocial stressors, the results indicate elevated levels of stressors across the seven EAEPCL factors (Table 5), with the highest means observed for job insecurity (M = 5.78, ±1.05) and lack of social support (M = 5.40, ±0.45). Conversely, the perception of safety climate was generally low, particularly at the organizational level (e.g., schedule flexibility, M = 1.50, ±0.89), although group-level factors such as supervision showed relatively higher means (M = 4.52, ±1.26).

The analysis of mean scores and standard deviations for psychosocial stressors and safety climate factors reveals a context of high job strain combined with limited organizational resources. The highest levels of job insecurity (M = 5.78) and lack of social support (M = 5.40) indicate chronic exposure to employment instability and weak interpersonal support networks, conditions widely associated with poorer mental health and increased occupational morbidity in precarious and outsourced work contexts (Koranyi et al., 2018; Lima & Oliveira, 2021; Martins et al., 2024; Swami & Wagle, 2024; Vives et al., 2013). Within the electrical sector, these stressors are compounded by highly demanding and risky physical tasks (Lamooki et al., 2022; Rogerson et al., 2024), producing psychophysiological overload consistent with the Demand-Control (Bronkhorst, 2015; Huth & Chung-Yan, 2023; Theorell, 2020) and Effort-Reward Imbalance models (Eddy et al., 2016; Lang et al., 2022), in which the combination of high demands and low control or rewards amplifies stress and inflammatory responses linked to musculoskeletal pain (Theorell, 2020; Eddy et al., 2016; Puntillo et al., 2021; Cool & Zappetti, 2019; Brewin et al., 2024; Ramos et al., 2022).

Simultaneously, low organizational-level safety climate scores (notably in schedule flexibility, investment in prevention, and field orientation) suggest an environment where safety is perceived as a secondary concern. Such conditions are empirically linked to unsafe behaviors and increased accident rates, while positive safety climates are shown to serve as protective factors that foster compliance and hazard awareness (Arooj et al., 2022; Baby et al., 2021; Beus et al., 2016; Bosak et al., 2013; Griffin & Curcuruto, 2016; Huang et al., 2013; Kiani et al., 2022). In electricity distribution companies, organizational arrangements associated with outsourcing further degrade safety climate and operational performance, reinforcing the elevated stressor profile found in this sample (Lima & Oliveira, 2021; Martinez & Fischer, 2009; Onafadeji et al., 2023). Altogether, the configuration of high psychosocial exposure and low organizational safety climate reflected in the mean scores of Table 5 provides a plausible explanation for the heightened prevalence and intensity of work-related musculoskeletal disorders (WMSDs) and their economic and social impact (Bevan, 2015; Killingmo et al., 2024), underscoring the need for organizational interventions that jointly reduce stressors and strengthen safety climate.

The SEM analysis examined the predictive relationships between psychosocial stressors, safety climate, and the prevalence of WMSDs (Figure 1). The model demonstrated a good fit to the data: χ^2 (159) = 280.45, p < 0.001; CFI = 0.95;

TLI = 0.93; RMSEA = 0.045 (90% CI [0.038-0.055]); SRMR = 0.06. The analysis indicated that psychosocial stressors demonstrated strong positive path coefficients with the musculoskeletal outcomes: problems in the last 12 months (β = 0.62, 95% CI [0.51, 0.69]), work impairment in the last 12 months (β = 0.61, 95% CI [0.55, 0.66]), medical care in the last 12 months (β = 0.55, 95% CI [0.45, 0.65]), and symptoms in the last 7 days (β = 0.45, 95% CI [0.30, 0.56]). In contrast, safety climate exhibited significant negative path coefficients with the same outcomes, indicating a protective effect: problems in the last 12 months (β = -0.51, 95% CI [-0.45, -0.62]), work impairment in the last 12 months (β = -0.55, 95% CI [-0.50, -0.60]), medical care in the last 12 months (β = -0.45, 95% CI [-0.36, -0.51]), and symptoms in the last 7 days (β = -0.27, 95% CI [-0.19, -0.35]).

Table 5. Mean Scores and Standard Deviations for Psychosocial Stressors and Safety Climate Factors

Measure	M	SD
Psychosocial Stressors		
Role conflict and ambiguity	3.45	1.21
Role overload	3.65	1.01
Lack of social support	5.40	0.45
Job insecurity	5.78	1.05
Lack of autonomy	3.56	1.02
Work-family conflict	4.81	1.56
Pressure from responsibility	4.92	0.89
Safety Climate		
Organizational level		
Safety proactivity	2.50	1.56
Training	3.22	0.97
Trucks and equipment	3.00	0.56
Field orientation	2.56	1.23
Investment in safety	2.78	1.10
Schedule flexibility	1.50	0.89
Group level		
Supervisory care	4.52	1.26
Encouragement of participation	2.56	0.88
Safety straight talk	3.50	1.12

Note. Higher scores indicate greater exposure to psychosocial stressors. Higher scores on safety climate dimensions reflect a more favorable perception of organizational or group-level safety.

Table 6 presents the SEM fit indices and standardized path coefficients, offering an overview of the structural relationships between psychosocial stressors, safety climate, and WMSDs. The results, therefore, suggest that WMSDs cannot be explained solely by physical effort; they arise from a labor context where organizational and relational factors intensify stress and, consequently, musculoskeletal disorders.

The SEM results demonstrate a robust and theoretically coherent model linking psychosocial stressors, safety climate, and WMSDs. The adequate model fit indicates that the proposed structure adequately captures the underlying relationships between these latent variables. The strong positive path coefficients between psychosocial stressors and all WMSD indicators (β = 0.45-0.62) confirm that higher exposure to psychosocial demands (particularly job insecurity, overload, and lack of support) substantially increases musculoskeletal symptom reports, functional impairments, and health-care utilization. These findings are consistent with previous research showing that cumulative exposure to job strain and low organizational resources amplifies physiological stress responses and inflammatory activation, predisposing workers to chronic musculoskeletal pain (Brewin et al., 2024; Eddy et al., 2016; Puntillo et al., 2021; Ramos et al., 2022; Theorell, 2020).

Conversely, the significant negative paths for safety climate (β = -0.27 to -0.55) highlight its protective role. When workers perceive their organization as committed to prevention, supervision, and communication, the likelihood and severity of WMSDs decline, reflecting a buffering mechanism against psychosocial stress. This pattern aligns with models emphasizing the interaction of organizational and individual factors in occupational safety and health (Beus et al., 2016; Bosak et al., 2013; Griffin & Curcuruto, 2016). Empirical studies in the electrical and energy sectors have similarly demonstrated that a strong safety climate promotes compliance, situational awareness, and collective responsibility, thereby reducing accident rates and injury severity (Arooj et al., 2022; Baby et al., 2021; Kiani et al., 2022).

Overall, the SEM findings confirm that WMSDs cannot be understood solely through biomechanical exposure. Instead, they emerge from a multidimensional system in which psychosocial stressors act as amplifiers of vulnerability, and safety climate functions as an important organizational safeguard. This dual pathway underscores the need for integrated risk-management strategies that combine ergonomic interventions with psychosocial and organizational reforms aimed at strengthening safety culture and worker well-being (Afsharian et al., 2023; Bronkhorst, 2015; Rodrigues et al., 2020).

The widespread practice of outsourcing in the electric sector provides important context for these findings. Literature shows that outsourced workers often face weaker employment ties, less stability, fewer benefits, and limited access to occupational health and safety programs (Lima & Oliveira, 2021; Martins et al., 2024; Onafadeji et al., 2023; Vives et al., 2013). These conditions intensify job insecurity and perceptions of organizational invisibility, both of which emerged as key stressors in this sample. Moreover, the pressure to reduce costs and increase productivity, inherent to outsourcing, frequently accelerates work pace and relaxes safety standards, thereby heightening risks of accidents and illness (Koranyi et al., 2018; Lima & Oliveira, 2021; Vives et al., 2013). Outsourcing thus functions as a structural factor that undermines safety climate by constraining investments, training, and organizational guarantees, generating an environment where workers do not perceive prevention as a priority. This convergence of precarious contracts, intense psychosocial stressors, and weak safety climate explains the magnitude of the results observed and helps clarify why outsourced distribution line workers constitute a particularly vulnerable group.

Despite the strengths of this study, some limitations must be acknowledged. First, the cross-sectional design precludes causal inferences regarding the relationships among psychosocial stressors, safety climate, and WMSDs. Second, the reliance on self-reported measures may introduce recall bias or social desirability effects, although validated instruments were used to minimize these risks. Third, the sample was restricted to outsourced electrical line workers in Brazil, which may limit the generalizability of the findings to other occupational groups or countries with different labor conditions.

Table 6. SEM fit indices and standardized path coefficients (β) with 95% CIs-Structural paths

Predictor → Outcome	β (Standardized)	95% CI
Psychosocial stressors → Problems 12 months (P12)	0.62	0.51–0.69
Psychosocial stressors → Work impairment 12 months (WI12)	0.61	0.55–0.66
Psychosocial stressors → Medical care 12 months (MC12)	0.55	0.45–0.65
Psychosocial stressors → Symptoms 7 days (S7)	0.45	0.30–0.56
Safety climate → Problems 12 months (P12)	−0.51	−0.62 to −0.45
Safety climate → Work impairment 12 months (WI12)	−0.55	−0.60 to −0.50
Safety climate → Medical care 12 months (MC12)	−0.45	−0.51 to −0.36
Safety climate → Symptoms 7 days (S7)	−0.27	−0.35 to −0.19

Note. Estimator = WLSMV. All paths are two-tailed. Negative coefficients for safety climate indicate protective associations with WMSD outcomes. Abbreviations: P12 = problems in the last 12 months; WI12 = work impairment in the last 12 months; MC12 = medical care in the last 12 months; S7 = symptoms in the last 7 days.

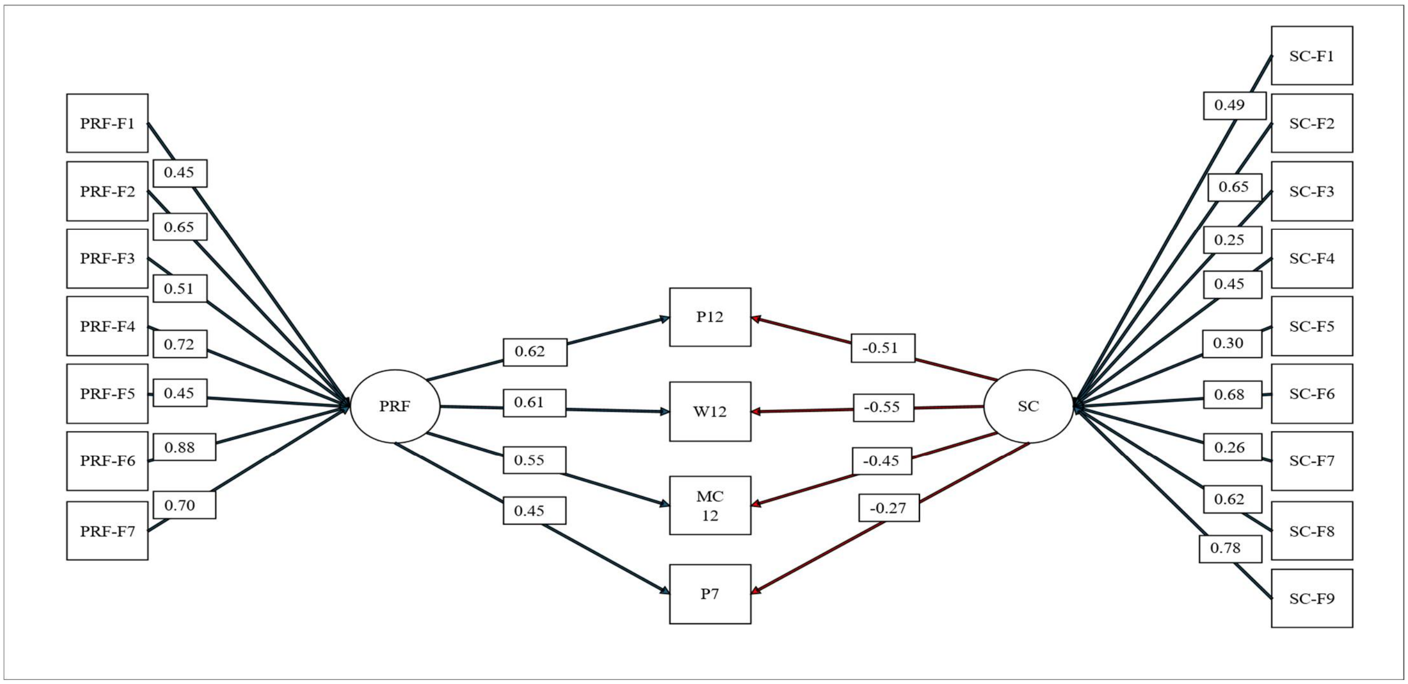

Figure 1. Structural equation model showing paths from psychosocial stressors and safety climate to work-related musculoskeletal disorders (WMSDs)
Note. Red arrows indicate negative paths (protective effects); blue arrows indicate positive paths (risk effects). Standardized β coefficients are shown. PRF = psychosocial risk factors; PRF-F1 = Role conflict and ambiguity; PRF-F2 = Role overload; PRF-F3 = Lack of social support; PRF-F4 = Job insecurity; PRF-F5 = Lack of autonomy; PRF-F6 = Work-family conflict; PRF-F7= Pressure from responsibility; SC = Safety Climate; SC-F1 = Safety proactivity; SC-F2 = Training; SC-F3 = Trucks and equipment; SC-F4 = Field orientation; SC-F5 = Investment in safety; SC-F6 = Schedule flexibility; SC-F7 = Supervisory care; SC-F8 = Encouragement of participation; SC-F9 = Safety straight talk; P12 = problems in the last 12 months; WI12 = work impairment in the last 12 months; MC12 = medical care in the last 12 months; S7 = symptoms in the last 7 days. Red lines indicate negative effects.

4. Conclusion

All four hypotheses were confirmed, reinforcing the interpretation that WMSDs among outsourced line workers result from a set of interdependent factors, ranging from biomechanical demands to work organization and management. The literature provides consistent support for this interpretation, whether by emphasizing the economic and social burden of WMSDs (Afsharian et al., 2023; Bevan, 2015; Vives et al., 2013), by documenting the impact of psychosocial risks (Martinez & Fischer, 2009; Rodrigues et al., 2020), or by underscoring the role of safety climate (Beus et al., 2016; Bosak et al., 2013; Kortum et al., 2010). By integrating these dimensions, this study advances a broader understanding of occupational health in the electric sector and underscores the need for preventive strategies that extend beyond traditional ergonomics to include organizational and regulatory policies that strengthen safety and reduce inequalities produced by outsourcing.

From a practical perspective, the results indicate that interventions limited to ergonomics and postural correction are insufficient to reduce the burden of WMSDs in this sector. An integrated approach is required, simultaneously addressing physical, psychosocial, and organizational factors. Interventions should aim to reduce work-related stressors, such as insecurity and overload, while strengthening safety climate through engaged leadership, transparent communication, investment in prevention, and effective worker participation in decision-making. Furthermore, policies and practices targeting the electric sector must address the disparities imposed by outsourcing, ensuring equivalent protection for outsourced and directly hired workers. Only in this way can the cycle connecting precarious employment, stress, negative organizational climate, and high prevalence of musculoskeletal disorders be disrupted.

Future research should employ longitudinal designs to capture causal pathways, integrate objective health and safety indicators, and expand the scope to other high-risk occupations and diverse cultural contexts. Intervention studies testing strategies to reduce psychosocial stressors and strengthen organizational and supervisory safety climates are also needed to provide actionable evidence for improving worker health and safety.

Authors' Contributions

Carlos Manoel Lopes Rodrigues: Conceptualization; methodology; formal analysis; investigation; resources; data curation; writing-original draft preparation; writing-review and editing; visualization; supervision; project administration.

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Conflicts of Interest

The authors declare no conflict of interest.

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Ethical Considerations

This study was conducted in accordance with the ethical standards of the Brazilian National Health Council (CNS Resolution No. 466/2012) and was approved by the Research Ethics Committee of the University Center of Brasília (CEUB) under protocol number CAAE 46687815.5.0000.0023. All participants provided informed consent before participation.

Using Artificial Intelligence

Artificial intelligence (AI) was used exclusively to assist with grammar refinement, stylistic consistency, translation from the original Portuguese manuscript into English, and reference formatting. All data analyses, statistical procedures, and theoretical interpretations were conducted entirely by the researcher. The model employed was OpenAI GPT-5 (ChatGPT, 2025). No AI-generated content replaced or determined the author's original analyses, interpretations, or scientific reasoning.

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